The geology of the Western Alps through the field notebooks of Secondo Franchi (1859-1932)

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ABSTRACT

Secondo Franchi (1859–1932) was one of the most important geologists of the *Regio Ufficio Geologico* of Italy. In collaboration with his colleagues of the Turin office, starting from 1888 Franchi surveyed in detail the Western Alps to contribute to the new Geological Map of Italy at the 1:100,000 scale. Franchi's studies contributed to the definition of a still largely accepted chronostratigraphic framework for the Alpine successions, and to the recognition of previously overlooked folding and faulting phases in the Western Alps. Eleven of Franchi's field notebooks are kept in the Library of *Istituto Superiore per la Protezione e la Ricerca Ambientale* in Rome. These notebooks are richly illustrated with geological sections and landscape sketches and represent an invaluable first-hand resource for the analysis of Franchi's mapping methods and interpretive procedures. This paper analyses Franchi's contribution to the geological knowledge of some specific localities of the Western Alps, integrating excerpts from his original field notebooks and published works.

KEY-WORDS: Secondo Franchi, field notebooks, geological map, stratigraphy, tectonics, Western Alps.

INTRODUCTION

Secondo Franchi (Castell'Alfero-Asti, 1859 – Rome, 1932; Fig. 1) was one of the most influential and prolific Italian geologists, whose activity spanned the late 19th–early 20th century. His maps and research activity were of great importance for the progress of the geological knowledge of the Western Alps. A relevant number of Franchi's papers and geological maps are still considered today as milestones of the Alpine geological literature. As a recognition of his work and contribution, the Italian Geological Society established in 2010 the annual "Secondo Franchi Prize", which is awarded to the author(s) of the best article published in the Society journals (https://www.socgeol.it/277/secondo-franchi.html).

Franchi graduated in 1884 in Civil Engineering at *Scuola di Applicazione per gli Ingegneri* of Torino. During the same year, Franchi was hired as "allievo ingegnere" (trainee engineer) by the *Corpo Reale delle Miniere* (Royal Corps of Mines). He was sent from 1884 to 1887 to the *École Nationale des Mines* (National School of Mines) in Paris to refine his geological skills (Brianta, 2007), following a well-established practice of this institution that had begun with Quintino Sella and Felice Giordano (Chiorino, 2013).

Once back to Italy, in 1888 Franchi was assigned to the *Regio Ufficio Geologico* (Royal Geological Survey), where he spent his entire career, earning the grade of *geologo superiore* (chief geologist) (Stella, 1933; Novarese, 1938; Spada Sermonti, 1998). The *Regio Ufficio Geologico* appointed Franchi to the Torino office to assist Domenico Zaccagna (1851–1940) and Ettore Mattirolo (1853-1923) (Mosca & Fioraso, 2016) in the surveys and mapping of the Italian Western Alps necessary to the compilation of the Geological Map of Italy at the 1:100,000 scale (Pantaloni, 2014). Within a few years, the Torino office grew further with the

Fig. 1 - Secondo Franchi - Picture taken during the "Franchi expedition" of 1912 in Tripolitania, Libya (ISPRA Library).

recruitment of Vittorio Novarese (1861-1948) and Augusto Stella (1862-1944) (Mosca & Fioraso, 2016). This remarkable team of "*maîtres du Regio Ufficio Geologico*", as they were defined by Argand (1923), produced accurate and detailed geological maps at the 1:100,000 scale, as well as numerous accompanying papers (resulting from an impressive amount of field activities), which turned out to be pivotal to a new interpretation of the structural and geological evolution of the Alpine region (e.g., Kilian & Haug, 1898). Until then, the main references for the geology of the Western Alps within the Italian Earth Sciences community were the regional maps by Angelo Sismonda published in 1866 and those coordinated by Bartolomeo Gastaldi during 1868-1879 (e.g., Dal Piaz et al., 2015; Mosca & Fioraso, 2016). Charles Lory (1858, 1863) and Alphonse Favre (1862, 1867) had also mapped in detail some sectors of the Western Alps.

Franchi carried out most of his field campaigns in the Western Alps, moving progressively from the Maritime-Ligurian Alps to the Cottian and Graian Alps. He also worked in the Central Alps, in central and southern Italy and participated to scientific missions for geological, agrarian and geographical studies to Tripolitania and Cyrenaica (Libya; Fig. 1), which, at that time, were Italian colonies. He also contributed to geological studies for important engineering projects, such as the Colle di Tenda railway tunnel (completed in 1898; Baldacci & Franchi, 1900), exploration activities for coal deposits (Franchi & Stella, 1903) and the never realised construction of an international railway tunnel under the Mont Blanc massif (Franchi et al., 1907).

Franchi had excellent skills in stratigraphy, structural geology, palaeontology and petrography and the impressive amount of his field observations is documented in his publications by accurate descriptions and detailed geological drawings and profiles.

Franchi undertook an important and systematic revision of the Alpine lithostratigraphy, always supported by a scrupulous search of fossils both in sedimentary and meta-sedimentary successions. The days he dedicated to fossil search and collection are systematically recorded in Franchi's field notebooks. As an example, the field campaign in the Maritime Alps of the summer of 1898 was opened by two days dedicated to fossil search and collection: "*3 e 4 Luglio 1898. Ricerca di fossili nella masse di calcari dolomitici di Rabas e Ruà di Mojola*" (3 and 4 July 1898. Fossil search in the masses of dolomitic limestones of Rabas and Ruà di Moiola [i.e., the hamlets of Tetti Rabas and Ruata, near Moiola in the lower Stura di Demonte Valley]; Notebook IV, see below). The fossil-bearing localities reported by Franchi represent the stratigraphic basis for the chronostratigraphic framing of the studied Alpine successions (e.g., Barale et al., 2018; Frasca, 2018). The fossils discovered by Franchi during the field campaigns in the Maritime Alps (Franchi, 1891) and in the Grana and Maira valleys in the Cottian Alps (Franchi, 1894a) were classified in collaboration with palaeontologist Giovanni Di Stefano (1856–1918), a colleague of his at the *Regio Ufficio Geologico*. Of paramount importance were the findings of Early Jurassic ammonites (originally ascribed to the genus *Arietites* by Franchi & Di Stefano, 1896) in the fossiliferous successions of the Vallone di Narbona in the Grana Valley, later also studied by Sturani (1961), Ellemberger et al. (1964), and Ricci (1967). Some fossils collected by Franchi in the Monte Chaberton-Grand Hoche ridge (Upper Susa Valley) were examined by Carlo Parona (1855-1939), professor of Geology at the Torino University (Franchi, 1910).

The lithostratigraphic and palaeontological studies in the Grana and Maira valleys (1894-1895) were supported by Di Stefano and Luigi Baldacci (1850-1927) and were fundamental to constrain the Mesozoic age of the *Zona delle Pietre Verdi* along the entire Western Alps. A Mesozoic age for this zone had also been proposed by Elie de Beaumont, Angelo Sismonda, Bernhard Studer, Alphonse Favre and Charles Lory (e.g., Dal Piaz, 2001; Dal Piaz et al., 2015; Mosca & Fioraso 2016). That zone had instead been attributed to the Archean by Bartolomeo Gastaldi (1818-1879) and by Zaccagna and Mattirolo (Zaccagna, 1887, 1892, 1901, 1902, 1903). Once Franchi had indisputably demonstrated the Mesozoic age of the *Zona delle Pietre Verdi*, Franchi could rightly affirm that "*the geological study of the Cottian Alps in particular, and that of the Western Alps in general, has entered a new phase*" (Franchi & Di Stefano, 1896, p. 180). However, Franchi noted that "*since the fossiliferous remains were few, it was necessary to use stratigraphy to give greater extension to the deductions*" (Franchi, 1898a, p. 1919).

Franchi reported the Mesozoic age of the Zona delle Pietre Verdi in his *Carta Geologica delle Alpi Cozie Italiane desunta dai rilevamenti dell'Ufficio Geologico* (Franchi, 1898a), and confirmed it by further palaeontological and lithostratigraphic studies throughout the Western Alps (Franchi, 1904).

The *Regio Ufficio Geologico* first reported a Mesozoic age for the Zone delle Pietre Verdi in the *Carta delle Alpi Occidentali* at the 1:400,000 scale (Regio Ufficio Geologico, 1908; Fig. 2) even if Zaccagna and Mattirolo disagreed with this interpretation. Some years later, following a geological excursion in the Southern Cottian Alps in 1910 led by Franchi and Zaccagna and attended, among the others, by Nicola Pellati (1835-1907) and Carlo Fabrizio Parona (1855-1939) (Regio Comitato Geologico, 1911), the *Regio Ufficio Geologico* accepted the Mesozoic age for the Zone delle Pietre Verdi in the publication of the official geological maps of Italy at the 1:100,000 scale.

Franchi integrated his fieldwork with accurate mineral-petrographic observations, as did his colleagues of the Torino office. In the alpine successions, he described mineral assemblages typical of eclogite-blueschist facies conditions (e.g., Franchi, 1896, 1897, 1900, 1901, 1902, 1903) and reported sedimentary

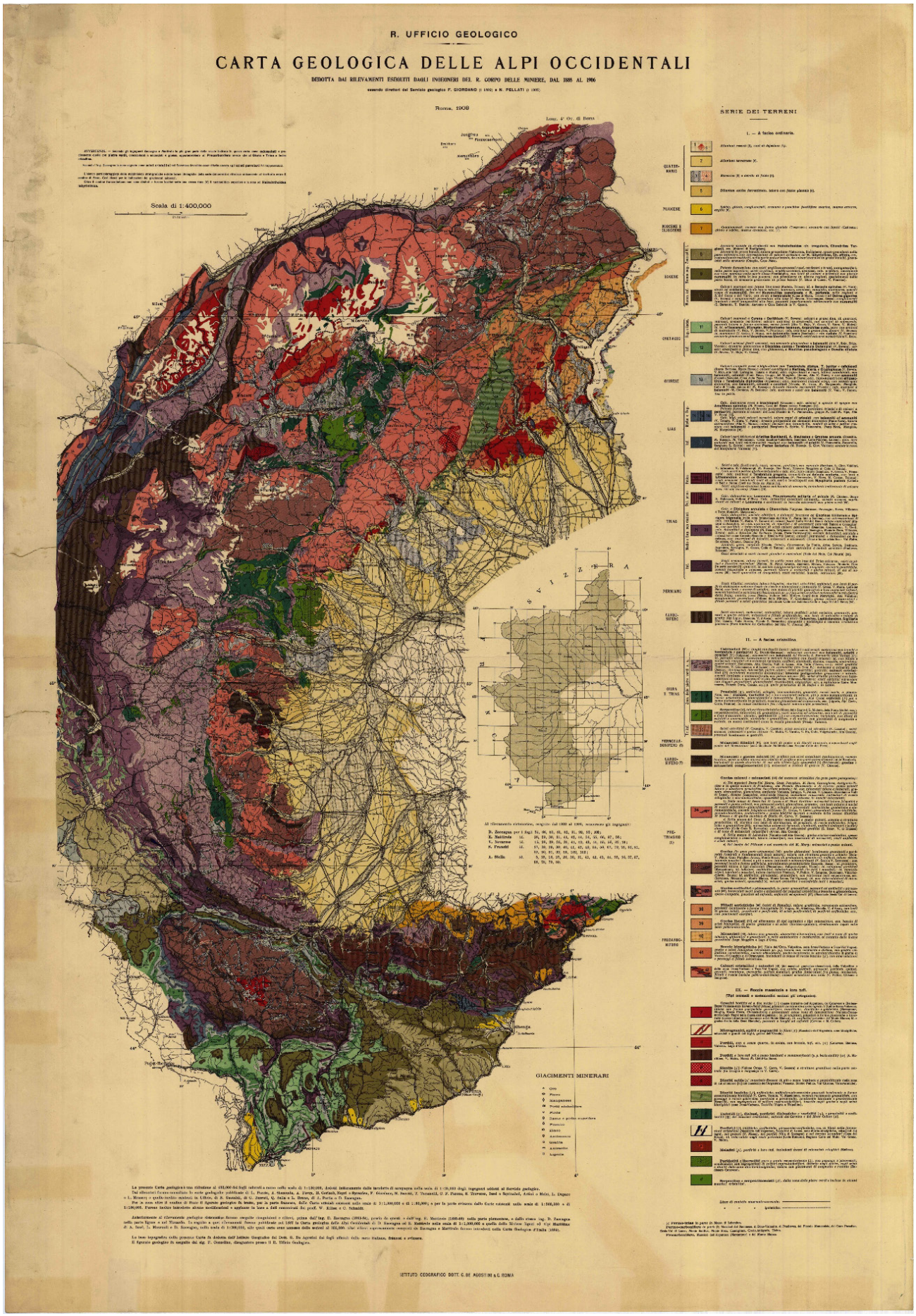

Fig 2 - The Carta geologica delle Alpi Occidentali in scala 1:400,000 (Regio Ufficio Geologico, 1908).

sequences metamorphosed in the internal parts of the Alpine Arc and slightly or not at all affected by metamorphism in the external ones (e.g., Franchi, 1902). Franchi thought that the metamorphism of the Alpine rocks resulted from heat and pressure, with an important role of water, during their burial (*inabissamento*) below younger successions and/or folded rocks, the latter later removed by erosion during subsequent uplift (Franchi, 1902, p. 307).

During his impressive field activity, Franchi investigated and mapped several thousand km^2 over the western Alpine region (Mosca & Fioraso, 2016). He collaborated in the realization of 22 Alpine geological sheets of the Geological Map of Italy at the 1:100,000 scale, gave fundamental inputs to the aforementioned *Carta delle Alpi Occidentali* at the 1:400,000 scale (Servizio Geologico d'Italia, 1908) and compiled the Italian sector of the Western Alps for the *Carte Géologique de la France* at 1:1,000,000 scale (Ministère des Travaux Publics, 1905).

In his papers, Franchi often compares his interpretations to those of other Italian and foreign geologists, in particular French geologists. Franchi's continuous keeping up with the literature was particularly important in a period when the tectonic interpretation of the Alps underwent significant changes, with the application of the "nappe theory" from the external cover units to the metamorphic basement nappes of the core and the internal part of the Alps, notably reported in the regional cross sections drawn by Émile Argand (1911, 1916) (see also Dal Piaz & Dal Piaz, 1984; Dal Piaz, 2001 for a detailed history of the tectonic interpretation of the Alps).

