Environmental problems and industrial archaeology in the Iglesiente mining district

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Abstract. This field trip in the Iglesiente district led the WRI-10 participants to visit the vestiges of an intensive, past mining exploitation. The dismantled mine of Monteponi, near Iglesias, was one of the largest mines for the extraction of Pb and Zn in Italy. At Monteponi Pb and Zn ores in Lower Cambrian limestone-dolomites were exploited at increasing depths over time. Here, a dewatering system was in operation down to –200 m. The first stop at the abandoned mining complex of Monteponi included (i) a visit to the Villamarina gallery that encounters, along its course, the shafts «V. Emanuele» and «Sella», (ii) a visit to the compressor room that represented the lifeblood of the mine, and finally (iii) a visit to the hill of «Red Muds», derived from electrolytic treatment of zinc ore, marking the landscape around Monteponi. The trip continued up to the mining village of Nebida. Along the main road to Nebida the red-violet continental conglomerate («Puddinga»), in angular unconformity (Ordovician unconformity) on the Cambrian slates, was observed. The last stop concerned the ingenious underground ore transportation and storage system at Porto Flavia.

Riassunto. Questo «field trip» nell’Iglesiente ha portato i congressisti del WRI-10 a visitare le vestigia di un’intensa trascorsa attività estrattiva. Vicino ad Iglesias si trova la miniera dismessa di Monteponi, che ha rappresentato, per l’Italia, una delle miniere più importanti per l’estrazione di Pb e Zn. I corpi minerari, localizzati prevalentemente nei calcari cambrici, sono stati sfruttati a profondità via via crescenti. Qui un impianto di eduzione era operativo ad una profondità di 200 m. Il primo stop nel complesso minerario abbandonato di Monteponi ha incluso (i) una visita alla galleria Villamarina che intercetta, lungo il suo tracciato, i pozzi «V. Emanuele» e «Sella», (ii) una visita alla sala compressori, che rappresentava il cuore di tutta la miniera, ed infine (iii) una visita alla «collina dei Fanghi Rossi», residui dell’impianto elettrolitico dello zinco, che contraddistinguono il paesaggio attorno a Monteponi. L’escursione è proseguita sino al villaggio minerario di Nebida. Lungo la strada principale per Nebida è possibile osservare un conglomerato rosso violaceo (la Puddinga ordoviciana) che giace in discordanza angolare sugli scisti cambrici. L’ultimo stop ha riguardato l’ingegnoso sistema sotterraneo per il trasporto ed il carico dei minerali di Porto Flavia.

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INTRODUCTION

Sardinia has been for centuries the most important mining region of Italy, from the first Nuragic excavations, to the exploitation in Punic and Roman times and medioeval times, under the Pisans, up to recent days. A large variety of metalliferous and industrial minerals were mined, but the most important activity was devoted to exploitation of Pb-Ag-Zn (Ba-F) ores. Such a protracted activity affected the history, economy and culture of the island in a very important way.

In the last decades, there was a marked decline of Sardinian mining activities, especially in the metalliferous sector, largely as a consequence of the competition of mines in other countries. Nowadays, following the example of other European countries, the plans for a revaluation and reconversion of the historical, industrial, naturalistic and human heritage are in progress in different areas of Sardinia, where mining exploitation had been the prominent economic resource for many centuries. The Iglesiente district, one of the most significant abandoned mining areas in Sardinia, is now part of a valuable cultural heritage recognised by UNESCO in the Environmental and Mining Historical Geopark of Sardinia.

On the other hand, the past mining activity, besides leaving an extraordinary heritage of industrial archaeology, produced about radical territorial transformations. Some of these changes, such as excavations and dumps, are quite evident in the landscape; others, such as pollution of the water system, are less noticeable.

The impact of the contamination from abandoned mines in Sardinia is enhanced by the environmental peculiarity of the region: a semi-arid climate with rare, but sometimes heavy rain events, long periods of drought and heat; scarcity of vegetable cover and limited groundwater resources. Large and numerous water reservoirs to collect runoff were built to meet the water demand in Sardinia, but without enough attention to quality. This environmental scenery implies, on the one hand, an easy development of the weathering processes responsible for mobilization of contaminants, and on the other hand a degradation of the scarce soil and water resources.

GEOLOGICAL SETTING OF THE IGLESIENTE AREA

The Iglesiente district, in south-western Sardinia, is known worldwide because it has been for centuries an important mining area for Pb and Zn. Most of the lead-zinc ores are hosted in Cambrian carbonate formations (Gonnesa Group), and to a minor extent in Ordovician sediments.

