

Antrona Valley's Gold Mines: from ore deposits to cultural opportunity for mining heritage (Piedmont, Italy)

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Abstract

The Antrona Valley falls within a very complex area on a geological and tectonic level, since during the Alpine orogeny there were important shifts along the faults, which led to intense deformations and which brought lithological units of different provenances and origins into contact, forming the so-called metalliferous “veins”, mainly rich in gold and silver. These veins are made up of quartz, associated with sulphides such as pyrite, arsenopyrite, pyrrhotite, galena, blende, chalcopryrite. Gold is mainly contained in pyrite and arsenopyrite, as free gold, in the form of very small particles. From a lithological point of view, the deposits are mainly located in gneissic rocks, mica schists and ophiolitic green rocks. In Valle Antrona the gold-silver veins, object of research with the creation of mines also highly developed, are: i) Mottone and Mee field, in the valleys of Trivera and Mottone, in the gneiss formations; ii) Prabernardo and Locasca field, along the Ovesca stream, in the gneiss formations; iii) Asino and Cama field, downstream from Alpe Cama, developed on contact between gneiss and green rocks. The MINERALP project is an Italy-Switzerland Interreg Project, working on a wide area across the two nations in western Alps, where a huge mining activity developed in the previous centuries, with a great impact on local communities and landscapes. A big heritage made of places (mostly abandoned), knowledge and Man's memories about the hard work in mines and quarries. What is needed is keeping this heritage still alive and give the opportunities to discover it as a new way of tourism, enriched with culture and adventure. The MINERALP project consisted in the recovery of 3 ex-mining sites (Kreas Mines in Alagna Valsesia, Gula Mine in Valsesia and Taglione Mine in Antrona Valley), the implementation of already recovered sites (Val Toppa Mine and Pink Granite Quarry in Baveno), the setting up of new visitor and document center (Valle Antrona and Saint-Marcel) and information points (Baveno). Within this framework, we studied the Prabernardo - Locasca field bringing to light nineteen gold mines. Among them, seventeen were unknown, while Taglione Mine and Polveriera Mine were adapted for tourist purposes. For all the mines, we carried out geophysical, biological and archeological studies to collect all the information useful to catalog mine and evaluate their usability. Aerology of Taglione Mine was studied using an ultrasonic anemometer, while the other mines were studied *via* hot-wire anemometer. As results, we discovered that Tony Mine is connected with other two mines (Miniera sopra Taglione and Frisa 2), while it is not connected with Taglione Mine, despite it was projected as Tony's shallow. Some mines were catalogued as “not accessible” since the support wood is rotting, and from a biological point, mines are inhabited by *Pipistrellus pipistrellus* and *Meta menardi*. Finally, we obtained 3D survey for each mine and we mapped all the ancient miners' trails in order to project a mining park accessible to organized groups, encouraging safe tourism.

Keywords: MINERALP Project, Antrona valley, gold mine, Taglione mine, tourism.

Introduction

Geological framework

The Antrona Valley is placed in a geologically and tectonically complex area, where significant displacements occurred along faults during the Alpine orogeny. These shifts resulted in intense deformations and brought together lithological units from various

sources and origins, creating the metalliferous “veins” that are primarily rich in gold and silver. These veins consist of quartz, accompanied by sulphide minerals such as pyrite, arsenopyrite, pyrrhotite, galena, blende, and chalcopryrite. The gold is predominantly found in pyrite and arsenopyrite as free gold particles of very small size. From a lithological perspective, the deposits are primarily located within gneissic rocks, mica schists, and ophiolitic green rocks.

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In the Antrona Valley, the gold-silver veins that have been extensively studied and developed through mining operations are as follows:

- i) The Mottone and Mee field, located in the Trivera and Mottone valleys within the gneiss formations.
- ii) The Prabernardo and Locasca field, situated along the Ovesca stream within the gneiss formations.
- iii) The Asino and Cama field, downstream from Alpe Cama, developed at the contact zone between gneiss and green rocks.

MINERALP project

The MINERALP project is an Italy-Switzerland Inter-reg Project that operates across the western Alps, encompassing a vast region spanning both nations. This area has a rich history of mining activity that significantly impacted local communities and landscapes. It holds a valuable heritage comprising abandoned locations, accumulated knowledge, and the memories of people who endured the hardships of working in mines and quarries. Preserving this heritage and offering opportunities for exploration has become essential, creating a novel form of tourism that combines cultural enrichment and adventure.

