Latera (Viterbo, Italy), the breath of the Earth

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Abstract

In this work we describe a sulphur mine inside a caolin outcrop bedding inside the calderic depression of Latera (Viterbo, Italy) not far from the ENEL geothermic plant, at the moment dismissed.
The mine was active since the end of the 19th century until the half of the 20th, and was then abandoned because of noxious gas exhalations. Nowadays in the forecourt there still is an active gas vent.
We performed analyses of some parameters of these exhalations and of the water of a nearby spring.
In this work we describe also the evolution steps of the caldera and its mineral deposits, particularly a large deposit of fluorite in the intracalderic beddings.

Key words: Sulphur, mines, acidic spring water, caolinization, Latera caldera, Volsinian volcanic system, gas vent.

Riassunto

Latera (Viterbo, Italia), il respiro della Terra

In questo lavoro viene descritta una miniera di zolfo alloggiata in un deposito di caolino, situato all'interno della caldera di Latera (provincia di Viterbo), poco distante dall'abitato omonimo e dalla centrale geotermica ENEL in dismissione.
La miniera fu coltivata dalla fine dell'Ottocento fino a metà Novecento, e venne abbandonata a causa delle esalazioni gassose.
Tutt'oggi nel piazzale antistante è presente una sorgente gassosa attiva. Sono state eseguite analisi di alcuni parametri del gas con rilevatore Draeger Quantimeter, e dell'acqua di una sorgente limitrofa.
Nel presente lavoro vengono anche descritte le tappe evolutive della caldera di Latera con particolare riguardo ai suoi giacimenti minerari, tra i quali un cospicuo giacimento di fluorite nell'area intracalderica.

Parole chiave: Zolfo, miniera, acidità delle acque sotterranee, caolinizzazione, caldera di Latera, sistema vulcanico Volsinio, emissioni di gas dal sottosuolo.

The Caldera of Latera

The study area of this work is located in Northern Latium, Italy, province of Viterbo (Fig. 1). By a village named Latera a mine in which sulphur was extracted was active until the 60s of the last century. Nowadays it is not possible to enter the tunnel because the atmosphere is saturated with noxious gas and in the ground of the mining area there is a copious gas vent approaching which could be dangerous, if not wearing a gas mask. The whole area is home to thermal fluid ascents. This mining site is part of a calderic trough generated following the sinking of a volcanic system, the Latera system, part of a larger sized apparatus, the Volsinian system, and together form a complex whose eruptive activity covers a time span of about half a million years, from 600,000 to 100,000 years ago (Peccerillo 2005) (Fig. 2).

The eruptive, activity of Latera system ranks from 380,000 to 150,000 years ago, and together with the most famous Bolsena apparatus constitutes the Volsinian system, among the largest volcanic systems active in the Tyrrhenian Quaternary (Peccerillo, op. cit.).

To provide an idea of the explosive violence of these volcanoes, it has been calculated that the approximate

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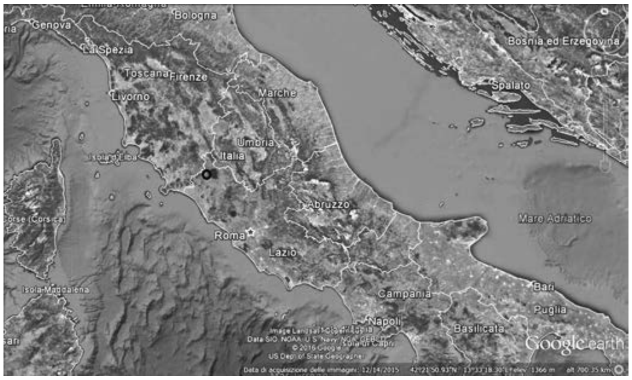

Fig. 1 - Map of Central Italy. The Latera mining site is in the black circle (by Google Earth, modified).
Fig. 1 - Mappa del Centro Italia. Il sito minerario di Latera si trova nel cerchio nero (da Google Earth, modificata).