The Cambrian-Lower Ordovician sequence, from bottom to top, has been subdivided into three main lithological units [1]:

- Nebida Group (Lower Cambrian) includes mainly terrigenous material with trilobite, and carbonate intercalations increasing toward the top. Because it is practically impermeable, this formation constitutes the structural bed of the aquifer.
• Gonnesea Group (Lower Cambrian) is exclusively composed of carbonate sediments, mainly dolostones at the base and limestones at the top. The carbonate formation of Gonnesea Group is confined between impermeable beds and forms the only major aquifer in the area [2] due to intense fracturing and karstification. This Group is known with the name of «Metalliferous Ring» because it hosts the most important deposits of Pb, Zn, Ag and Ba (e.g. Monteponi, San Giovanni, Barega).

• Iglesias Group (Middle Cambrian-Lower Ordovician) made up of nodular marly limestone (Campo Pisano Fm.), rich in fossiliferous layers containing trilobites, echinoderms and brachiopods, and slates (Cabitza Fm.) almost impermeable. Both these formations record the deepening of the sedimentary basin. A few calcareous beds or small lenses also occur in this formation.

During Ordovician, the Cambrian succession was weakly folded and faulted by the Caledonian orogeny («Fase Sarda») characterised by E-W trending lineations. The deformational activity was followed by uplift and erosion, and finally by transgression of the Ordovician sequence. Erosion and deposition in angular unconformity of the so-called «Puddinga», a polygenic unsorted conglomerate with a red-violet silty-shale matrix, followed this phase. The Puddinga is overlain by richly fossiliferous marine slates, lasting until Late Ordovician-Silurian time, and limestone lenses containing Orthoceras of Silurian age [3].

All these sediments were involved in the Hercynian orogeny, which produced at least two compressional phases and one extensional phase of deformation [4], followed by the emplacement of the granitic batholith. Interference of these thrusts and associated folds with older E-W trending folds of Caledonian age produced a very complex structure.

The Hercynian tectonics and magmatism were followed by a long continental period. The first sediments correspond to the upper Carboniferous lacustrine deposits (San Giorgio basin) [5, 6], and lie unconformably on formations deformed by Hercynian orogeny. This continental phase, which persisted until the beginning of the Mesozoic age, led to the more or less evident peneplanation of extensive areas, and to the intensive karstification of the Cambrian limestone [5, 7, 8].

Mesozoic sediments are rare, whereas the coal deposits (Eocene), the arenaceous sediments of the Cixerri Formation (Oligocene) [9], and volcanic rocks of Tertiary age are fairly widespread. Quaternary sediments are limited.

Notes on ore deposits

The ore deposits of the Iglesiente district exhibit various compositional and genetic aspects, resulting from different depositional and diagenetic environments, as well as from remobilization processes, and can be subdivided into two main categories: pre-Hercynian (stratabound or stratiform), and late- to post-Hercynian (skarn, vein and paleokarst fillings) deposits. Economically, the pre-Hercynian deposits have been the most important, for their high tonnages and remarkable grades of Pb, Zn and Ba, and also for the presence of Ag, Cu, Sb and Hg [10].
The most important deposits have been exploited by some 40 mines spread out over about 150 km², an area known as the «Metalliferous Ring» (fig. 1; [11]). They consist of massive sedimentary exhalative sulphides (SEDEX) hosted in slaty dolomites in the lower part of the Cambrian sequence, and lower-grade sulphide concentrations (Mississippi Valley Type – MVT) hosted in the uppermost part of the Cambrian carbonate sequence [12]. Massive sulphide bodies and stratabound deposits show metal contents variable from area to area. The mineral assemblage mainly consists of sphalerite, galena and pyrite (containing up to 1000 ppm As and small chalcopyrite inclusions), and more rarely barite [10].

At the surface, an oxidized mineralization was present. These ores (the so-called «calamine»), mostly consisting of smithsonite, hydrozincite and cerussite, were extensively...
exploited until the 1960s. The environmental changes deriving from this intense open pit mining activity are still evident (e.g. Cungiaus at Monteponi).

