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## **Eruptions, earthquakes and geothermal resources at Campi Flegrei and Ischia**

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### **Abstract**

The volcanic activity of Campi Flegrei and Ischia ranges between 150 ka and the present. The last eruption at Ischia occurred in 1302 CE, and that in Campi Flegrei in 1538. Eruptions at Ischia were more frequent during Greek and Roman times, whereas Campi Flegrei was more active between 5000 and 3000 a BP.

The use of thermal baths flourished at Campi Flegrei during Roman and the Middle Age, and balneo-therapy became a popular remedy that rivalled with the activity of the Salerno school of medicine.

All this activity came to an end with the eruption of Monte Nuovo in 1538, that, although there was a modest magnitude, it caused a strong commotion and altered the state of springs for long times. Soon after the eruption of Monte Nuovo, a calabrian physician, Giulio Iasolino (1588), wrote a treatise named "*De Rimedi Naturali che sono nell'Isola di Pithecusa; hoggi detta Ischia*", enumerating the springs of Ischia and describing their curative properties. Since then, the thermal springs of Ischia have slowly become renowned firstly in the kingdom of Naples and subsequently in Italy.

Volcanic activity and earthquakes have strongly influenced the exploitation of the geothermal resources and the fears of possible eruptions has affected for long time the attitude of people against the benefits resulting from it.

### **1- Introduction**

The active volcanoes in the bay of Naples (Vesuvius, Campi Flegrei and Ischia) share a common behavior, in that they alternate long periods of quiescence lasting several centuries to millennia, with prolonged periods of activity with numerous eruptions in a relatively short span of time (centuries).

Vesuvius had its last period of activity between 1631 and 1944 preceded by a quiescence of several centuries and followed by a new quiescence lasting since 1944, and longer by an order of magnitude than any quiescence of the preceding period (Carta et al, 1981). A longer quiescence period preceded the eruption of 79 AD and the following eruptions.

Campi Flegrei in the last 15 ka had at least three periods of activity lasting several centuries with numerous explosive and effusive eruption; each period was followed by a period of quiescence lasting several millennia (Rosi and Sbrana, 1987, Di Vito et al, 1999). The last period of activity between 4.8 and 3.8 ka Bp was followed by a quiescence until 1538 with the single eruption of Monte Nuovo and, since 1950, there has been a period of unrest with uplift of the ground and swarms of earthquakes (Del Gaudio et al, 2010).

Ischia island had at least two major periods characterized by numerous eruptions between 6 and 4.3 ka Bp and 2.9 and 1.6 ka Bp (De Vita et al, 2010, Vezzoli et al, 2009), with the last eruption occurring in 1302 CE.

The causes of such periodization may be related with processes of magma ascent and stocking at shallow level in the crust; the activity period could represent the activation and evacuation of the magma emplaced in a shallow reservoir (Di Vito et al, 2016).

The succession of long period of quiescence followed by long period of activity had an economic impact on the communities living in the area, with period of prosperity followed by sudden economic decline.

## **2- Campi Flegrei and Ischia from Neolithic to Roman age**

The Campanian plain has been the site of numerous human settlements since at least Neolithic age (Di Vito et al, 2013). The settlements are rarer in Campi Flegrei because of the frequent volcanic activity. It appears that the area was settled during the period of quiescence and abandoned as a consequence of volcanic activity.

The eruption of the Neapolitan Yellow Tuff at 15000 a BP left a wide gulf extending inland with respect to the present coastline (Scandone et al, 1991). A Neolithic village was settled on the border

of the gulf at Monte di Procida and was subsequently buried by the products of Fondi di Baia eruption (Albore Livadié, 1986) dated at 8560 y BP belonging to the second Epoch of activity (Di Vito et al, 1999).

At Ischia, at Cilento locality, there are traces of a settlement of middle-late neolithic age overlain by a thick ash deposit called Piano Liguori Formation (Buchner and Rittman, 1948, Buchner, 1986) dated between 5.1 and 5.5 ka. In locality S.Michele, there are traces of a more recent settlement dated between 5000 and 3000 a BP.

After the second epoch of activity, the central part of Campi Flegrei rose above sea level, leaving a large portion of land dry. New settlements of Eneolithic age, and Bronze age were located on the side of Gauro volcano, and at Montagna Spaccata and were buried by the deposits of the last phase of activity of Campi Flegrei (Albore Livadié, 1986).

