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Napoli SEG Student Chapter

Sardinia Field Trip Report 2019

3rd-10th September 2019

On the 3rd of September, the Napoli SEG Student Chapter started its one-week field trip in Sardinia. Six members of the chapter, together with other non-members from the Earth Science Department of Naples, attended to this field trip (see annual report for details on participants). This activity has benefited of the guidance of our field trip leader Dr. Nicola Mondillo (DiSTAR, UNINA, Italy), and of Dr. Fabio Granitzio (SEG chapter industry advisor, Clariant SpA). We are also indebted to the Companies: IGEA SpA, Fluorite di Silius SpA and Carbosulcis SpA, who provided access and guidance to several former mining sites and infrastructures during the fieldtrip. The main targets of the fieldtrip were the pre- and post-Variscan mineralizations in the historical Iglesiente mining district (Fig. 1a-b). Moreover, we had the opportunity to visit the former Carbosulcis (Fig. 1a), Furtei (Fig. 2) and Montevecchio (Fig. 3) mines, as well as the Silius mine (in care and maintenance) (Fig. 4).

The southern district of Sardinia was characterized by a very long-lasting geological evolution that played a primary role in defining the optimal conditions for the genesis and the modification of the mineralization occurring in the area. Overall, the main mineralizing events can be classified based on their chronological relationship to the Variscan orogenic cycle:

- The formerly economic pre-Variscan ores, deformed by the Variscan compressive tectonics, are sediment-hosted and occur in the lower Cambrian carbonates. They belong to syndiagenetic massive sulphides (Zn+Ba, SEDEX, Lower Cambrian) and to epigenetic (Pb+Zn>Ba,Ag, MTV, Cambrian - Ordovician) types;
- The post-Variscan hypogene ores (Permo-Mesozoic) are undeformed and can be mainly ascribed to both high- and relatively low-temperature processes. The former deposits are mainly related to the late and post-Variscan emplacement of acid plutons that led to the formation of skarn (e.g. the Su Zurfuru, Perda Niedda and Pb-F ores) and to the genesis of the Montevecchio-Ingurtosu (Zn-Pb-Ba>>Cu) and Silius (F-Pb>>REEs) vein systems. The lower temperature mineralizations consist of barite and base metals veins as paleokarst infills (i.e. the so-called Ricchi Argento Pb-Ba>>Ag mineralization) and are likely related to Mesozoic tensional tectonics;

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- Another significant metallogenic stage in the Iglesiente area resulted in the formation of carbonate-hosted Zn-Pb Nonsulphides mineralization, the so-called "Calamine ores". This ore type is the product of the oxidation of the hypogene sulphide ores occurring in the Lower Paleozoic carbonates and occurs mainly as karstic and *in situ* concentrations of oxidized Zn-Pb minerals (e.g. smithsonite, hemimorphite and cerussite). These "secondary" ores were exploited both historically and in the modern age (up to 1998). The main operative sites were the Planu Sartu, Campo Pisano, Monteponi and Nebida mines. Both the sulphide/barite and nonsulfide ores are currently care of the IGEA former mining company, whereas the Silius mine is care of the Miniera di Silius mining company;
- Another important metallogenic period is associated with the Oligo-Miocene calc-alkaline magmatism, leading to the formation of low- to high-sulfidation gold systems, such as the Furtei Au deposit. The Furtei operation was held by the Sardinia Gold Mining, a Joint Venture company that exploited the deposit in the period between 2001 and 2008.

In the following pages we provide a brief description of our itinerary.

- **Day 1 (3rd September):** flight from Naples to Cagliari and drive toward the Iglesias (SW Sardinia) historical mining town;
- **Day 2 (4th September, The Iglesiente sedimentary succession):** The Iglesiente region in SW Sardinia is one of the oldest mining districts in the world. In this area the past extensive exploitation for base metals (Zn+Pb) and Ag was mainly focused on the Paleozoic sedimentary rocks. Therefore, during the first day of the field trip we conducted several observations on the Cambro-Ordovician sedimentary succession (Fig. 5), in order to understand the sedimentological and structural settings of the entire area. A particular focus was dedicated to relationships of the above quoted settings with the location of the historical mines;
- **Day 3 (5th September, Pre-, Post-Variscan and Nonsulphide ores in the Iglesiente area):** Our survey was kept on the Paleozoic successions of the Iglesiente, but the main attention was shifted to the post-Variscan and Nonsulphide ores. We visited the old barite exploitation sites of the Gonnesa group (Fig. 6a and 6b). We visited the surficial outcrops of the former Monteponi Calamine mine (Fig. 6c to 6f) enjoyed the panoramic view of the "Scavo Cungiaus" open pit, under the