The MINERALP project involved the restoration of three former mining sites: Kreas Mines in Alagna Valsesia, Gula Mine in Valsesia, and Taglione Mine in Antrona Valley. Additionally, existing restored sites such as Val Toppa Mine and Pink Granite Quarry in Baveno were enhanced, while new visitor and document centers were established in Valle Antrona and Saint-Marcel, along with information points in Baveno.

Antrona Valley

Within this project, the main area of study and research in the Antrona Valley focused on the region above the locality of Locasca, identifying and marking the entrances of the following: Priest Gallery (903 meters above sea level), Chietta Vein or Gallina Mine (960 meters above sea level), S. Barbara Gallery – Polveriera (865 meters above sea level), Taglione Gallery (880 meters above sea level), Toni Gallery (950 meters above sea level), Frisa 1 Gallery (1060 meters above sea level), Frisa 2 Gallery (1018 meters above sea level), Cava del Bosco Gallery (1121 meters above sea level), Frisa 3 Gallery (950 meters above sea level), Boscone Gallery (elevation not present on historical maps), Santa Barbara Gallery (elevation not present on historical maps), as well as minor excavations and test pits of no exploratory significance (but later discovered and cataloged during the exploration and campaign phase).

The entrances marked on old surveys have been reported by also historical records, which state: *“Near the village, there are two tunnels that extend about 500 meters into the mountain. They advance for 350 meters into the rocks until reaching and intersecting*

the “Cava del Bosco” and “Toni” veins, then continuing for about 100 meters in the northwest-southeast direction, without finding any significant mineralization. The Taglione tunnel opens at an elevation of 880 meters, and the Toni tunnel at 950 meters. Other tunnels that have become inaccessible were opened at: La Chietta, 960 meters; Prete, 905 meters; Frisa 2, 1018 meters; Frisa, 1060 meters. In the Taglione tunnel, after passing the Toni vein, a large mineralized water vein is encountered a few meters ahead” (Bruck, 1986).

We also studied the area near Mulini Alp, since some historical documents reported that: *“Regarding the Mulini area, there were marked but poorly defined cultivations. In the same area, on another survey from the late 1800s, there was a projected downward tunnel at an elevation of 1468 meters above sea level, connecting the MEE cultivation located at 1642 meters above sea level.”*

The second cultivation, known as Miniera Fajot, according to the documents is said to be located within the Trivera Stream, but it has not been found to date. In this context as well, confirmation of the “Ribasso in Progetto” or “Ribasso Mulini” (lowering in the project) comes from some traces of historical documentation: *“From the village of Locasca, a mule track with 52 switchbacks leads to the Mulini. Just below, in the Trivera Stream, the Fajot tunnel opens. The Ribasso Mulini is at an elevation of 1462 meters, beyond the reach of the MEE mine’s vein column 2. From the Ribasso Mulini, a cableway departs to the Locasca facility, and another one arrives from the upstream Ribasso Mee”* (Bruck, 1986).

Materials and Methods

With respect to the mining sites above Locasca, apart from the Taglione Mine and the Toni mine, there was poor knowledge about the other entrances. This is also due to the topography of the area, as it is characterized by nearly vertical walls, interspersed with extensive and visible rocky ledges. Over the years, this terrain configuration contributed to the loss of trails that connected the various mining sites after mining activities were abandoned. Moreover, no official references were found, except the Bruck’s report, and we based our search on oral communications with peoples from Locasca (Antrona Valley).

However, during field exploration, we discovered traces of rock steps and footholds on some rock walls, allowing for movement between the different sites situated at elevations ranging from 880 meters to 1,120 meters.

Specifically, the mines were found and studied with over 20 field visits, as follows:

- Taglione Mine and Polveriera (Taglione’s powder magazine) were already known to the Park Authority;
- Toni Mine was known to the Gruppo Grotte Gallarate due to previous explorations;
- Gallina Mine, samples at turn 9 of the road con-

necting Locasca to Mottone, and the Ribasso Progettato were known to Flavio Caffoni, a former resident of Locasca and a member of the research group;

- Frisa 2 Mine, Frisa 3 Mine, Cava nel Bosco Mines, Priest Mine, Boscone Mine, and Santa Barbara Mine were identified through the digitization of a 20th-century map and its georeferencing.
- The mines above Toni and Taglione Mines were identified during a search expedition for Frisa 1 Mine, which has not yet been located.