The aim of this work is to present a few of Franchi's main contributions to the geology of the Western Alps by integrating published papers with unpublished material (Figs 3 and 4) archived in the Library of the *Istituto Superiore per la Protezione e la Ricerca Ambientale* (ISPRA) in Rome. In particular, Franchi's field notebooks are the focus of this paper (Fig. 3). These notebooks mainly report geological sketches, often with synthetic but accurate explanations, and contain localities and topography for reference such that the geological features portrayed in cross sections and views can be easily located. Several of these accurate and commonly coloured drawings served as the basis for the figures of Franchi's publications. Many pages of the notebooks also contain comments and highlights, as well as drawings of different subjects (buildings, persons, plants) observed by Franchi during his fieldwork.

MATERIALS

The work of Franchi (as well as that of his colleagues) for the *Regio Ufficio Geologico* is found in several documents archived at the ISPRA Library, which we consulted for the present paper.

Reports

Engineers and geologists described and detailed their activities in reports that were summarised by the Director in the official proceedings of the *Bollettino del Regio Ufficio Geologico*. The official proceedings report the progress of the project for the realization of the Geological Map of Italy at the scale 1:100,000 and of other related maps, and summarise the main scientific results obtained and the analyses of the collected samples both for the geological mapping and for other technical or scientific inspections.

In the folders of the Archive of the *Regio Ufficio Geologico*, the handwritten reports are collected in fascicles divided by year under the title "Reports of the geological surveyors: Western Alps". In the folders of the 1888-1924 years, there are numerous documents by Franchi. These are reports periodically sent by Franchi to the Director of the *Regio Ufficio Geologico* to describe the progress of his field campaigns and the conclusion of his annual field work, requests for expense reimbursements, requests for holidays, and correspondence with the Office and with his colleagues in Rome.

Field notebooks

In the historical archive of the ISPRA Library, the collection of the *Quaderni di campagna* (Field notebooks) is rather exiguous in proportion to the number of geologists who worked in the office. Franchi's collection is the most conspicuous and interesting because it covers the entire period of his surveying activity. There are 11 signed field notebooks of Franchi dated to between 1890 ("Realdo, Briga, Bassa Valle Roja, Ventimigliese" notebook) and 1924 ("Dintorni di Ormea e di Garessio, M. Alpe, Nasino" notebook). Some of these are 'official' notebooks bearing on the frontispiece the heading of the *Corpo Reale delle Miniere* (Royal Corps of Mines) (Fig. 3B), whereas others were probably bought by Franchi himself, because they bear the label of the ancient stationery *Cartoleria Antonietti* of Torino.

Field notebook I

The oldest notebook dates back to 1890 and is labelled "Realdo, Briga, Bassa Valle Roja, Ventimigliese" on the cover page. It covers the field work carried out in the Argentina and Roja valleys (Ligurian and Maritime Alps) and contains several geological sketches and some descriptions of the followed paths . The inner pages contain dates from the 13th to the 17th of November 1890.

Field notebook II

The second field notebook, in chronological order, is of a different type from all the others and on the cover reports, "Val Maira, Valle dell'Iso, Savona"; this notebook refers to the field campaign of 1892.

It begins with the date of September 2, 1892, and contains geological sketches taken in the upper Maira Valley (Mount Maurfreit, Vallone Maurin, Vallone di Elva), in the Genova hinterland (Isoverde, Gallaneto and Lencisa in the Polcevera Valley), and near Savona (Cadibona).

The notebook, which consists of a few pages of yellowed paper, is difficult to read because it is written in pencil with a light stroke.

Field notebook III

A third notebook has the date 8 June 1894 on the front page and, on the cover, indications of the following localities: "Colle del Ferro, R.ca Peyron, Serie del Vallone Pourriac, Lago Roburent".

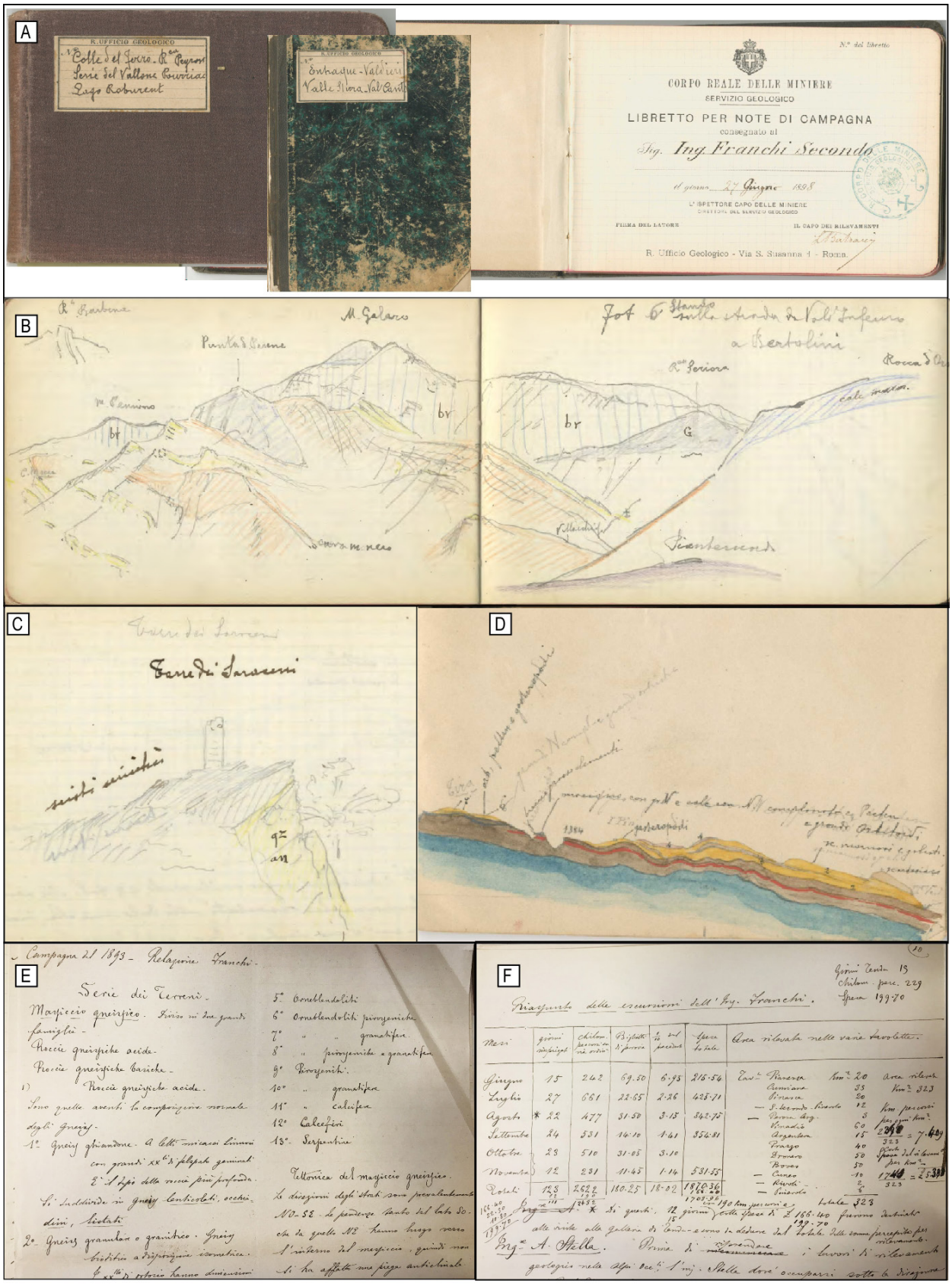

Fig. 3 - Examples of documents kept in the ISPRA Library and consulted for this paper. A) Field notebooks. B-D) examples of geological sketches reported in the field notebooks. B (from Notebook VIII) is a section of the Monte Galero in the Ligurian Alps (Br-polygenic Breccias; G, Jurassic; Mesozoic in brown; Eotrias in yellow); C Sketch of the so-called "Torre dei Saraceni" [Saracenic tower] near Garessio in the Tanaro Valley, Ligurian Alps (from Notebook VIII) resting on a cliff made up of Lower Triassic quartzite (Qz) and Permian (?) "Anagenite" (An). D) Watercolor sketch of the stratigraphic succession of Cima di Marta/Mont Vaquet (on the drainage divide between Roja and Argentina valleys, western Ligurian Alps), showing the superposition of the different intervals of the Alpine Foreland Basin succession (in brown, red, and yellow) resting on the Cretaceous Provençal succession (in light blue) (from Notebook I). E) Report containing geological results of field campaigns. F) Report with details of mapped areas and reimbursement of costs.

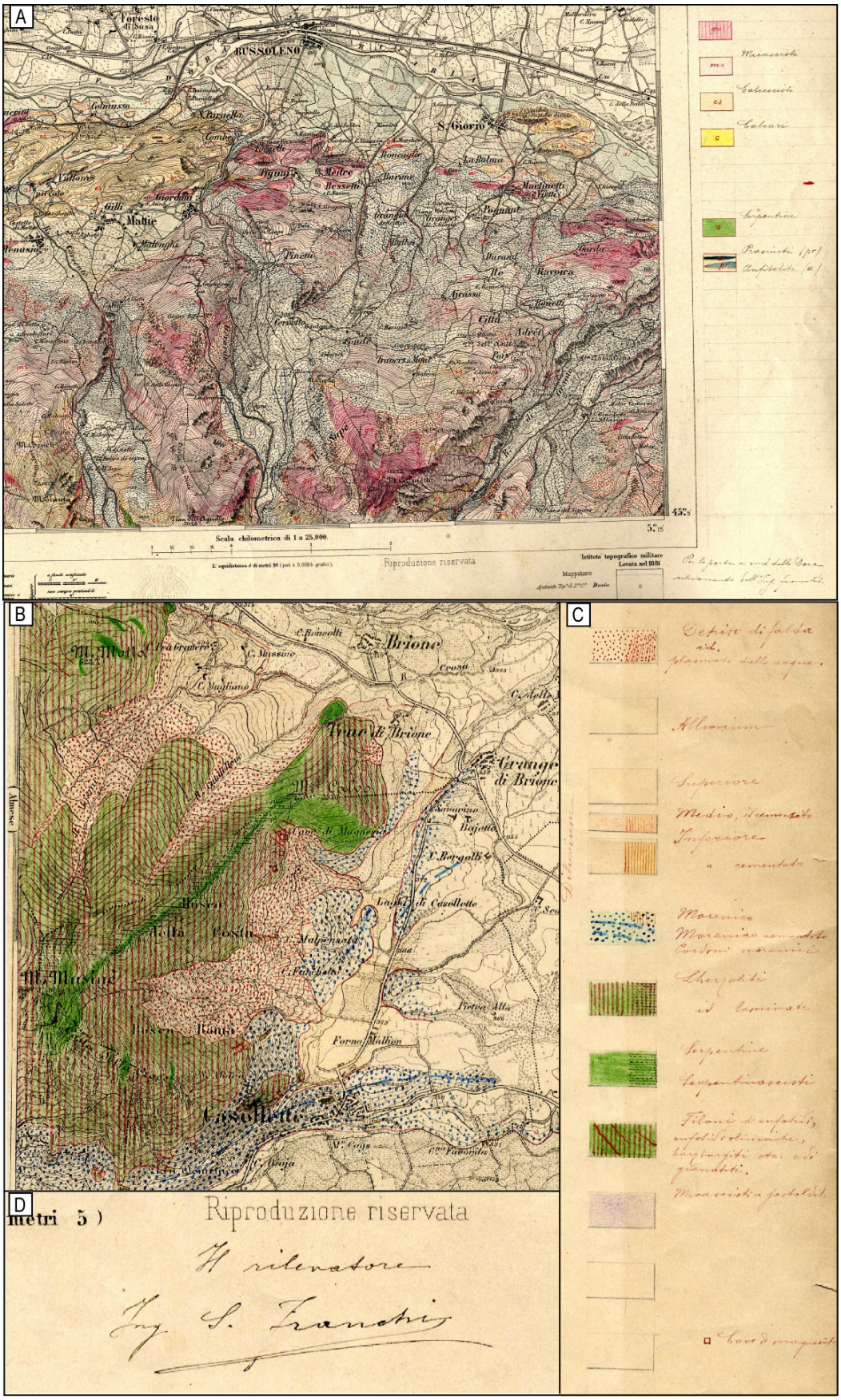

Fig. 4 - Examples of Franchi's hand-drawn geological maps at 1:25,000 scale. A) Excerpt from the Bussoleno sheet (Susa Valley); the mapped area mainly consists of "Gneiss" (in red) and "Micaschists" (in pink) of the Dora-Maira Massif. B-D) Excerpts from the Pianezza sheet, at the outlet of the Susa Valley (Cottian Alps). The area shown in B) corresponds to the Monte Musinè in the southern part of the Lanzo Ultrabasic Massif, mainly consisting of "Lherzolites" (Green with vertical red stripes), "Serpentinites" (Green) and "Serpentine- schists" (Green with horizontal black stripes and dotted lines). In D), the signature of Franchi is present: "Il rilevatore S. Franchi" [The surveyor S. Franchi].

The first pages contain chronological descriptions of the observations made in the period June 21 - July 22, 1894, when Franchi carried out field surveys in the Pinasca and Perosa Argentina areas, east of the Chisone Valley. He then went to the Dronero and Venasca areas, where he met Augusto Stella, with whom he shared information about his work. Later, Franchi went to the Stura di Demonte Valley, where he mapped the Rio Freddo and Piz valleys.

On the back of the notebook, in an inverted form, he reported the itineraries and distances covered for both periods of time described above and also for a later period of time from August to October 1894.

From a handwritten report it appears that after a particularly rainy September, Franchi spent the month of October mapping an area in the Vinadio geological sheet and then headed to Borgo San Dalmazzo to map the lower parts of the Stura di Demonte and Gesso valleys.

A handwritten letter sent by Franchi to Director Baldacci summarises the obtained scientific results. It shows that in those months Franchi surveyed a total of 323 square kilometres at a total cost of about 5,400 Italian Lire.

