Rend. Online Soc. Geol. It., Vol. 51 (2020), pp. 9-24, 14 figs. (https://doi.org/10.3301/ROL.2020.08)

The aluminum and iron mines of the Comino Valley-Sora area (Central Apennines, Italy): sites of the geological memory

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Document type: Article.
Manuscript submitted 16 March 2020; accepted 15 April 2020; published online 11 June 2020; editorial responsibility and handling by M. Pantaloni.

ABSTRACT

The Mesozoic bauxitic-limonitic deposits of the Comino Valley-Sora area have been exploited since proto-historic times, but this area became crucial for the "iron rush" in the Bourbon era. The Kingdom of Naples decided to finance scientific researches in the area between Pescosolido and Picinisco (southeastern Lazio), in order to strengthen military defenses and to combat invasive or rebellious pressures. This led to the realization, in the period between 1770 and 1860, of the Royal Mines of Canneto, San Donato Val di Comino and Campoli Appennino, and of the Royal Forges of Canneto and Rosanisco. Fundamental was the supervision of technicians, including the engineer and geologist Gaetano Tenore. Following the Bourbon crisis of 1860, the industrial activity of the area was abandoned with, in many cases, its definitive loss of evidence (e.g. many of the mines of Campoli and San Donato Val di Comino, as well as the Canneto forge). The geological relevance of the mineralogical and stratigraphic studies performed in this area (with their socio-cultural and economic implication), coupled with the fact that most of this geological heritage is disappearing, allowed to identify several "sites of geological memory" in this area.

KEY WORDS: mines, bauxites, limonites, Mesozoic, Gaetano Tenore, Campoli Appennino, San Donato Val Comino, Pescosolido, Rosanisco Forge, Canneto Forge, History of Geology.

INTRODUCTION

The extraction and processing of iron and aluminum represented, with ups and downs, one of the most important elements in the economy of the area delimited by the flow of the Melfa and Liri rivers (e.g. Tutinelli & Visocchi, 1998; Reggiani, 2003). The aim of this manuscript is to reconstruct the evolution of the mining activities in the Comino Valley-Sora area (Frosinone, Lazio, Central Italy) in the XVIII and XIX century, providing historical, bibliographic and cartographic data. This area was part of "*Terra Laboris*" from Roman times up to 1927, when it was definitively suppressed by the fascist regime, to then become part of the province of Frosinone.

Evidence of mining activities in the Comino area is from proto-historic times. The discovery of lithic industry on pebbles in the Atina area suggests the exploitation of iron-rich deposits in the La Meta Mountains since the lower Paleolithic (Solin, 2005). Mining activities are, however, certain 400 years BC, when the Samnites took possession of the mines on the slopes of the La Meta Mountains. This brought the Roman poet Virgil to define the city of Atina as "*potens*" (*powerful*) in the VII book of Aeneid, and to consider it among the five cities of Lazio that forged new weapons in the war between Latins and Trojans ("*Quinque adeo magnae positis incudibus urbes tela novant, Atina potens Tiburque superbum, Ardea Crustumerique et turrigerae Antemnae.*" – Aeneid, VII, verses 629-631).

The need to increase the production of iron and cast iron to enhance the armaments on the naval units of the Navy of the Kingdom of Naples, pushed the Bourbon authorities to carry out mineralogy studies in the Comino-Sora area. Fundamental were some professional figures commissioned by the Kingdom of the Two Sicilies, among which the architect Mario Gioffredo, the engineer-mineralogist Giuseppe Tenore, the Captain of Artillery Luigi Melluso, immediately replaced by Gennaro Isastia as director of the Royal mines, and the scientific smelter of the Real Corps of Artillery Salvatore Giancotti.

As a result, the Comino-Sora sector, coupled with the Mongiana, Stilo, Ferdinandea and Assi in Calabria (Southern Italy – Rubino, 1988), represented an important mining-metallurgical district for the Kingdom of the Two Sicilies from 1770 to 1860, albeit if mining activities also took place at the beginning of the twentieth century. This vast mining complex consisted of the "Royal Mines" of (from south to north): Canneto Valley (Settefrati-Picinisco municipalities), San Donato Val di Comino and Campoli Appennino; to these must be added the mine of Colle Carovenzi (about 3 km NW of Pescosolido - see Fig. 1). Forges were built in Canneto Valley and Rosanisco (Atina).

The crisis of the Bourbon Kingdom in the 1860, and the demise of iron extraction and processing activities at the end of the XIX century, caused the abandonment and degradation of most of the sites discussed in this paper. The disappearing of most of the mines and forges, coupled with the need to re-evaluate, preserve and disseminate this cultural and geological heritage (Cipriani et al., 2016; Pantaloni & Console, 2019), allowed to identify several "sites of geological memory" for the study area (Cipriani, in press). According with Console et al. (2018) and Pantaloni & Console (2019) a "site of geological memory" or "historical geosite" is a peculiar type of geosite that represented an important place of geological-landscape interest in the past but that, due to its geomorphological/anthropic evolution, is no longer visible today.

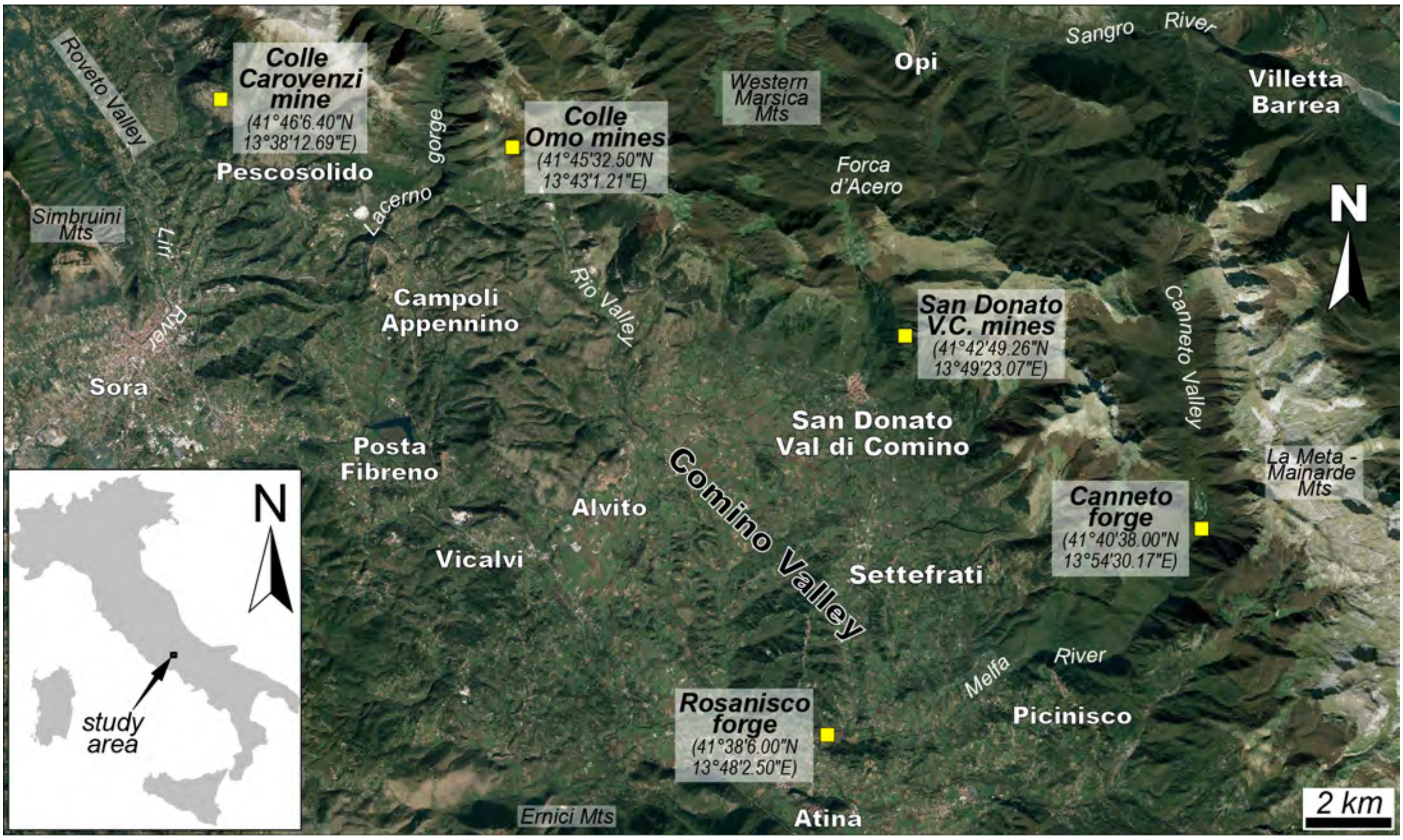

Fig. 1 - Geographic localization of the study area. Reported are the discussed mining activities and forges (modified from Google Earth©2018).

THE BAUXITIC-LIMONITIC DEPOSITS OF THE COMINO VALLEY-SORA AREA

The study area is at the southeastern borders of Lazio, close to the boundary with the Abruzzo and Molise regions, and is partially involved in the Lazio-Abruzzo-Molise National Park. The Comino Valley-Sora area is characterized by the presence of the Melfa and Liri rivers and is bounded i) southeast-ward by the La Meta-Mainarde mountains, ii) south- and southwest-ward by the Ernici mountains, iii) north- and northeast-ward by the Western Marsica mountains and iv) northwest-ward by the Roveto Valley, the southern Simbruini mountains and the Quaternary Sora plain (Fig. 1). The exploited deposits for mining activities were bauxitic and limonitic deposits embedded in Jurassic-Upper Cretaceous *p.p.* shallow-water carbonates, widely exposed in the Western Marsica and La Meta mountain ridges.

Supratidal and lateritic facies occur as laterally discontinuous bodies (*i.e.* lenses or dykes) and rest on extremely irregular paleokarst surfaces. Breccias/conglomerates fixed by reddish-greenish carbonate cements or red to dark shales and marls occur at the base of, or are embedded in, the bauxitic/limonitic facies (Fig. 2A, 2B). In the field, these deposits have an earthy look and are overlain by shallow-water limestones (see also Damiani et al., 1991; De Vivo et al., 2009) (Fig. 2C). Lithologically are oolites or pisolites, ranging from red to light red and pink to ferruginous brown in color (Fig. 2D, 2E). The very high content (ranging from 30 to 70 %) of aluminum hydroxide [$Al(OH)_3$] in the bauxitic facies, and of hydrated iron oxide ($2Fe_2O_3{\cdot}3H_2O$) in the limonitic ones, made (and makes) these deposits a favorite among the metallurgical industries.

The first geological studies on the aluminum and iron-rich deposits of the Comino-Sora area were by Tenore (1856a ,1856b, 1863, 1872, 1876). The Author recognized five different types of iron and aluminum-rich deposits: *"Ematite bruna manganesifera; Limonite di Montagna; Limonite stratificata in roccia; Limonite stratificata oolitica; Limonite pisiforme o Ferro di alluvione"* (*"Brown manganese-rich hematite;, Mountain limonite; Bedded limonite in rock; Oolitic and bedded limonite; Pisiform limonite or Alluvial iron"* – Tenore, 1856a). Furthermore, Tenore subdivided the Mesozoic limestones of Western Marsica and La Meta Mountains (*"calcarea appennina"* – Tenore, 1856a) into two main units: *"Calcarea bianca granellosa molto tenace […] con giacimenti irregolari d'idrossido di ferro"* (*"Really tough white granular limestone […] with irregular deposits of iron hydroxide"* – Tenore, 1872, pp. 29-30) Early Jurassic in age, and *"Calcarea compatta o litografica; Calcarea brecciforme varicolored; Calcarea bituminifera; Calcarea terrosa o Creta […] con Limonite terrosa ed oolitica a strati regolari"* (*"Compact or lithographic limestone; Polychrome brecciated limestone; Bituminous limestone; Earthy limestone or* Creta *[…] with well-bedded earthy and oolitic limonite"* – Tenore, 1872, p. 30), Cretaceous in age.

