Furtei gold deposit
and thermal waters at Sardara

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Abstract. Furtei and Sardara areas are located in the Campidano Graben, a tectonic structure which extends for about 100 km in the NW-SE direction from the Gulf of Oristano to the Gulf of Cagliari. At Furtei, an Au-Cu-Ag high-sulfidation deposit is associated to the Oligo-Miocene calcalkaline volcanic cycle. During the visit to the mine, the hydrothermal alteration zonation and the different styles of mineralization are shown. Sardara springs represent the main thermal occurrence of the Campidano geothermal system whose emerging points are located along the borders of the graben. The main characteristics of the Sardinia thermal occurrences are also illustrated.

Riassunto. Le aree di Furtei e Sardara sono situate nel graben del Campidano, struttura tettonica che si estende dal Golfo di Oristano al Golfo di Cagliari per circa 100 km con direzione NW-SE. A Furtei un deposito Au-Cu-Ag «high-sulfidation» è associato al ciclo vulcanico calcoalcalino oligomiocenico: durante la visita nella miniera sono illustrati la zonazione di alterazione idrotermale e i diversi stili di mineralizzazione. Le acque di Sardara rappresentano invece la manifestazione più importante del sistema termale del Campidano; le principali caratteristiche delle aree termali della Sardegna sono anche descritte.

1. FURTEI VISIT

Introduction

Epithermal precious metal deposits are an important class of hydrothermal deposits. In Europe, the most significant epithermal gold-silver mineralizations are hosted in Oligocene-Miocene volcanics that formed in a convergent margin setting. The epithermal metal deposits of Sardinia associated with the Tertiary calcalkaline volcanic cycle were discovered in the late 1980s [1,2].

The volcanic products crop out along a 200 km long NS trending rift structure in western Sardinia [3]. The most relevant area for precious metal mineralization in Sardinia is the Au-Cu-Ag high-sulfidation deposit currently being mined at Furtei [4].
General information

During the first exploration campaign at Furtei (1988-1993), the joint venture partners Progemisa and SIM discovered the mineralized bodies of Monte Santu Miali, Is Concas and Sa Perrima. In 1994 a new joint venture between Progemisa and Gold Mines of Sardinia was formed. Subsequent exploration programs concentrated on targets around the main orebodies and expanding the mine resource of the area. Since the beginning of mine activity in mid 1997, Furtei has produced nearly 29,000 oz per year. The published resource is 6.2 Mt at 2.7 gold grade (g/t) [5].

Geology

The high-sulfidation gold mineralization is hosted in a Oligocene-Miocene volcano-sedimentary sequence, which unconformably overlies metasandstones, metapelites and quartzites of the Paleozoic basement and a late Eocene sedimentary unit (figure 1).

The Oligocene-Miocene volcanic complex, from the oldest unit to the youngest comprises:
- *horneblende porphyry andesite domes*;
- the lower *volcanoclastic unit*; it consists of siltstone, sandstone, conglomerate and ash deposits. The upper part of this unit (Upper Volcanoclastics in figure 1) crops out at Coronas Arrubias;
- *diatreme breccia* which hosts the main Au-Cu ore bodies. The breccia is polygenic and heterometric and contains clasts and fragments of andesite and volcanoclastic unit formations and Paleozoic basement;
- the *tuff apron breccia* contains andesitic blocks and ash deposit overlie by ignimbrite. It represents the ring surrounding the diatreme.

The Furtei volcanic complex is partially overlain by marine Miocene sedimentary deposits and a Pliocene-Pleistocene sequence of conglomerate, sandstone and marlstone.

The hydrothermal activity is bracketed in the narrow time span between the eruption of Upper Oligocene volcanic products, that host the mineralization, and the deposition of the Lower Miocene sandy marls that are unaffected by hydrothermal alteration [5,6]

Precious metal mineralization

Hydrothermal circulation affects the volcano-sedimentary sequence over an area of 10 km². The hydrothermal alteration zonation shows that control on alteration and mineralization are both structural and lithological.