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supervision of the IGEA staff (Dr. Salvatore Corriga and Dr. Andrea Maciocco). We had an interesting stop in the "Scavo San Paolo" open pit, where the spatial and temporal relationships between the foliation caused by the Variscan orogeny, the epigenetic hydrothermal dolomite and the recent karstification of the carbonates are well exposed. We visited Monte San Giovanni, the type locality in the Iglesiente for the post-Variscan paleokarst mineralization (Fig. 6h and 6i), that was exploited historically for Ag by the Phoenicians and Romans, and then by the Pisans in the Middle Age;

- **Day 4 (6th September, Ores related to the emplacement of the Variscan granites):** we left the Iglesias area, driving north to visit the small deposits related to the late- to post-Variscan metallogenic cycle. First, we visited the Capo Pecora headland (Fig. 7a), a type locality where several generations of Variscan granites are well exposed (Fig. 7a and 7b). Afterward we went inland to visit the skarn mineralization at the old Perda Niedda mine site (Fig. 7c to 7 f). This site was exploited in the past (since 1853) and the mining activity was mainly based on the exploitation of Fe minerals such as hematite and magnetite. Afterwards we visited part of the old Montevecchio mine (Fig. 7g to 7i), located in the Arburese-Fluminese district, under the supervision the former project geologist (Dr. Efisio Cadoni). The mine workings lasted at Montevecchio for more than one century (1848 to 1991), focusing on zinc, copper and lead along a series of hydrothermal veins;
- **Day 5 (7th September, The Silius fluorite-galena vein system):** site visit of the Silius (Fig. 8) underground mine in the Sarrabus-Gerrei region (SE Sardinia). The visit has benefitted by the guidance of the Director and project engineer Guido Mura (Fluorite di Silius SpA), who explained the history of the deposit, the past exploration strategy and the potential future perspectives of the project;
- **Day 6 (8th September, The Furtei Au mine):** visit to the former Furtei Au mine (Fig. 9 and 10). The site visit has been supervised by our industry advisor (Dr Fabio Granitzio) and by two members of the IGEA staff (Dr Mauro Diana and Dr Andrea Loddo). During the first decade of the 21th century the Furtei operation was held by Sardinia Gold Mining. Currently, the whole area is under the administration of the IGEA, whose aim is to carry out a complete environmental restoration of the site. The visit at Furtei was very functional, because in this site the typical alteration facies (dickite+kaolinite and vuggy silica) of this high sulfidation Au deposit are still exposed and well visible in the open cuts. Moreover, the skillful and experienced guidance of Dr Granitzio and of the IGEA staff could provide the student very insightful information both on the geology and exploration in the whole the district,

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and on the processing methods used for the different ore types (hypogene and supergene) occurring in the deposit;

- **Day 7 (9th September, The Carbosulcis Coal Mine):** Visit to the Monte Sinni underground Coal mine (Fig. 11), under the supervision of the Carbosulcis staff (project engineer Matteo Testa, Dr Pietro Piras and Dr Stefano Farenzena). Visit to the cryogenic distillation of the stable isotopes (e.g. ^{40}Ar) plant hosted in the Carbosulcis facilities;
- **Day 8 (10th September):** Flight from Cagliari to Naples.

Archeology and cultural heritage (Fig. 12): during the excursion week, we had the additional opportunity to visit part of the very extensive Sardinia cultural heritage. Such heritage witnesses the very long-lasting relationship between humans and resources, which in the specific case of the Sardinia island manifest itself already during the bronze age with the Nuraghe civilization. The strict association between ore deposit and the development of the Sardinian society during the modern age also produced many facilities and infrastructures that are currently open both for touristic tours and for protectionists (geologist and mining engineers) interested in the past mining activities. The sites we visited sites are the following:

- The Barumini Su Nuraxi (an impressive nuragic village near Furtei mine) (Fig. 12 a to Fig. 12c);
- The Porto Flavia underground loading plant, built in the first half of the 20th century to load the ore from the mines directly on the ships (Masua, Fig. 12d);
- Galleria Villamarina and Monteponi facilities (Fig. 12e to 12 h);
- Istituto Minerario Giorgio Asproni, where the mining technicians were (and still are) formed (Iglesias, Fig. 12i-j);
- The Su Zurfuru museum, near the old mine (Fluminimaggiore, Fig. 12k-l).