Cassetti (1897, 1898, 1899, 1900, 1901a, 1901b, 1902) provides the first substantial contributions to the knowledge of the geology of the area, as a result of the geological mapping project related to the realization

Fig. 2 - Field aspects of the study bauxitic-limonitic facies. A) Polygenic and heterometric breccia made of shallow-water limestone clasts dispersed in an earthy, reddish, matrix. Colle Carovenzi, Pescosolido. B) Sub-angular and decimetric clasts of peritidal limestones in a pink-reddish carbonate matrix. Colle Omo, Campoli Appennino. C) Lens-shaped bauxitic deposits overlaid by shallow-water limestones. Arrowed hammer for a scale. Colle Carovenzi, Pescosolido. D) Oxidized, sub-centimetric pisolites embedded in reddish earthy laterites. Colle Omo, Campoli Appennino. E) Red bauxitic and yellow-brownish limonitic facies resting on paleokarst breccias and passing up-ward to peritidal limestones. Colle Carovenzi, Pescosolido.

of the first edition of the Geological Map of Italy at 1:100,000 scale (Regio Ufficio Geologico, 1928, 1931). In particular, in 1901 Cassetti understood the geometric and stratigraphic relationships of the lateritic deposits exposed in the Western Marsica within the sedimentary succession, framing them in the "*Urgonian limestones, just below the overlying Turonian limestones with* Hippurites *and* Actaeonella" (Cassetti, 1901b, p. 17-18) (Fig. 3A, 3B).

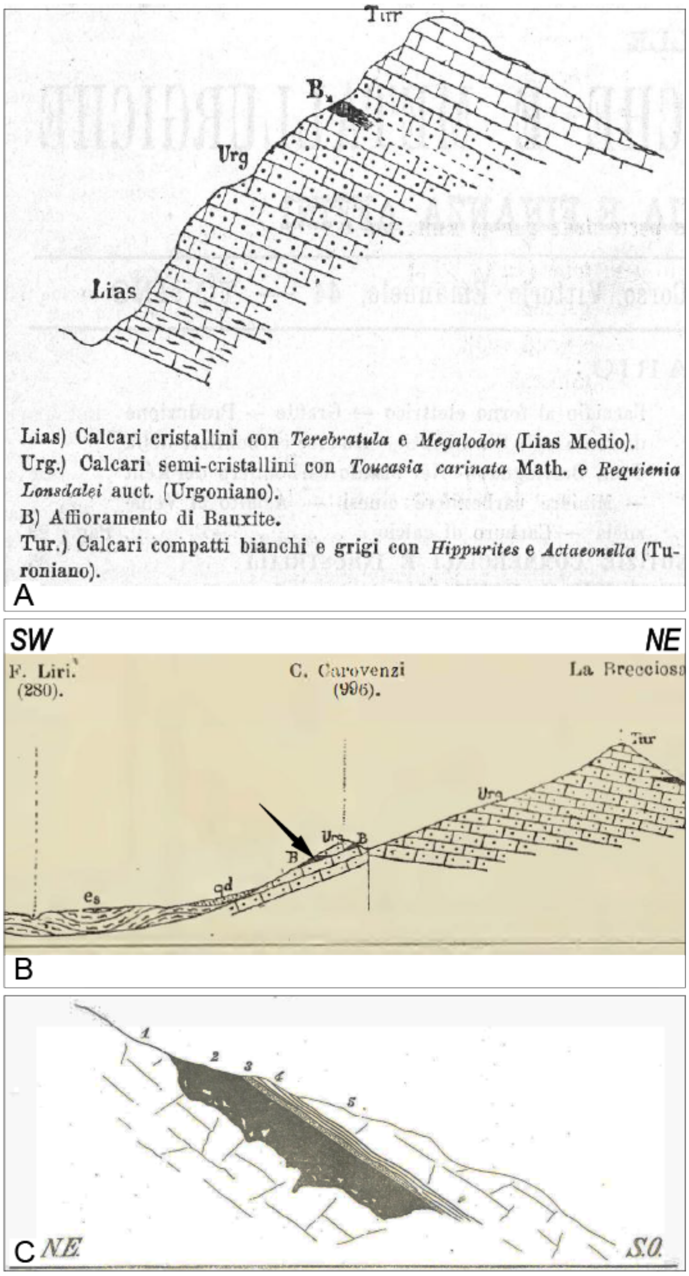

Fig. 3 - A) Stratigraphic relationships between the Cretaceous bauxites and the Mesozoic succession (modified from Cassetti, 1901). The Author refers these deposits (B) as to embedded in the "*Urgonian*" facies. B) Essay of a geological cross section involving Colle Carovenzi and its bauxitic (B) facies (black arrow – modified from Cassetti, 1902). C) Iconographic documentation of the Colle Carovenzi bauxitic interval by Lotti (1903). Legend (from Lotti, 1903): "1) underlying white ceroid limestone; 2) bauxitic level; 3) ocher clayey level at the top of the bauxitic level; 4) very thin beds of yellow-gray and violet limestone (thickness: 50 cm); 5) overlying massive, ceroid limestone".

The same relationships were identified and described for the bauxitic deposits of Colle Carovenzi (Pescosolido) by Lotti (1903 - Fig. 3C).

The loss of interest in iron and aluminum-rich deposits as mining fields led to the decrease in scientific interest toward the study area. In fact, after Lotti (1903) there is no scientific literature focused on the bauxitic/limonitic deposits of the Comino Valley-Sora area. References occur only in Accordi et al. (1967, 1969), Praturlon (1968) and Damiani et al. (1991).

HISTORICAL CARTOGRAPHY

First cartographic evidence for mining activities in the study area is in the *"Atlante geografico del Regno di Napoli* (*"Geographical atlas of the Kingdom of Naples"* – Rizzi-Zannoni, 1810). This pioneering topographic map reports the toponyms *"Miniera del Ferro" ("Iron mine")* west of San Donato Val di Comino, in *Rave rosse* locality (see also Tenore, 1856a), and *"Ferriere" ("Forges"*) in the Melfa gorge (Canneto Valley - Fig. 4). *Rave Rosse* is a toponym which indicates *"erti pendii rocciosi dal colore rosso"* (*"steep rocky slopes with a red color"*), related to presence of iron-rich deposits embedded in carbonate rocks (Del Lungo, 2001, p. 114).

In the 1: 100,000 scale Sheets 152 "Sora" and 160 "Cassino" of the *Carta Idrografica del Regno d'Italia* (*Italian Kingdom Idrographic Map* – Ministero di Agricoltura, Industria e Commercio, Direzione Generale dell'Agricoltura, 1890a, 1890b), the toponym *"Miniera di Ferro" ("Iron mine")* is used to indicate the mines of Colle Omo (Campoli Appennino) and -erroneously- the Royal Forge of Rosanisco (north of Atina). These topographic maps were used as base maps of the first edition of the Geological Map of Italy (see below).

The mines of Campoli Appennino (*"Le Miniere"* toponym, north of Colle Omo - Fig. 5A) and Colle Carovenzi (Pescosolido; *"Miniera di bauxite"* toponym - Fig. 5B) occur, respectively, in the Sheet 152 - II NO "Pescasseroli" and Sheet 152 - III NE "Monte Cornacchia" at 1:25,000 scale (sections of the Italian Topographic Map at 1: 100,000 scale – Istituto Geografico Militare, 1963). The *Real Magona* of Atina (*"la Ferriera"*) is reported in the Sheet 160 - I NO "Atina" at 1:25,000 scale (section of the Italian Topographic Map at 1: 100,000 scale – Istituto Geografico Militare, 1960) (Fig. 5C).

The first reference to a geological map for the study area is in Tenore (1852 in Bassani, 1904), but there is no evidence of it in the work. The same is true for the *"Carta geologica del Bacino del Melfa"* (*"Geological map of the Melfa Basin"* – Tenore, 1863). Bassani (1904) mentions the presentation of an essay of this map at the Paris International Exposition in 1867 (Tenore, 1867 in Bassani, 1904), of which only a table with 2 geological cross sections remains (Fig. 6A – see also Pantaloni et al., 2016). Consequently, the *"Saggio di carta geologica della Terra di Lavoro"* (*"Essay of geological map of Terra di Lavoro"*) at 1: 280,000 scale represents the first available geological map for the Comino-Sora area (Tenore, 1872 – Fig. 6B). Nine main geological units were mapped by Tenore: i) the Jurassic limestones (*"Calcarea salina"*); ii) the Cretaceous *"compact or lithographic, brecciated or bituminous"* limestones, rich in rudists and gastropods;

Fig. 4 - Historical cartography by Rizzi-Zannoni (1810, modified) involving the Comino area. Arrowed are the "*Miniere del Ferro*", east of San Donato, and the "*Ferriere*" in the Canneto Valley, close to the sanctuary of Santa Maria di Canneto (S.M. di Candito in the topographic map of Rizzi-Zannone).

iii) the "*Eocene*" marls ("*Calcarea idraulica; Macigno; Scisti argillosi e selciosi*"); iv) the "*Miocene and Pliocene*" sandstones, sands and clayey marls ("*Arenaria e marna argillosa; Argille scistose; Sabbie gialle*"); v) the "*Pliocene*" tuffs and vi) lavas; vii) the calcareous conglomerates ("*Conglomerato calcareo a grossi ciottoli)* and *terre rosse* ("*Argilla diluviana*"); viii) travertines ("*Calcarea lacustre [travertino]; Laghi e Sorgenti minerali*"); and ix) alluvial deposits, peat and beaches. The latter three continental units (*i.e.* vii-ix) are "*post-Pliocene or diluvian*" to Recent in age. Furthermore, the iron- and manganese-rich deposits coupled with bituminous emanations were reported (Tenore, 1872). Two geological cross sections are companions of the main map; one of these ("*Fig. II*") coincides with the cross section in Tenore (1867), involving the Canneto Valley-Atina sectors.

The Meso-Cenozoic carbonate rocks stratigraphy reported in the first edition of the Geological Map of Italy at 1:100,000 scale (Regio Ufficio Geologico, 1928, 1931 - Fig. 7A-D) is still poorly differentiated. However, the main bauxitic-limonitic deposits cropping out in the Western Marsica mountains are mapped (except for the San Donato Val di Comino-Canneto area).

In 1965-1966, the field-works related to the realization of the second edition of the Geological Map of Italy at 1:100,000 scale (Sheets 152 "Sora" and 160 "Cassino" – Servizio Geologico d'Italia, 1966, 1967) and performed in the Comino-Sora area were completed (see the original field maps at 1:25,000 scale by Alessandro Paradisi, Gianfranco Francioni and Domenico Menichini in Fig. 8A-D). Iron and aluminum-rich emersive deposits were mapped in the Western Marsica range, while no bauxitic-limonitic outcrops are reported in the San Donato Val di Comino-La Meta area. Geological maps display a differentiated stratigraphy for the Meso-Cenozoic limestones, a mirror of the complex depositional architecture that characterized the present-day Western Marsica-La Meta range from the Jurassic to Miocene. As recognized and described by Accordi et al. (1967), Praturlon (1968) and Parotto (1969), this area was characterized by a complex physiography of the seabed, made of peritidal to subtidal, slope and deep-water depositional environments. In particolar, inner and marginal carbonate platform facies characterize the Simbruini-Ernici and Western Marsica area, slope deposits occur in the San Donato Val di Comino-Forca d'Acero-La Meta area, and deeper-water pelagites crop out southeast-ward in the Molise basin (Colacicchi & Praturlon, 1965; Damiani et al., 1991; Ghisetti & Vizzani, 1998; Festa et al., 2006). This architecture was produced by the rifting stage that affected the Western Tethys in the Early Jurassic (e.g. Bertotti et al., 1993; Santantonio & Carminati, 2011). The Hettangian *p.p.*-Sinemurian *p.p.* normal faulting dismembered a vast shallow-water carbonate platform ("paleoplatform" in Chiocchini & Mancinelli, 1978) and led to the formation of fault-bounded blocks. The footwalls of Jurassic faults preserved shallow water conditions (*i.e.* Simbruini-Western Marsica – Colacicchi & Praturlon, 1965; Mostardini & Merlini, 1986; Chiocchini et al., 2008, 2012, 2019), while the downthrown blocks deepened, entering in pelagic conditions (*i.e.* La Meta-Mainarde; Ghisetti & Vizzani, 1998; Festa et al., 2006; for comparable paleogeographic settings in Central Italy, see Cantelli et al., 1978; Colacicchi & Bigozzi, 1995; Galluzzo & Santantonio, 2002; Rusciadelli et al., 2009; Rusciadelli & Ricci, 2013; Cipriani, 2016, 2019; Fabbi et al., 2016; Romano et al., 2018a, 2018b, 2019; Cipriani & Bottini, 2019a, 2019b; Citton et al., 2019; Cipriani et al., 2019a, 2019b, 2020).