On the other hand, for Mulini Alp, the entrance of Ribasso Progettato was known by Gruppo Grotte Gallarate for previously exploration, while the entrance of Fajot Mine is still unknown.

All the GPS positions of found mines have been deposited to the databases of Federazione Speleologica Piemontese and are available only for Corpo Nazionale del Soccorso Alpino e Speleologico (CNSAS).

Survey

We created a GPS track for each exit to locate the entrances in order to map also ancient trail. For each track, a statistical algorithm was developed to correct the track itself using three Garmin Etrex 30 devices simultaneously and generate the modal track.

The entrance was georeferenced using a MobileMapper120Field device, utilizing GPS and GLONASS networks with associated error below 3 m in position and below 10 m for elevation.

For the survey, a modified DistoX LEICA with a digital compass and non-magnetic battery was used, which communicated with a handheld device running the TopoDroid application. The surveys were drawn in CSurvey.

Anemometric Studies

Each mine was studied from an environmental perspective to determine its aerology. For each mine, details of the air circulation were recorded on its respective data sheet. A hot-wire anemometer was used as a probe to first identify the presence of air circulation and, if present, the point of maximum airflow. A measurement grid was then created for each mine, using at least 9 points, three at the bottom, three in the middle and three at the top of gallery.

The measurement grid was recorded both at the mine entrance and at any branching points, including secondary ones.

Subsequently, an ultrasonic anemometer with an AIO Compact sensor and Alpha-Log datalogger was positioned to measure any micro-air circulations in the Taglione and Gallina mines.

For each mine, the ultrasonic anemometer was placed at the convergence point of multiple galleries and near the entrance at a height compatible with possible airflow. Approximately one month of sampling was conducted for each mine. In the case of the Taglione Mine, the ultrasonic anemometer was also moved along the main gallery to map the entire Mine.

Results

Of the dozen known or mapped mines, only Frisa 1 Mine remains unretrieved, while 12 other new mines or mine samples have been found (fig. 1). The most interesting area is undoubtedly the one above Toni: Taglione Mines, where five new mines have been discovered. Only one of them is positioned above the central gallery of Taglione Mine, while the others intersect the Toni faults (fig. 2).



Fig. 1 – Overview of the Locasca – Mulini Alp area from SwissTopoMap, Federal Office, Suisse.