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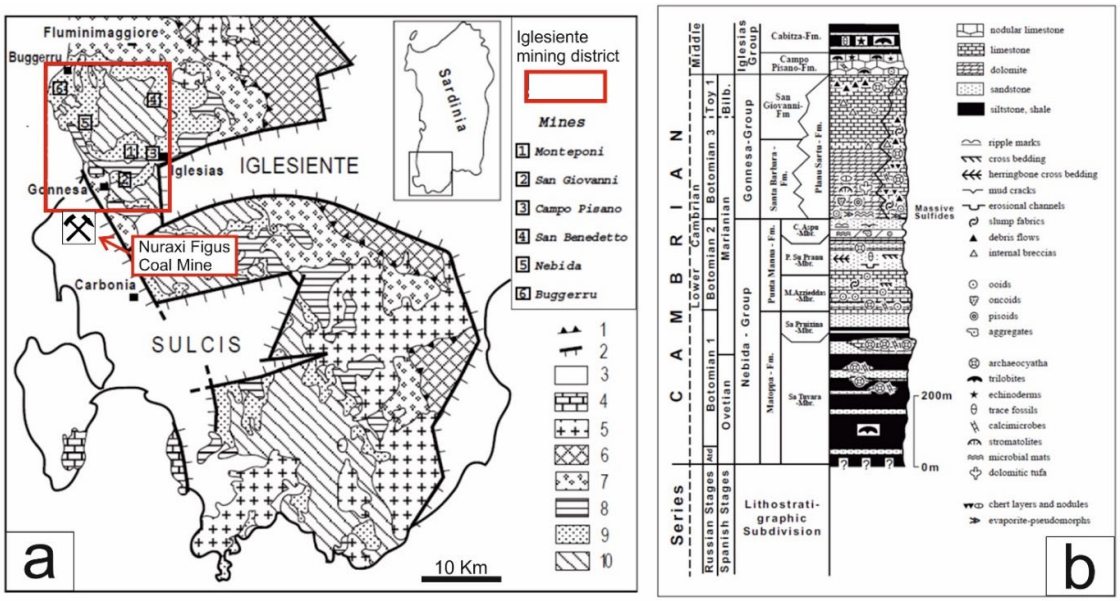

Figure 1: a) Geological map of Southwest Sardinia showing the location of the Iglesiente mining district and of the Nuraxi Figus Coal mine (modified after Boni et al., 2000); **b)** Stratigraphic column of the Lower Palaeozoic in SW Sardinia (modified after Bechstädt et al., 1985). Abbreviation of Fig. 1a: 1 = overthrust; 2 = normal fault; 3 = Cenozoic; 4 = Mesozoic; 5 = Variscan granites; 6 = Palaeozoic (allochthonous); 7 = Ordovician to Devonian succession; 8 = Iglesias Group; 9 = Gonnesa Group; 10 = Nebida Group.

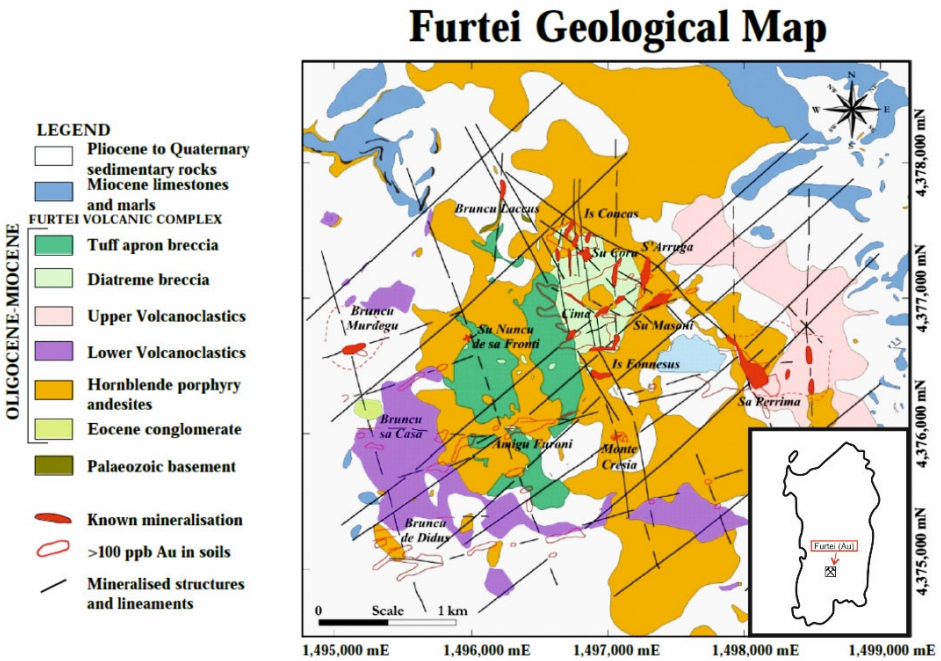

Figure 2: Geological sketch map of the Furtei area (modified after Ruggieri et al., 1996).