Field notebook IV

The frontispiece of the fourth notebook is dated 27 June 1898. The cover indicates "Mojola (Ruà), Colle Tenda, San Damiano, Bardonecchia, Valle Stretta, Colle Rho, Grand Roc, Valgrisenche".

The first page indicates the beginning of the geological campaign on the 4th of July 1898, with a search for fossils in the dolomitic limestone outcrops of Rabas and Ruà hamlets near Moiola (lower Stura di Demonte Valley).

The notebook contains many geological cross sections with text descriptions. The texts are easily readable and well preserved because they are written in Indian ink.

The back of the book shows the itineraries from the 28th of June to the 30th of September 1898, without interruptions.

Field notebook V

The fifth notebook is titled "Carbonifero della Thuile, Courmayeur, Morenico Mongrando" and is dated 1901. As always, on the inverted side, it shows dates, kilometres covered and itineraries from June 17 to July 28 1901, starting in Turin and ending in Pont San Martin (Aosta Valley). It then resumes in September and October 1901 and again in June 1902.

Field notebook VI

Another notebook, with the indication "Alta Valtellina, V.ne Frache - Livigno" on the cover, is almost completely written in. The front contains only geological cross sections with a few notes on the margins. One cross section on the first pages bears the date August 11 1908.

On the reverse side, as usual, itineraries, kilometres covered and expenses incurred are reported day by day.

A transcription of this notebook, which appears to be of great interest, has not yet been made.

In the archive file with the correspondence and reports of the Office's geologists, there are no manuscripts or sent letters, probably due to a lack of documentation.

The synthesis of the work of years 1906, 1908 and 1909 is instead published in Franchi (1911). That work was presented at the 30th Congress of the Italian Geological Society held in Lecco.

Field notebook VII

A further notebook is titled "Val Maira, Stura, Val Gesso". The title page has the generic date of 1915; inside, cross sections and geological sketches from almost exclusively the Maritime and southern Cottian Alps are reproduced. One section (Vall'Onersio [Unerzio Valley]) is dated 'August 1918'. It seems therefore that the surveys began in 1915 and were suspended, possibly due to the First World War, in 1918.

This notebook contains one of the few photos that have survived (see section 5).

The back of the notebook shows the personal expenses incurred in the various locations during the field survey.

Field notebook VIII

This notebook, entitled "Dintorni di Ormea e di Garessio, M. Alpe, Nasino", is dated 1924 and contains, as usual, numerous geological cross sections and relatively few descriptive pages, related to field work in the Ligurian Alps.

Field notebook IX

The notebook No. 9 is the richest in notes. The first pages indicate the locality of "Entraque" (today Entracque), to which all the first geological cross sections reproduced belong. Other drawings are dated September 17 (without the year) and represent geological sketches from Borgata Santa Lucia, Valdieri, S. Lorenzo di Brignola (all located between the lower Stura and Gesso valleys).

A later report starts on October 24 (1926) and ends on November 8, and in it Franchi describes the itineraries from the Valle del Gesso to Cuneo - Limone Piemonte.

Two pages describe in words the "tectonic question of the Cima del Gros near Andonno".

Other pages describe the "Carreggiamento di Sant'Antonio", the "Carreggiamento T.te Chero - M. Plunea" and a profile of the "anticlinale carreggiata Bandita di Vola - Plunea".

Franchi pays particular attention to a cross section drawn between M. Brutto and the Argentera Massif.

This notebook is the most enriched with drawings and cross sections; the indicated dates, often without the year of reference, seem incompatible with a single survey campaign, which makes us think that this notebook was used in different years and in different locations, even though always within the Maritime Alps.

The last pages of this notebook contain landscapes (a few dated 1926) of the upper Susa Valley (Ambin massif and Monte Chaberton).

Field notebook X

The cover of the album marked 'Valtellina' contains the sentence "Sketches to complete the Valtellina notebook" (notebook VI). The notebook contains numerous pencil sketches, sometimes coloured, without the dates of execution. It is therefore difficult to place these notes in time.

Field notebook XI

The cover of the notebook entitled "Entraque, Valdieri, Valle Stura, Val Canto" contains only geological and panoramic cross sections without any chronological indications. It is therefore not possible to place this document chronologically in the series of Franchi's field notebooks.

Geological field maps

The Cartographic Collections of the Geological Survey of Italy - ISPRA Library include numerous copies of original field maps (consisting of topographic maps at the scale 1:25,000 on canvas support) realised by all the authors who contributed to the official project of Geological Map of Italy at the 1:100,000scale. These maps show the original data collected during the field survey and thus represent documentation of inestimable scientific value.

In particular, the Cartographic Collections include original maps signed by Franchi and produced for the final publication of the official geological maps. Franchi is author or co-author of 22 Alpine sheets of the Geological Map of Italy at the 1:100,000 scale (see details in the map of Fig. 2 and below).

Papers and miscellaneous

The ISPRA Library holdings include volumes that collect the miscellaneous of scientists who have worked over the years for the Geological Survey. The collection by Franchi consists of three volumes containing over 100 scientific papers published in Italy and abroad. His work on the relationships between damage and type of rocky substrate in the occasion of the Messina - Reggio di Calabria Earthquake of 1908 is also worth mentioning (Franchi, 1909).

In addition to the vast bibliographic and cartographic production specific to the area of the Western Alps, during his long career Franchi published papers and maps from the Central Apennines (e.g., Franchi, 1918, 1922) and northeastern Italy. During his activity, Franchi produced as author or co-author about 30 geological and geothematic maps, sometimes attached to publications.

Franchi, moreover, was Expedition Leader in Tripolitania and Cyrenaica (Petti et al., 2016). From this expedition, an album containing over 100 photographic images reproducing some interesting geological and naturalistic features of the region is preserved in the ISPRA Library.

THE WESTERN ALPS GEOLOGY IN FRANCHI'S NOTEBOOKS

In the following, we present part of the content of Franchi's field notebooks to recall a few of his fundamental contributions to the geological interpretation of the Western Alps. We focus on three key areas for Franchi's activity, i.e., the upper Susa (or Dora Riparia River) Valley in the Cottian Alps, the Southwestern Aosta Valley in the Graian Alps and the Maritime – Ligurian Alps sector (Fig. 5).

Upper Susa Valley in the Cottian Alps

A few field excursions by Franchi and colleagues of *Regio Ufficio Geologico* from the 24th to the 26th of July 1898 in the Bardonecchia and Oulx regions (upper Susa Valley) are described in notebook IV. These field campaigns (whose results were partially reported in the 1898 paper) had been organised by the *Regio Ufficio Geologico* so that all its geologists busy with the mapping of Alpine sheets of the Carta Geologica d'Italia at the 1:100,000 scale could discuss and appreciate the impact of Franchi's research directly in the field.

With the same aim, other field excursions were organised also in other sectors of the Cottian Alps (in particular in Maira and Grana valleys).

In detail, Franchi demonstrated that the *Zona delle Pietre Verdi* (as intended by Gastaldi and mapped by Zaccagna & Mattirolo in 1887) of the Cottian Alps, actually includes Carboniferous and Permian rocks (already recognised by Zaccagna) covered by Lower Triassic quartzite, Middle-Upper Triassic limestone-dolostone and carbonate-micaschist, and Lower Jurassic (and younger) schist commonly containing 'greenstone' bodies. At the regional scale, in the Southern Cottian Alps, the Triassic-Jurassic successions are preserved in the Acceglio and Viso synclines separated by the Pelvo d'Elva anticline of Carboniferous-Permian rocks (Fig. 6, Franchi, 1898a).

The Susa Valley had already been visited in 1889 by Franchi together with Zaccagna and Mattirolo, and the French geologists Marcel Bertrand and Alfred Potier of the *Service de la carte géologique de la France* (Franchi, 1898a; Regio Comitato Geologico, 1890).

In 1898, Franchi sketched and described overturned folds with west-dipping axial planes along the French-Italy border, bringing the calcschists of *Zona delle Pietre Verdi* below Triassic carbonates and older rocks (Figs. 6A and B). However, at Colle della Rho, Franchi recognised decimetric layers of polygenic breccias with Triassic dolostone clasts interbedded in the calcschists (Fig. 6C), a strong evidence against the formerly proposed Archean age for the calcschists. Franchi noted how these breccias perfectly resemble the polygenic breccias cropping out in the Grana Valley (*queste breccie ricordano perfettamente quelle poligeniche di Valgrana*). In fact, Franchi had already discovered similar breccias in the calcschists outcropping in the Grana, Maira, Rittana and Valloriate valleys (Southern Cottian Alps) and near the Mont Grammont in Valgrisenche (Aosta Valley) (Franchi & Di Stefano, 1896; Franchi, 1898a).

Figure 6D is a field sketch (NNW-SSE oriented) of the Gran Roc (Punta Muta) ridge between the valleys of the Thuras and Ripa rivers in the Sestriere region, characterised in map view by the exposure of dolostone successions surrounded by calcschists. Franchi had already gone to this sector with Italian and French colleagues in the aforementioned excursion of 1889. However, nine years later, in 1898, Franchi observed that the Triassic coarse-crystalline dolostones gradually pass up section to calcschists (such as those

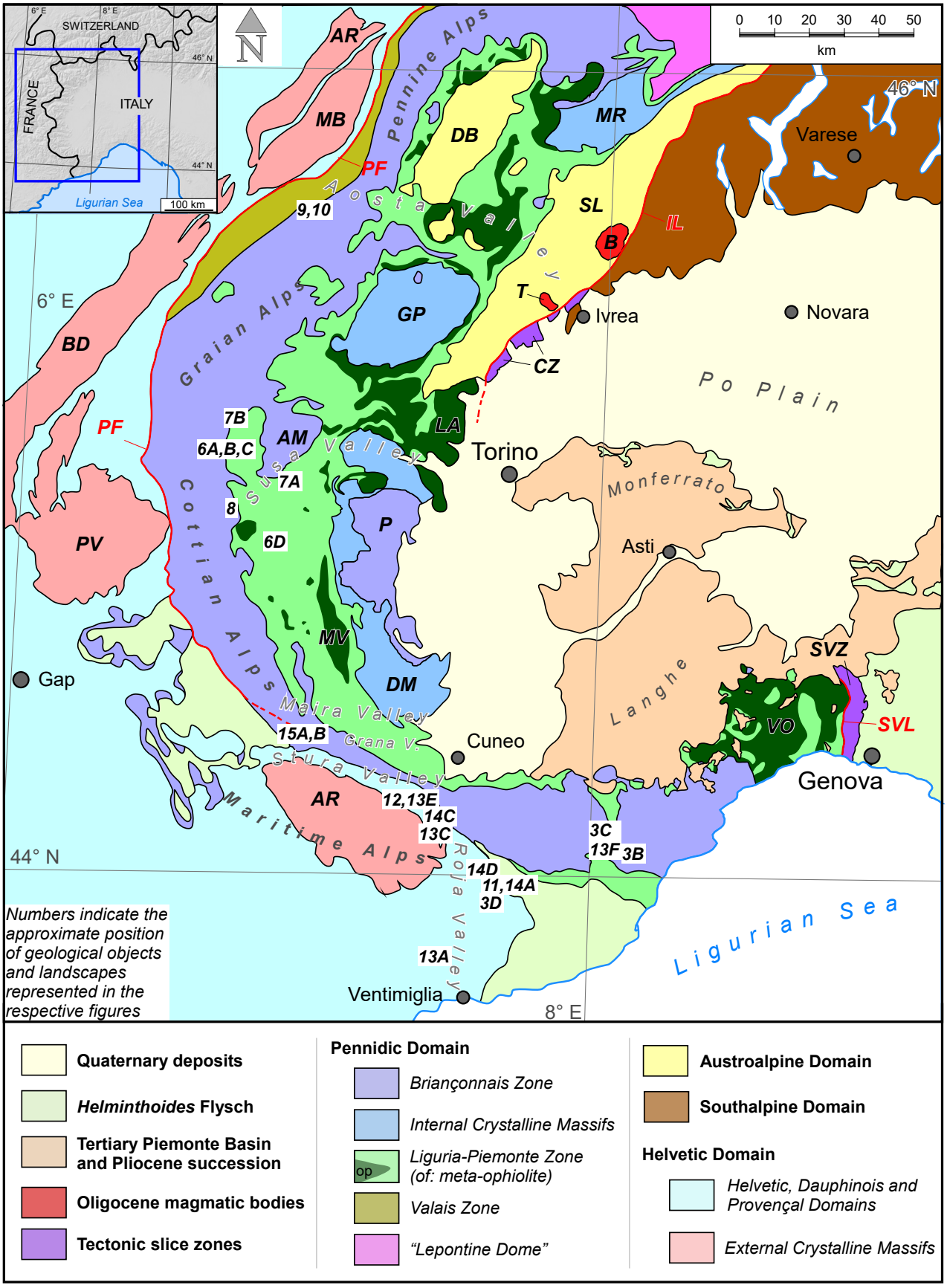

Fig. 5 - Simplified geo-tectonic map of the Western Alps (modified after Bigi et al., 1990). Acronyms: AM, Ambin Massif; AR, Aiguilles Rouges Massif; B, Biella (Valle del Cervo) Pluton; BD, Belledonne Massif; CZ, Canavese Zone; DB, Dent Blanche Nappe; DM, Dora-Maira Massif; GP, Gran Paradiso Massif; IL, Insubric Line; LA, Lanzo Massif; MB, Mont Blanc Massif; MR, Monte Rosa Massif; MV, Monviso Massif; P, Pinerolo Unit; PF, Pennidico Front; PV, Pelvoux Massif; SL, Sesia-Lanzo Zone; SVZ, Sestri-Voltaggio Zone; SVL, Sestri-Voltaggio Line; T, Traversella Pluton; VO, Voltri Massif. Numbers indicate the approximate position of the geological objects/landscapes represented in the respective figures.