Five main styles of mineralization have been recognized so far [5,6,7] (summarized in figure 2).
- *Enargite-gold zone*: closely associated with the diatreme structure, where the most conspicuous mineralization is comprised of the Monte Santu Miali and Is Concas zones (figure 2). The main path of mineralizing fluids seems to be related to the intersection between the vuggy silica body along the andesite-diatreme breccia contact and NS
trending structures. There is a vertical zonation. Typical sulfide assemblage at higher elevation consists of pyrite-enargite ± luzonite ± native gold; at depth tennantite and
tetrahedrite occur accompanied by a variety of tellurides [3].

- **Pyrite-gold-sphalerite zone or stratabound ore**: hosted in the volcanoclastic sequence. The best example of this mineralization style is Sa Perrima deposit. This mineralization outcrops along the main north-south structure at Furtei, the «Sa Perrima
fault». The mineralization is structurally and lithologically controlled. The N150° direction is the main trend for Sa Perrima mineralization. The high permeability of the volcanoclastic sequence and the contact with the underlying low permeability andesite formed the typical stratabound mineralization, where micro-fractures in the volcanoclastic sequence are filled by pyrite (up to 10%), lesser sphalerite and galena, and gold.

- **Low sulfidation** mineralization: occurs in quartz veins that crop out in the western area of the Furtei deposit and consists of gold - pyrite - silver ± sphalerite ± galena. The veins are narrow (less than 1 m) and discontinuous.
  - **Barite-gold** mineralization: occurs as overprint of the low sulfidation style quartz vein. A late stage of hydrothermal activity led to the emplacement of barite veinlets carrying gold in the shallow part of the Furtei deposits (i.e. Sa Perrima and Santu Miali) cutting massive and vuggy silica.
  - The **oxidized zone**: most of the primary sulfide of the enargite-gold mineralization has been destroyed by weathering, and gold is encapsulated in jarosite and arsenates associated with Fe-oxides and hydroxides.

The following temporal sequence for mineralized events has been established by crosscutting relationships [5,6,7].

- **Pyrite-sphalerite-gold (stratabound)** mineralization surrounds the diatreme breccia, and formed before the diatreme. Petrographic studies indicate that the enargite-gold mineralization in vuggy silica crosscuts the stratabound mineralization. The low sulfidation mineralization vein deposits occur peripheral to the enargite-pyrite style of mineralization.
  - The **quartz-barite** mineralization is interpreted as a late stage of hydrothermal activity, and overprints both stratabound and low sulfidation styles.

**Oxide mineralization** is the recent supergene event [2,4].

### Hydrothermal alteration

Distinctive hydrothermal alteration assemblages are associated with each mineralization style, reflecting the chemical-physical changes of the hydrothermal fluids with time in the volcanic field (figure 3 and figure 4). Seven hydrothermal mineral assemblages have been recognized at Furtei [6,7,8].

- **Silicified rock and silica bodies.** In the mineralized area silification consists of massive (replacement) silica and vuggy (residual) silica bodies. Massive silica usually replaces epiclastic-pyroclastic unit and the matrix of the diatreme breccia. Vuggy silica is developed in and around the diatreme breccia and is characterized by voids in the silica groundmass originated by dissolution processes. Sulfides commonly fill the voids, forming the enargite-gold mineralization.
  - **Quartz-dickite-pyrite ± alunite** assemblage is commonly found as an envelope to the vuggy silica alteration which is hosted in the diatreme breccia at Santu Miali and Is Concas. This assemblage indicates an acid environment with temperature between 150°C and 230°C [8,9]. This range of temperature is also confirmed by measurement on fluid
Figure 3: SW-NE vertical section of Sa Perrima (Sardinia Gold Mining S.p.A., all rights reserved).
Figure 4. SW-NE vertical section of Santu Miali (Sardinia Gold Mining S.p.A., all rights reserved).
inclusions hosted in quartz. Alunite occurs in the proximity of mineralized structures.

- **Quartz-pyrophyllite ± anhydrite ± illite** alteration indicates a deep circulation of acid fluids with temperatures ranging from 240° to 320°C. At Furtei this assemblage occurs at depth at Santu Miali, at Amigu Furonì and at the Su Nuncu De Sa Fronti areas.