The Comino Valley-Sora area is not involved in the new cartographic project at 1:50,000 scale of the Italian Geological Survey (CARG Project); for an updated stratigraphy, see the neighbouring geological maps of Abruzzo (Vezzani & Ghisetti, 1998) and Molise (Vezzani et al., 2004).

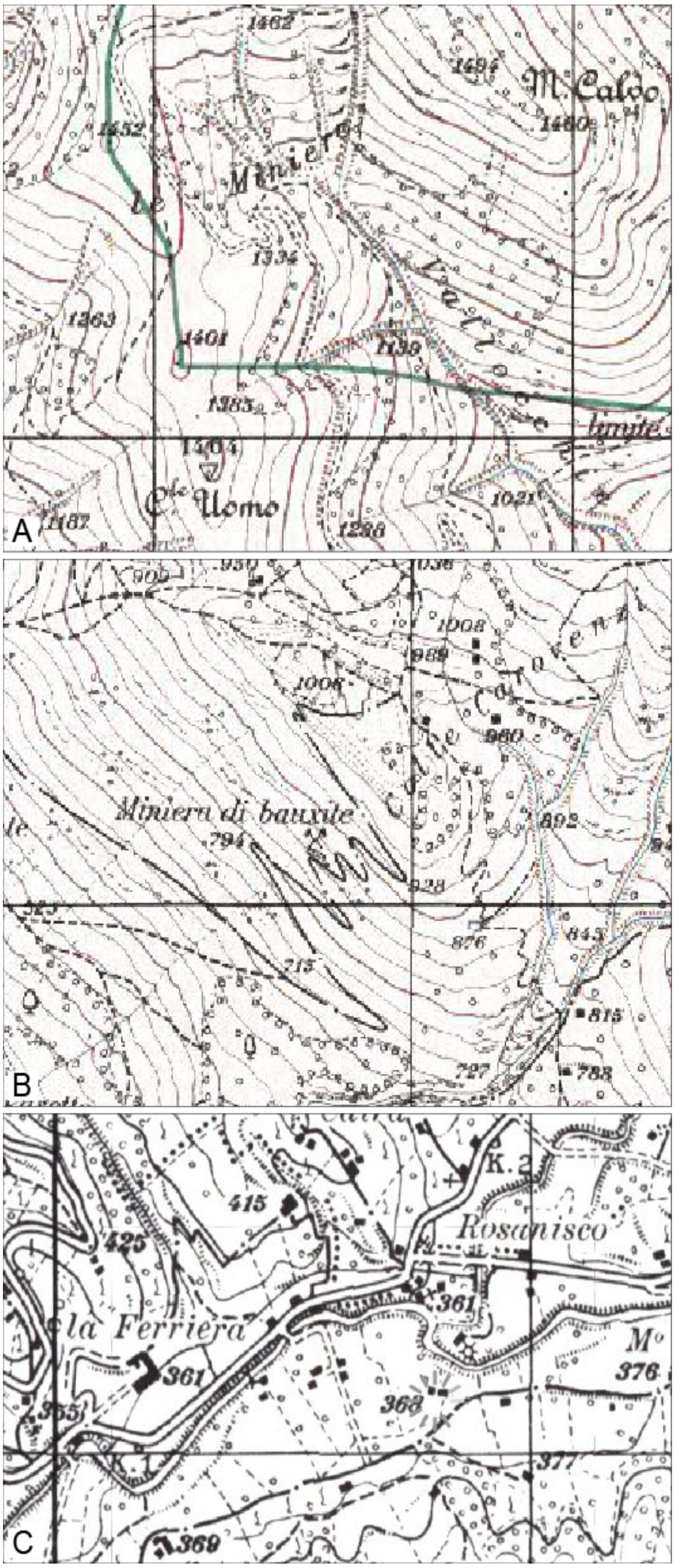

Fig. 5 - Essays of the sections at 1:25,000 scale of the sheets 152 "Sora" and 160 "Cassino" (Italian Topographic Map at 1: 100,000 scale – Istituto Geografico Militare, 1960, 1963). A) Part of the Sheet 152 - II NO "Pescasseroli" at 1:25,000 scale; the Campoli Appennino mining district is represented by the *"Le Miniere"* toponym north of Colle Omo (*"C.le Uomo"* toponym). B) Part of the Sheet 152 - III NE "Monte Cornacchia" at 1:25,000 scale; the Colle Carovenzi *"Miniera di bauxite"* is reported. C) Essay of the Sheet 160 - I NO "Atina" at 1:25,000 scale; the Atina *Real Magona* (*"la Ferriera"* toponym) is reported.

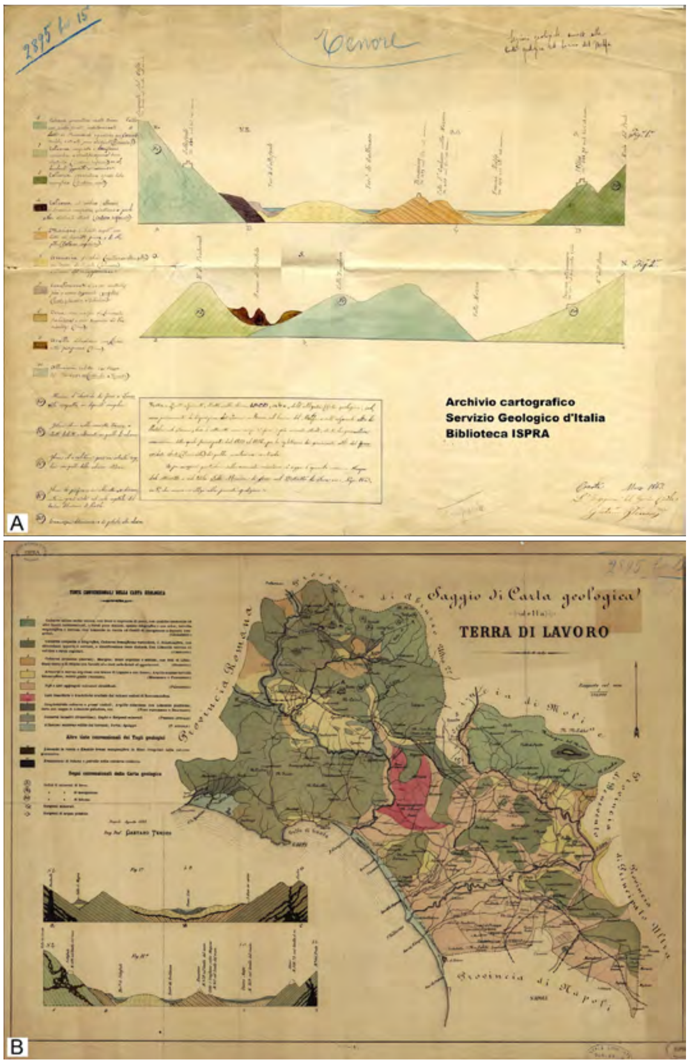

Fig. 6 - A) Two hand-made geological cross sections reported in a table companion of the *"Geological map of the Melfa Basin"* (Tenore, 1867). In the *"Fig. II"* geological section (lower), the mines of Colle Omo are reported. B) *"Essay of geological map of* Terra di Lavoro" (Tenore, 1872). Cartographic collection, ISPRA Library.

MINES AND FORGES OF THE COMINO VALLEY-SORA AREA

CANNETO VALLEY DISTRICT

Mining activities are known since pre-Roman times near the springs of the Melfa River, in a deeply-incised gully (Canneto Valley) on the western slopes of the La Meta Ridge. The Virgilian "power" of Atina was linked to iron and steel activities carried out by the Volsci and the Samnites in this area (Solin, 2005).

The discovery in 1770s of iron-rich deposits in the Canneto Valley, probably by Mr. Domenico D'Ambrosio (Memorie per le Belle Arti, 1788; Pistilli, 1798), placed the Comino area at the center of the interest of the Bourbon government for the industrial exploitation of the limonite deposits. The architect Mario Gioffredo, previously engaged with the Royal Forge of Mongiana (Calabria), was commissioned by the King Ferdinand IV to carry out a survey in the Canneto Valley in order to define the quality and the quantity of the lateritic deposits and to build a forge.

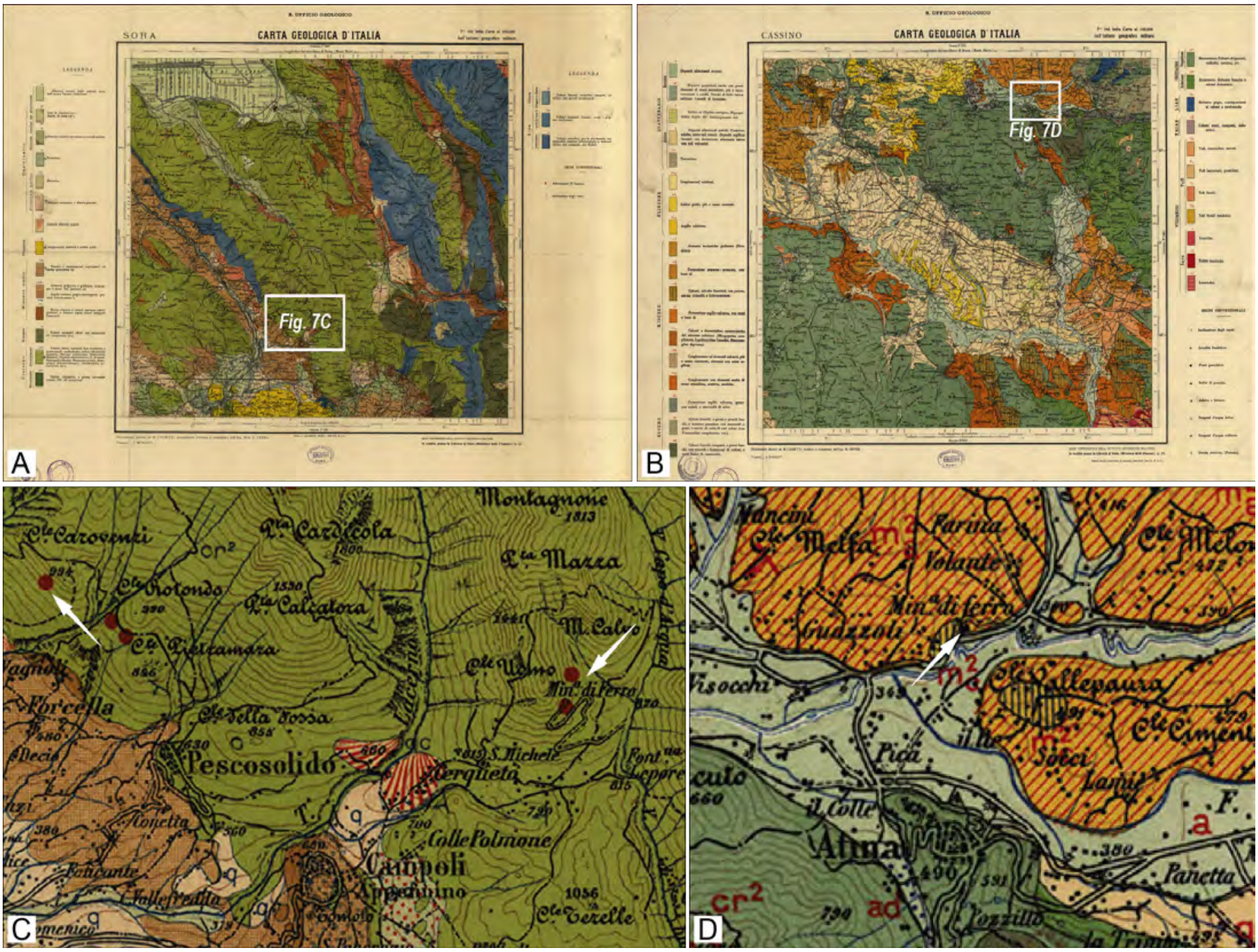

Fig. 7: First edition of the Italian Geological Map at 1:100,000 scale, sheets 152 "Sora" (A) and 160 "Cassino" (B). C) Detail of A), where the Colle Carovenzi and Colle Omo mines are arrowed. D) Detail of B), where the erroneous *"Miniera di ferro"* toponym (white arrow) indicates the Rosanisco forge.