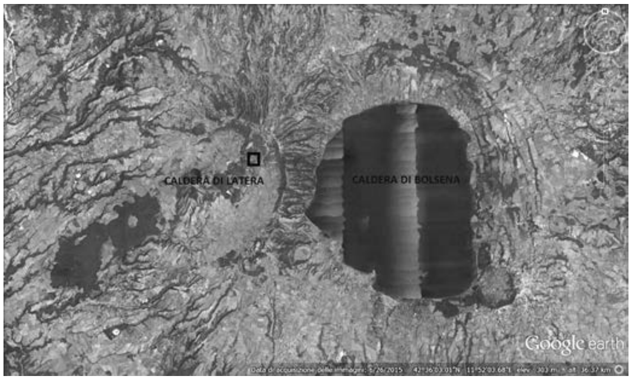

Fig. 2 - Map of the Volsinian Calderas, showing the Bolsena Caldera on the right and the Latera Caldera on the left (by Google Earth, modified).
Fig. 2 - Mappa delle Caldere Volsiniane, che mostra la Caldera di Bolsena sulla destra e la Caldera di Latera a sinistra (da Google Earth, modificata).

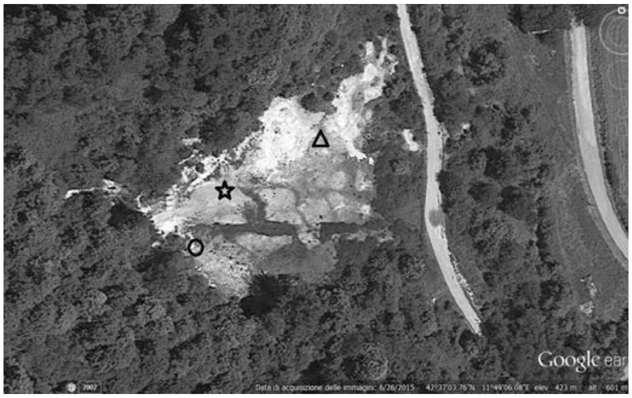

Fig. 3 - Map of the mining site. In the circle there is the tunnel leading to the cultivation front, the star shows the location of the water acidic spring, the triangle the location of a noxious gas vent (by Google Earth, modified).
Fig. 3 - Mappa del sito minerario. Nel cerchio si trova il tunnel che porta al fronte estrattivo, la stella mostra la posizione della sorgente di acqua acida, il triangolo la posizione di uno sfiato di gas nocivi (da Google Earth, modificata).

Fig. 4 - What remains of the wide mining yard in Latera Caldera (photo E. Bellocchi, M. Morucci).
Fig. 4 - Cosa resta dell'ampio cantiere minerario nella Caldera di Latera (foto E. Bellocchi, M. Morucci).

volume of material erupted between lavas and pyroclastics, would reach a volume of 900 km^3 of products placed on the surface (Peccerillo, op. cit.).

Latera is one of the phases of Volsinian volcanism, corresponding to a phase of evolutionary maturity of the system, and generated three minor stages of paroxysmal activity.

The Sulphur Mine and its Spring

The sulfur mine consists of a large open space bordered by the hill slope towards the north, on a side of which opens the gallery leading to the cultivation area of the mineral (Fig. 3).

The gallery is currently closed by a heap of detritic material brought in place with a caterpillar to prevent access (Fig. 4). In fact the gallery cannot be explored without breathing apparatus because the atmosphere is saturated with carbonic gas and sulfide which makes the air unbreathable even wearing a gas mask. We took pictures of the tunnel fastening a camera to a pole and pushing it forward from the outside.

The photos, by operating the zoom, reveal a continuation beyond a modest landslide front, and in the darkness the direction of the tunnel seems to bend inward, within the massif.

At the entrance there is air movement, and on summer days colder air is coming out, considerably colder than the temperature outside.

A strong sulfurous smell can also be felt as a further confirmation of the high danger inside the mine. As noticed through observation, the chestnut leaves that have fallen in the autumn season: the outer ones are dry, while those inside appear dark, as if they underwent a carbonization process.

To be in condition of working in the tunnel, the miners required an efficient air ventilation inside the tunnel, and this was guaranteed by a pipe connected to a fan transferring inside air from outside.