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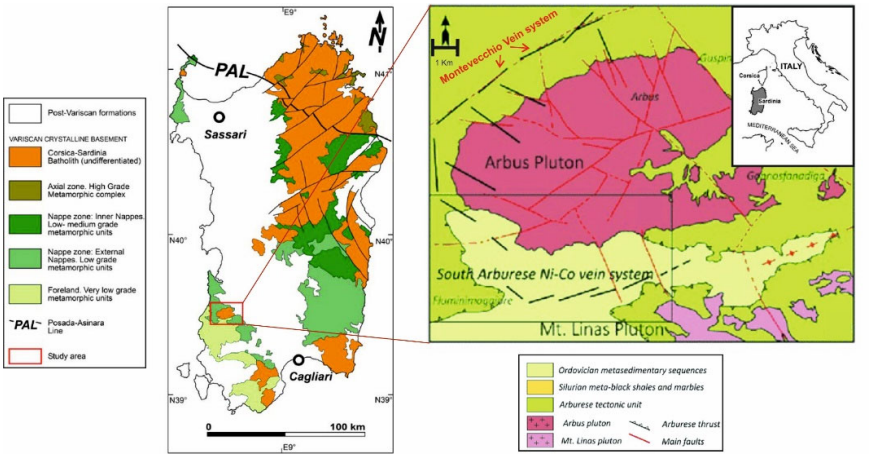

Figure 3: Geological sketch map of the Arbus pluton showing the location of the Montevecchio vein system (modified after Moroni et al., 2000).

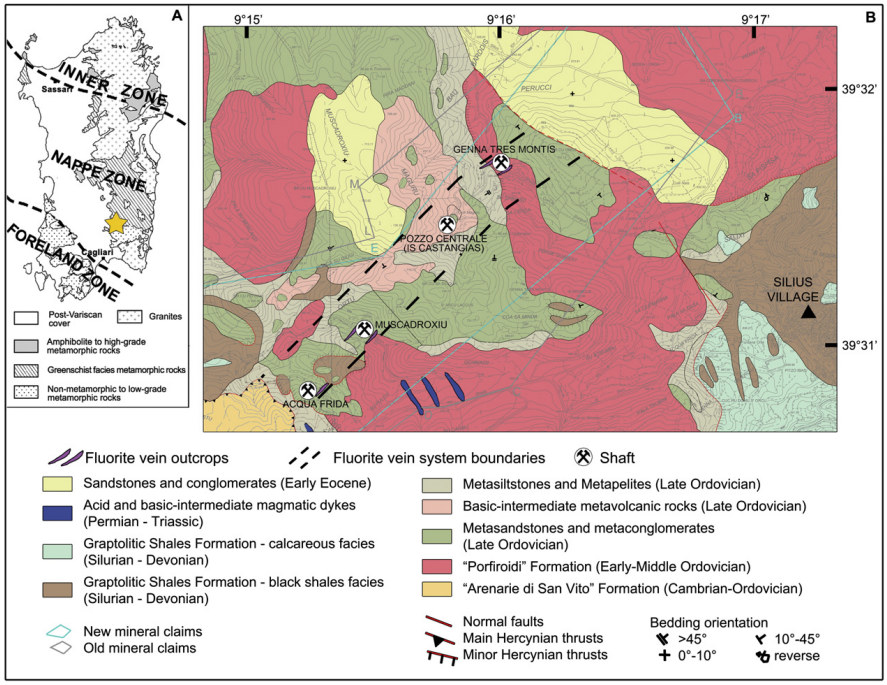

Figure 4: a) Major tectonic and metamorphic zones of the Hercynian basement in Sardinia (Italy) (modified from Carmignani et al., 2001); yellow star = Silius area. B) Geological sketch map of the Silius area (Mondillo et al., 2016).