At Ischia there are evidences of a Mycenaean trading post around 1000 BC (as shown in the archeological museum of Ischia) during a short lull of the volcanic activity. Subsequently Greek colonists from Euboea in 770 BC settled on the island on Monte Vico above the present village of Lacco Ameno. The settlement was called Pythecusa and was probably a port of commerce and trade before the large wave of Greek colonization in southern Italy. Greek and roman authors (Strabo, Plinius Seniore) report that seismic and volcanic activity, several times drove away the settlers from Ischia. Strabo reports that the Syracusans which established a garrison on the island after 474 BC, were driven away by an eruption and earthquakes, probably occurred, in 470 BC (Buchner, 1986). Frequent eruptions affected the island throughout this period, till late roman age (Buchner, 1986, De Vita et al, 2010, Vezzoli et al, 2009). The last eruption occurred in 1302 in a locality that was called Arso (Burned) and caused a widespread emigration from the island toward Pozzuoli. A testimony of the fact is the presence at Pozzuoli of the common surname "Schiano" deriving from the abbreviation of "Ischitano->Ischiano->Schiano" (Annechino, 1960).

### **3- The beginning of the exploitation of the thermal Baths**

The abundance of thermal spring and hot pools recalled the attention of the Romans, who were very fond of the thermal baths, especially if the warm water was of natural origin, as recalled by Cassiodorus in 530 CE "hot thermal baths not heated by smoky furnaces but directly by Nature".

The first testimony of the use of the thermal waters of Campi Flegrei for therapy is referred by T. Livii to 176 BC when, the consul Cneus Cornelius came to Campi Flegrei to cure arthritis, but the therapy did not have the desired effect “ad Aquas Cumanas profectus ingravescente morbo **Cumis** decessit”.

Rich Roman patricians in the late republican period (Caius Marius, Caesar, Pompeius Magnus, Cicero, Antonius, etc) had their summer villas in the area which soon became a popular summer resort.

The luxury of the place caused the contempt of Propertius because of the betrayal of his girlfriend Cinthia “A pereant Baiae, crimen amoris, aquae”. Similar words were used by Seneca to describe the place. Horatius remembers the place with better words “nullus in orbe sinus Baiis preluet Amoenis”, and the thermal baths were also mentioned by Martial and Plinius Senior.

Several emperors, Caligola, Nero, Severus, Adrianus, lived in Baia and made it renown and built a vast complex of baths annexed to the royal palace. The archeological remains of the thermal complex give, nowadays, a poor image of what should have been the place (fig.1).



Figure 1 – A panoramic view of the thermal complex of Baia

The so-called temples of Diana, Venus and Mercury were thermal complexes and are currently partially below sea-level as the imperial villa, which is now completely submerged below the sea (Maiuri, 1958).

The use of the baths in Campi Flegrei is recorded till the beginning of Middle age in the Dialogues of the Pope Gregorius Magnus (540- 604) when he speaks of the roman Diacon Germanus in the thermae of Agnano.

During Roman time, there is not a comparable use of thermal baths in the island of Ischia as that of Campi Flegrei. The only findings of Roman age are some votive tablets found at Nitrodi in Barano d'Ischia where there was a small shrine dedicated to the Nitrodian Ninphs (fig.2).



Figure 2- Votive tablet found at the spring of Nitrodi at Ischia

The frequent volcanic eruptions during Greek and Roman age probably dissuaded the Roman from the frequentation of the area. The emperor Augustus in 29 BC traded the island of Ischia to the Neapolitans with the island of Capri, possibly because of the seismic and volcanic activity which continued also in late Roman age (De Vita et al, 2010)

The thermal baths of Campi Flegrei are mentioned in the XI Century in the report of a Jewish traveller, Benjamin de Tudela (Toaff, 1965). Their use became universally known when the emperor Frederick II of Svevia sojourned there for a brief time. The most important description about the baths was made by Peter of Eboli, in a Latin poem written around 1200, for the Roman Empire Emperor, Frederick II. The poem is entitled "Liber Balneorum Terrae Laboris or De Balneis Puteolanis" and provides the description and properties of the thermal waters of Campi Flegrei. The poem was subsequently expanded and used as a true guidebook describing 35 thermo-mineral baths between Naples and Baia, illustrating the diseases cured by each. Twenty-eight different copies of the manuscript still survive, some of which are illustrated with miniatures, depicting the baths (fig.3).



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Figure 3 – Miniature of the bath called Tritoli (near Lucrino lake) in the Codex Bodmer of the De Balneis Puteolanis

A complete and extensive analysis of the existing copies of the Balneis Puteolanis has been made by D'Amato (2014). During the Angevin period in 1299, a hospital (Santa Marta) was built at Tripergole on the side of Lucrino lake with 120 beds for the cure of the poor. The popularity of the cure of thermal baths became extremely popular and rivalled the cure of the famous and expensive medical school of Salerno causing also frequent quarrels.

The earthquakes and the eruption of Monte Nuovo of 1538 destroyed the village of Tripergole, the hospital and 10 thermal baths and caused the decline of the use of all the others.