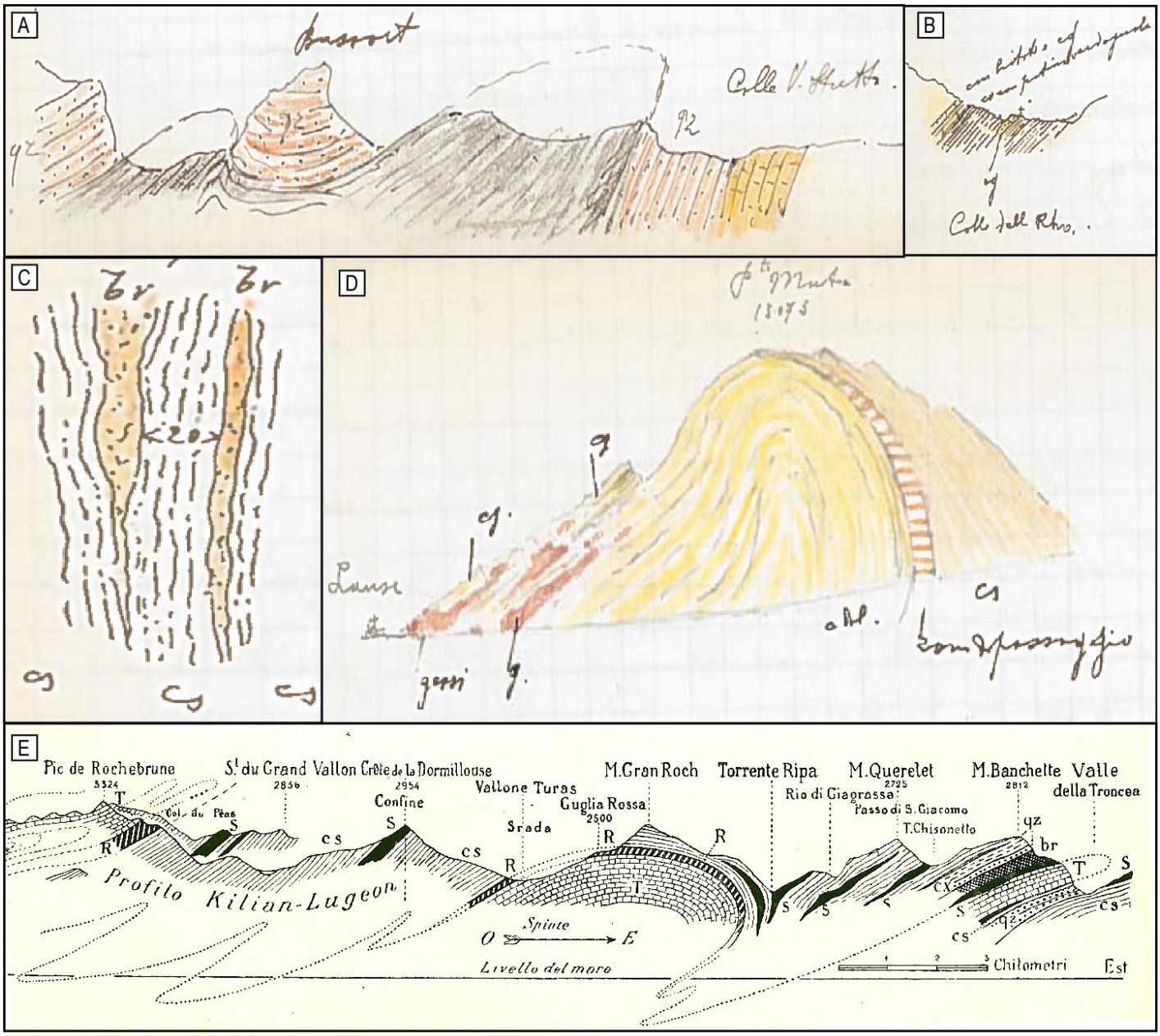

Fig. 6 - Geology of the upper Susa Valley - A) cross section in the uppermost Valle Stretta, showing an anticline of Permian-Carboniferous rocks (in grey) with quartzite (qz, in brown) and dolomitic beds (in yellow). B) Sketch of the overturned succession at the Colle della Rho (just to the east of the cross-section reported in A), with calcschists (dotted line) below Triassic dolostone (in yellow). C) Sketch details of polygenic breccia (br) interbedded in the calcschists (cs). D) Sketch of the calcareous Gran Roc-Punta Muta massif drawn from the south along the Thuras river valley. This little dome-shaped massif consists of Triassic dolostone (in yellow) gradually passing (zone with brown lines) to calcschists (cs, in light brown). Note the masses of gypsum on the steep south-western side of the massif. E) Detail of the geological profile crossing the Gran Roc -Punta Muta massif (Franchi, 1929a). Acronyms: br, Liassic polygenic breccias; cs, Calcschsits; cx, calcaire; qz, quartzite; S, Serpentinite; T, Triassic (mainly Norian) dolostone. A, B, C and D are sketches from Notebook IV.

he had described in the Vallone di Elva in the Southern Cottian Alps) and that the overall geometry corresponded to a km-scale overturned anticline with axial plane dipping towards the west (Fig. 6E). The calcschists originally on the top of the dolostone massif would have been removed by erosion. For these reasons, Franchi noted in his notebook that the Gran Roc (Punta Muta) is "one of the most interesting points for the debated question", i.e., the lithostratigraphy of the *Zona delle Pietre Verdi.* Later, in 1925, Franchi returned there with the French colleagues Wilfrid Kilian, Pierre Termier and Eugène Raguin (Termier, 1925; Franchi, 1926), who suggested a different interpretation, proposing a tectonic contact at the base of the calcschists.

In the Savoulx area (to the west of Oulx, on the left side of the Susa valley), Franchi annotated on his notebook IV that s*i vedono i calcescisti soprastare in concordanza su certi micascisti bianchi quarzitici ai quali sottostanno dei calcari cristallini marmorei e che a loro volta ricoprono i gessi e le anidriti..... i colleghi ritenendo questo micascisto quarzitico come equivalente delle quarziti del Trias inferiore, ritengono cosi il Trias rovesciato e che su di essi i calcescisti verrebbero a trovarsi per rovesciamento o scorrimento*

(the calcscshists cover white quartz-micaschists resting on marble which, in turn, overly gypsum and anhydrite [...] the colleagues considering this quartz-micaschist as equivalent to the Lower Triassic quartzite, describe the Triassic as overturned and the calcschist resting on it by overturning or sliding [...]). However, Franchi observed at several places that these quartz-micaschists do not correspond at all to Lower Triassic quartzites (exposed just to the east above the Carboniferous-Permian micaschists of the Ambin massif) but they are intercalations (a distinct facies) in the calcschists. These calcscshists, in turn, are clearly observed directly on the quartzite (*si vedono nettamente ricoprire le quarziti)*) so that they can be interpreted as etheropic with the Middle Triassic dolostones. Still in this area, Franchi drew anticlines and synclines folding the Carboniferous-Permian gneiss and micaschists of the Ambin massif and their overlying younger successions, producing also a sort of 3-D block diagram resulting from the intersection of horizontal and vertical (projected) cross sections (Fig. 7A). On the upper margin of the page reported in Fig. 7A, Franchi wrote that his interpretation of the lithostratigraphic and structural setting of this area is quite different (*io interpreto le cose ben altrimenti*) from that proposed by his Italian colleagues (i.e., Zaccagna and Mattirolo).

At a larger scale, Franchi placed the calcschists of the *Zona delle Pietre Verdi* in the large Bardonecchia (or Frejus) syncline, comprised between an anticline of Permo-Carboniferous and Triassic rocks (Gran Tempesta - Rocca Boussort and Chaberton - Grand Hoche sectors), to the west, and the western side of the Ambin massif to the east (Figs 6B and 7B). More to the east, he recognised a second major km-scale syncline of calcschists between the Ambin massif and the Dora Maira crystalline massif. In this setting, Franchi described the same Ambin massif as an ellipsoid of Carboniferous-Permian rocks that separated in two branches the northern extension of the Monviso syncline.

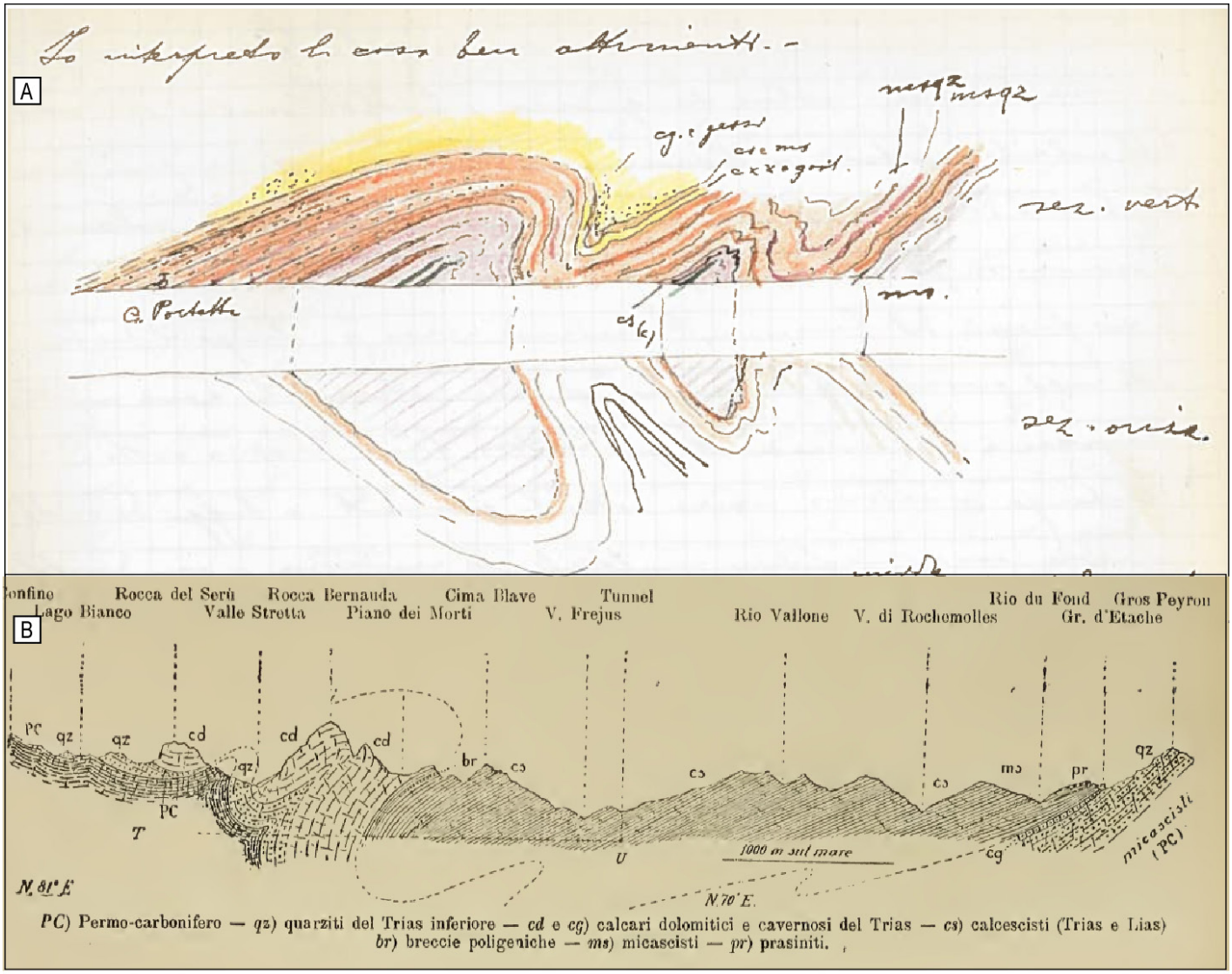

Fig. 7 - Geology of the upper Susa Valley – A) Folds observed on the south-western side of the Ambin Massif (Notebook IV). The Permo-Carboniferous rocks (in pink) are gneiss and micaschists (ms) with levels of prasinites (in green), quartzites (in red brown) and thin carbonate schists (cs). They pass upsection to Lower Triassic quartzites (in brown) including levels of quartz-micaschists (msqz). The lower part of the Middle Triassic carbonates (in yellow) includes thin levels of dolomitic marbles with "gastaldite" (i.e., glaucophane; cxx), calcschists (cs) and micaschists (ms), followed by gypsum and carnieules. B) Regional cross section showing calcschists of the Bardonecchia syncline between the anticline of Permian-Carboniferous and Triassic quarzites and carbonates of Rocca Bernauda (to the west) and the western flank of dome-shaped Ambin Massif (Franchi, 1898)

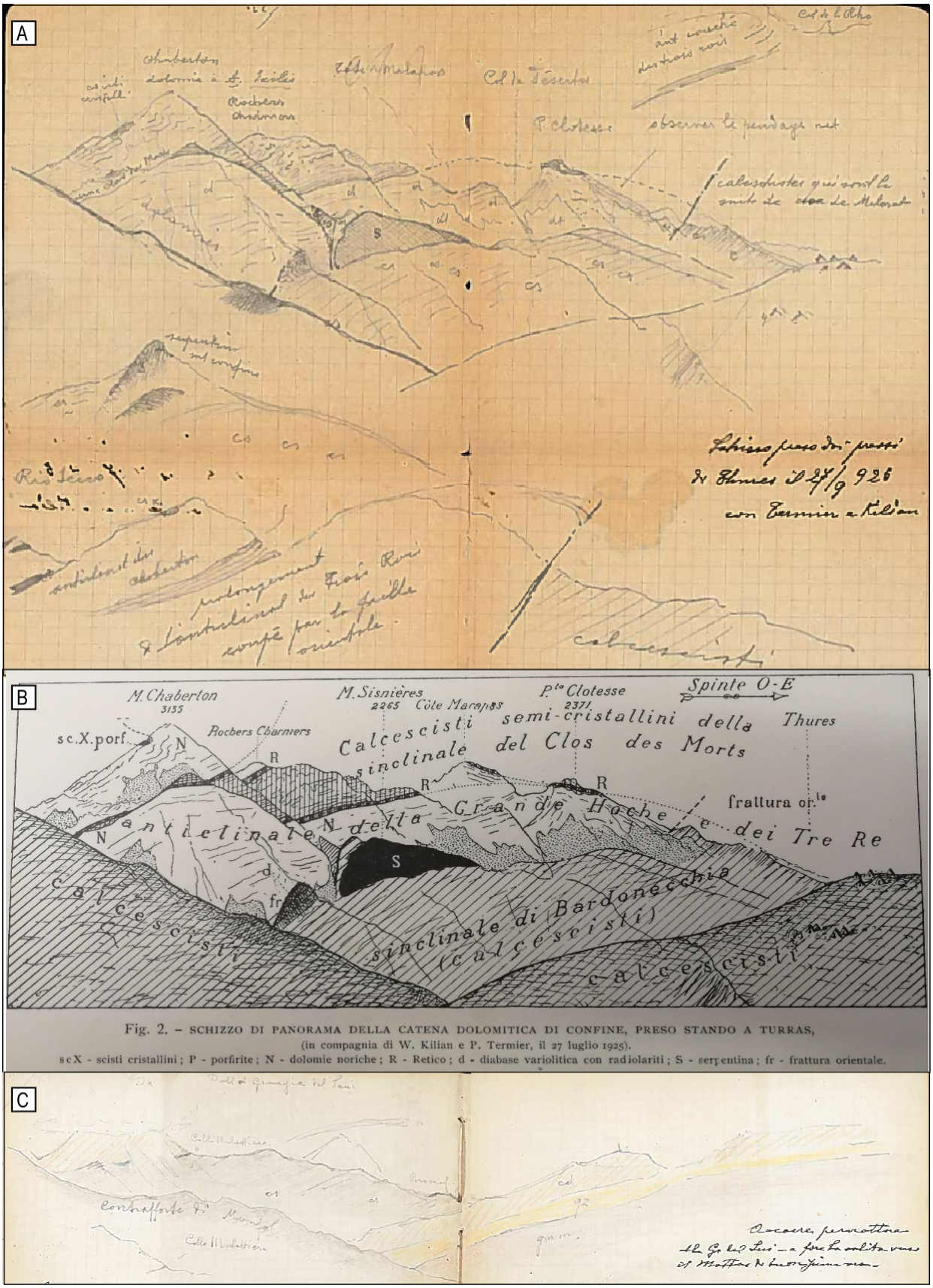

Fig. 2. – SCHIZZO DI PANORAMA DELLA CATENA DOLOMITICA DI CONFINE, PRESO STANDO A TURRAS,
(in compagnia di W. Kilian e P. Termier, il 27 luglio 1925).
scX - scisti cristallini; P - porfirite; N - dolomie noriche; R - Retico; d - diabase variolitica con radiolariti; S - serpentina; fr - frattura orientale.