- **Kaolinite-pyrite-dickite**-association is very common at Furtei. It commonly occurs in the shallow parts of the mineralized conduits or as an envelope to the quartz-dickite-pyrite ± alunite assemblage. It also forms the alteration products of the volcanioclastic unit at Sa Perrima, Coronas Arrubias and Monte Porceddu kaolin deposit area.

- **Carbonate-smectite-pyrite ± chlorite** alteration indicates temperatures lower than 140°C and a slightly acid pH. It formed by progressive neutralization of fluids moving away from the mineralized channels. It occurs as a cap to the stratabound mineralization and as pervasive alteration in most of the andesites. It pre-dates the acid mineral assemblages.

- A neutral pH style assemblage consists of illite-pyrite-quartz. It is related to low sulfidation quartz veins of Amigu Furonì, Bruncu de Didus and Su Nuncu De Sa Fronti. This assemblage indicates temperature higher than 230°C [8]. At Amigu Furonì and Bruncu de Didus, the occurrence of silica replacing platy calcite suggests that boiling process was involved for gold deposition.

- The supergene alteration consists of Fe-oxides and hydroxides-jarosite-gypsum-kaolinite-rare natroalunite. It occurs in fractures, overprinting the enargite-gold mineralization and the stratabound mineralization. It does not appear to extend more than 60 m below the current surface.

**Environment of formation**

The epithermal gold deposit of Furtei formed at less than 500 m below the paleo-surface in a temperature range between 100°C and 320°C [8,9,10]. The evolution of the system occurred in different stages.

- Pervasive alteration of the host rock (forming the carbonate - smectite - pyrite ± chlorite association).

- Acid fluids that separated at depth generated a vapor plume, which interacted with shallow water, probably of meteoric origin. This produced intense leaching (dissolution processes), due to vapor-dominated phase, and originated vuggy silica and deposited massive silica bodies [6,10].

- The main ore deposition event derived from reduced, acid, liquid-dominated fluids rising from depth. The ore minerals occur in cavities and fractures, suggesting that the mineral deposition was not pervasive, but focused in the most interconnected channelways. The sulfide vertical zonation in the enargite-gold mineralization (with pyrite-enargite ± luzonite ± native gold at higher elevation and tennantite-tetrahedrite-tellurides at depth) suggests an increase in oxidation state with elevation during ore deposition, probably due to the interaction with meteoric water [11,12]. The kaolinite-dickite-pyrite alteration within the volcanioclastics probably represents the alteration products from less acid
fluids than those responsible for the later vuggy silica alteration. Perhaps, the early pulses of the mineralizing fluids which percolated through the permeable horizons of the volcanoclastic units were partially neutralized by a combination of wall rock interaction and mixing with connate water producing the pyrite-sphalerite-gold mineralization.

- The low sulfidation mineralization and alteration in the south-west part of Furtei suggests circulation of neutral pH water at temperature higher than 220°C. The presence of platy calcite (replaced by silica) suggests that boiling of the mineralizing fluid occurred. This style of mineralization is common in the distal areas from the main upflow in high sulfidation epithermal systems [5, 9, 10].

- The late barite-gold mineralization assemblage indicates a mixing of low temperature highly oxidized surface derived water that penetrates in depth. Usually this mineral assemblage forms at or above the water table level, and it occurs at Furtei in the shallow parts of both low and high sulfidation style deposits [10].

- The oxide alteration forms in response to exposure of the ore to recent weathering and development of intense surficial supergene alteration. It overprints the primary mineral assemblage.

2. THERMAL WATERS AT SARDARA

Introduction

In Sardinia no high-temperature geothermal fields occur, however many springs show anomalous temperatures up to 76°C. The emerging points of thermal waters are located close to important regional faults, including the Plio-Quaternary Campidano graben, where thermal waters flow out close to the fracture systems at eastern and western margins.

Since the 1970s an extensive research was carried out in order to evaluate the geothermal potential of the island. The Italian National Research Council and later the European Union supported these studies.