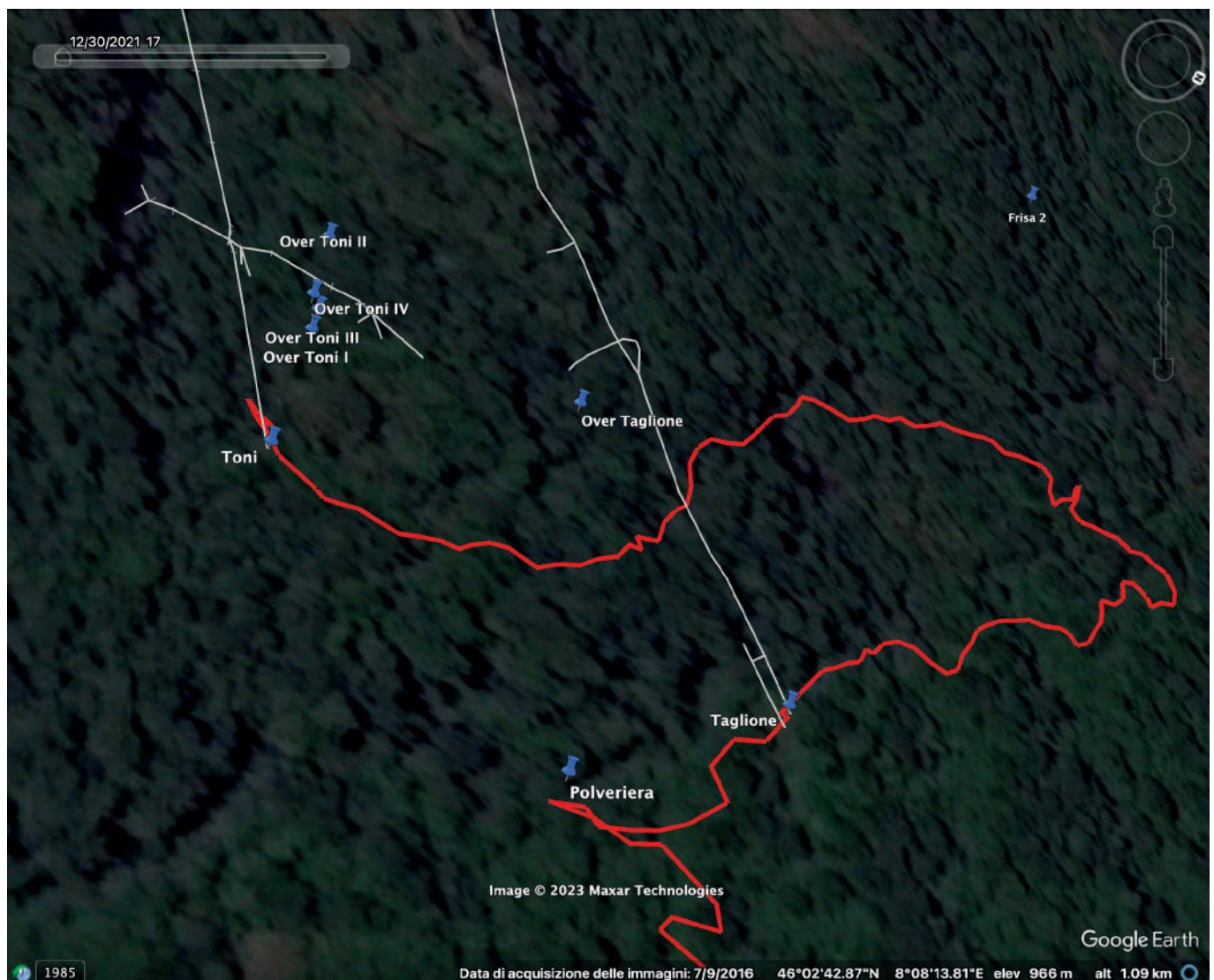


Fig. 2 – Focus on over Toni/Taglione area. In red are represented the miners' trail discovered during the study. Blue pins represent discovered mines, while white lines are the Taglione and Toni Mines' survey. Images from Google Earth.

The “Scavo in faglia sopra Toni - Over Toni I” is particularly interesting (fig. 3). After descending about 15 meters, a well and a subsequent horizontal gallery are observed. However, the gallery is inaccessible due to precarious ceiling conditions that make it unsafe for exploration. Access to these mines is *via* a dry-stone staircase that leads to a very exposed traverse on rock. None of these mines have air circulation.

From the same area, it is also possible to reach Frisa 2 Mine, which should be the longest mine in terms of linear gallery length according to the maps. Unfortunately, its entrance has collapsed, rendering it inaccessible. Despite the collapse, there is a small opening approximately 20 cm high where air flow of about 1 m/s is present, suggesting a direct connection with Toni.

To understand the further real connections of Toni Mine (fig. 4A), it was necessary to study it in relation to Taglione. Two methodologies were employed for this purpose: i) direct examination by ascending the

chimneys present in Taglione Mine and ii) Instrumental analysis.

For the direct examination, excluding the presence of descending shafts in the Toni gallery, the focus was on ascending chimneys in the Taglione Mine. The “high areas” of Taglione Mine can be summarized as four locations: three chimneys and a larger chamber (fig. 4B).

At the intersection, approximately 70 meters from the entrance, where a safety grate was installed, there is a vertical chamber reaching up to 6 meters in height from the floor. This area was ascended without the use of safety equipment as it was immediately determined that there was no further passage.

In the same area, there is another chimney measuring five meters in height; approximately 350 meters from the entrance, another chimney extends to a height of 15 meters. The chimney was initially ascended freely and then with the aid of self-tapping anchors for safety points. The top of the chimney



Fig. 3 – Edoardo Rota at the entrance of Over Toni I. (photo Luca Palazzolo).

was not reached as it was closed and impassable after a few meters.

About 360 meters from the entrance, another chimney with a height of 10 meters is found. It was also partially ascended without the use of anchoring equipment. Similarly, the top was not reached as it was closed and impassable.