Fig. 8 - Geology of Monte Chaberton-Grand Hoche ridge. A) landscape drawn during the field campaign of 1925 with Kilian and Termier (Notebook VIII). The lower profile simplified the geology of the western side of Monte Chaberton towards the Rio Secco. B) Landscape published in Franchi (1929a). C) Field sketch in Notebook IX showing the calcschists (cs) of the Bardonecchia syncline between the Monte Chaberton-Grand Hoche successions (in yellow) and the south-western side of the Ambin massif (gn. m. gneiss and micaschists; qz, Lower Triassic quartzite; cd Middle Triassic dolostone and carbonate schists). Note the summit of Monte Chaberton hidden in the clouds and, at the margin of the profile, the Franchi's footnote "Occorre pernottare alla Grange del Seu e fare la salita verso il Mottas di buonissima ora" (it is necessary to stay overnight at the Grange del Seu and make the ascent towards the Mottas in the early morning).

In this sector of the Cottian Alps, famous are the detailed studies of the "dolomitic" Chaberton - Grand Hoche ridge where Franchi described and mapped Norian, Raethian and Lower Jurassic successions (Franchi, 1910, 1929). Notebook IX contains a few landscapes of this ridge (Fig. 8A), drawn during a field excursion with French colleagues. Franchi was clearly fascinated by these mountains and their geology, and defined the geological sketch in his paper of 1929 (Fig. 8B) as "miserable simulacrum of such beauty" (Franchi, 1929, p. 27). The folded Norian, Raethian-Hettangian and Lower Jurassic successions of this mountain chain are separated to the East from the calcschists of the Bardonecchia syncline (here characterised by the large mass of serpentinites of the Monte Sisnière, now called Cresta Nera) by a west dipping fault (*frattura orientale*). On the summit of the Monte Chaberton, a syncline includes the easternmost part of the micaschists cropping out to the west along the Rio Secco (near the Italian-French border), whose geology is simplified by the lower profile of Fig. 8A.

While rejecting the presence of the Monte Rosa nappe (nappe V of Lugeon & Argand, 1905) in this sector of the Alps, only later Franchi ascribed the whole succession of the Monte Chaberton - Grand Hoche (including Mesozoic rocks and the adjacent micaschists of Rio Secco) to a "new" east-verging fold-nappe (whose existence is now no longer confirmed) that he labelled Briançon - Monte Chaberton nappe (Franchi, 1926, 1929a, 1929b).

Uppermost Aosta Valley in the Graian Alps

Franchi carried out extensive fieldwork in the Graian Alps, describing crystalline basement rocks and finding further lithostratigraphic evidence and palaeontological data to prove the Mesozoic age of the *Zona delle Pietre Verdi* (Franchi, 1896, 1898, 1899, 1904). Franchi collaborated with his colleagues of the Torino office to map all the geological sheets of the Geological Map of Italy at the 1:100,000 scale covering the Aosta Valley (e.g., Franchi & Stella, 1912). Notebook V describes the geological features of the southern side of the Western Aosta Valley from Pré-Saint-Didier to Mt. Blanc, thus from the uppermost Carboniferous rocks at La Thuile to the lowermost Mesozoic rocks presently cropping out near the Mt. Blanc massif, improving previous cross sections by Lory (1860), Favre (1862), and Baretti (1893) (Franchi, 1902, 1907a, 1929d; Franchi et al., 1908). Moving from east to west, Notebook V first contains sketches of the area to the NW of the Petit Saint Bernard Pass (figs 9A and 9B). There, the Mesozoic age of the *Zona dei Calcescisti con Pietre Verdi* was confirmed thanks to belemnite findings (Franchi, 1899). Te essential traits of the local regional geology were outlined in cross sections based on field observations (figs 9C and 9D). During the excursions of 1901 Franchi further analysed the current and palaeogeographic relationships between the Paleozoic La Thuile and Mesozoic Petit-

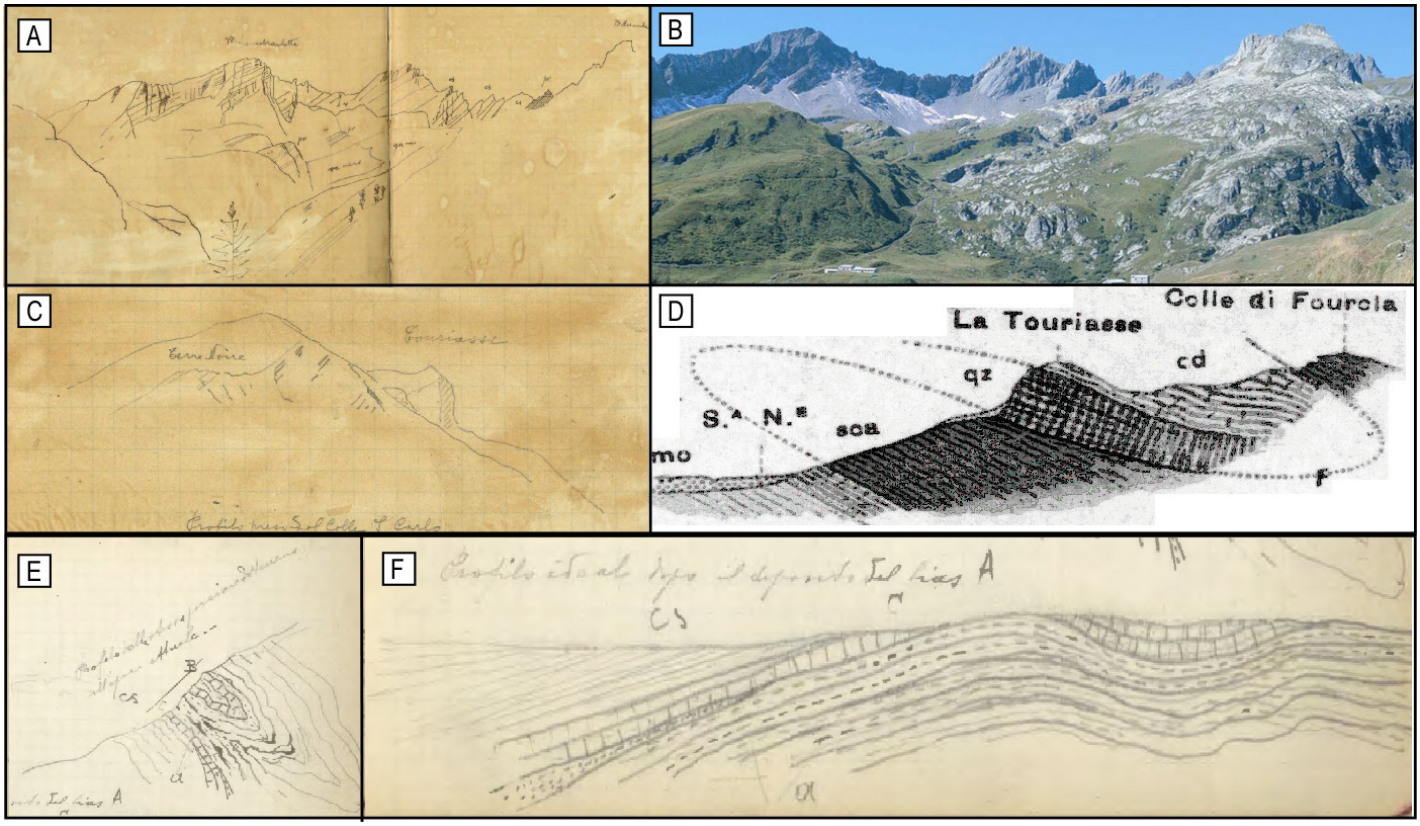

Fig. 9 - Mesozoic succession SW of La Thuile (Aosta Valley) - Notebook V. A) Landscape view of the ridge NW of the Petit Saint Bernard Pass, looking to the South. pr. = Prasinite; cs. = carbonate schists; sc nero = carbonaceous schists; gneiss = Punta Rossa metagranitoid. B) Panoramic view of the ridge NW of the Petit Saint Bernard Pass as sketched in A. C) Landscape view of the quartzitic cliff of the Touriasse peak (west) and of the Carboniferous Terre Noire peak (east) from Colle San Carlo, near La Thuile. D) Geological cross-section corresponding to C outlining rock folding (Franchi, 1899). Note that the orientation is opposite to C. E) Sketch of a cross-section representing present-day relationship between Paleozoic and Mesozoic rocks (top left: "Profilo della stessa porzione deformata sull'epoca attuale" "Section of the same region deformed at present-day"). F) Sketchy palinspastic restoration of the relationships between Paleozoic and Mesozoic successions at Early Jurassic time (top left: Profilo ideale dopo il deposito del Lias "Ideal section after deposition of the Lower Jurassic").

Saint Bernard rocks, interpreted to be in stratigraphic continuity. A cross section sketch of the present-day relationships and a preliminary palinspastic restoration of the original stratigraphic configuration of Paleozoic and Mesozoic successions in the Jurassic are reported in Notebook V (Figs 9E and 9F).

The main focus of the Notebook V was the study of Carboniferous successions to assess the economic exploitation potential and to quantify the resources hosted in graphitic schists of the Aosta valley (see also Franchi & Stella, 1903). Franchi focused on the coal mining districts north of La Thuile (Aosta), called Villaret, Cretaz, Bois de Gotelle, La Tour, Prellat, Garin and Preilet. He suggested to avoid the region near Morgex and Dolonne for future mineral explorations "*Io non fui poco stupito di non ritrovar più traccia degli scavi…*" (I was surprised not to find any (past) mining signs…). For each of the coal mining localities near La Thuile, Franchi recognised a variable number of possible productive layers (with anthracite) that now are locally missing due to exploitation. He consistently described for each sector (1) the quality of the material, (2) the size of the layer, (3) layer orientation and (4) the shape and thickness changes in the case of folded layers (Fig. 10). Franchi carefully sketched the complex polyphase structural evolution of this sector, with landscape-scale observations supported by outcrop description of stretched and folded layers (Figs 10A and 10B). The relationship between folded layers and foliation is clearly sketched showing the local axial plane relationships (Figs 10C and 10D, see also Franchi & Stella, 1903). Estimation of the size of the productive ore bodies was done through the accurate measurement reported in the notebook (Fig. 10E). Franchi considered not only the effects of ductile deformation but also those from brittle faulting when estimating the size of coal ores (Fig. 10F). Furthermore, Franchi applied simple trigonometry while in the field to directly derive the position at depth of the observed bodies (Fig. 10G). 2D sketch drawings are common and the 3D correlation of the productive