Geology

The island is characterised by two main geological domains: the Paleozoic crystalline basement that crops out mainly in the eastern and south-western part of the island, and the Tertiary volcano-sedimentary complex (figure 5).

The basement is made up of metamorphic rocks and of the Carboniferous granitic batholith. The basement is dismembered in several blocks, mainly faulted by NE-SW and NW-SE fault systems of late Hercynian tectonic phases reactivated by Alpine tectonics. These blocks represent the structural heights of the Oligo-Miocene Sardinian rift, that roughly divides the island in two parts from the Asinara Gulf at the north to the Cagliari Gulf at the south. The rift is filled by Miocene marine sediments and Oligo-Miocene andesitic and ignimbritic volcanic products. The Plio-Quaternary tectonic dismembered the Oligo-Miocene Sardinian rift, originating the Campidano graben in the southern part
Figure 5. Schematic geologic map of Sardinia with location of the main geothermal areas. 1) Paleozoic basement; 2) Cambrian carbonates; 3) Mesozoic carbonates; 4) Tertiary volcanosedimentary complex; 5) Main Quaternary volcanos; 6) Main faults; from [13] modified.
of the rift. In figure 5 a schematic geologic map of Sardinia with the location of main geothermal areas is reported [13, modified].

The Campidano graben extends approximately 1500 km². Deep wells, drilled for oil exploration, showed that the graben is filled by continental Plio-Pleistocene sediments (over 800 m thick); these deposits cover an Oligo-Miocene volcanic-sedimentary series (1500 m thick). Eocene conglomeratic sandstones and clays occur at the base and probably lie on the Paleozoic basement. The NW-SE trending fracture system, which bounds the eastern and western margins of Campidano, derived from Oligocene and Hercynian features. The volcanism at the boundaries of the graben consists of Oligo-Miocene products from rhyolite to andesite and successively Pliocene basalts (M. Arci and M. Ferru). In figure 6 a schematic geologic map [14] of the Campidano graben with the location of main thermal springs is reported.

Based on the geological and geophysical results, in the Campidano graben the depth of the Paleozoic basement has been estimated between 2000 and 5000 m [15]. The same authors show that the Campidano graben is subdivided at depth into three main basins (from the north to the south: the basin of Oristano, S. Gavino and Cagliari), which are separated by saddles or structural highs. Between the S. Gavino and the Cagliari basin there is a further axial division in two parallel sub-basins: the S’Acquacotta basin and the Serramanna-Serrenti basin (figure 7). The former is the southern extension of the S.Gavino basin, that deepens eastwards and reaches a maximum depth at the foot of the thermal spring of Sardara, while the latter includes the Su Campu area and seems to be linked with the Cagliari basin.

The thermal area of S. Maria Is Acquas is located near Sardara along the eastern border of the Campidano graben at the bottom of the Monreale hill. This area includes five springs emerging in a little valley having a NW-SE direction. The valley was formed by the dismembering of the schistose Monreale hill in four blocks. In fact, geophysical investigation pointed out a tectonic discontinuity, with W-E direction, that crosses the eastern master fault of the Campidano graben [16].

The Paleozoic schistose basement of the Monreale hill is in contact with Tertiary quartzose sandstones and conglomerates [16]. A marine transgressive sequence composed of sandstone intercalated with yellow-grey marls and andesitic products (Oligo-Miocene) is also present. Towards the Campidano plain, a Pliocene continental sedimentary formation crops out. Close to the thermal springs, Quaternary travertine deposits were recognised, sometimes at higher elevation than the present day springs, probably indicating a different location of emerging points in the past.

**Main thermal areas in Sardinia**

The main thermal areas in Sardinia are:

- The Anglona district (northern Sardinia)
- Logudoro (northern Sardinia)
- The Tirso Valley (central-northern Sardinia)
Figure 6. Schematic geologic map of the Campidano graben with location of thermal springs.  
1) Quaternary deposits; 2) Pliocene continental deposits (Samassi Formation); 3) Pliocene basalts; 4) Miocene sediments; 5) Oligo-Miocene volcanic products; 6) Eocene sediments (Cixerri Formation); 7) Paleozoic basement; 8) Thermal waters; 9) Main rivers; 10) Main faults; (from [14], modified).
All these systems are water-dominated and have a low-medium temperature. Among them, the main difference is the presence or absence of deep-origin CO₂ with important consequences in the water-rock interaction processes. Groundwater evolution of the Anglona, Tirso Valley and Campidano systems takes place prevalently in the Paleozoic crystalline basement which appears relatively homogeneous and vertically continuous, and deeply faulted.