As reported in the Mario Gioffredo's eulogy, *"to Gioffredo [...] the reconnaissance was ordered [...] he recognized the mineral, the woods, the site, the waters, and found everything suitable and considered the project to be very useful to the Court [...] This sentiment [...] was believed [...] by the Artillery Officers, and by the Court of the Regia Camera [...] an imposture, and that Mario was a solemn madman to run into such trials: which punctured his heart [...] sure of his experiments he set about erecting the ironworks in the Canneto Valley at his own expense; with the agreement, however, if unsuccessful, he would lose his expenses and efforts, and on the contrary, if he succeeded in the undertaking, he would have third of the profit and the prize from the Court"* (Memorie per le Belle Arti, 1788, p. CXXIII).

Mario Gioffredo built the forge near the sanctuary of "Santa Maria di Canneto" (41°40'38.00"N; 13°54'30.17"E), on the walls of an ancient Benedictine monastery (Antonelli, 1920), which became operational in 1785 (Rubino, 1988). The ironworks included a first melting plant and refining plants which, also with the collaboration and competence of skilled artillerymen sent from Mongiana to Canneto, began to produce both soft iron for civil use, as well as artillery shells and other casting products. In 1789 Gioffredo ceded the forge to the Bourbon Royal Government, which established Lorenzo Damiani as director (Tenore, 1856b, p. 123), and the same remained productive for few years. According to Tenore (1856b), the forge was abandoned and in ruins in 1799.

The reasons for abandoning the forge were related to a series of contributing factors, such as: i) the inconvenience of the site which, especially in winter with intense cold and snow, became inhospitable; ii) the total or near absence of communication routes which entailed enormous problems for the transport of the products; iii) the poor quality of the raw material (or of the melt product). Possible sabotages (albeit without certainties) by the Papal States or the ironworkers who, due to the uncomfortable conditions experienced in living in that *Magona*, would have added silver and copper to the blast furnace making the product of poor quality, were hypothesized by Tenore (1856b).

In 1792, Pistilli presented to the Bourbon Kingdom projects to enhance the municipality of Sora exploiting the water potential connected to the presence of the Liri River and, in particular, the impressive waterfall of Isola del Liri

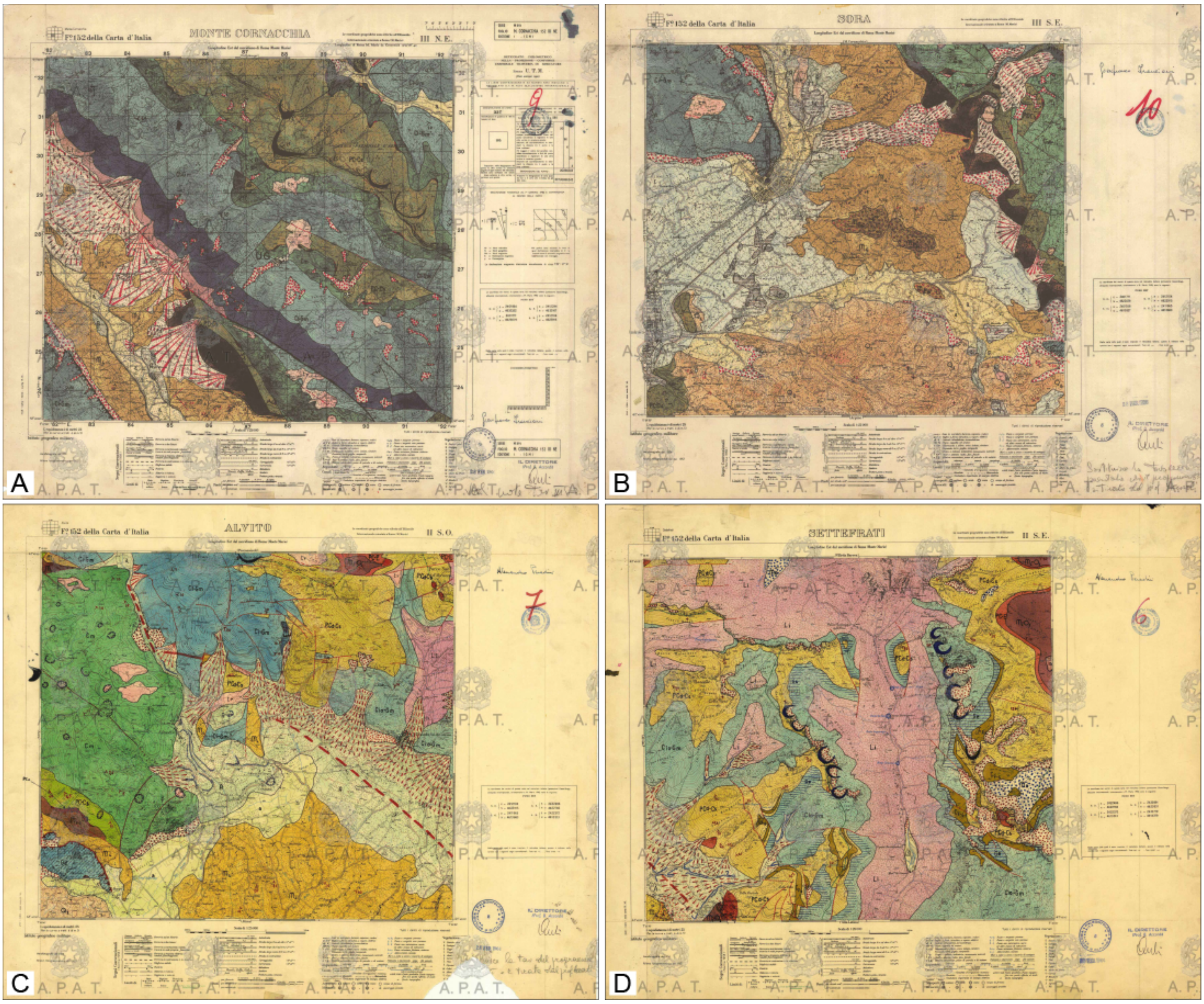

Fig. 8 - Original field maps at 1:25,000 scale, sections "Monte Cornacchia" and "Sora" by Gianfranco Francioni (A-B), and "Alvito" and "Settefrati" by Alessandro Paradisi (C-D), as part of the Sheet 152 "Sora" of the Italian Geological Map at 1:100,000 scale (2nd edition). Cartographic collection, ISPRA Library.

("*Isola di Sora*" at the time), and the nearby presence of iron-rich deposits in the Canneto Valley and Morino (Roveto Valley, Abruzzo). Among these projects, he suggested to construct a spun iron factory at "*Isola di Sora*" in order to obtain wire and to build cannons. According to Giacinto Pistilli, the construction of a metallurgic plant in "*Isola di Sora*" would have been advantageous to the Kingdom because the transport costs would have been negligible, but above all it would have benefited the Sora area and the whole nation as both the wire and the cannons were imported from Germany and Sweden (Pistilli, 1792).

Rubino (1988) reports a comparable project by Giovanni Antonio Sampieri, who officially proposed to the Bourbon Kingdom to build a large complex for the wire drawing of iron for civil use in "*Isola di Sora*", declaring himself willing to take on the contract. The project established the construction of a foundry, nine forges and a modern building for the "iron wire drawing", all according to typological and architectural models of establishments in the Papal States. But the political events of the Parthenopean Republic and the French invasion of the Kingdom, prevented the accomplishment of the undertaking.

Rubino (1988) transcribes the report in full of army officials sent by the Minister of War and Navy from the Mongiana distric in Calabria to Canneto in 1813, in order to inspect the *status* of the forge and of the mining area. In this "mildly argumentative" report (related to the controversial interest of the Royal Government to divert public investment from Calabria to the Comino area), the detailed description of the (already ruined) forge and of some of the exploited mines is reported.

In 1852, the renewed need to exploit iron deposits for war reasons, combined with the decisive progress of the metalworking industry, pushed the Bourbon authorities to carry out further mineralogy-stratigraphic studies in the Comino Valley, enlarging the interest toward the surroundings of Sora. Consequently, Giuseppe Tenore, Luigi Melluso (replaced by Gennaro Isastia) and Salvatore Giancotti were sent from Calabria to the Terra di Lavoro area by King Ferdinand II of Bourbon. The ancient underground researches were re-evaluated, the topographical conditions of the territory were investigated, and economic investments were planned to build the mines, the forges and the new communication routes (or to expand the existing ones).

An attempt to reactivate the Canneto's forge was made, improving the access routes to the valley and restoring the old ironworks (Fig. 9A-C). The construction of the road from the center of Settefrati to the *Magona* dates back to this period (1856-1860) and is still very busy today for access to the sanctuary of Canneto. On April 20, 1853, under the control of the Director Gennaro Isastia, the second life of the Royal Forge of Canneto began. The previously explored deposits were reused both on the slopes of the Meta Mountains ("*Ponte S. Croce, Vallone rondinella, Liscia, Grotta del vaccaro, Chiaiarino*" – Tenore, 1856a, p. 53), and on the slopes of the Settefrati mountains (*i.e.* Western Marsica; "*Colle minerale, Colle acrifoglio o Monticelli [...] Colle mulattieri e Pezzillo [...] Monte di Costapriori*" – Tenore, 1856a, p. 53), on the hydrographic left and right of the Melfa River respectively. There is no evidence, however, of these toponyms in modern cartography. The iron and steel activity in Canneto continued until 1856, when the forge was definitively abandoned (Giancotti, 1857).

In the spring of 1852 two main mining districts were identified (although limonite and bauxite-rich deposits were also recognized in the territories of Picinisco, Settefrati, Alvito, and Pescosolido – Tenore, 1856a, 1872; Giordano, 1864; Jervis, 1874; Cassetti, 1899; 1902; Lotti, 1903): the San Donato Val di Comino and Campoli Appennino districts.