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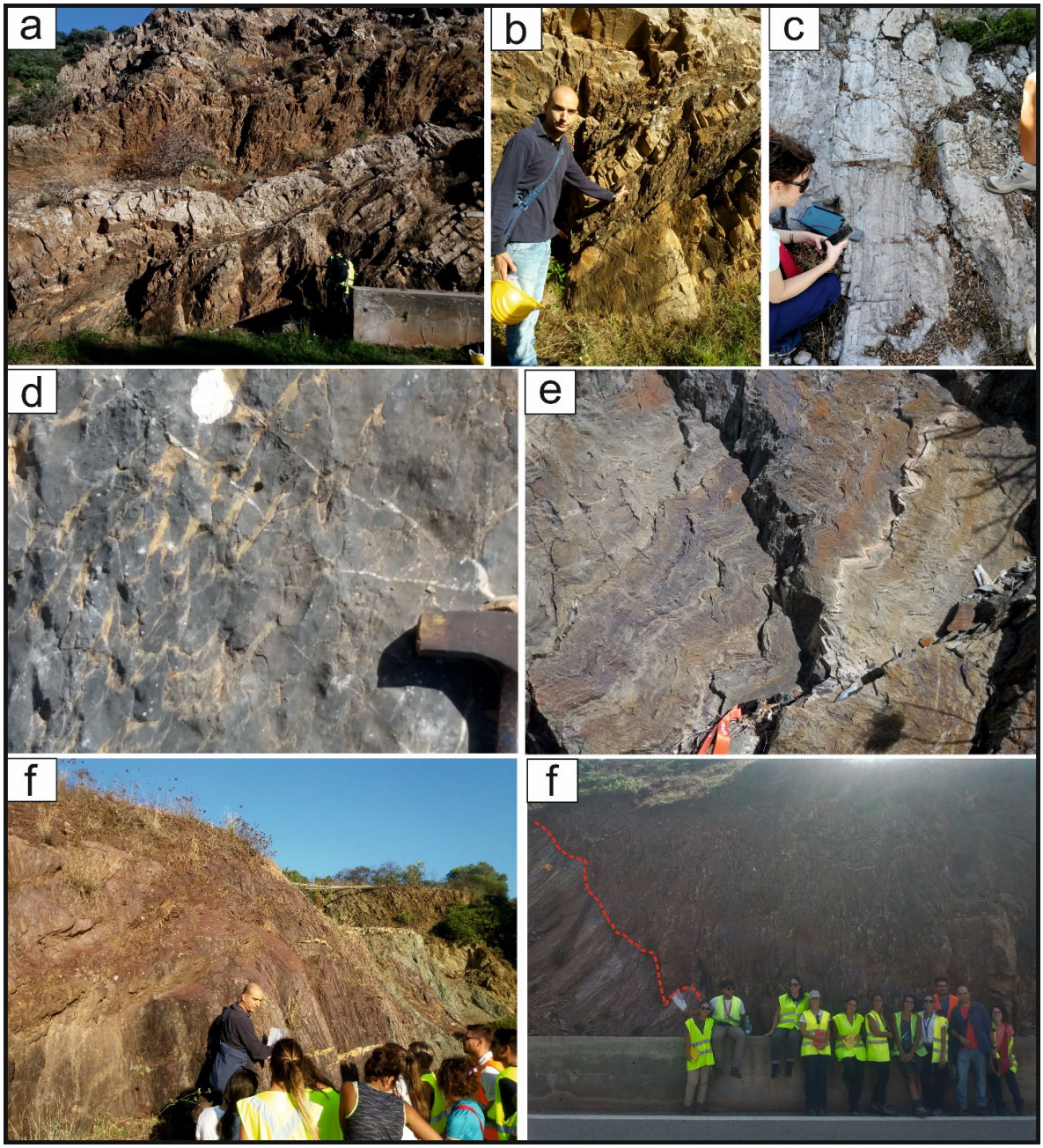

Figure 5 (2nd day): a) and **b)** refraction of cleavage between the slate- and sandstone-rich levels in the Punta Manna formation; **c)** Early laminated dolomite of the Santa Barbara formation; **d)** Brecciated facies of the Black limestone (namely San Giovanni Formation); **e)** Ptygmatic folds within the Scisti di Cabitza formation; f) Our field trip leader explaining the Variscan deformative structures visible in the so-called Rumsey fold (Scisti di Cabitza formation); **f)** The angular unconformity between the Ordovician "Puddinga" conglomerate and the Cambrian Cabitza shales that marks the so-called Caledonian Sardic phase.

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Figure 6 (3th day): **a)** and **b)** Canali Acquas: stratabound barite mineralization (SEDEX) in the Gonnesa group; **c)** and **d)** view of the main open pit (i.e. the Scavo Cungiaus) of the former Monteponi mine; e) Field trip participants posing in front of the Monteponi calcination furnaces for Zn-oxides; **f)** Our field trip leading giving a general introduction on the geology of the local Calamine deposits; **g)** Field trip participants while discussing about the timing between the Variscan orogeny, the epigenetic dolomitization and the karstification process; **h)** collapse breccia and cockade ores with calcite, barite and Ag-rich galena in the Monte San Giovanni paleokarst ores; **i)** View of the old "Scavi Pisani" for Ag.