**Anglona district**

The northern part of the Sardinian geothermal system is the thermal area of Casteldoria. The thermal water emerges at the tectonic contact between the Sardinian rift and the Paleozoic granitic basement.

Water has a temperature of 76°C, near neutral pH, salinity about 5 g/l, a prevalent sodium-chloride composition, with a subordinate calcium component.

The hydrogeological context, isotopic data [17], and the high content of minor elements (Li, Rb, Cs and B, while F is controlled by equilibrium with fluorite) indicate a deep circulation in the granitic basement [18]. Chemistry of the Casteldoria thermal water is the result of mixing process with seawater (11%) and a subsequent interaction...
with hot rocks at depth [17]. Another proposed evolutive scheme [18], without ruling out the hypothesis of mixing with seawater, derives the final chemical composition of Casteldoria deep waters from hydrolysis reactions of aluminosilicates.

Different deep temperatures were calculated: 107°C [19], a value ranging between 104 and 139°C [14] and 120°C [20].

**Logudoro district**

In the Logudoro area (northern Sardinia) several cold or slightly warm springs occur (20-24°C) with high $P_{CO_2}$ values. The main springs are S.Martino and Abbarghente. Waters have Na(Ca)-HCO$_3$ or Na-HCO$_3$ chemical composition, and salinity up to 5.0 g/l with high contents of Li, Rb and B, and F content controlled by fluorite; the pH is close to the neutrality, or slightly acidic (6.3-6.4). Calculated deep temperature ranges between 50 and 70°C. The most recent study [22] pointed out that groundwater circulation likely occurs in the Oligo-Miocene volcanics, where a CO$_2$ inflow takes place at depth.

**Tirso Valley system**

All thermal waters (Benetutti, Oddini and Fordongianus) emerging in the Tirso Valley derive from the same circuit. In fact, the waters show the same characteristics: sodium-chloride composition, low salinity (<1 g/l), low level of calcium and alkalinity, very low content of Mg and a high pH [21]. The low carbonate level in the thermal waters of the Tirso Valley can be referred to the absence of any deep-origin CO$_2$ flux and carbonate deposit in this area. These features indicate infiltration of meteoric waters into the Paleozoic basement, a deep circulation in the granitic complex and a rapid emergence. A deep temperature ranging between 60 and 80°C has been estimated [21], while recent calculated temperatures are close to 100°C [20].

**Sulcis district and Maladroxia water**

This thermal area is located in south-western Sardinia where about 15 thermal springs are located in the Sulcis area, in the Cixerri graben, and in the S.Antioco island. One of these waters is located inside a coal mine (Nuraxi Figus) and another one (Maladroxia) is close to a tectonic fracture in the coast line in the S. Antioco island. The other thermal springs have their emergence at tectonic contacts between Cambrian carbonate formations and Tertiary sedimentary deposits.

Water temperatures are low (21 to 30°C), except at Nuraxi Figus and Maladroxia (about 40°C). The main characteristics of these waters are: near neutral pH, TDS ranging between 0.3 and 1.3 g/l, with an earth-alkaline carbonate composition. Water circulation takes place in the Cambrian carbonate rocks at greater depth than the corresponding cold water of the area [23].

The warmest waters of Maladroxia (mixed with seawater) and Nuraxi Figus differ from the other springs; in fact they present a prevalent sodium-chloride composition, with salinities of 36 and 1.6 g/l, respectively.
Campidano district

The main thermal waters of the Campidano area (S. Maria Is Acquas near Sardara, S’Acquacotta near Villasor, Su Concali near Uta, and Podere Montaldo near Capoterra) emerge along the graben borders. They show temperatures up to 60°C, sodium-bicarbonate(chloride) chemical composition, near neutral pH and salinity up to 3.3 g/l. These waters are characterised by the presence of CO₂ and N₂ as free gases [24].