THE SAN DONATO VAL DI COMINO DISTRICT (41°42'49.26"N; 13°49'23.07"E)

Huge quantities of iron and aluminum-rich deposits were discovered on the slopes of the mountains surrounding San Donato Val di Comino. Originally the name of the town was only San Donato (e.g., Tenore, 1856a), but in 1862 it took on today's name of San Donato Val di Comino following the Royal Decree of 12 December in implementation of the City Council resolution of 26 October, to avoid confusion with other municipalities equally called San Donato (Volante, 2005, De Angelis Curtis, 2008). Jervis (1874) in his monumental work "*I tesori sotterranei dell'Italia*" ("*The underground treasures of Italy*") already quotes the

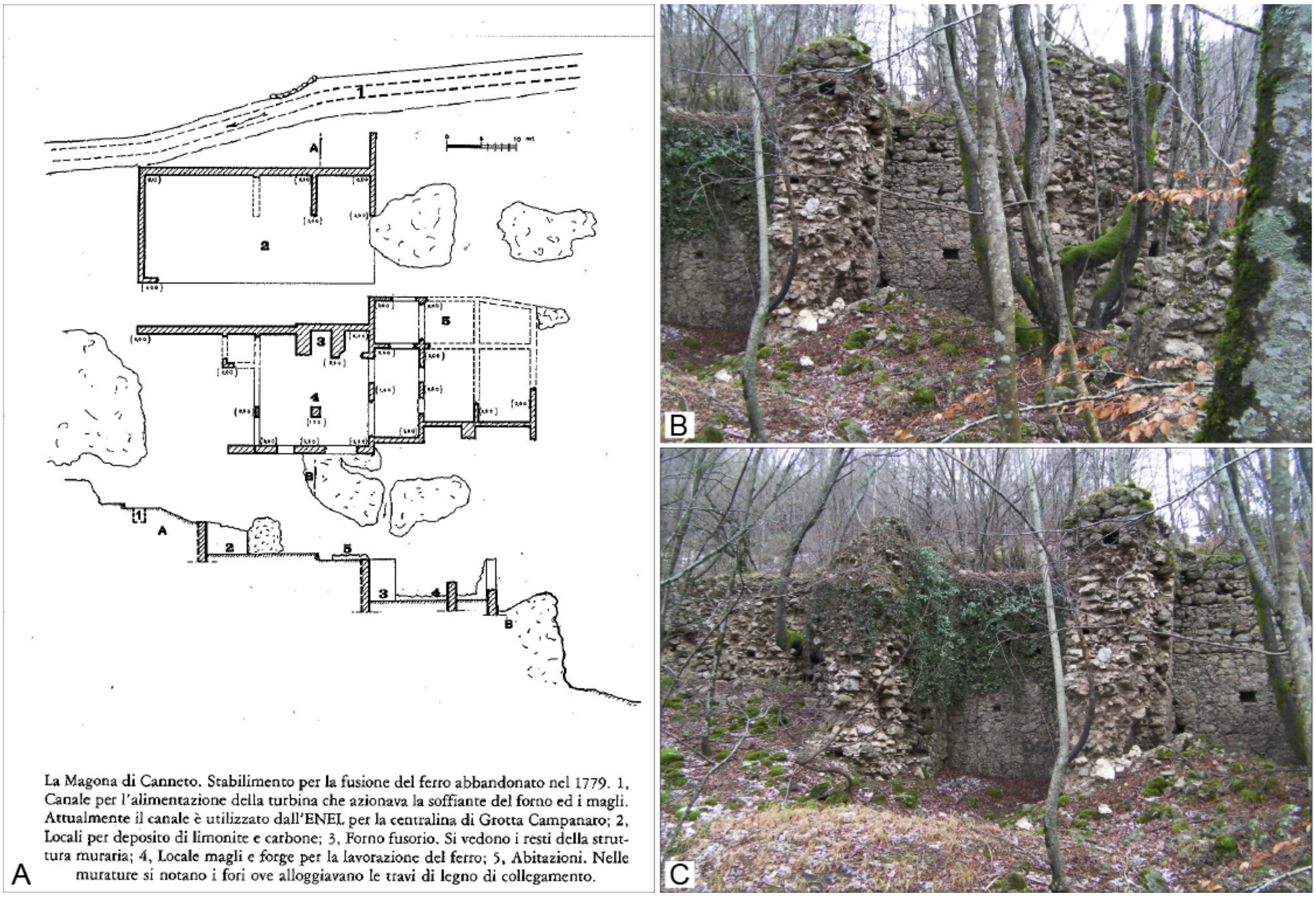

Fig. 9 - A) Planimetric reconstruction of the Royal Forge of Canneto Valley (from http://www.settefrati.net/). B-C) Ruins of the *Real Magona* of Canneto (da http://www.settefrati.net/).

toponym San Donato Val di Comino. On the present-day Calvario Mount (*"Monte di Cunnola"* in Tenore, 1856a), mining deposits made of *"brown manganese-rich hematite"* (Tenore, 1872) in the form of *"discontinuous dykes filling caves and fissures in limestones"* (Tenore, 1856a, p. 53) were identified. Excavation works began in May 1853, under the guidance of artillery captain Gennaro Isastia and the chief miner Giovanbattista Oroud (Tenore, 1956a, Rubino, 1988). The mining park of San Donato Val di Comino (Fig. 10A, 10B) was made up of five tunnels: *"an upper tunnel penetrates the mountain of Rave Rosse, and two other lower ones not far from each other, the other tunnel of Cunnola having multiple branch tunnels, in order to follow the trend of limonite deposits, which now swell, or shrink, or meander in various ways, here they go up, and there they go down. In addition to these main galleries, two other vans behind the outcrops that appeared on the same mountain, about 75 m away from the first"* (Giancotti, 1857, p. 122). Tenore refers to tunnels excavated also on the slopes of *"Fontecardegna Mount (located behind* [northward] *the slope of Cunnola Mount) [...] Castelluccio Mount, near the road* [that connects San Donato Val di Comino] *to Pescasseroli along the valley of Forca d'Acero [...] and Guadolargo Mount"* (Tenore, 1856a, pp. 55-56), the latter indicated as *"Monte Pizzuglia"* in Rizzi-Zannoni (1810 – see Fig. 4) and coinciding with the present-day Pizzuto Mount. In addition to the above-mentioned tunnels, two holes – one of which is the *Rave Rosse* hole, already exploited in the XVIII century (Rizzi-Zannoni, 1810; Tenore, 1856a – see *"Miniera di Ferro"* in Fig. 4) – an open-air excavation, several essays and a deposit of waste rock material (Giancotti, 1857). Tunnels were appointed *"San Ferdinando"*, *"Santa Teresa"*, *"San Francesco"*, *"Sant'Agostino"*, *"Castelluccio"* (https://www.altaterradilavoro.com/miniere-limonite-nella-valle-comino/). Chemical analyses performed on the lateritic deposits of San Donato Val di Comino by Giancotti revealed a content of iron oxide ranging between 56 and 65% (Giancotti, 1857 – Fig. 11). According to Jervis (1874), associated with the limonitic deposits were chalcopyrite and pyrite, and pyrolusite as well.

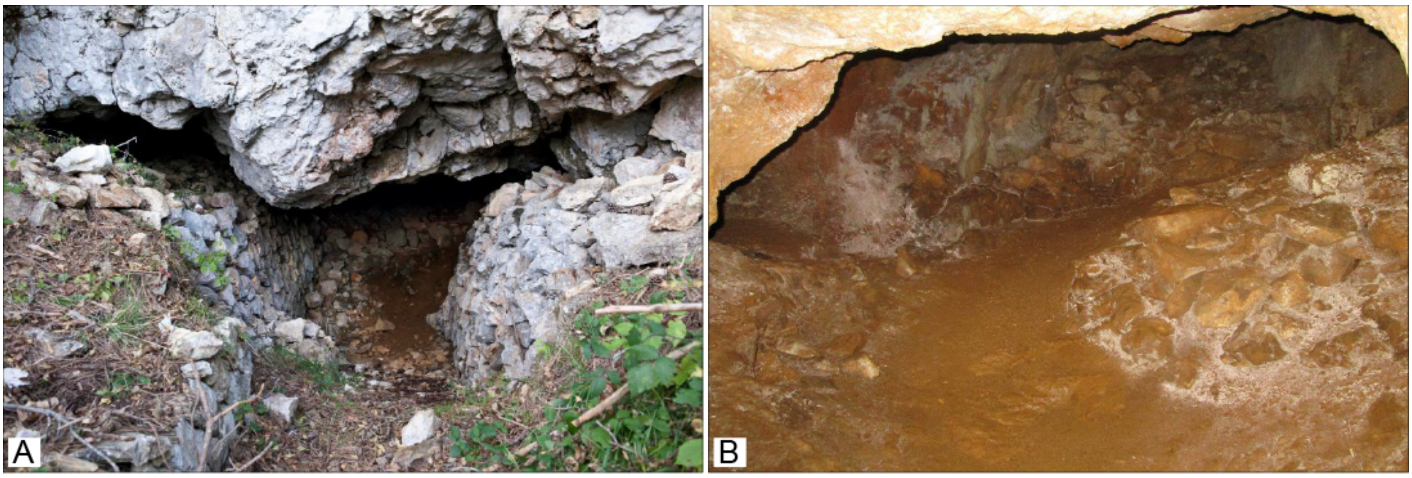

Fig. 10 - A) Entrance and B) interior part of the "San Ferdinando" gallery, on the western slopes of Cunnola Mount (San Donato Val di Comino).

Indicazione delle sostanze	Limonite di S. Donato: Compatta e bruna	Limonite di S. Donato: Cellulosa ocracea terrosa	Limonite di Campoli: Argillosa bruna	Limonite di Campoli: Argillosa terrosa	Limonite di Pratola: Pisolitica	Limonite di diverse contrade, e di palude	Calcarea di S. Donato: Compatta semi-granulare	Calcarea di S. Donato: Dolomitica terrosa
Perossido di ferro. . .	65. 402	56. 156	56. 58	50. 87	75. 86	43. 59	1. 16	tracce
Idem di Manganese. .	1. 705	1. 452	1. 89	1. 32	75	60	»	»
Acqua a 23° centigradi.	9. 610	9. 820	12. 36	10. 79	12. 28	7. 83	5. 27	1. 00
Silice	1. 500	2. 770	4. 76	8. 48	4, 72	8. 76	1. 50	50
Allumina	2. 457	6. 874	6. 47	9. 23	1, 89	9. 32	3. 14	98
Calce	8. 780	11. 240	7. 46	8. 95	1. 76	12. 21	41. 33	36. 94
Magnesia	840	685	1. 72	89	»	3. 38	6. 83	14. 61
Ossido di rame . . .	620	»	»	»	»	»	»	»
Acido carbonico . . .	8. 176	9. 590	7. 76	7. 99	1. 38	13. 30	40. 19	45. 22
Perdita.	910	1. 413	1. 00	1, 48	1. 36	1. 01	58	75
Totale	100.	100.	100.	100.	100.	100.	100.	100.

Fig. 11 - Chemical analyses of the different kinds of limonitic deposits from Campoli Appennino and San Donato Val di Comino districts, compared with the limestones and dolostones sampled near San Donato Val di Comino (modified from Giancotti, 1857).