The unexplored high areas due to unsound rock conditions were illuminated with high-intensity LED torches. The visual result was that all chimneys in Taglione Mine were completely blocked.

This finding is also confirmed by the anemometric study (fig. 5), which certifies essentially zero airflow in Taglione Mine, except for local effects of micro-air circulation due to barometric or seasonal phenomena. For instance, near one of the chimneys where the lighting wire passes, a weak flow of dry air braking the condensation of water on the wire was observed, unlike throughout the rest of the mine.

Based on these findings, it can be stated that the two galleries, Taglione and Toni Mines, are not directly connected by traversable sections. Taglione Mine appears to be a cavity without connections to other systems, while Toni is likely connected to Frisa 2 Mine and the Over Toni I. However, certainty regarding these connections is lacking due to a lack of direct verification of viability. Such a connection would explain the convective airflow measured in Toni (wind speed of approximately 2 m/s).

Regarding the study of underground meteorology, inconclusive results were obtained in each of the other mines above Locasca, as there is no convective air cir-

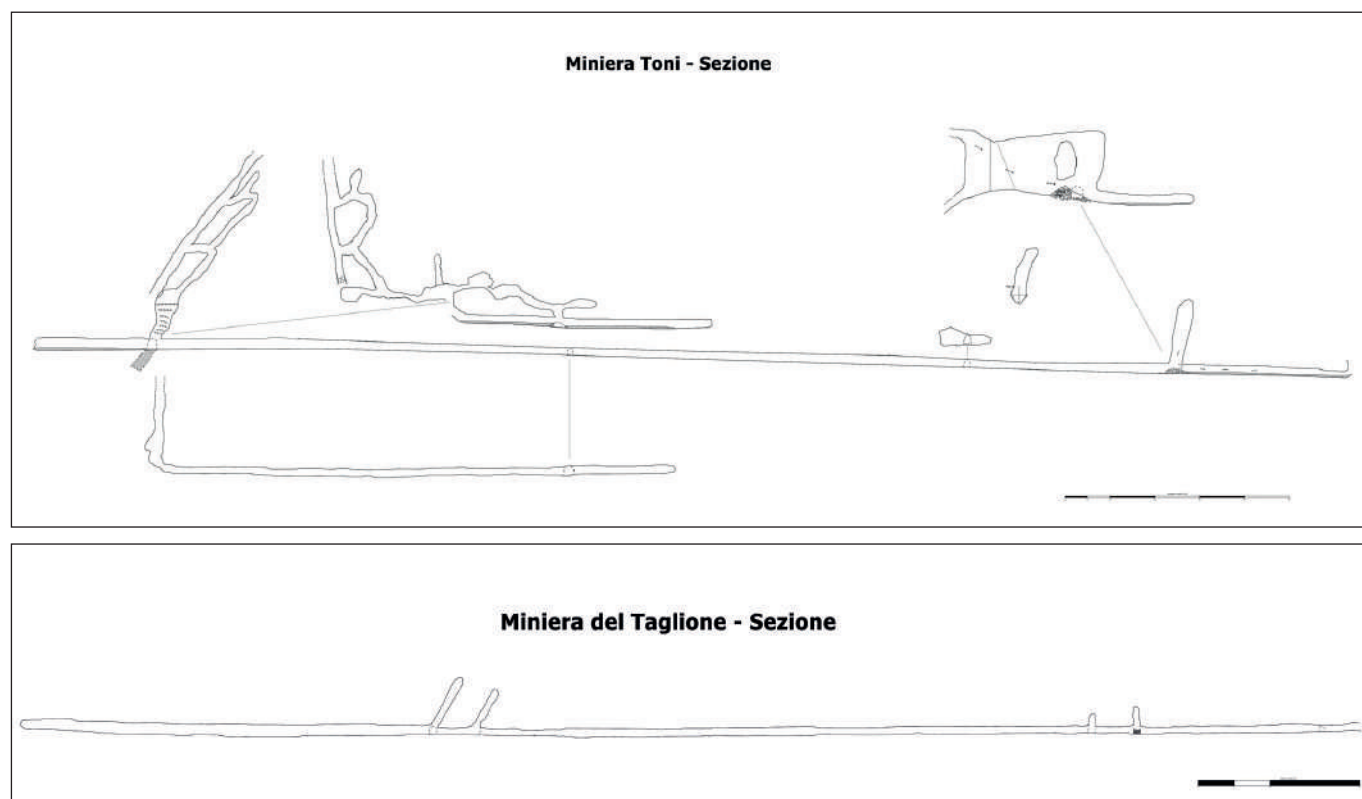


Fig. 4 – A) Toni and B) Taglione Mine surveys.