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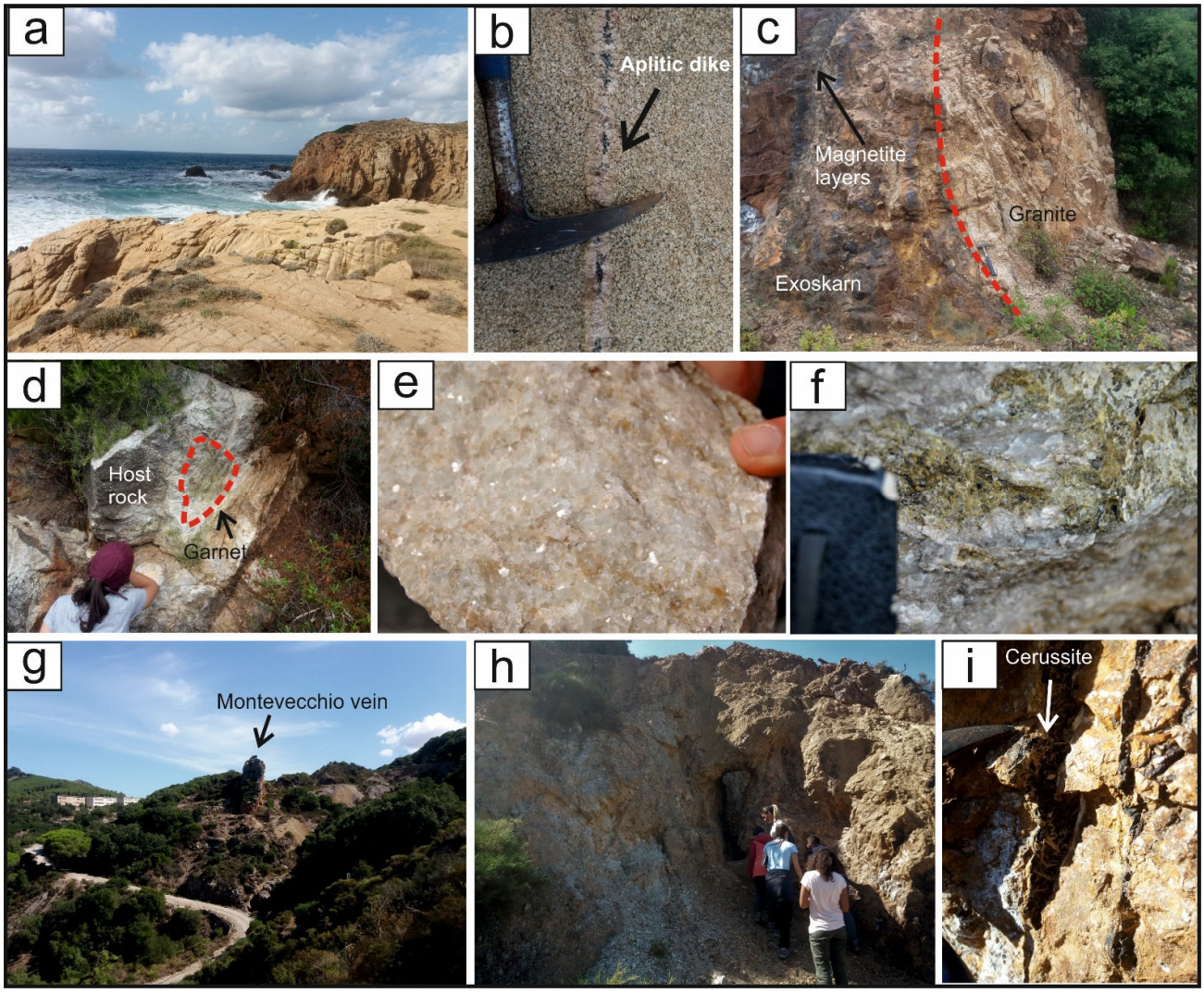

Figure 7 (4th day): a) Variscan granites with the typical cooling fractures pattern (Capo Pecora); **b)** Aplitic dike crosscutting the Variscan granite; **c)** Skarn front at Perda Niedda; **d)** Spatial relationship between the Ca-garnet and the marble host rock (near the Perda Niedda intrusion); e) Detail of the recrystallized limestone; **f)** Detail of Ca-garnet; **g)** View of the Montevecchio vein on surface; **h**) Chapter members collecting samples from the Montevecchio vein; **i)** Detail of cerussite acicular crystals in the oxidized section of the Montevecchio vein system.