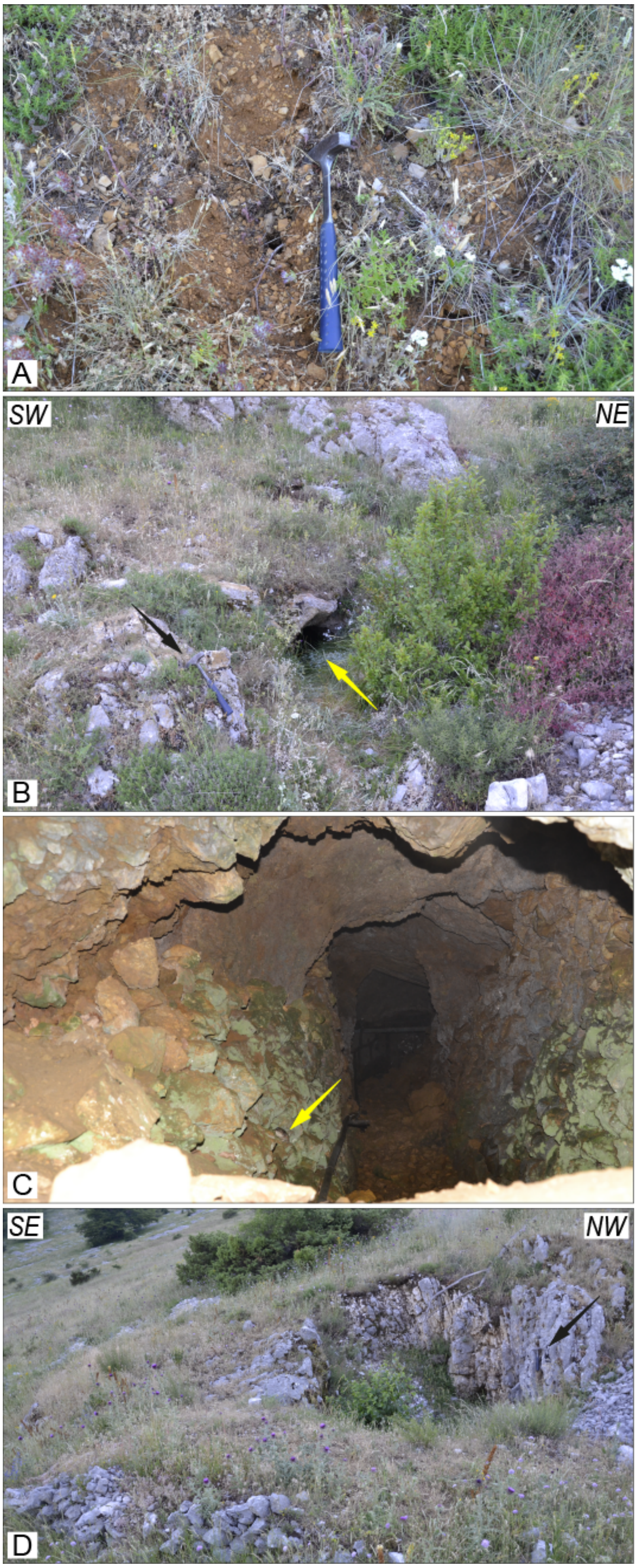

Fig. 12 - A) Field aspect of the brownish and earthy limonitic facies at Colle Omo. B) Partially-hidden very small entrance of the Colle Omo gallery (yellow arrow). Hammer for a scale (black arrow). C) Interior part of the Colle Omo gallery. Arrowed frog for a scale. D) Collapsed entrance of a mining tunnel on the northeastern slopes of Colle Omo, few tens of meters far from the gallery in fig. 12B.

Once extracted, the iron-rich material was brought to "*Capolavalle*" (the present-day "*Piazza Carlo Coletti*" of San Donato Val di Comino), thanks to wicker baskets that were transported by quadrupeds; often, women who carried limonite on their heads or shoulders also participated in the transportation from the mines to San Donato Val di Comino and *viceversa*. As soon as the material arrived in the square, it was weighed and paid to the workers and subsequently transported to the Atina forge where it was worked (see below).

THE CAMPOLI APPENNINO DISTRICT (41°45'32.50"N; 13°43'1.21"E)

On the eastern slopes of Colle Omo (about 4 km NE of Campoli Appennino), bauxitic/limonitic deposits were discovered by Tenore following indications given by local shepherds. These deposits are interbedded in the shallow-water limestones and occur as discontinuous lenses, ranging from few centimeters to few meters in thickness and resting on extremely complex paleokarst surfaces (Tenore, 1856b). Yellow-greenish marls and shales occur at the top of the bauxitic-limonitic facies, and were used at the end of the 1800s to obtain mineral dyes such as yellow ocher (Tenore, 1872) (Fig. 12A). Tenore describes the Campoli Appennino iron-rich facies as brownish "*clayey-glassy limonite*" (Tenore, 1856b), or "*clayey-earthy limonite*" (Tenore, 1872). Chemical analyses performed by Giancotti on these facies revealed an iron hydroxide content ranging between 50 and 56% (Giancotti, 1857 – see Fig. 11). The excellent outcrop and topographical conditions allowed the construction of five tunnels and of a road that facilitated the transport of the excavated minerals (Fig. 12B, 12C). Giancotti refers to three holes "*pushed more than 100 meters into the interior of the mount [...] and connected by other communication arms with the main sections [...] so that the whole surface is of about 8400 square meters*", and to a fourth tunnel excavated along the newly-built road "*about 80 m below the previous ones*" (Giancotti, 1857, p. 123). The name of one of the tunnels ("*galleria d'Agostino*") is reported in Tenore (1856b, pp. 118-119). To date, only one tunnel is still visible at about 1250 m.a.s.l., while the others are collapsed or occluded (Fig. 12D). This altitude has a good response with the indications given by Gaetano Tenore, according to which the entrance of the mines (or one of them) must have been 320 m above the bottom of the "Valle Mozza" (the present-day Rio Valley, at 930 m of altitude), as reported on the geological section that from "*Monte di Pratoroveto*" reaches "*Monte dell'Omo*" ("*Colle Omo*" – Tenore, 1867; see also Fig. 6A).

THE BORN OF THE ROSANISCO ROYAL FORGE (41°38'6.00"N; 13°48'2.50"E)

Following the discoveries in 1850s of the important mineral deposits in the Comino Valley-Sora area, the construction of a foundry was necessary. The assignment was given to the engineer of "Bridges and Streets" Giovanni Rossi, which strategically selected Rosanisco, a small hamlet of the Atina town (Giancotti, 1857; Amati, 1868a). The engineer selected this area as it was 200 m from the right bank of the Melfa River, and 800 m from "*Via Spezzacavalli*" (today "*Via Sferracavalli*"), the first

Fig. 13 - A) Outer wall of the Rosanisco *Real Magona*. B) Bourbon coat of arms carved in stone occurring on the wall of the forge. C) Planimetric view of the Royal Forge of Rosanisco (from Rubino, 1988).

consortium road of Terra di Lavoro that connected (and connects) Sora with "San Germano" (*i.e.* Cassino).

In 1854, work began to erect the forge, with the construction of a melting furnace, workshops and several warehouses (Fig. 13A, 13B). In order to obtain the water as a driving force, a large tank fed by a recharging channel from the Melfa was built, as swell as a water wheel and cylinders blowers. For a more detailed architectural description of the forge, see Giancotti (1857), while for a planimetric map see Rubino (1988 – Fig. 13C).

In June 1858 there was the inauguration ceremony of the "*Royal Forge of Atina*" which, in the short period of activity (1858-1860), produced a daily average of 3,100 kg of raw iron (Tenore, 1872).

THE COLLE CAROVENZI MINE (41°46'6.40"N; 13°38'12.69"E)

A separate but necessary speech must be made for the Colle Carovenzi mine. Gaetano Tenore identified lateritic deposits also in the surroundings of Pescosolido. These sites were exploited before 1860 with the material transported to the Atina forge, but the amount of iron contained in the minerals was scarce (due to its chemical composition, being mainly bauxitic facies and, consequently, rich in aluminum hydroxide) and the mining activities were immediately abandoned. A second life for the aluminum-rich deposits of Pescosolido began in the earliest 1900s. Following the geological fieldworks conducted by Cassetti (1902) in the southernmost part of the Roveto Valley (the valley connecting Sora to Avezzano and in which the upper tract of Liri River flows), further bauxitic deposits were found near Pescosolido, among which the exposures of Colle Carovenzi stood out (see Fig. 3). The bauxitic samples collected here by Cassetti were chemically analyzed by the engineer of the "*Royal Mines Authority*", Ettore Mattirolo. According to Mattirolo, "*the bauxite of the Liri Valley is not very coherent, has an irregular fracture, is reddish-brown and presents a finely oolitic mass in which numerous pisolites, more or less deformed, and fragments also with sharp edges, generally dark and often submetallic black in color, are porphyry disseminated. Under the microscope, colloidal oolites have mostly concentric structure, touch each other, and are bound by very scarce cement [...] Its* [the bauxite] *specific weight ranges[...] between 3.22 and 3.45, with an average of several determinations of 3.33*" (Mattirolo, 1901, p. 229).

After the sampling of Cassetti, the municipality of Pescosolido requested further chemical analyses on three samples from Colle Carovenzi to Ettore Mattirolo. These data

Fig. 14 - A) Signs for the "*Regie Miniere*" that marks the Lazio-Abruzzo-Molise National Park hiking path connecting San Donato Val di Comino to the Bourbon mines. B) Entrance of the "San Ferdinando" mining tunnel, marked and signed by panels. C) Panoramic view of the abandoned open-air mine of Colle Carovenzi. Note the bauxitic deposits, well exposed in the more than 10 meters-high escarpments. Arrowed hammer for a scale.

were kindly referred to the engineer-geologist Bernardino Lotti from the town hall itself, in which the high content of aluminum hydroxide (55-58%) stands out (Lotti, 1903). In the same work, the engineer provides a detailed description of the Colle Carovenzi bauxite interval and a schematic iconographic reproduction of the stratigraphic setting (see Fig. 3). The author highlights the irregular morphology of the basal surface of the deposit, with the bauxitic facies that penetrate *"into the joints and hollows of the limestone, of which* [the bauxite] *envelopes fragments more or less rounded and of varying sizes, sometimes forming breccias or conglomerates bound by bauxitic cement."* (Lotti, 1903, p. 164). The author associates the morphological irregularity of the base with the action of the waves or with the action of iron-aluminous acid solutions that corroded the underlying limestone. This also allowed him to infer the age of formation of the bauxite deposits, which had to be contemporary *"to the embedding rocks or, more precisely, simultaneously to the overlying rocks with which there is perfect continuity, concordance and passage"* (Lotti, 1903, p. 164).

Due to the high aluminum hydroxide content of these deposits, in 1903 the municipality of Pescosolido granted the Lawyer Praga the exploitation of the mine to obtain aluminum, but without the latter carrying out any mining activity on it. In 1917, the concession of exploitation of the Colle Carovenzi mine was purchased by the Bombrini-Parodi-Delfino Company (Ministero dell'Agricoltura, 1918). The same owners of the company carried out further chemical analyses on the bauxitic deposits, identifying an aluminum hydroxide content of 55.51%, an iron oxide content of 27.32% and a titanium oxide content of 1.97% (Ministero dell'Agricoltura, 1918). The bauxite integral processing occurred in the aluminum-works of Segni (Rome), built by the company itself (Ministero dell'Agricoltura, 1920) and subsequently converted into a factory for the production of lime and cements.

THE FALL OF THE BOURBON KINGDOM AND OF THE "IRON RUSH"

The political and patriotic events that led to the fall of the Bourbon government and the rise of Garibaldi in 1860, caused the decay of any type of industrial project in Southern Italy and, consequently, the abandonment of mining and foundry activities in the Comino Valley-Sora area (Amati, 1868a, 1868b).

The Royal Forge of Atina was closed, abandoned and robbed, but still today the wall structures of the large steel complex (see Fig. 13A), the first blast furnace and the Bourbon coat of arms carved in stone placed in a key to the main arch (see Fig. 13B), can be appreciated.

The ruins of the Royal *Magona* of Canneto are still visible among the dense vegetation of the Canneto Valley (see Fig. 9B, 9C), while unfortunately there are no traces of the places of excavation of the minerals.

With the exception of one tunnel, there is no clear evidence for the other mines of Colle Omo (Campoli Appennino district) (see Fig. 12D). By contrast, the road built for the exploitation of mines and transport of minerals is actually a forest road.

After a long period of abandonment, in 2015 the Royal Mines of San Donato Val di Comino became a naturalistic site integrated into the hiking trails of the Abruzzo, Lazio and Molise National Park. In particular, the San Ferdinando Gallery is clearly visible and indicated by specific signage along a nature path of the park (Fig. 14A, 14B).

The mine of Colle Carovenzi was exploited for a short period at the beginning of the XX century (see above) and then abandoned. Nowadays there is little recognition of that mining activity, although the bauxitic deposits are still very well exposed in an about 10-m height escarpment (Fig. 14C).