Fig. 5 – Ultrasonic anemometer at Taglione Mine (photo Luca Palazzolo).

ulation present, and barometric-type circulation is not measurable for the volumes. However, it is possible to hypothesize the presence of sub-convective circulation due to seasonal changes, although it is not possible to relate this phenomenon due to its complexity and slow nature, which is beyond the scope of the data acquisition campaign.

Minor mines (samples) or vertical mines were not tested with the instrumentation.

The Ribasso Progettato mine (fig. 6), on the other

hand, showed convective airflow in the anemometric analysis using a hot-wire anemometer (approximately 3 m/s). There is a potential connection with the Mee mine. Most of the airflow comes from a 49-meter chimney and flows through the left side branch. Beyond the left side branch in the main branch, there is no airflow, only pockets of “stagnant air” near the pipe deposit, where decomposing organic material (wood) is present. Other secondary branches on the left contribute to the overall airflow in Ribasso Progettato. Nu-

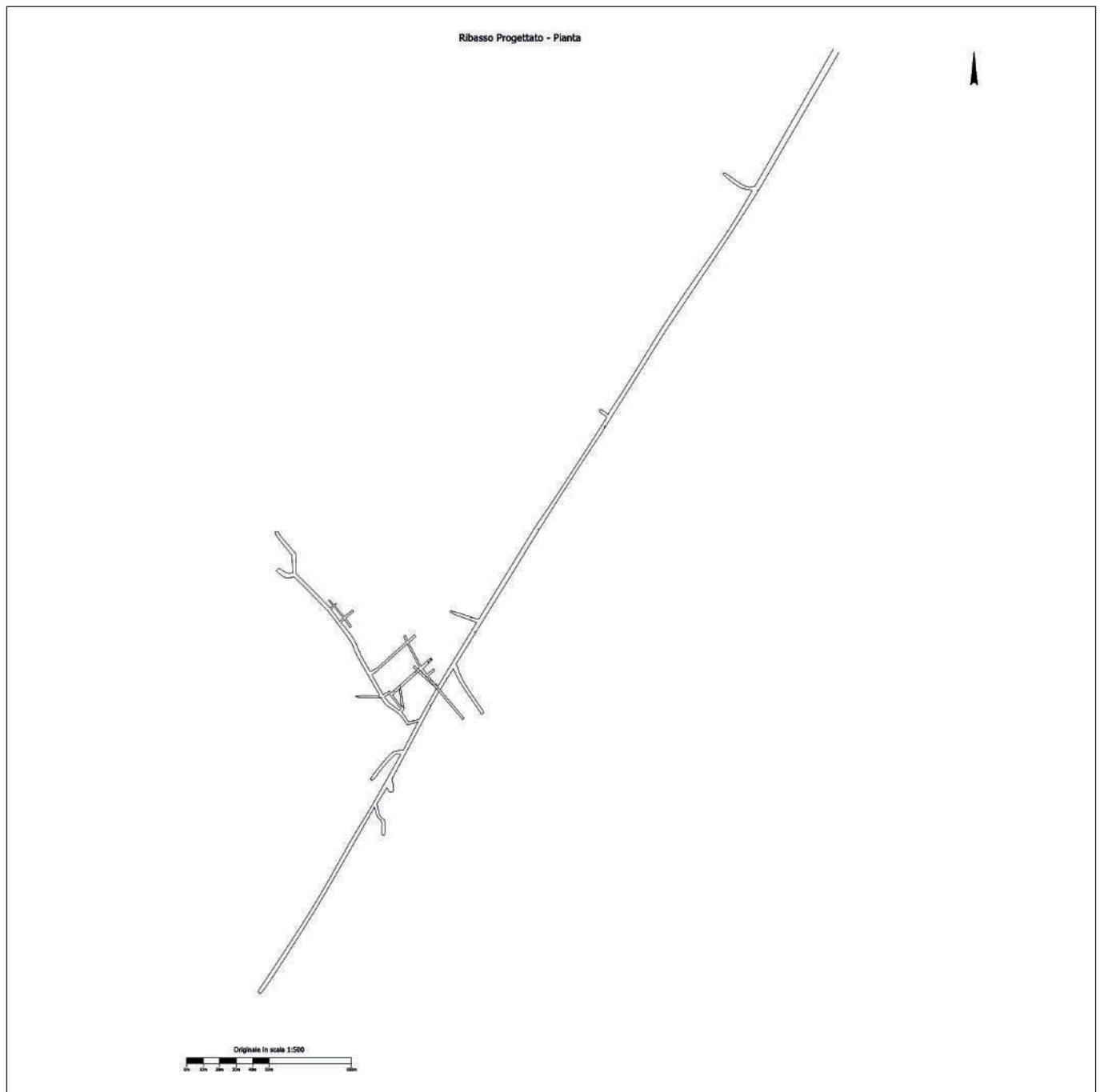


Fig. 6 – Survey of Ribasso Progettato.

merous artifacts of mining archaeology, such as shovels, picks, oxidized fuses, carts, and metal water pipes, have also been found in this mine. Ribasso Progettato is the only mine that still has cart tracks among the many explored and has specific tourist potential after general safety measures are implemented, as certain parts are currently unstable.

Specifically, the entrance is viable but unstable as the reinforced concrete structure has partially collapsed. The gallery has water presence for about 200 meters due to both the collapsed entrance and some deposits of material. All galleries up to the end, where the connecting chimney with the upper system (Mee) is lo-

cated, are self-supporting and safe to traverse. Structures located outside the mine were used for initial intervention. As mentioned in some documents, this was the midway point between the cable car to the Locasca facility and the one coming from Ribasso Mee upstream. Remnants of grinding stones used for material processing can be found near the Mulini residences.

“The most important mining area is undoubtedly the one known as Mottone Mee, which was exploited to a certain depth (as far as the means of the old cultivators allowed). The Morandini family, who installed about a hundred small mills at the location known as

"Molini," mined this area. The minerals in the Antrona mines are not entirely amalgamable but contain visible free gold and gold finely disseminated in sulfides. Especially at depth, amalgamation does not yield satisfactory results, but the mineral is suitable for cyanidation. The "Anglo Italian Mining Co." was the first company to establish significant treatment facilities.