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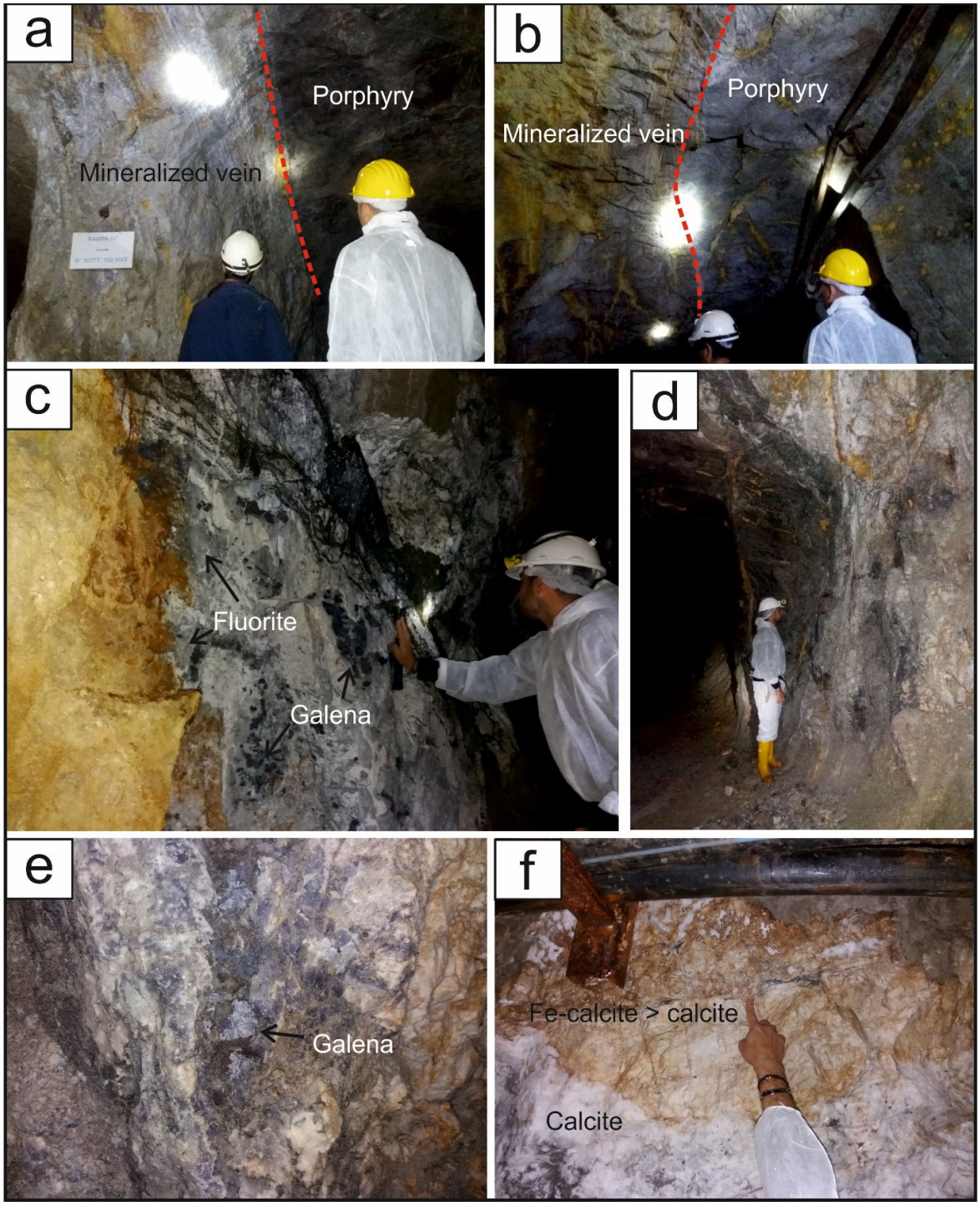

Figure 8 (5th day): a) and **b)** Our field trip leader and the Silius project engineer introducing the chapter members to the spatial relationship between the mineralized vein system and the porphyry country rock; **c)**, **d)** and **e)** Detail of the Silius fluorite+galena mineralization; **f)** Detail of the calcite gangue and of the potential LREEs-enriched Fe-calcite.

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Figure 9 (6th day, Part I): a) The student chapter industry advisor (Dr. Fabio Granitzio) while giving to the field trip partecipans a short introduction on the former Furtei Au operation; **b)** Dr. Mauro Diana (IGEA) explaining to the chapter members the ore processing methods used at Furtei; **c)** The former Furtei flotation plant used for the hypogene mineralization; **d)** Dr. Fabio Granitzio illustrating the old exploration campaign in the Furtei project; **e)** Dr. Andrea Loddo (IGEA) showing the environment restoration strategy in the former open pit area; **f)** The SEG chapter members posing with the field trip leader and their industry advisor.