On the other hand, a new hydrothermal occurrence in the Campidano system, the Su Campu borehole near Monastir (43°C), shows sodium(calcium)-chloride chemical composition, alkaline pH (8.6) and salinity of 4.5 g/l, similar to the Casteldoria thermal water in the Anglona district (northern Sardinia). The Su Campu occurrence is characterised by the only presence of N₂ as free gas [25, 26].

The Na–HCO₃(Cl) waters of the Campidano graben generally show very low content of Ca (< 3 meq/l) and Mg (< 2 meq/l). Table 1 reports the main physical-chemical parameters of the thermal waters of Campidano area [25]. Based on isotopic data (δD and δ¹⁸O) of cold and thermal waters of the Campidano area, a meteoric origin for all waters was established with an elevation of the recharge area ranging between 300 and 600 m a.s.l. [27]. At these elevations, the tectonic contact between the Paleozoic basement and the Tertiary and/or Quaternary sedimentary formations occurs. Recharge waters deepen into the Paleozoic basement, that constitutes the deep reservoir where CO₂ of deep origin is added to the system. The thermal waters rise along the eastern and western border faults.

The Na(Ca)-Cl water at Su Campu origins in a Campidano sub-system, closed to the deep-origin CO₂, probably because of particular deep structural conditions. After infiltration and deepening into the Paleozoic basement and the acquisition of the baseline geochemical characteristics, this water rises along the Campidano eastern border fault and interacts with Oligo-Miocene volcanics and with Miocene clayey marly formations [25, 26].

A deep temperature ranging between 100 and 120°C at Sardara was estimated [19], while temperatures between 90 and 110°C at S’Acquacotta and Sardara, and 100°C at Su Campu were recently calculated [20].

In figure 8 the Na/Cl (molar ratio) vs. salinity (mg/l) is reported. This plot shows: 1) a low Na/Cl ratio (< 0.6) in the high salinity thermal waters of Su Campu and Casteldoria, which are systems closed to the CO₂ inflow at depth, and characterised by a strong increase in Ca content; the solubility calculations show that Ca and Na concentrations of these waters are controlled by prehnite-albite and laumontite-albite equilibria, respectively; 2) a higher Na/Cl ratio (1.39 to 2.26) in the Na–HCO₃(Cl) waters, as a consequence of the important contribution to the salinity of the HCO₃⁻ concentration following the addition of CO₂; in these waters, Na is controlled by the albite solubility [25].

At Sardara the warmest and most saline water (spring n. 3) appears in equilibrium with respect to calcite, fluorite and chalcedony, slightly oversaturated with respect to quartz,
Table 1. Physical-chemical composition of the Campidano thermal waters (data from [25]).

<table>
<thead>
<tr>
<th>Samples</th>
<th>Location</th>
<th>T °C</th>
<th>Sal. mg/l</th>
<th>pH</th>
<th>Free gases</th>
<th>Aquifer(1)</th>
<th>Na</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>HCO₃⁻</th>
<th>Cl</th>
<th>SO₄²⁻</th>
<th>Si</th>
<th>F</th>
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<tbody>
<tr>
<td>Sardara</td>
<td>Eastern border</td>
<td>55</td>
<td>3328</td>
<td>7.20</td>
<td>CO₂+N₂</td>
<td>Gr (+Sch)</td>
<td>870</td>
<td>41</td>
<td>27</td>
<td>6.7</td>
<td>1746</td>
<td>512</td>
<td>77</td>
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<td>1908</td>
<td>6.79</td>
<td>CO₂+N₂</td>
<td>Gr (+Sch)</td>
<td>517</td>
<td>21</td>
<td>34</td>
<td>13</td>
<td>908</td>
<td>322</td>
<td>50</td>
<td>19</td>
<td>7.9</td>
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<td>Western border</td>
<td>24</td>
<td>929</td>
<td>7.15</td>
<td>–</td>
<td>Gr (+Sch)</td>
<td>174</td>
<td>7.4</td>
<td>60</td>
<td>29</td>
<td>401</td>
<td>193</td>
<td>40</td>
<td>12</td>
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<td>Western border</td>
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<td>1528</td>
<td>7.00</td>
<td>–</td>
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<td>8.64</td>
<td>N₂</td>
<td>Gr (+Sch+ And)</td>
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<td>631</td>
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<td>17</td>
<td>2540</td>
<td>287</td>
<td>14</td>
<td>3.6</td>
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</table>