CONCLUSIONS

The "iron rush" in pre-Bourbon and Bourbon times had important repercussions both in economic, socio-cultural and geological terms for the Comino Valley-Sora area. The search for these deposits has, in fact, given a major contribution to the knowledge both of the mineralogy-chemistry of the bauxitic-limonitic facies and of the stratigraphy of the area. From the second half of the 18th century until the early decades of the 20th century, the iron deposits of the Comino-Sora area aroused the interest of numerous geologists and mineralogists. With the fall of the Bourbon kingdom, however, the traces of mining activity and of ironworking were left to neglect and abandonment with, in some cases, the definitive loss of evidence. As a result, most of these important geological sites rest in the historical memory, a strict consequence of the presence of cartographic and bibliographic documentation. The combination of these factors makes it possible to recognize several sites of geological memory in this area.

ACKNOWLEDGEMENTS

Marco Pantaloni and Fabiana Console are warmly thanked for providing iconographic and bibliographic data, and for involving me in the project "*sites of the geological memory*" ideated and developed by *ISPRA - Servizio Geologico d'Italia*, *Regione Lazio - Direzione Regionale Capitale Naturale, Parchi e Aree Protette* and *Città Metropolitana di Roma Capitale*. The author is grateful to the Editor-in-Chief Domenico Calcaterra, the Associate Editor and two anonymous reviewers for their editorial and revision work.

Scilla Roncacè, Tonino Cipriani, Federico De Benedictis, Giovanni "Giannino" Corgnale, Barbara Conflitti and Bernardino Serapiglia are also thanked for discussions on the mines of Campoli Appennino.

REFERENCES

Accordi B., Angelucci A. & Sirna G. (1967) - Note Illustrative della Carta Geologica d'Italia alla scala 1:100.000, F. 160 Cassino. 76 pp., Nuova Tecnica Grafica, Roma.

Accordi B., Angelucci A., Avena G.C., Bernardini F., Boni C.F., Bruno F., Cercato M., Coppola B., Fiore G., Funiciello R., Giglio G., Lamonica G.B., Lupia Palmieri E., Mattioli B. & Parotto M. (1969) - Idrogeologia dell'alto bacino del Liri (Appennino centrale). Ricerche geologiche, climatiche idrogeologiche, vegetazionali, geomorfiche e sistematorie. Geol. Rom. 8, 177-559.

Amati A. (1868a) - Dizionario corografico dell'Italia. I v. Francesco Vallardi, Tipografo-Editore, Milano, 1120 pp.

Amati A. (1868b) - Dizionario corografico dell'Italia. II v. Francesco Vallardi, Tipografo-Editore, Milano, 1152 pp.

Antonelli D. (1920) - La Chiesa di S. Maria di Canneto: dalle antiche costruzioni all'attuale ristrutturazione generale. Sora. http://www.settefrati.net/libro1.htm

Bassani F. (1904) - Gaetano Tenore. Boll. Soc. Geol. It., 23(1), CLXXIV-CLXXXIV.

Bertotti G., Picotti V., Bernoulli D. & Castellarin A. (1993) - From rifting to drifting: Tectonic evolution of the South-Alpine upper crust from the Triassic to the Early Cretaceous. Sediment. Geol., 86(1-2), 53-76. https://doi.org/10.1016/0037-0738(93)90133-P

Cantelli C., Castellarin A. & Praturlon A. (1978) - Tettonismo giurassico lungo l'Ancona-Anzio nel settore Monte Terminillo-Antrodoco. Geologica Romana, 17, 85-97.

Cassetti M. (1897) - Sul rilevamento geologico di alcune parti dell'Appennino, eseguito nel 1896. Boll. R. Com. Geol. d'It., 28, 347-371.

Cassetti M. (1898) - Rilevamento geologico nell'Abruzzo Aquilano e in Terra di Lavoro, eseguito nel 1897. Boll. R. Com. Geol. d'It., 29, 122-138

Cassetti M. (1899) - Osservazioni geologiche su alcuni monti tra le valli del Volturno e del Liri eseguite nel 1898. Boll. R. Com. Geol. d'It., 30, 218-243.

Cassetti M. (1900) - Rilevamenti geologici eseguiti l'anno 1899 nell'alta valle del Sangro e in quelle del Sagittario, del Gizio e del Melfa. Boll. R. Com. Geol. d'It., 31, 255-277.

Cassetti M. (1901a) - Dalla valle del Liri a quella del Giovenco e del Sagittario. Rilevamento geologico eseguito nell'anno 1900. Boll. R. Com. Geol. d'It., 32(2), 218-243.

Cassetti M. (1901b) - La bauxite in Italia. Rass. Mineraria, 15(2), 17-18.

Cassetti M. (1902) - Dal Fucino alla valle del Liri. Rilevamento geologico fatto nel 1901. Boll. R. Com. Geol. d'It., 33(2),168-177.

Chiocchini M. & Mancinelli A. (1978) - Ricerche geologiche sul Mesozoico del Gran Sasso d'Italia (Abruzzo). III. Correlazioni microbiostratigrafiche tra facies di margine della piattaforma carbonatica e facies pelagiche del Giurassico e Cretacico inferiore. Studi Geol. Camerti, 4, 19-36.

Chiocchini M., Chiocchini R.A., Didaskalou P. & Potetti M. (2008) - Ricerche micropaleontologiche e biostratigrafiche sul Mesozoico della piattaforma carbonatica laziale-abruzzese (Italia centrale). Mem. Descr. Carta Geol. d'It., 84, 5-170.

Chiocchini M., Chiocchini R., Marino M. & Pichezzi R.M. (2019) - Microfacies e microfossili delle successioni carbonatiche mesozoiche del Lazio e dell'Abruzzo (Italia centrale). Triassico Superiore-Giurassico. Mem. Descr. Carta Geol. d'It., 18. ISPRA, Servizio Geologico d'Italia e Dipartimento di Difesa del Suolo, Roma, 190 pp.

Chiocchini M., Pampaloni M.L. & Pichezzi R.M. (2012) - Microfacies e microfossili delle successioni carbonatiche mesozoiche del Lazio e dell'Abruzzo (Italia centrale): Cretacico. Mem. Descr. Carta Geol. d'It., 17. ISPRA, Servizio Geologico d'Italia e Dipartimento di Difesa del Suolo, Roma, 269 pp.

Cipriani A. (in press) - Le miniere di alluminio e ferro della Val di Comino. Mem. Descr. Carta Geol. d'It., 106, 173-184.

Cipriani A. (2016) - Geology of the Mt. Cosce sector (Narni Ridge, Central Apennines, Italy). J. Maps, 12(1), 328-340. http://dx.doi.org/10.1080/17445647.2016.1211896

Cipriani A. (2019) - Geological map of the central part of Narni-Amelia Ridge (Central Apennines, Italy). Geological Field Trips and Maps, 11(2.2), 1-26. https://doi.org/10.3301/GFT.2019.04

Cipriani A. & Bottini C. (2019a) - Early Cretaceous tectonic rejuvenation of an Early Jurassic margin in the Central Apennines: The "Mt. Cosce Breccia". Sediment. Geol., 387, 57-74. https://doi.org/10.1016/j.sedgeo.2019.03.002

Cipriani A. & Bottini C. (2019b) - Unconformities, neptunian dykes and mass-transport deposits as an evidence for Early Cretaceous syn-sedimentary tectonics: New insights from the Central Apennines. Ital. J. Geosci., 138(3), 333-354. https://doi.org/10.3301/IJG.2019.09

Cipriani A., Caratelli M. & Santantonio M. (2020) - Geological mapping reveals the role of Early Jurassic rift architecture in the dispersal of calciturbidites: new insights from the Central and Northern Apennines. Basin Res., https://doi.org/10.1111/bre.12438

Cipriani A., Citton P., Romano M. & Fabbi S. (2016) - Testing two open-source photogrammetry software as a tool to digitally preserve and objectively communicate significant geological data: the Agolla case study (Umbria-Marche Apennines). Ital. J. Geosci., 135(2), 199-209.

Cipriani A., Fabbi S., Lathuilière B. & Santantonio M. (2019a) - A reef coral in the condensed Maiolica facies on the Mt Nerone pelagic carbonate platform (Marche Apennines): The enigma of ancient pelagic deposits. Sedimentary Geology, 385, 45-60. https://doi.org/10.1016/j.sedgeo.2019.03.007

Cipriani A., Zuccari C., Innamorati G., Marino M.C., & Petti F.M. (2019b) - Mass-transport deposits from the Toarcian of the Umbria-Marche-Sabina Basin (Central Italy). Ital. J. Geosci., 139(1), 9-29. https://doi.org/10.3301/IJG.2019.14

Citton P., Fabbi S., Cipriani A., Jansen M. & Romano M. (2019) - Hybodont dentition from the Upper Jurassic of Monte Nerone Pelagic Carbonate Platform (Umbria-Marche Apennine, Italy) and its ecological implications. Geol. J., 54, 278-290. https://doi.org/10.1002/gj.3174

Colacicchi R. & Bigozzi A. (1995) - Event stratigraphy and carbonate platform-basin interrelations during the Jurassic in the Central Apennines. Palaeopelagos, 5, 111-128.

Colacicchi R. & Praturlon A. (1965) - Stratigraphical and paleogeographical investigations on the Mesozoic shelf-edge facies in Eastern Marsica (Central Apennines, Italy). Geologica Romana, 4, 89-118.

Console F., Fabiani M., Giovagnoli M.C., Mancinella D., Rotella G. & Testardi M. (2018) - Geological memory sites in the Latium region: a new pilot project. Congresso congiunto SGI-SIMP, Catania 12-14 settembre 2018, Abstract book, p. 743.

Damiani A.V., Chiocchini M., Colacicchi R., Mariotti G., Parotto M., Passeri M. & Praturlon A. (1991) - Elementi litostratigrafici per una sintesi delle facies carbonatiche meso-cenozoiche dell'Appennino centrale. In: Tozzi M., Cavinato G.P & Parotto M. (*eds*.), Studi preliminari all'acquisizione dati del profilo CROP 11 Civitavecchia-Vasto. Studi Geol. Camerti, Vol. Spec. 1991/2, 187-213.

De Angeli Curtis G. (2008) - Le variazioni della denominazione di alcuni comuni dell'alta Terra di Lavoro. Studi Cassinati, 8(2), 93-106.

De Vivo B., Bove M., Lima A., Albanese S., Cicchella D., Grezzi G., Frizzo P., Sabatini G., Di Lella A., Protano A., Raccagni L. & Riccobono F. (2009) - Atlante geochimico-ambientale d'Italia. Aracne editrice S.r.l., Roma, 516 pp.

Del Lungo S. (2001). Toponimi in archeologia: la provincia di Latina, Italia. J. & E. Hedges and Archaeopress. Oxford, England. 153 pp.

Fabbi S., Citton P., Romano M. & Cipriani A. (2016) - Detrital events within pelagic deposits of the Umbria-Marche Basin (Northern Apennines, Italy): Further evidence of Early Cretaceous tectonics. J. Mediterr. Earth Sci., 8, 39-52. https://doi.org/10.3304/JMES.2016.003

Festa A., Ghisetti F. & Vizzani L. (2006) - Carta Geological del Molise (Scala 1:100.000) - Note Illustrative. 87 pp., Litografia GEDA - Nichelino.

Galluzzo F. & Santantonio M. (2002) - The Sabina Plateau: A new element in the Mesozoic palaeogeography of central Apennines. Boll. Soc. Geol. It., Volume Speciale 1, 561-588.

Ghisetti F. & Vezzani L. (1998) - Segmentation and tectonic evolution of the Abruzzi - Molise thrust belt (central Apennines, Italy). Ann. Tectonicae, 12, 97-112.

Giancotti S. (1857) - Cenno su le miniere di ferro, e lo stabilimento siderurgico nel distretto di Sora. Annali civili del Regno delle Due Sicilie, 59, 118-133.