**GENERAL FEATURES OF THE MONTEPONI AREA**

The Monteponi mining complex is situated in the Iglesiente district, south-western Sardinia, in the surroundings of the town of Iglesias, about 50 kilometres west of Cagliari. Southern Sardinia shows a semi-arid climate, characterised by rainfall in the range of 400-900 mm/y, with a mean of 50 rainy days, and long periods of dry weather. At the Monteponi meteorological station, the long-term mean rainfall is 800 mm/y, mean annual temperature 17°C, evapotranspiration 57%, and runoff 24% [13].

The main drainage in the area is the Rio San Giorgio, that flows in an E-W direction in the structural valley of Iglesias. The mouth is in the Sa Masa pond, near to the sandy beach of Funtanamare, about 10 km downstream.

Nowadays the Iglesiente district is characterised by deep environmental changes, that are consequence of intensive mining exploitation carried out for centuries.

**Brief historical notes**

Mining activities carried out in the Metalliferous Ring in the Iglesiente area date back to the Phoenician and Carthaginian periods, but the Romans, from the 2nd century B.C., gave rise to the systematic exploitation of surface deposits of Ag-bearing galena. Extraction was performed by means of shafts reaching depths down to 100 metres along the mineral seams. This type of exploitation has been testified in the Monteponi area by the finding of tools, lamps and amphorae dating back to pre-Roman and Roman times.

With the fall of the Roman empire, mining activities declined. However, under the Pisan dominion (XII-XIV centuries) the Monteponi deposits were once again exploited. During the Aragonese rule throughout the XIV century the mining activities rapidly declined. From 1720, under the Savoy rulers, activities started up once again; private concessions were alternated with direct management by the State authorities. The production of galena increased considerably, also due to the introduction of explosives in 1744 (in 1804 the Monteponi mine produced 259 tons of galena). Production at industrial level started in 1850 when extraction activities were authorised by concession to the «Monteponi Company».

In 1868 when the exploitation reached 70 m a.s.l., the natural level of the water table, the problem of dewatering acquired great importance. The dewatering was carried out with adapted pumps, installed in the shafts (Vittorio Emanuele and Sella). At Monteponi, records from 1870 indicate that the water table was lowered from 70 m to 45 m a.s.l. [13, and references therein]. However, because of the existing technical limits, this equipment soon appeared insufficient to allow works to proceed further. The problem was solved through the construction of the «Umberto I» drainage gallery. Works started in 1880 and the gallery, originating in the Sa Masa pond and terminating inside the Monteponi mine,
through a 6 km long drain, was completed in 1910. In 1889, when the gallery had been excavated to a length of about 4 km, a large fracture was intercepted, called the «Gran Sorgente». Large quantities of water drained off into the sea at an estimated rate of 3600 l/s. It was at this point that the aquifer began to slowly empty. When the drainage was in operation the water table settled at 14 m a.s.l.

In the twenty-year period between the two world wars, the metallurgic activities were characterised by the development of the electrolytic zinc plant in Monteponi (1923-1925) and by the contemporaneous enlarging of the zinc oxide factory; furthermore, a chemical plant for the production of sulphuric acid was constructed (1927-1928) to complete the electrolytic plant.

In order to go on in exploitation of the ore deposits, pumping stations were successively installed at increasing depths: in 1928 at –15 m; in 1936 at –60 m; in 1956 at –100 m and in 1990 at –200 m below sea level [2, 14].

At Monteponi, $2.5 \times 10^9$ m$^3$ of water were pumped out from 1890 to 1990 [15]. In the period from 1990 to 1996 the mean flow rate was 1800 l/s. The effects of drainage on the water table extended to a large area westward and southward of Monteponi. Figure 2 shows a schematic profile of the mining area of Monteponi and surroundings [16].

The closure of the mine in 1996 implied the cessation of the expensive pumping system (about 258,000 Euro per month to keep the pits dry): the pumping was gradually reduced starting on January 1997, until it was shut down completely on July of the same year.

**Influence of dewatering and flooding in the Monteponi mine on water quality**

As the water table level was lowered with time, causing the inflow of seawater in the mine, a marked increase in salinity (up to 12 g/l Cl over about 90 years (fig. 3; [11])) and heavy metal concentration (particularly, Hg rose to 60 µg/l [2, 17, 18]) in deep groundwater occurred.
Chloride acts as a complexing agent for some metals, especially Hg and Ag. In particular, the concentration of Hg is linked to the availability of leachable Hg, and to conditions which favour its aqueous transport, such as chloride addition by forming Hg-Cl complexes (fig. 4; [11]).