Around 1875, they built large "aratras" in Locasca, where the current mineral treatment plant is located, capable of grinding and amalgamating 800 kg of ore per day. The Swiss company that managed it from 1898 to 1901 constructed a large workshop in Locasca, consisting of a crusher, a battery of ten Kupfer piles, and a cyanidation." (Bruck, 1996).

Conclusions and Future Perspectives

Within the MINERALP Project, around twenty mines have been identified in the area above Locasca and Alpe Mulini. Among the many mines, Taglione is about to be opened to the public for tourism purposes, aiming to raise awareness among citizens about the immense work carried out by miners in the valley. Overall, the studied area shows potential for tourism and cultural development.

The area above Locasca is characterized by a unique terrain, although the overlying mines may not have significant tourist appeal. However, it could be possible to create an equipped "miner's trail" connecting the various mines, involving the local sections of the Italian Alpine Club. Of particular interest is the Toni Mine, which requires specialized studies to ensure its safe utilization for tourism, addressing the areas categorized as structurally compromised.

The Mulini/Trivera/Mottone area is the most significant extraction zone, with Mulini featuring a miners' village that holds considerable potential for tourism. Its development would require addressing elevation differences and creating support points in the area, as well as ensuring the structural stability of the mine for tourism purposes.

Overall, the research and working group prioritize the creation of a hiking trail that allows access to the following mines: Prete Mine, Frisa 3 Mine, Boscone Mine, and Santa Barbara Mine. Subsequently, it would be interesting to extend the trail for experienced hikers, connecting the Cava nel Bosco Mines and potentially creating an equipped trail with chains leading to the Risalita sopra Toni. The group believes that these mines are traversable with simple precautions, based on their preliminary assessments and knowledge. Further attention can be given to the Toni Mine and Gallina Mine, as they present more significant structural challenges.

Lastly, the research and working group maintains the opinion that Ribasso Progettato has the highest potential, once the entrance and other structural elements are secured. It is also conceivable to revitalize existing structures in proximity to this mine by creating support facilities.

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