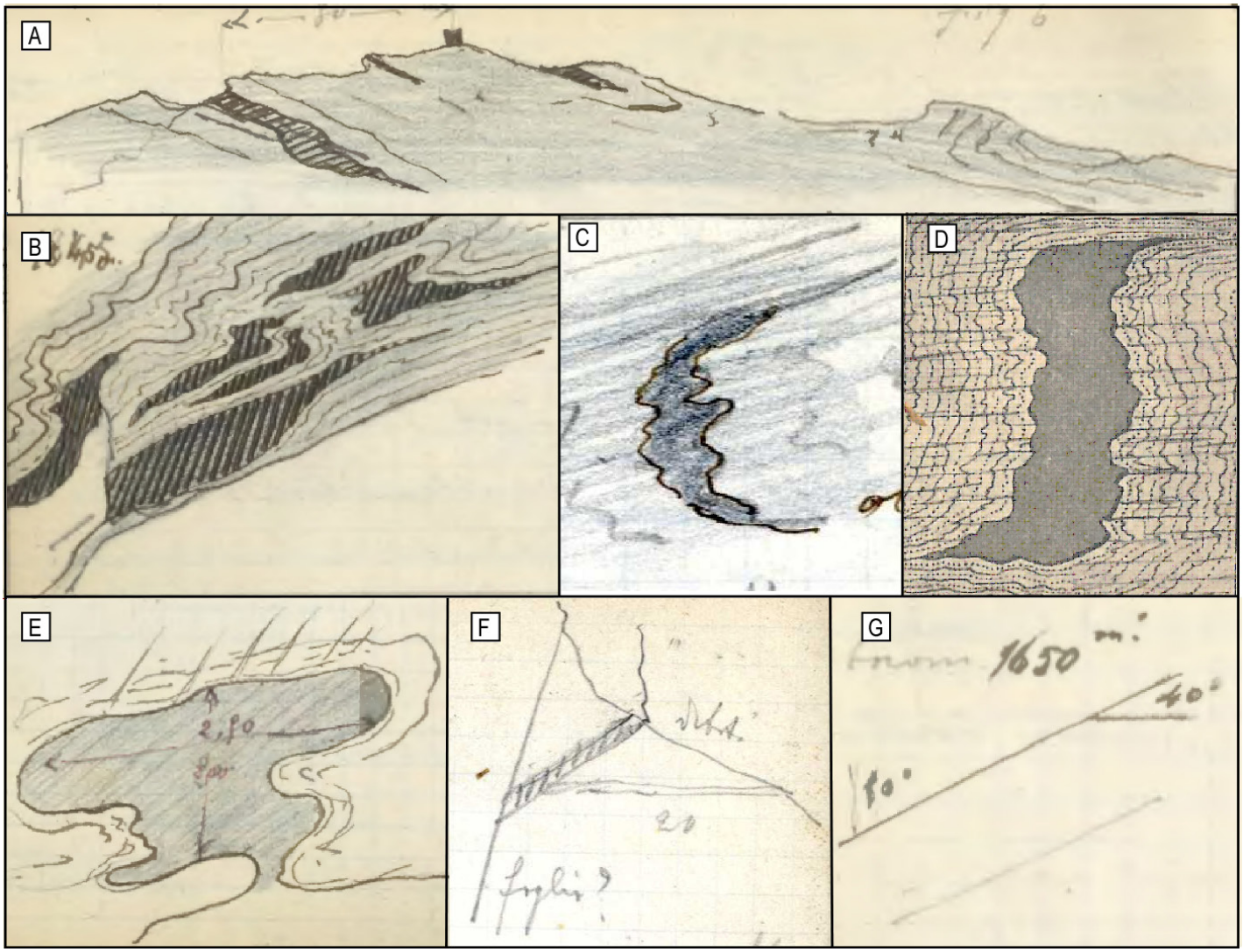

Fig. 10 - Carboniferous mining district near La Thuile (Aosta Valley) - Notebook V. A) Landscape view of the Terre Noire peak, S of La Thuile, showing productive layers (in black) and Permian-Carboniferous country rocks. Note the scale (30 m), top left, and the reference to the figure in Franchi and Stella, 1903, top right of the drawing. B) Discontinuous folded layers of Carboniferous coal. C) Penetrative axial plane foliation (in grey) perpendicular to a coal layer at fold hinge. D) Foliation as drawn in the article by Franchi & Stella (1903). E) Details on the size of potential Carboniferous coal (concessione la Tour). F) Sketch of fault cutting the coal layer and reducing the size of the mineral resource. G) Precise measurement of layers with simple trigonometry considered for prediction of the amount of the mineral resource.

layers is reported directly in the long text of the notebook, unfortunately often not readable. For example, he wrote "*La galleria precedente, allo stato -attuale? n.r.- aperta nella-?- roccia, diviene al bivio il proseguimento di questi banchi*, (the previous -reported, n.r- gallery continues at the crossroad where it meets those -previously described, n.r- layers).

Maritime–Ligurian Alps

In the Maritime–Ligurian Alps sector, Franchi was involved in the mapping of four sheets of the Geological Map of Italy at the 1:100,000 scale: Demonte and Argentera-Dronero (with Augusto Stella), Boves (with Domenico Zaccagna), and Sanremo. Noteworthy, the Boves and Sanremo sheets, published in 1928 and 1934, respectively, and only three decades after the field campaigns, have been never revised (except for a part of the Sanremo sheet, recently mapped for Geological Map of Italy at the 1:50,000 scale), and represent to date the official cartographic document for those areas.

On the southern side of the Maritime Alps (Argentina-Roja valleys), the work of Franchi was eased by the good preservation of the sedimentary successions, and by the detailed stratigraphic work already carried out by French geologists on the same successions cropping out in French territory (Barale, 2016). On the other hand, on the internal sector of the Maritime and Ligurian Alps, Franchi had to undertake a significant work of stratigraphic revision of the Mesozoic successions, which, at the time, were almost entirely attributed to the Triassic (Barale et al., 2018). In particular, thanks to the detailed field work leading to the discovery and characterization of numerous fossil-bearing intervals "*erano rivendicati al Giurese ed al Cretaceo ampie zone di terreni fra il Colle di Tenda e il Gesso, dapprima ascritte al Trias*" [*were regained to the Jurassic and to the Cretaceous wide areas between the Colle di Tenda and the Gesso river, once ascribed to the Triassic*] (Franchi, 1915, p. 245).

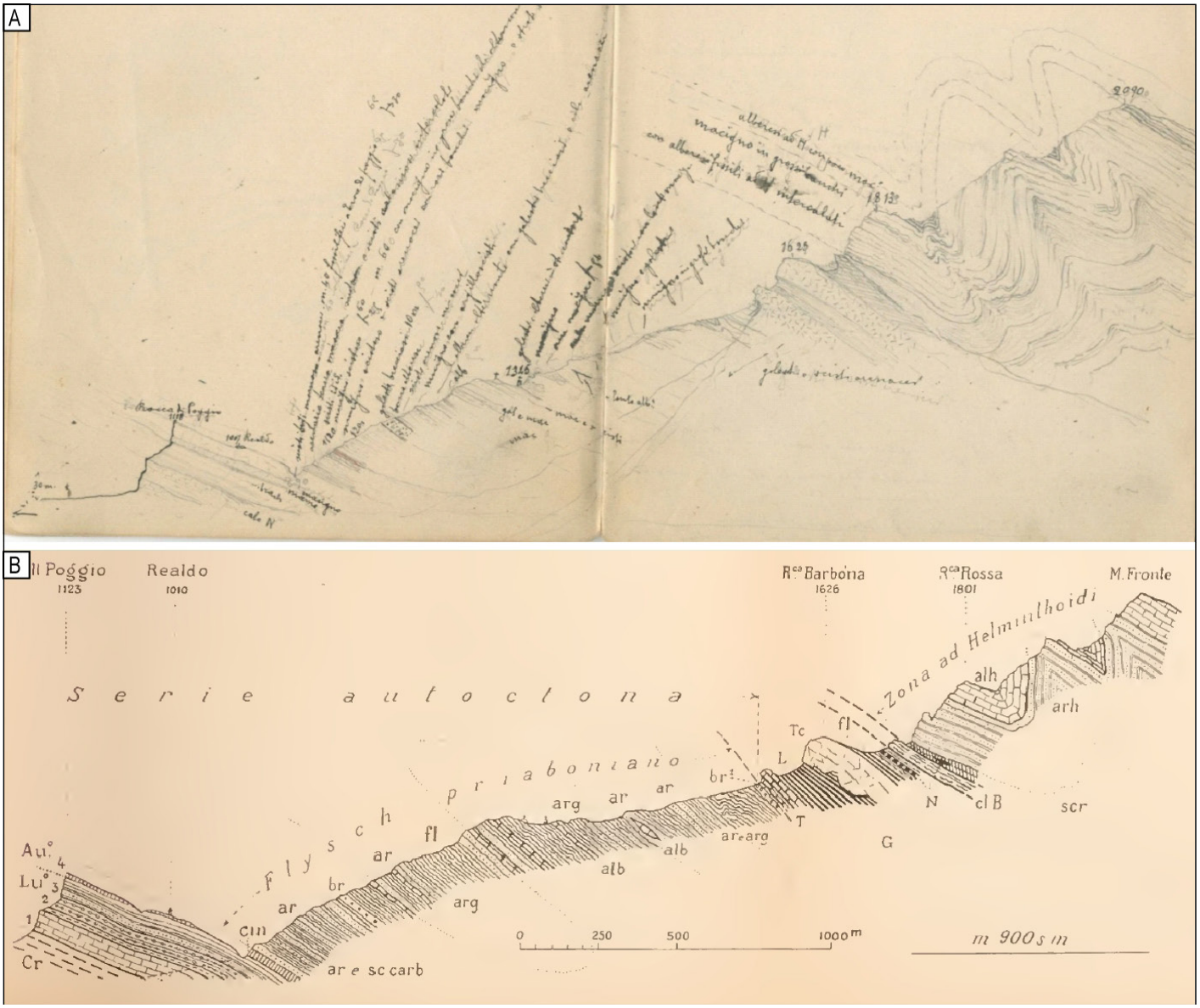

Fig. 11 - A, B) Geological section showing the superposition of the *Helminthoides* Flysch (repeatedly folded on the right) on the Eocene Alpine foreland basin succession on the southern side of Monte Fronté, Argentina Valley. A) Original sketch from Notebook I. B) Table 3, Fig. 6 of Franchi (1915).

The only important 'mistake' made by Franchi in the Maritime–Ligurian Alps sector concerns the geometric-stratigraphic interpretation of the *Helminthoides* Flysch. This is a Cretaceous 'flysch' succession, thrusted over the Cenozoic Alpine Foreland Basin succession and cropping out over hundreds of square kilometres in the Ligurian Alps (Lanteaume, 1968). Franchi, following the opinion of previous authors (see the geological maps of Pareto, 1846, Sismonda, 1866, Issel et al., 1887, Zaccagna & Mattirolo in Zaccagna, 1887), considered the superposition of the *Helminthoides* Flysch over the Foreland Basin succession as stratigraphic, and thus assigned a latest Eocene (late Priabonian) age to the *Helminthoides* Flysch (e.g., Franchi, 1894a, 1905; see also the field sketch of Fig. 11). Franchi (1915, 1929c) did always defend his idea of a stratigraphic continuity between the Alpine Foreland Basin succession and the overlying *Helminthoides* Flysch, and dismissed the hypothesis of a thrust contact, carried forward in the meantime by French geologists (e.g., Boussac, 1910, 1912).

Even though Franchi did not recognise the presence of the large *Helminthoides* Flysch nappe, he did recognise the existence of thrusts in the Maritime Alps, as those that cause the stacking of several tectonic units made up of Mesozoic and Cenozoic successions in the Gesso Valley (Fig. 12; e.g., Franchi, 1894a, 1906, 1907b, 1915).

Clear evidence of thrusting was also recognised by Franchi in the Colle di Tenda area, which he investigated in detail together with Luigi Baldacci during the geological studies for the Colle di Tenda railway tunnel (8080 m long, completed in nine years between 1889 and 1898). The design and realization of this tunnel represented a wonderful opportunity to investigate the geology of this part of the Maritime Alps, whose essential traits were outlined by the two in a joint paper (Baldacci & Franchi, 1900). Here the authors described *la presenza evidente di un fenomeno di slittamento (charriage) di un vasto lembo di terreni secondari con tutto il loro manto eocenico sugli scisti eocenici di una sinclinale più esterna (rispetto all'arco alpino) e con uno spostamento in senso orizzontale non molto inferiore ai tre chilometri* [*the evident presence of the slip (charriage) of a large portion of secondary terrains with all their Eocene cover, on the Eocene schists of a more external (with respect to the Alpine arc) syncline, with a horizontal displacement not much lower than three kilometres*] (Baldacci & Franchi, 1900, p. 61).

In the notebooks related to field campaigns in Maritime-Ligurian Alps (Notebooks I, III, IV, VII, VIII, IX, XI), Franchi sketched numerous examples of large-scale folds (Figs 13A-D), kilometre-scale structures resulting from the superposition of different folding phases (Fig. 13E), and detailed outcrop sketches showing overprinting relationships between different generations of foliations (Fig. 13F).

FOSSIL SKETCHES IN FRANCHI'S NOTEBOOKS

As seen, most of the sketches in Franchi's notebooks are geological cross sections, landscapes and details of outcrops; less common are, instead, the sketches of fossils, which are found only in some notebooks related to the Maritime–Ligurian Alps sector (Notebooks I and XI; Fig. 14). In some cases, Franchi drew these sketches by directly tracing the fossil details from the outcrop surface, as indicated in the accompanying notes (*ammonite ricalcata sul rilievo naturale della roccia* [ammonite traced from the natural rock relief]; Notebook I, Fig.14A). Fig. 14C shows the sketch of a belemnite rostrum found in the succession of the Roaschia Valley (San Bernardo hamlet) and attributed (with a question mark) to the Early Cretaceous genus *Duvalia*. The finding of this and analogous fossils, as reported in later papers (Franchi, 1894a, 1906, 1907b, 1915), allowed the distinction, on a palaeontological base, of Lower Cretaceous sediments in the reduced Mesozoic successions running from the Colle di Tenda to the lower Stura di Demonte Valley on the Italian side of the Maritime Alps (now ascribed to the Provençal Domain; Barale et al., 2016). Fig. 14B shows the drawing of *Chondrites* trace fossils found in the Cretaceous *Helminthoides* Flysch and Fig. 14D is a sketch of a gastropod (probably a nerineid) from the Upper Jurassic Provençal limestones of Cima di Boseglio (now Mont Chaberta, near la Brigue, Roja Valley, France).

PHOTOGRAPHS

Especially in the latest notebooks (e.g., Notebook VIII), Franchi made frequent references to photographs taken in the field. However, only a few of these photographs are still available, as inserted into the notebooks or pasted onto their pages, whereas the greatest part of them was probably lost. Fig. 15A shows a photograph from Notebook VII, portraying a geological landscape of the high Maira Valley in the southern Cottian Alps (a note on the back of the photograph reads *Oronaye e Colle Feuillas salendo alla Gardetta* [*Mount Oronaye and Feuillas Pass going up to the Gardetta Pass*]).

Fig. 15B shows a photograph from Notebook III, with two *Carabinieri* posing on a lake shore and a third man on a canoe. The image was shot from a point on the southern shore of the Lago superiore di Roburent (2426 m asl) in the southern Cottian Alps (northern flank of Stura di Demonte Valley); the dark coloured rocks forming the promontory and the left background of the photograph are Permian volcanites. The light coloured rocks making up the cliffs on the right background are Middle Triassic dolostones of the Briançonnais Domain. On the opposite shore, there is a military camp with several drywall shelters for soldiers, typical of this area, known as *trune*.