The cultivation front was at the end of the gallery, in a large room excavated in kaolin and sulphur called “luoghi caldi” (warm places), and inside this hall there was a spring of undrinkable water, exactly the same water as the spring outside (Fig. 5).

Fig. 5 - The tunnel leading to the cultivation front (photo E. Bellocchi, M. Morucci).
Fig. 5 - Il tunnel che porta al fronte estrattivo (foto E. Bellocchi, M. Morucci).

To study the outcrop and its characteristics it is not necessary to expose to the risk of death by asphyxiation within the gallery, because the springs in the nearby area can provide by their own some valuable information on the geochemical processes.

In detail (Fig. 6), there are a spring and a gas vent at a short distance one from the other, and the spring emits gas as well as water.

Fig.6 - Sulphur on Kaolin (photo E. Bellocchi, M. Morucci).
Fig.6 - Zolfo su Caolino (foto E. Bellocchi, M. Morucci).

We have analyzed the water of the source with respect to certain parameters, and the results are reported in Table 1:

Temperature	14,3	°C
pH	2,39	
Eh	39	mV
Conductivity	2,24	mS/cm
Sulphide	11	microg/l
Potassium	33,3	mg/l
Fluoride	0,43	mg/l
Silica	82	mg/l
Iron	6,92	mg/l
Manganese	2,55	mg/l
Carbon Dioxide	600	mg/l

Table 1: Chemical analysis of the spring water.
Tabella 1: Analisi chimiche delle acque di sorgente.

These hydro-chemical data are very significant and highlight the geochemical processes occurring in the subsurface by fluid coming up from deep below.

The first thing to notice is the relationship between silica, potassium and pH. The first two have very high concentration values, while the third is very low, therefore marked acidic conditions have to be recorded. All this proves a kaolinization process is going on.

The kaolinization is a process, very important in geochemistry, by which there is the formation of a secondary mineral, kaolinite, by the action of acidic fluids that break and recompose a primary mineral, potassium feldspar, sanidine in our case (Faure, 1990).

Both the starting mineral and the product are aluminosilicates: in detail, tectosilicate the feldspar, phyllosilicate the kaolinite.

The tectosilicates are structurally constituted by a rigid packing of tetrahedra with a central atom of silicon and four oxygen atoms at the vertices, which are shared by the adjacent tetrahedral units, thereby generating a single block in which each unit cell is the tetrahedron (Faure, op.cit.).

The phyllosilicates are instead constituted by an alternation of an upper layer with a central tetrahedral silicon and a lower octahedral layer with aluminium which coordinates six oxygens (Faure, 1990).

The two layers are bound together by oxygen bridging atoms.

The kaolinization process of feldspars is represented by the following equation:

$$\mathbf{2KAlSi_3O_8 + 2\ H^+ + H_2O = Al_2Si_2O_5(OH)_4 + 2\ K^+ + 4\ SiO_2}$$

For this process to take place, two factors are essential: water and acidity. The water is also essential to remove the soluble products of the reaction, potassium ions and silica in the form of silicic acid. The presence of water at a marked acid pH (2.39) and with a significant concentration of potassium ions and silica (33 and 82 mg, respectively) indicates that the kaolinization process is ongoing.

We performed even semi-qualitative analysis on the gaseous exhalation in the same mining area by the spring by using a gas detector Draeger Quantimeter 1000. We used a vial for high range carbon dioxide, clearly positive, one for hydrogen sulfide, which provided an approximate value of 75 parts per million, and one for arsenic trioxide, which has given a positive result. Of the latter compound, we could detect the presence only, but not the concentration.

We carried out some measurements of the radioactivity with a Geiger counter to which was connected a very sensitive probe, which does not discriminate single radiation components. The results obtained, in dosimetric units, are always between 0.3 and 0.4 MicroGray/h, being the value of the Italian standard background about 0.1-0,2 (measurements recorded by the authors in several environments).

This source emits copious amounts of gas with intensity of the flow which can be appreciated by feeling the difference of temperature in the summer days: all around the white floor of kaolin burns, due to the heat wave, while the point where the gas is escaping is cold. It is definitely not advisable to kneel over the source without wearing a gas mask, because the gas is more dense than air and forms a layer on the ground, up to knee height.