The Hg-Cl complexes are very stable, allowing mercury transport over several kilometres to the sea, and persist in the tap water supplied to Iglesias after the water treatment used for domestic use. In low salinity, shallow groundwater, mercury dissolution is favoured at alkaline pH by forming Hg-OH complexes [11]. The presence of Hg is not surprising considering that 3522 kilograms of mercury were (at times) recovered as byproduct from the galena processed at Monteponi during the 1906-1918 period [19].

When in 1996 the mining activity was stopped, the rise of deep saline waters, consequent to the mine flooding, prompted the assessment of the contamination risk for shallow groundwater. In fact, water demand in the area exceeds water reserves, and restrictions on the water supply are frequent, especially during the summer. Therefore, mine waters are regarded as an important potential resource. A project for monitoring the water level and some chemical parameters was carried out by the company (former

Figure 3. Lowering of the water table level induced by pumping at Monteponi during the 1900-1995 period. Increasing flow rates at Monteponi over this period and corresponding chloride concentrations are shown (data from the former Miniere Iglesiente S.p.A, [11]).
Miniere Iglesiente S.p.A.) managing the mines. With the progress of flooding at Monteponi, a salinization process has been observed in the surrounding shallow groundwater, due to the rise of the deep saline water and the consequent mixing [11]. The salinization will decrease and be negligible only after a stratification process occurs; stabilisation was expected in a relatively short time, and indeed occurred after three years of flooding. However, the progressive mine flooding is causing an increase of Zn and Cd in waters, mainly due to the weathering of ore minerals, and remobilization of metals in the mine waste accumulated in the pits during the long period of exploitation [11]. The amount of mine wastes present in the flooded galleries is considered to be high, but the exact extent is unknown, especially the quantity and composition of materials related to the ancient mine works and processing, and therefore the time required for flushing is difficult to estimate. Therefore, the leaching of metals represents a long-term (probably several years) hazard for the quality of shallow groundwater.

**STOP 1: THE MONTEPONI MINING COMPLEX**

a) The «Villamarina» gallery

The Villamarina level, excavated at +174 m above sea level, is characterised by two
entrances approximately 70 m apart, one of which is referred to as the «Nursery school» and the other as the «Nuns». These names derive from the fact that, in the vicinity of the entrances to the gallery, there is a Nursery school dedicated to Renzo Sartori. It was built in the 1920’s and could accommodate up to 70 miners’ children. On the other side, there were the premises of the Charity Nuns, who assisted the children in the nursery school and sick people in the nearby mining hospital, built in 1866 to provide care for ailing or wounded miners.

Digging of the Villamarina gallery was commenced in 1852 and along its course the two most important shafts of the Monteponi mine are encountered: the Vittorio Emanuele and the Sella shafts. The mining shafts are mainly represented by cylindrically or rectangular shaped excavations used to house the lifts employed by the miners to reach the deepest areas of the mine; in miners’ slang these lifts are known as «cages» and were used to transport both men and minerals.

The Vittorio Emanuele shaft was excavated in 1863 and, originating from an elevation of 206 metres above sea level, goes down to 100 metres below the sea level. The lift became operational at the beginning of the 1900, and was fed by electricity generated by steam-powered machines, which were later replaced by electric winches. A total of 30 miners or four loaded trucks could be transported at a time.

The «Sella» shaft, dedicated to the politician Quintino Sella, who was largely involved in the promotion of mining activities on a national level, was excavated in 1874 according to a project drawn up by Adolfo Pellegrini, who was at the time Director of the Monteponi mine. This shaft was conceived to house the large steam-powered pumps which were designed and built in Belgium in 1874, and were subsequently situated in the purpose-built premises above the shaft.

b) The compressor room

The building which housed the compressor room was built in 1906 over an already existing construction which had been used to lodge the burners of the steam pump of the Vittorio Emanuele shaft. Initially these premises contained a steam turbine used in the production of electricity necessary for the entire mine. The burners were fed with lignite supplied from a neighbouring mine belonging to the Monteponi Company.

When the Tirso electric plant became operating, and electricity was distributed on a network basis, the Compressor Room was renovated and used as a plant to produce compressed air for the entire mine. The room maintained its original function, housing four compressors (the largest one was an ER8 machine with a capacity of 63,000 litres), three of which operated 24 hours a day in three distinct shifts. The operational pressure of the compressors was 8.5 atmospheres; the compressed air produced was directed into two large tanks situated outside the building, where it was then purified of the condensation formed from oil and water incorporated during the compression process. These tanks were equipped with specific valves for discharging the residual dregs. The fourth compressor was kept as a reserve in the case of accidental breakdown of the other machines, or for use when the
latter ones were being overhauled. The room was equipped to serve as an efficient workshop, where both emergency and routine repairs could be carried out.