NOT ONLY GEOLOGY

In his notebooks, at the margin of geological drawings and annotations, Franchi left numerous sketches of various objects, including buildings and persons (Figs 16A and 16B), providing us with interesting views of life during the late 19th–early 20th century. Franchi drew similar sketches also at the margin of his working geological maps (Pantaloni, 2013). A recurring theme in Notebook VIII are chestnut trees (Figs 16C, 16D, and 16E):

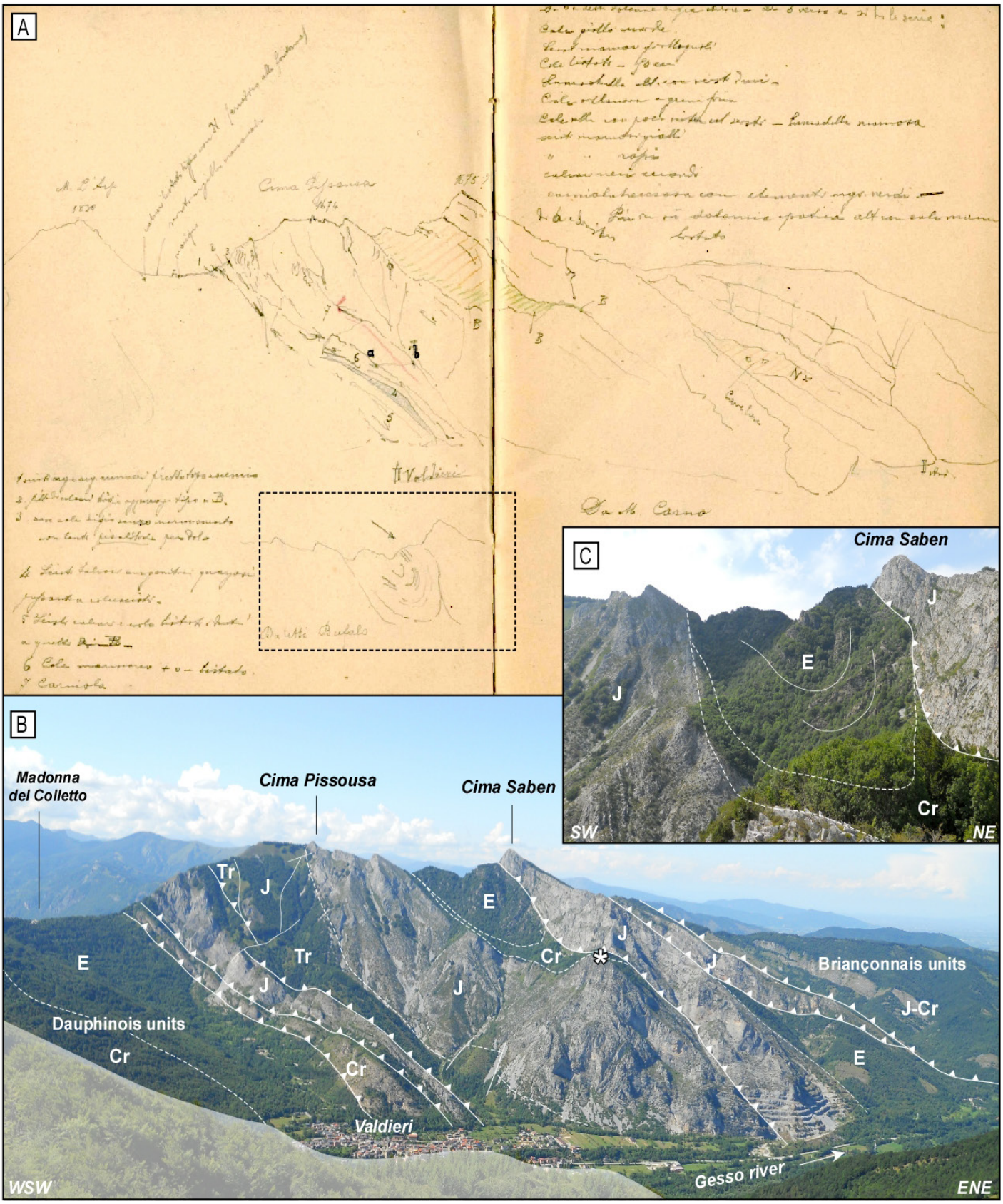

Fig. 12 - Thrusts and folds. A) Sketch from Monte Corno of the left side of the Gesso Valley from Valdieri to Andonno. The "B" letters indicate the sites where Franchi found belemnite rostra within the Lower Cretaceous Provençal succession (Notebook XI). B) Same landscape sketched by Franchi in A), showing the juxtaposition of the Briançonnais units of lower Gesso Valley on the Provençal units of Cima Pissousa–Cima Saben, in turn thrusted over the Dauphinois units on the left side of the image. (Tr: Upper Triassic – Early Jurassic succession, and carnieules; J: Middle–Upper Jurassic succession; Cr: Cretaceous succession; E: Eocene succession; dashed lines: stratigraphic contacts; full lines: tectonic contacts; geological interpretation based on Barale et al., 2016 and Malaroda, 1970). Image taken from Punta di Giaime; the asterisk indicates the shooting point of the image in C). C) Detail of the folded Eocene succession of Cima Saben, as outlined by Franchi in the dashed rectangle in A), from Ciabot Martinot.

Fig. 13 - Folds. A) Hectometre-scale fold in the Upper Cretaceous successions of Monte Maltempo, near Airole (lower Roja Valley) sketched in Notebook I. B) Photo of the fold of fig. 9A. C) Folded Mesozoic succession near Entracque (Gesso Valley) reported in Notebook XI. D) Panoramic view of structures reported in Fig 9C. E) The refolded structure (piega a fungo rovesciato , "overturned mushroom fold") of the Monte la Piastra (W of Valdieri) sketched from SE (Notebook VII). F) Crenulation cleavage observed in Briançonnais Mesozoic meta-marls (Calcescisti) of the Garessio area (Notebook VIII).

Franchi outlined 13 sketches of chestnut trunks and stumps, thus showing his particular interest for those with bizarre contortions or shapes.

Also, the last pages of some notebooks contain the annotations of all the transfers he made during his field campaigns, and the list of the costs incurred for travels, board and lodging (Fig. 16F), as well as other needs (e.g., *Porto roccie sul mulo dal Poggetto* [rock transport by mule from Poggetto]; Notebook I). Lastly, Franchi's notebooks remind us of the 'typical problems' of fieldwork, as, for example, limited visibility due to fog (Fig. 16G), low clouds masking mountains and field activity program changes (see Fig. 8C).

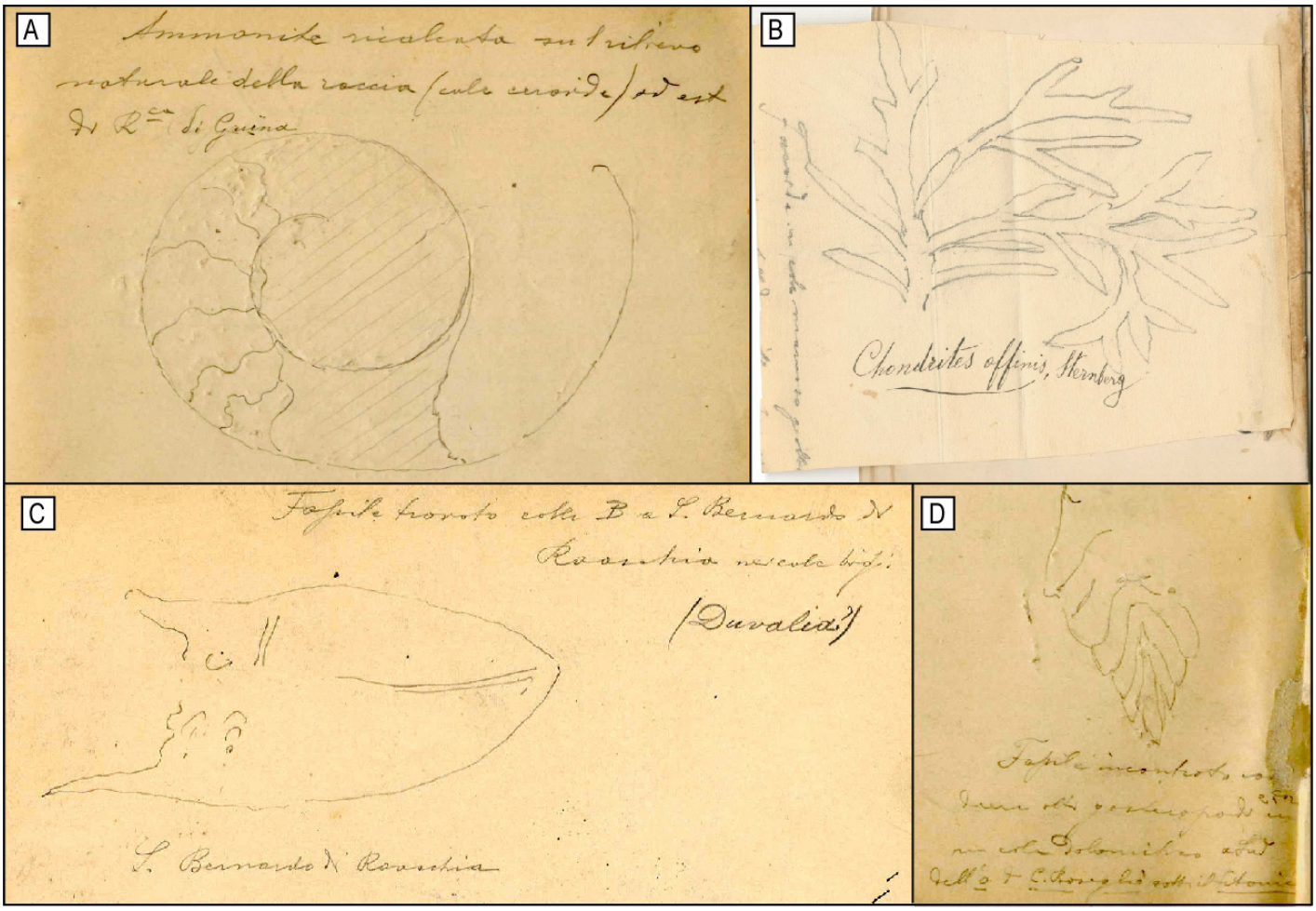

Fig. 14 - Sketches of fossils and trace fossils. A) Ammonite internal mould traced from the natural rock relief—note the ruffling of the paper in correspondence of the left part of the fossil, where the page was pressed against the rock surface; Notebook I (the fossil was found near Rocca di Goina—spelled "Guina" by Franchi— in the upper Argentina Valley, Ligurian Alps). B) Accurate drawing of a *Chondrites* trace fossil, commonly found in the Cretaceous *Helminthoides* Flysch of Ligurian Alps, in a fold-out sheet pasted at the end of the Notebook I. The pencil note (in vertical on the left side and truncated) reads "Fucoide in calc. marnoso giall[ognolo]" [fucoid in yellowish marly limestone]; the specific attribution "*Chondrites affinis*, Sternberg", in pen, appears to have been added later. C) Belemnite rostrum "(*Duvalia*?)" found in the grey limestone "calc bigi" near Roaschia, Maritime Alps; Notebook XI. D) Gastropod section (probably a nerineid) from the Upper Jurassic limestones near La Brigue, Roja Valley; as in a), the ruffling of the paper suggests that the fossil outline was traced directly from the rock surface; Notebook I.

CONCLUSIONS

Franchi and his colleagues from the *Regio Ufficio Geologico* were busy during the late 19th–early 20th century with numerous field studies carried out for several important geological assignments. In particular, their detailed field studies in the Alpine regions as part of the mapping of the geological sheets at the 1:100,000 scale and 1:400,000 scale map of the Western Alps remain very impressive even today.

This paper focuses on the main contributions by Franchi to the geology of the Western Alps, integrating published papers and unpublished documents. The presented notebooks by Franchi are only small fragments of the intensive field activities of this geologist, who is otherwise mostly known for his publications and geological maps, but their content is the foundation of the present-day geological knowledge of the Western Alps.

Franchi's notebooks document the skills of this eminent geologist, who approached the study of the Alpine successions by integrating stratigraphy, structural geology, petrography and palaeontology. His studies were crucial for the chronostratigraphic framing of the Alpine successions (in particular for the Mesozoic age of the *Zone delle Pietre Verdi*) and had a great and immediate impact upon the geological community. On the other hand, although Franchi recognised several thrusts and recumbent folds, he did not accept large horizontal transports of nappes in the Western Alps.

Franchi's notebooks are very rich with sketches and descriptions both at outcrop and landscape scale, allowing insights into the working methods of the time to produce maps and publications. In addition, they contain beautiful and curious sketches of the world as observed by Franchi during his field activity and offer us a view of everyday life at his times.