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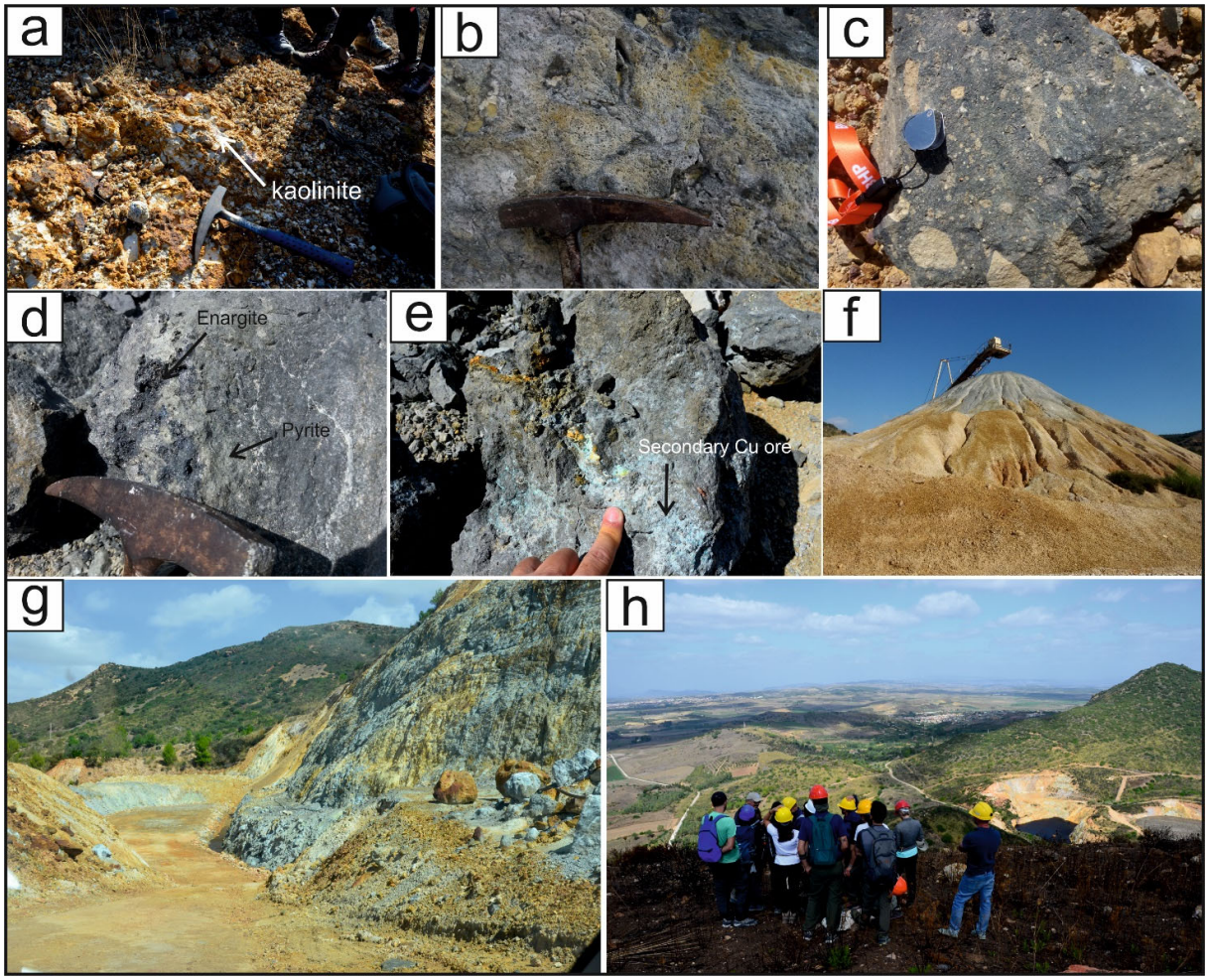

Figure 10 (6th day at Furtei mine, Part II): a) Kaolinite alteration facies; **b)** Typical vuggy silica alteration; **c)** Barren diatreme breccia; **d)** Pyrite+enargite mineralization in the hypogene section of the deposit; **e)** Secondary Cu minerals; **f)** Gold-rich stockpile; **g)** Wall of an open pit exposing the hydrothermally altered volcanoclastic rocks; **h)** Panoramic view of the open pit.

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Figure 11 (7th day): Group photo in front of the Carbosulcis processing plant. N.B.: due to security issues no photo was allowed during the visit of the underground part of the mine.

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Figure 12 (Archeology and cultural heritage): a), b) and **c)** Visit to the Barumini Nuraghe village; **d)** Visit to Porto Flavia; **e)** and **f)** The Monteponi mining facilities; **g)** and **h)** The Villamarina gallery; **i)** and **j)** Visit to the Giorgio Asproni mining school in Iglesias; **k)** and **l)** Visit to the Su Zurfuru museum.

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