A series of iron tubes led out from these tanks and, passing through the Sella and Vittorio Emanuele shafts, reached all sites of activity with a progressively decreasing diameter in order to compensate for the loss of load caused by the distance from the source of production.

The compressed air was mandatory in maintaining life and operations in the mine. The Compressor Room is often compared to the beating heart of the large body represented by the mine itself. All the machinery used in the galleries both to perforate the rock (perforators) and to transport the minerals (loading paddles), the small winches used to lift the heavy equipment, as well as the fans which provided ventilation for the deeper, insalubrious galleries, functioned thanks to the compressed air produced in this large room.

Because of the high management costs of the distribution network and the compressors, these were stopped in the 1980’s. As an alternative, smaller mobile electric compressors were provided; they operated directly in the galleries where compressed air machinery was in use.

c) Red Muds

The «Red Muds» tailings lie in a very sensitive position, at one side of the main road of the district, and are surrounded by other mine byproducts such as lead furnace slags, and waste rocks (fig. 5; [20]).
The «Red Muds» are the metallurgical wastes from an electrolytic plant, which used sulphuric acid, FeSO₄ and MnO₂ in processing oxidized Zn-ores («calamine»), from 1935 to the early 1970’s (fig. 6; [21]).

Figure 6. Diagram of «calamines» processing [21, modified].
The wastes, deposited on an area of 15 ha with a volume of 500,000 m³, are stored in enormous banks, rising up to 30 meters of total height, supported by cane fences on the slopes [22]. Nowadays the spoils show deep cuts due to the erosion by run-off and wind action. In the two largest spoils there are also some tunnels, created by the water flowing between the impervious (schistose) basement and the spoils [22]. These tailings, now under the management and monitoring by Miniere Iglesiente S.p.A. (EMSA-IGEA group), are subject to preservation regulations as an industrial monument.

The «Red Muds» contain iron oxy-hydroxides, associated with zinc amounts in the range of 8-10 wt. %, calcium sulphate, and minor toxic elements, such as cadmium and lead. The physical and chemical features of the tailings, as determined in a study carried out in the framework of the EU-funded project ROLCOSMOS [22], are summarised in tables 1-3.

The potential pollution from the «Red Muds» is extremely high, due to their heavy metal content and very fine grain size, mostly below 40 µm [23]. The runoff, removing and transporting large quantities of fine solids into the Rio S. Giorgio, contaminates the entire Sa Masa marsh downstream. Contini et al. [23] have estimated an annual transfer to the Rio S. Giorgio of 9000 kg of solids, and dissolved contents of 3000 kg Zn, 150 kg Mn, 90 kg Cd, and 20 kg Pb.

Moreover, during the dry season, the winds (most notably, «Sirocco» from SE and

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**Table 1. Main physical features of «Red Muds».

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>15,000 m²</td>
</tr>
<tr>
<td>Volume</td>
<td>500,000 m³</td>
</tr>
<tr>
<td>Tonnage</td>
<td>930,000 t</td>
</tr>
<tr>
<td>Average height</td>
<td>20 m</td>
</tr>
<tr>
<td>Max slope angle</td>
<td>35°</td>
</tr>
<tr>
<td>Average dry density</td>
<td>1.75 g/cm³</td>
</tr>
<tr>
<td>Average Bulk density</td>
<td>1.86 g/cm³</td>
</tr>
<tr>
<td>Angle of internal friction</td>
<td>33° 37'</td>
</tr>
<tr>
<td>Particle density</td>
<td>3.2 g/cm³</td>
</tr>
<tr>
<td>Average permeability</td>
<td>UNI 100014 Class-Group: 8-A4</td>
</tr>
<tr>
<td>Average Moisture</td>
<td>27%</td>
</tr>
<tr>
<td>Cohesion</td>
<td>8.8 Kpa</td>
</tr>
</tbody>
</table>

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**Table 2. Mineralogical composicion of «Red Muds».

<table>
<thead>
<tr>
<th>Mineralogical phases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major</td>
</tr>
<tr>
<td>Smithsonite, Goethite, Gypsum</td>
</tr>
<tr>
<td>Minor</td>
</tr>
<tr>
<td>Hematite, Magnetite, Dolomite, Barite, Hemimorfite, Quartz</td>
</tr>
</tbody>
</table>
Table 3. Chemical composition of «Red Muds».