The Spanish vice-king Pietro d'Aragona in 1667, commissioned to his physician Sebastiano Bartolo, a study to identify and assess the state of the thermal baths of Campi Flegrei. Bartolo (1667) identified all the 40 baths existing before the eruption from Naples to Miseno but ascertained that only 9 still remained in use and proposed the restoration of all the others. Unfortunately, the cost of restoration was too high to allow a total recovering of all the baths. The list of all the thermae was engraved in three marble epigraphs, two of which are still preserved in Naples and Pozzuoli. The third was stolen in 1800 by English mariners and what still remain is the name of the place "Punta dell'Epitaffio" near Baia (fig. 4).



Figure 4- Oblique view of Punta dell'Epitaffio where was one epigraph of Sebastiano Bartolo. To the right is toward Lucrino with the remains of Tritoli thermal bath. To the left, after the pier, is the area of Baia with the partially submerged remains of the bath Sol et luna.

The decline of the balneotherapy at Campi Flegrei favoured the development of the cures in Ischia island.

In 1519 Giovanni Elisio published the book *Succincta instauratio de balneis totius Campaniae* with an appendix on Ischia *Li bagne anexi de la insula de hiscla dicta enaria*, citing the baths of Castiglione, Scrofa or Spelonca, Gurgitello and Cotto sauna.

The true renaissance of Ischia thermal baths is due to a physician from Calabria, Giulio Iasolino, who wrote the book *De Rimedi Naturali che sono nell'Isola di Pithecusa; hoggi detta Ischia* (1588) where he enumerated all the springs of the island with their curative properties.

At the beginning of 1600 the curative properties of the waters prompted the building in the village of Casamicciola of a hospital for the poor, named "*Pio Monte della Misericordia*" which became the largest SPA of Europe. The edifice, destroyed by the earthquakes of 1881 and 1883, was subsequently rebuilt and remained in operation until the 70' of the last century (fig.5).



Figure 5- Casamicciola seen from the sea. At the lower left is the abandoned edifice of the Pio Monte della Misericordia re-built after the 1883 earthquake

The frequent earthquakes on Ischia, such as those of 1796, 1828, 1881, 1883, caused numerous victims and destruction of buildings especially at Casamicciola. After the 1828 earthquake, the public restoration and works paid by the King of Naples permitted a fast recovery of the island with the building of new roads, the connection of a telegraphic line and the opening of a new port. Such works permitted a flourishing of the island, and of the balneotherapy also during the following period under the kingdom of Italy. During this period Ischia became a renown international resort and it is not a case that, among the 2333 casualties caused by the 28 July 1883 earthquake, 625 were foreigners (Placanica, 1998). In such a sense, the 1883 earthquake was the first “international catastrophe” affecting a wide number of different nationalities such as that, more than a century later, of the Sumatra earthquake and tsunami of 2004.

The temporary decline of Ischia thermal baths due to the earthquake led to a rapid revival of Campi Flegrei, favored also by the construction of a new urban railway line connecting Naples to Pozzuoli (Cumana line). The thermal baths flourished especially in the area of Bagnoli, with the realization of numerous resorts (fig.6) and the building of the new settlement of Bagnoli.



Figure 6 – One of the thermal baths built at Bagnoli in the late 1800{

Unfortunately, the building of a new factory (Armstrong) of naval Artillery at Pozzuoli in 1886 and a steel factory at Bagnoli in 1910, caused the progressive decline of the Campi Flegrei thermal baths (Di Bonito, Giamminelli, 1992).

It would be desirable that, after the decline of such industrial activities, the Spa activities may flourish again in this area.

#### 4- Conclusions

Earthquakes and eruptions have affected in different periods the area of Campi Flegrei and Ischia. The temporal shift of the activity in the two areas caused that when one area flourished the other declined and vice-versa. Although such natural phenomena have been known, since at least three

thousand years, people have always resettled after the eruptions and earthquakes, rebuilding their homes and the activity related with the natural resources.

In more recent times different dynamics related with the uncontrolled expansion of urban settlements have completely altered the delicate balance between environment and man, and even the recent seismic and deformation crises of Campi Flegrei (Luongo et al, 1985) have not prevented the continuous expansion of the city of Naples within the area at highest risk (Alberico et al, 2002). In the island of Ischia, even a moderate earthquake of magnitude 4.0, such as that occurred on 30 August, 2017 (Bollettino INGV-OV, Agosto 2017), has caused extensive damage at Casamicciola in the same places as the ones of 1881 and 1883.

The city of Naples is nowadays a large metropolitan conglomerate of more than three millions people that comprise the areas of Campi Flegrei and Vesuvius with Ischia as its summer resort. The knowledge of the seismic and volcanic phenomena gained in the area during the last millennia, and the detailed scientific studies of the last century seem unable to stop or at least drive the growth of a metropolitan settlement toward more secure places. Such a growth has become particularly relevant during the last 70 years when all the three volcanoes became dormant and will result in a sudden economic collapse when one of the three will reawake.

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