Giordano F. (1864) - Industria del ferro in Italia. Tipografia Cotta e Capellino, Torino, 437 pp.

Istituto Geografico Militare (1960) - Carta Topografica d'Italia alla scala 1: 100.000, F. 160 Cassino.

Istituto Geografico Militare (1963) - Carta Topografica d'Italia alla scala 1: 100.000, F. 152 Sora.

Jervis G. (1874) - I tesori sotterranei dell'Italia. Parte Seconda: Regione dell'Appennino e vulcani attivi e spenti dipendentivi. Ermanno Loescher, Roma. 624 pp.

Lotti B. (1903) - Sul giacimento di bauxite di Colle Carovenzi presso Pescosolido (circ. di Sora) nella valle del Liri. Rass. Mineraria, 18(11), 163-165.

Mattirolo E. (1901) - Bauxiti italiane. Rass. Mineraria, 14(15), 229-230.

Memorie per le Belle Arti (1788) - Tomo IV. Stamperia Pagliarini, Roma, 299 pp.

Ministero di Agricoltura, Industria e Commercio, Direzione Generale dell'Agricoltura (1890a) - Carta idrografica del Regno d'Italia, scala 1:100000, F. 152 Sora. Stab. Cart. Bruno e Salomone, Roma.

Ministero di Agricoltura Industria e Commercio, Direzione Generale dell'Agricoltura (1890b) - Carta idrografica del Regno d'Italia, scala 1:100000, F. 160 Cassino. Istituto Cartografico Italiano, Roma.

Ministero dell'Agricoltura (1918) - Rivista del Servizio Minerario nel 1917. Parte prima, statistica della produzione delle miniere, delle officine metallurgiche e mineralurgiche, delle torbiere e delle cave. Tipografia Nazionale Bertero, Roma, 63 pp.

Ministero dell'Agricoltura (1920) - Rivista del Servizio Minerario nel 1918. Stabilimento Poligrafico per l'Amministrazione della Guerra, Roma, 141 pp.

Mostardini F. & Merlini S. (1986) - Appennino centro-meridionale. Sezioni geologiche e proposta di un modello strutturale. Mem. Soc. Geol. It., 35, 177-202.

Pantaloni M. & Console F. (2019) - Il Ponte Sfondato sul torrente Farfa (Sabina, Lazio). Rend. Online. Soc. Geol. It., 47, 162-177. https://doi.org/10.3301/ROL.2019.28

Pantaloni M., Console F. & Petti F.M. (2016) - 1867: notizie geologiche dalle Province del Regno d'Italia. In: Console F., Pantaloni M. & Tacchia D. (eds.), La cartografia del Servizio Geologico d'Italia. Mem. Descr. Carta Geol. d'It., 100, ISPRA - Servizio Geologico d'Italia, Roma, 8-43.

Parotto M. (1969) - Geologia. In: Accordi B., Angelucci A., Avena G.C., Bernardini F., Boni C. F., Bruno F., Cercato M., Coppola B., Fiore G., Funiciello R., Giglio G., La Monica G.B., Lupia Palmieri E., Mattioli B. & Parotto M. (*eds*.), Idrogeologia dell'alto bacino del Liri (Appennino centrale). Ricerche geologiche, climatiche idrogeologiche, vegetazionali, geomorfiche e sistematorie. Geol. Romana, 8, 187-217.

Pistilli G. (1798) - Dimostrazione de' progetti presentati alla Maestà del Sovrano. Napoli, 182 pp.

Pistilli F. (1798) - Descrizione storico-filologica delle antiche, e moderne Città, e Castelli, esistenti accosto I fiumi Liri, e Fibreno: arricchita di vetusti momenti in gran parte ineditim con un saggio delle Vite degl'illustri personaggi ivi nati. Presso Amato Cons., Napoli, 288 pp.

Praturlon A. (1968) - Note Illustrative della Carta Geologica d'Italia alla scala 1:100.000, F. 152 Sora. Poligrafica e Cartevalori, Ercolano (Napoli), 76 pp.

Reggiani A.M. (2003) - Il distretto minerario della valle di Comino una chiave di lettura della media valle del Liri. In: Cassatella A., Cetorelli Schivo G., Nicosia E. & Tanzilli S. (eds.), La via dei metalli. Dalla materia alla forma tra il Melfa e il Rapido. Catalogo della mostra, Cassino - Museo Archeologico Nazionale, 5 maggio - 5 giugno 2003, Cassino. 10-27.

Regio Ufficio Geologico (1928) - Carta Geologica d'Italia alla scala 1:100.000, F. 152 Sora. Stab. L. Salomone, Roma.

Regio Ufficio Geologico (1931) - Carta Geologica d'Italia alla scala 1:100 000, F. 160 Cassino. Prem. Stab. Cartogr. G. Giardi, Firenze.

Rizzi-Zannoni G.A. (1810) - Atlante geografico del Regno di Napoli delineato per ordine di Ferdinando IV re delle Due Sicilie. Foglio 6: Campobasso, Trivento, Agnone. Giuseppe Guerra Inc., Napoli.

Romano M., Cipriani A., Fabbi S. & Citton P. (2018a) - First remains of Neoginglymodi actinopterygians from the Jurassic of Monte Nerone area (Umbria-Marche Apennine, Italy). Ital. J. Geosci., 138(1), 88-102. https://doi.org/10.3301/IJG.2018.28

Romano M., Citton P., Cipriani A. & Fabbi S. (2018b) - First report of hybodont shark from the Toarcian Rosso Ammonitico Formation of Umbria-Marche Apennine (Polino area, Terni, Central Italy). Ital. J. Geosci., 137, 151-159. https://doi.org/10.3301/IJG.2018.01

Romano M., Manni R., Venditti E., Nicosia U. & Cipriani A. (2019) - First occurrence of Tylosaurinae mosasaur from the Turonian of the Apennine Carbonate Platform (Italy). Cretaceous Res., 96, 196-209. https://doi.org/10.1016/j.cretres.2019.01.001

Rubino G.E. (1988) - L'industria siderurgica nel distretto Sora in età borbonica. In: Viscogliosi A. (*ed*.), Trasformazioni industriali nella media Valle del Liri in età moderna e contemporanea. Atti del ciclo di conferenze tenute in Sora, I.T.C. C. Baronio, novembre 1984-aprile 1985. Frosinone: Rotaract Club - Editrice Pisani. 131-168.

Rusciadelli G. & Ricci C. (2013) - Carbonate production of ancient debris-dominated reefs: An outcrop-based example from the Upper Jurassic reef complex of the central Apennines (Italy). GSA Bulletin, 125(9-10), 1520-1538. https://dx.doi.org/10.1130/B30850.1

Rusciadelli G., D'Argenio B., Di Simone S., Ferreri V., Randisi A. & Ricci C. (2009) - Carbonate-platform production and export potential recorded in upper Jurassic base-of-slope deposits (Central Apennines, Italy). In: B. C. Kneller, O. J. Martinsen, & B. McCaffrey (*eds*.), External Controls on Deep-Water Depositional Systems. SEPM Special Publication, 92, 279-301. https://doi.org/10.2110/sepmsp.092.279

Santantonio M. & Carminati E. (2011) - Jurassic rifting evolution of the Apennines and Southern Alps (Italy): Parallels and differences. GSA Bulletin, 123(3-4), 468-484. https://doi.org/10.1130/B30104.1

Servizio Geologico d'Italia (1966) - Carta Geologica d'Italia alla scala 1:100.000, F. 160 Cassino. Litografia Artistica Cartografica, Firenze.

Servizio Geologico d'Italia (1967) - Carta Geologica d'Italia alla scala 1:100.000, F. 152 Sora. Litografia Artistica Cartografica, Firenze.

Solin H. (2005) - Sulla storia di Atina - alcuni appunti. In: Solin, H. (ed.), Le Epigrafi della Valle di Comino. Atti del secondo convegno epigrafico cominese. San Donato Val di Comino, Teatro comunale, 28 maggio 2005. 107-117.

Tenore G. (1852) - Osservazioni geologiche da servire di dichiarazione alla Carta geologica della catena dei monti compresa tra Montecassino ed il fiume Melfa in provincia di Terra di Lavoro [Con un abbozzo di carta geologica]. Napoli.

Tenore G. (1856a) - Breve ragguaglio delle peregrinazioni geognostiche eseguite su le montagne circostanti al bacino di Alvito e dei lavori della Commissione destinata a ricercare le Reali miniere di ferro nel distretto di Sora durante gli anni 1853-54-55. Annali civili del Regno delle due Sicilie, 53, 44-58.

Tenore G. (1856b) - Breve ragguaglio delle peregrinazioni geognostiche eseguite su le montagne circostanti al bacino di Alvito e dei lavori della Commissione destinata a ricercare le Reali miniere di ferro nel distretto di Sora durante gli anni 1853-54-55. Annali civili del Regno delle due Sicilie, 54, 117-125.

Tenore G. (1863) - Ragguaglio sulle miniere di ferro nel distretto di Sora e sui lavori della commissione destinata a ricercarle durante gli anni 1853-54-55 (2ª edizione). Stab. tip. G. Nobile, Napoli, 48 pp.

Tenore G. (1867) - Carta geologica della provincia di Terra del Lavoro 1:280,000 [1 foglio e una tavola di sezioni, colorati a mano]. Caserta.

Tenore G. (1872) - Saggio sull'industria mineraria e sulla costituzione geologica della Terra di Lavoro [con la Carta geologica della Provincia]. Periodico "La scienza e l'arte dell'Ingegnere-Architetto", organo della Sezione architettonica dell'associazione di Scienziati, Letterati ed Artisti. Grande Stabilimento Tipografico di Gennaro de Angelis, Napoli, 39 pp.

Tenore G. (1876) - L'industria del ferro e dell'acciaio in Italia dopo il 1860. Atti del R. Istituto d'incoraggiamento alle scienze naturali, economiche e tecnologiche, 218 pp.

Tutinelli G. & Visocchi P. (1998) - L'utilizzazione delle acque nel rapporto uomo-ambiente: il caso del fiume Melfa in Valle di Comino in Terra dei Volsci. Annali del Museo Archeologico di Frosinone, 1, 121-134.

Vezzani L. & Ghisetti L. (1998) - Carta geologica dell'Abruzzo. Scala 1:100.000. Ed. S.EL.CA. Firenze.

Vezzani L., Ghisetti F. & Festa A. (2004) - Carta geologica del Molise. Scala 1:100.000. Ed. S.EL.CA. Firenze.

Volante E. (2005) - San Donato Val di Comino: il soggiorno di Carolina Bonaparte e il primo servizio di diligenze. Studi Cassinati, 5(3), 177-178.

SITOGRAPHY

https://www.altaterradilavoro.com/miniere-limonite-nella-valle-comino/ (accesso 20/10/2019)

http://www.aurorapedia.it/reali-miniere-di-san-donato-parco-minerario/ (accesso 20/10/2019)

http://www.bibliotecauniversitarianapoli.beniculturali.it/index.php?it/342/atlante-geografico-del-regno-di-napoli (accesso 10/01/2020)

http://www.caisandonato.it/index.php/sentieri-lazio-abruzzo-molise/64-miniere-di-re-ferdinando.html (accesso 22/12/2019)

http://www.cassino2000.com/cdsc/studi/archivio/n23/n23p06.html (accesso 22/12/2019)

https://www.geoitaliani.it/2017/10/tenoremelfa.html (accesso 20/10/2019)

http://www.mineralieminiere.com/foto-depoca-miniere-del-lazio/ (accesso 26/12/2019)

http://www.opac.isprambiente.it/ (accesso 20/10/2019)

http://www.settefrati.net/ (accesso 26/12/2019)

http://www.viviciociaria.com/leminieredisandonato/?fbclid=IwAR2YaVKLoo2uT3iDKXy0i5tJlOipTtkv1gxBtv00KspKsopSInPfdZGwyak (accesso 20/10/2019)