The gas is colorless and smells somewhat like rotten eggs, so that only a few seconds are needed to feel dizzy and passing out; these symptoms of asphyxia disappear wearing a gas mask. With the mask you breath an atmosphere poor of oxygen, but it filters the hydrogen sulphide and arsenic fumes.

As regards the fluoride, it is interesting to note that in the south-western part of the caldera, in the town of Farnese, there is a fluoride outcrop of about 10 sq km, made up of sedimentary deposits bedded in between pyroclastic material with a high fluoride concentration (LOCARDI & BATTISTELLA, 1987).

This deposit is the roof of a series of layers of the final phase of the Latera system, probably the last of the large eruptions, and is overlaid by other volcanic series emitted from fractures inside the caldera in the course of minor paroxysmal events (MASTRANGELO, 1976).

In the vicinity of the sulphur mining area there is a fluoride deposit, of smaller size than that one previously mentioned, that underwent exploitation in the recent past as well as the major deposit of fluoride.

The latter deposit was originated on the edge of a diatrema, an explosion crater (MASTRANGELO, 1976), now occupied by a small lake with circular section shaped like a funnel, the lake of Mezzano, the site of a prehistoric settlement of the Bronze Age (cfr. Piano di Gestione SIC IT 6010012 Lago di Mezzano, sez. 7).

The origin of these deposits is not linked to the simple evaporation of ancient lake basins, as was initially thought, but it is now accredited hypothesis of an exhalative origin, related to ascents of huge amounts of hot endogenous fluids; therefore, they cannot be ascribed to evaporitic beddings, but rather have a hydrothermal genesis (MASTRANGELO, 1976).

Hot gases, coming from deep below and channeled into pipes, have been pushed towards the surface by several pressure waves. These gases were able to exert a chemical alteration of the silicates of lava and pyroclastic materials, particularly the potassium feldspar, abundantly contained in these volcanics. As a result of this alteration, wide kaolinized areas can be formed.

The depositions of fluoride correspond to groundwater levels, the mineralising agents therefore were and are contained in the groundwater and not in lake basins evaporated for the intake of hot vapours, as previously believed.

A research performed between 1960s and 1970s has estimated about 100 million tonnes of ore with a fluoride concentration greater than 50% (LOCARDI, 1986).

In the depths of the caldera of Latera large volumes of fluid above the critical temperature and pressure (374 °C and 200 atm) have conveyed the mineralizing agent (HF, hydrofluoric acid) of the outcrop of the two fields of Latera system. These fluids originate far below the volcanic deposits; the large content of carbon dioxide comes from the disintegration of Mesozoic limestones accelerated by the acidity of the fluids circulating inside them, for displacement of a weak acid (carbonic acid) from its salt (calcium carbonate) by stronger acids (hydrohalic acids, particularly the hydrocloric), according to the Lowry-Bronsted acid-base universally accepted theory.

Another set of interesting parameters is the concentration of some metal ions sensible to variations of redox potenzial.

Iron and Manganese are among the main of this set, and they can be accurately determined with VIS spectrophotometry (Iron TPTZ Hach-Lange Method and Manganese PAN Hach-Lange Method).

The concentration of these metals in the water is very high, many times higher than in normal waters (the maximum concentration allowed for drinkable waters is 200 micrograms per liter of Iron II and 50 for Manganese – D. Lgs 31/2001 – compare with the concentration values present in our spring).

These parameters witness the redox conditions of the environment in which they are dissolved, and in normal conditions, iron concentration is higher than manganese.

During the transition between hypogenic and supergenic environment they pass fron reductive to oxydizing environment, so they precipitate from the solutions containing them.

Iron and manganese require different potential levels to transform and precipitate, iron being the former and manganese the latter.

It is thus possible to find waters with a higher concentration of manganese than iron, being these, transition waters between the two environments.

In the spring of Latera mine the ratio between the two metals respects the relation as normal waters, the only difference being the concentration level, very high, witnessing marked acidic conditions and low redox potential, suggesting that these waters before reaching the surface have a reducing environment, thus preventing oxydation of cations, confirmed by the heavy presence of hydrogen sulphide, requiring the latter acidic and reducing conditions.

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