<table>
<thead>
<tr>
<th>Elements</th>
<th>Solid material range (wt. %)</th>
<th>Pore water* (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb</td>
<td>0.7-0.8</td>
<td>5</td>
</tr>
<tr>
<td>Zn</td>
<td>7.6-9.6</td>
<td>1120</td>
</tr>
<tr>
<td>Cd</td>
<td>0.02-0.03</td>
<td>60</td>
</tr>
<tr>
<td>As</td>
<td>0.01</td>
<td>–</td>
</tr>
<tr>
<td>Hg</td>
<td>0.004-0.009</td>
<td>–</td>
</tr>
<tr>
<td>Fe</td>
<td>46.1-47.8</td>
<td>5.9</td>
</tr>
<tr>
<td>Ba</td>
<td>0.25-0.45</td>
<td>0.09</td>
</tr>
<tr>
<td>Mn</td>
<td>0.46-0.90</td>
<td>56</td>
</tr>
<tr>
<td>S</td>
<td>3.82-4.65</td>
<td>–</td>
</tr>
</tbody>
</table>

* [21].

«Mistral» from NW) cause a transport of dusts from the «Red Muds» to the surrounding areas. In the Iglesias valley, the level of soil contamination is several orders of magnitude above the limits for residential land use [22]. However, the specific contribution of the «Red Muds» to soil pollution cannot be singled out, because of the overlapping of several different contamination sources in their vicinity.

To reduce contamination from the Red Muds, the company EMSA-IGEA has planned a series of measures of environmental restoration; among them, a network of canals to avoid runoff into Rio S. Giorgio.

STOP 2: PORTO FLAVIA

The transportation of minerals deriving from exploitation of the mines in the Iglesiente district invariably constituted a considerable problem with regard to the economic yield of these mines.

The majority of mines, considering the lack of ports or docks on the cost suitable for loading the large ships, required to transport their products, used the services of the Galanzé watermen from the S. Pietro island. These watermen ferried goods from the beaches of Masua, Funtanamare, Cala Domestica, Canal Grande and Buggerru to the spacious storehouses situated in the S. Pietro island; goods were subsequently taken from there to be finally stowed in large ships. These operations of loading and unloading naturally increased the expenses and costs, thus rendering the exploitation of mines unprofitable for the managing Company.

In an attempt to overcome this considerable problem, in 1922 the Belgian company Vieille Montagne, managing the Masua mine, designed a device capable of loading minerals directly onto the ships. This project was completed in 1924 and was named Porto Flavia after the daughter of the designer. In figure 7 is reported a geological plane section.
Porto Flavia was developed by excavating two overlapping galleries in the mountain: the 600 m gallery at 37.4 m a.s.l., equipped with an electric convoy originating from the processing plants (Masua washing plant), and the 100 m gallery at 16 m a.s.l., containing
a long transporter belt which terminated outside the mountain over the sea with a mobile lever arm. Nine silos were dug between the two galleries and were filled from the upper gallery; these silos were capable of containing up to 10,000 tons of minerals which were subsequently unloaded onto the transporter belt in the lower gallery by means of mechanical hoppers. The silos were used to contain different types of minerals: galena, sphalerite and «calamine». The 20 m long lever arm enhanced the direct loading of minerals onto the ship at the end of the bay underlying Porto Flavia, in front of Pan di Zucchero, an imposing calcareous rock so called because of its sugar-white colour. This is high 134 meters, has an extension of 4 hectares and is crossed by invisible galleries left by a short, but intense, mining activity. It was the natural shelter of the ships during loading operations.

The mineral was stowed directly into the ships hold by means of a thick rubberized fabric tube termed «buttafuori» (bumpkin) which originated in the opening situated at the end of the mobile lever arm and terminated inside the ships’ hold, thereby preventing both
the dispersion of powdery matter by the wind or by the movement of the waves during
the download of the minerals.

In figure 8 is drawn the original scheme of the ore storage and transport system [25].
In spite of the advantages afforded by the new loading system, which was perfectly
integrated in the large mining complex, the Company was not able to avoid closure during
the economic crisis of the 1930’s. The Porto Flavia plant came into use once again
immediately after the war, and operated until the beginning of the 1960’s; subsequently
the plant became obsolete and was totally abandoned.

Figures 9 and 10, dating back to 1930’s, respectively show the ore transport and load
systems.

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