(1) Gr = granite rocks; Sch = schistose rocks; And = andesite rocks.
and undersaturated with respect to trona (Na$_2$CO$_3$·NaHCO$_3$·2H$_2$O). In spite of undersaturation with respect to trona this mineral was recognised around the springs [28]. Trona is a non marine evaporite mineral, typical of alkaline environments; it is a common constituent of efflorescent crusts, forming in playa and other areas by capillary evaporation.

Figure 8. Na/Cl (molar ratio) vs. Salinity (from [25], modified). Thermal waters: CO= Su Concali; PM= Podere Montaldo; AQ= Acquacotta; SA= Sardara; SC= Su Campu; and CA= Casteldoria.

Figure 9. Scheme of surficial circulation. 1) Alluvia; 2) Altered and argillaceous schists; 3) Schists (from [16], modified).
Table 2. Minor and trace elements in the Campidano thermal waters (data from [25]).

<table>
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<th>Samples</th>
<th>Location</th>
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<th>B</th>
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<th>Mo</th>
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<th>Be</th>
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<td>229</td>
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<td>Pod. Montaldo</td>
<td>Western border</td>
<td>459</td>
<td>88</td>
<td>12</td>
<td>0.07</td>
<td>479</td>
<td>8.7</td>
<td>6.5</td>
<td>42</td>
<td>6.7</td>
<td>738</td>
<td>262</td>
<td>52</td>
</tr>
<tr>
<td>Su Campu</td>
<td>Central-eastern graben</td>
<td>233</td>
<td>18</td>
<td>3.5</td>
<td>&lt; 0.03</td>
<td>3431</td>
<td>7.5</td>
<td>54</td>
<td>631</td>
<td>0.4</td>
<td>17</td>
<td>2540</td>
<td>287</td>
</tr>
</tbody>
</table>
The same mechanism of capillary evaporation could operate in forming trona deposit at Sardara.

Some minor and trace elements of the Campidano thermal waters are reported in Table 2 [25]. At Sardara, on the basis of the contents of the minor elements, the deep component of thermal waters in springs has been computed to be more than 80% [16]. In fact, geophysical investigations by electric methods identified a subvertical rising (figure 9) of the thermal water along a belt of about 50 meters close to the warmest springs [16]. The springs having a lower temperature are derived from a mixing of thermal and cold waters of the area.

STOPs DESCRIPTION

Stop 1 Sardinia Gold Mining office, Furtei.
Overview of exploration, project description and Au-Cu-Ag epithermal mineralization.

Stop 2 Santu Miali Cima.
Overview of the Diatreme Breccia deposit. Both structural and lithological control of the mineralizing fluids can be observed. The enargite - gold mineralization and the oxide mineralization styles are well exposed in this area.

Stop 3 Sa Perrima area where the sphalerite - pyrite - gold (stratabound) mineralization crops out. View of Furtei Plant side.

Stop 4 Emerging thermal waters at Sardara.
The thermal area of S. Maria Is Acquas, located near Sardara, includes five springs with temperature ranging from 33 to 60°C, with a sodium-bicarbonate(chloride) chemical composition, and a total flow of 11 l/s. At present only one spring, tapped in the Roman period, is easily visible. In fact, the waters of the others springs are tapped by wells and utilised in two modern spas.

ACKNOWLEDGEMENTS
The authors would like to acknowledge the support and availability of SGM staff at the Furtei mine site for making the visit possible.

We would also like to thank the Comune di Sardara, the Società Termale Millepini and the Idroterme Sardara for their assistance.

REFERENCES