OFFICIAL MAPS OF THE CARTA GEOLOGICA D'ITALIA AT A SCALE 1:100,000

Franchi collaborated to the following sheets covering the Italian western Alps:

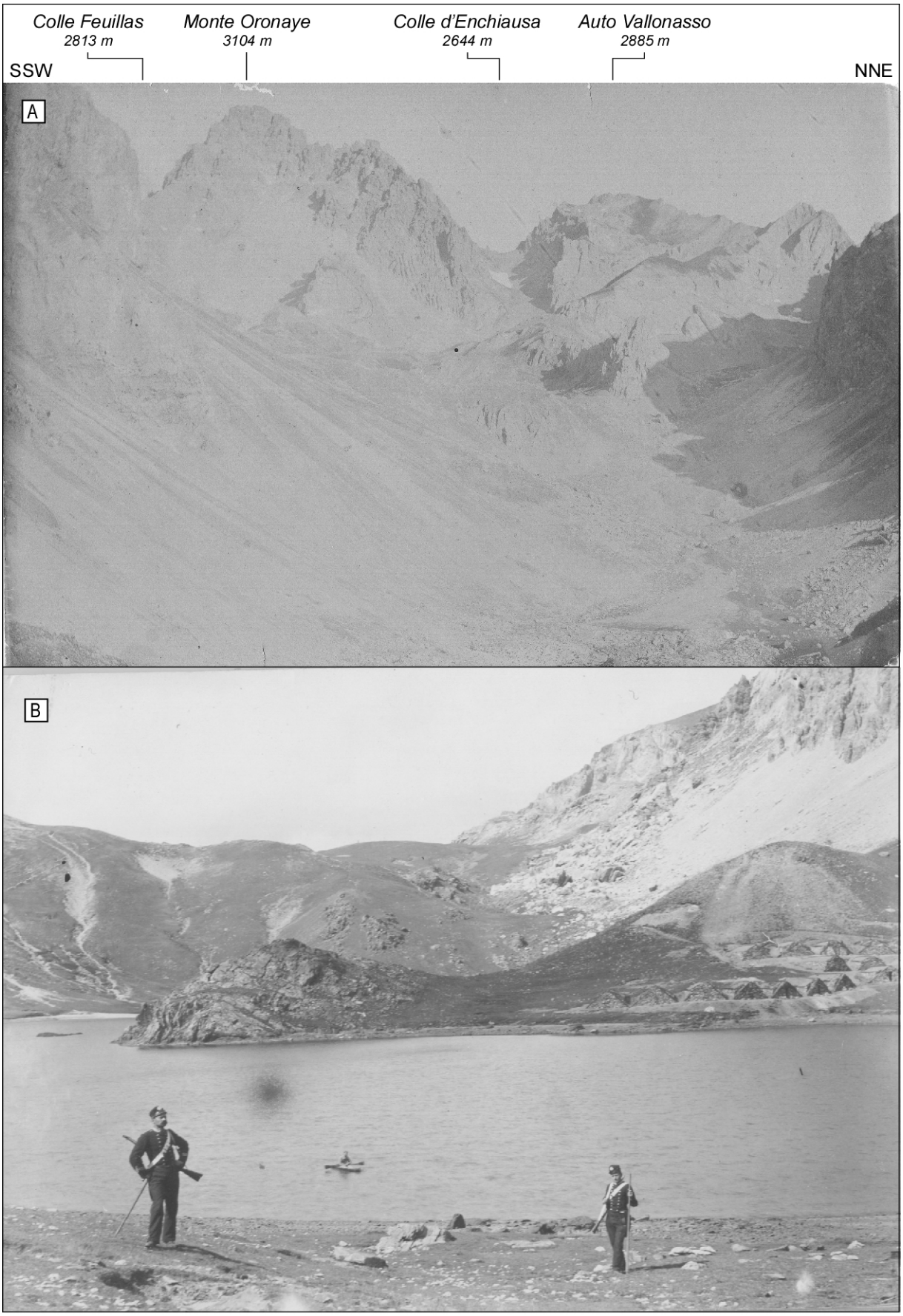

Fig 15 - Photographs – A) view of "Mount Oronaye and Feuillas Pass going up to the Gardetta Pass" in the upper Maira valley (see detail in the text), from Notebook VII. B) Lago Superiore di Roburent in the upper Stura di Demonte valley (see details in the text) from Notebook III.

Fig 16 - Not only geology – A) Drawing of women and B) scene of rural life with fisherman and priest in the Notebook I. C), D) and E) drawings of chestnut trunks (Notebook VIII). F) Page detailing all the stages of field campaign and costs in Notebook IV. G) ...that day, the fog prevented the completion of geological observations (the caption reads "scheme of a profile that I could not complete due to the fog"; Notebook VIII).

Foglio 27 Monte Bianco (1912)
Foglio 28 Aosta (1912)
Foglio 29 Monte Rosa (1912, ris. 51)
Foglio 30 Varallo (1927)
Foglio 41 Gran Paradiso (1912)
Foglio 42 Ivrea (1912)
Foglio 43 Biella (1933)
Foglio 54 Oulx (1914)
Foglio 55 Susa (1913)
Foglio 56 Torino (1925)
Foglio 66 Cesana Torinese (1914)
Foglio 67 Pinerolo (1913)
Foglio 78-79 Argentera-Dronero (1930)
Foglio 80 Cuneo (1931)
Foglio 81 Ceva (1936)
Foglio 82 Genova (1907)

Foglio 90 Demonte (1933)
Foglio 91 Boves (1934)
Foglio 93 Albenga-Savona (1935)
Foglio 102 San Remo (1928)
Foglio 103 Imperia (1928)

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REFERENCES

Argand É. (1911) - Les nappes de recouvrement des Alpes Pennines et leurs prolongements structuraux. Mat Carte Géol. Suisse, 31, 1-26.

Argand É. (1916) - Sur l'arc des Alpes Occidentales. Eclogae Geol. Helv. 14, 145-191.

Argand É. (1923) - La géologie des environs de Zermatt. Actes de la Société Helvétique des Sciences Naturelles, 104, 96-110.

Baldacci L. & Franchi, S. (1900) - Studio geologico della Galleria del Col di Tenda (linea Cuneo-Ventimiglia). Boll. R. Com. Geol. It., 31, 33-87.

Barale L. (2016) - The early geological exploration of the Nice region (French Maritime Alps) in the late 18th-19th centuries. Proceedings of the Geologists' Association, 127(6), 747-760.

Barale L., Bertok C., d'Atri A., Martire L., Piana F. & Domini G. (2016) Geology of the Entracque–Colle di Tenda area (Maritime Alps, NW Italy). Journal of Maps, 12(2), 359-370.

Barale L., Mosca P. & Fioraso G. (2018) - Il "periodo d'oro" degli studi geologici nelle Alpi Marittime tra il XIX e il XX secolo. Rend. Online Soc.Geol. It., 44, 64-71.

Baretti M. (1893) - Geologia della Provincia di Torino. Casanova, Torino.

Bigi G., Castellarin A., Coli M., Dal Piaz G.V., Sartori R., Scandone P. & Vai G.B., (1990) - Structural Model of Italy scale 1:500.000, sheet 1. C.N.R., Progetto Finalizzato Geodinamica, SELCA Firenze.

Boussac J. (1910) - Les grands phénomènes de recouvrement dans les Alpes Maritimes italiennes et la «fenêtre» de Castelvecchio. C. R. Acad. Sci. Paris, 151, 1163-1165.

Boussac J. (1912) - Études stratigraphiques sur le Nummulitique alpin. Mémoire du Service de la Carte Géologique de France, Paris, 662 pp.

Brianta D. (2007) - Europa mineraria. Circolazione delle élites e trasferimento tecnologico (secoli XVIII-XIX). Franco Angeli editore, Milano, 447 pp.

Campanino F. & Polino R. (2002) - Carta geologica delle Alpi Piemontesi (1860-1879 ca.).

Fotomosaico al 1:380.000 dei 29 fogli al 1:50.000 rilevati da M. Baretti, B. Gastaldi, H. Gerlach, con la collaborazione di C. Bruno, L. Bruno e G. Michelotti. Regione Piemonte, Museo Regionale Sci. Nat. di Torino, Litografia Geda, Nichelino.

Chiorino A.M. (2013) - Quintino Sella: tra scienza e cultura politecnica. Atti dei Convegni Lincei, Quintino Sella scienziato e statista per l'Unità d'Italia, Roma, 5-6 Dicembre 2011, 269, 237-270.

Dal Piaz G.V. (2001) - History of tectonic interpretations of the Alps. Journal of Geodynamics, 32, 99-114.

Dal Piaz G.B. & Dal Piaz G.V. (1984) - Sviluppo delle concezioni faldistiche nell'interpretazione tettonica delle Alpi (1840-1940). In "Cento anni di geologia italiana. Volume giubilare". Soc. Geol. It., 41-70.

Dal Piaz G.V., Bistacchi A., Gianotti F., Monopoli B., Passeri L. & Schiavo A. (2015) – Note illustrative della Carta Geologica d'Italia alla scala 1:50.000, F. 70 Monte Cervino. Mem. Descr. Carta geol. d'It. 101, ISPRA, Servizio Geologico d'Italia, Roma, 258 pp.

Dal Piaz G.V. & Argentieri A. (2021) - 150 years of plans, geological survey and drilling for the Fréjus to Mont Blanc tunnels across the Alpine chain: an historical review. Italian Journal of Geosciences, 140, 169-204.

Ellenberger F., Michard A. & Sturani C. (1964) - Découverte d'Ammonites et observation stratigraphique dans les "Schistes lustrés" du Val Grana (Alpes Cottiennes). Comptes Rendus de l'Académie de Sciences de Paris, 159, 3047-3050.

Favre A. (1862) - Explication de la carte géologique des parties de la Savoie, du Piémont et de la Suisse, voisines du Mont Blanc. Arch. Sc. Genève, 15, 1-39.

Favre A. (1867) - Recherches géologiques dans les parties de la Savoie, du Piémont et de la Suisse voisines du Mont-Blanc. Vol. I, 464 pp.; vol. II, 437 pp.; vol. III, 587 pp., Atlas: 32 Planches. Masson et Fils Editeurs, Paris.

Franchi S. (1891) - Il Giuraliasico ed il Cretaceo nei dintorni di Tenda, Briga Marittima e Triora nelle Alpi Marittime. Boll. R. Com. Geol. It., 22, 226-239.

Franchi S. (1894a) - Contribuzione allo studio del Titonico e del Cretaceo nella Alpi Marittime italiane. Boll. R. Com. Geol. It., 25, 31-83.

Franchi S. (1894b) Relazione sui principali risultati del rilevamento geologico nelle Alpi Marittime eseguito nelle campagne 1891-92-93. Boll. R. Com. Geol. It., 25, 231-258.

Franchi S. (1896) - Sulla presenza del nuovo minerale lawsonite come elemento costituente in alcune roccie italiane. Atti R. Acc Scienze Torino, 32, 3-7.

Franchi S. (1897) - Sopra alcuni nuovi giacimenti di roccie a lawsonite. Boll. Soc. Geol. It. 16(1), 3-6.

Franchi S. (1898a) - Sull'età mesozoica della zona delle pietre verdi nelle Alpi Occidentali. Boll. R. Com. Geol. It, 29(3), 173-247 ; (4), 325-482.

Franchi S. (1898b) - Sulla geologia di alcuni punti delle Alpi Marittime e Cozie. Boll. Soc. Geol. It, 17, 261-271.

Franchi S. (1899) - Nuove località con fossili mesozoici nella zona delle pietre verdi presso il colle del Piccolo San Bernardo (Valle d'Aosta). Boll. R. Com. Geol. It., 10, 303-324.

Franchi S. (1900) – Sopra alcuni giacimenti di roccie giadeitiche nelle Alpi Occidentali e nell'Appennino Ligure. Boll. R. Com. Geol. It., 31, 119-158.

Franchi S. (1901) - Sulla dispersione nei pirosseni alluminio-ferrico-sodici di alcune roccie cristalline delle Alpi occidentali. Boll. R. Com. Geol. It, 4, 3-8.

Franchi S. (1902) - Contribuzione allo studio delle roccie a glaucofane e del metamorfismo onde ebbero origine nella regione ligure alpina occidentale. Boll. R. Com. Geol. It., 33, 255-318.

Franchi S. (1903) - Sul rinvenimento di nuovi giacimenti di roccie giadeitiche nelle Alpi Occidentali e nell'Appennino Ligure. Boll. Soc. Geol. It., 22, 130-134.

Franchi S. (1905) - A proposito della riunione della Società geologica di Francia in Torino nel settembre 1905. Boll. R. Com. Geol. It., 36, 298-313.

Franchi S. (1906) - Sulla tettonica della zona del Piemonte. Boll. R. Com. Geol. It., 37, 118-144.

Franchi S. (1907a) - Escursioni in Valle d'Aosta, 12-13 settembre 1907. Boll. Soc. Geol. It., 26, 165-173; 183-186.

Franchi S. (1907b) - Osservazioni sopra alcuni recenti lavori sulla geologia delle Alpi Marittime. Boll. R. Com. Geol. It., 38, 145-170.

Franchi S. (1909) – Il terremoto del 28 Dicembre 1908 a Messina, in rapporto alla natura del terreno ad alla riedificazione della città. G. Bertero & C., Roma, 48 pp.

Franchi S. (1910) - Il Retico quale zona di transizione fra la Dolomia principale ed il Lias a 'facies piemontese' - calcescisti con Belemniti e pietre verdi - nell'alta Valle di Susa. Boll. R. Com. Geol. It., 41, 1-37.

Franchi S. (1915) - Le «Arenarie di Annot» e la «Zona a Helminthoida» nell'Eocene delle Alpi Marittime e dell'Appennino Genovese. Boll. R. Com. Geol. It., 45, 233-335.

Franchi S. (1918) - Traccie glaciali nell'alta Valle del Liri. Boll. Soc. Geol. It., 37, XLII-XLIV.

Franchi S. (1922) - Sulla presenza di banchi calcari con scutelle e con Amphistegina Niasi e di sedimenti planctonici nella formazione marnoso-arenacea della Valle del Liri. Boll. Soc. Geol. It., 41, 100-104.

Franchi S. (1926) – Principali risultati scientifici delle escursioni geologiche fatte nelle Alpi Cozie con P. Termier e W. Kilian. Boll. R. Uff. Geol. It., 51, 1-16.

Franchi S. (1929a) - Sulla tettonica delle alpi Cozie Franco-Italiane. Mem. Desc. Carta Geol. It., 22, 5-62.

Franchi S. (1929b) - La inesistenza delle grandi faldi dette "Nappe du Mont Rose" e "nappe du gran Saint Bernard" nelle Alpi occidentali. Rend. Acc. Naz. Lincei, 9, f. 6, 134-136.

Franchi S. (1929c) - Sull'importanza dei fogli «Sanremo» e «Imperia» della Carta geologica d'Italia al 100.000, per la soluzione di grandi quesiti di geologia alpina ed appenninica. Atti della R. Acc. Naz. dei Lincei, Rend. Classe di Scienze fisiche, matematiche e naturali, S.6, 9, 265-271.

Franchi S. (1929d) - Sul confine franco-italiano tra il Colle del Piccolo San Bernardo ed il Colle della Seigne, a sud del Monte Bianco. Rend. Accad. Nazion. Lincei, 10, 617-621.

Franchi S. & Di Stefano G. (1896) - Sull'età di alcuni calcari e calcescisti fossiliferi delle valli Grana e Maira nelle Alpi Cozie. Boll. R. Com. Geol. It., 27, 171-180.

Franchi S. & Stella A. (1903) - I giacimenti di antracite della Valle d'Aosta. Mem. Descr. Carta Geol.It., 12, 13-92.

Franchi S., Kilian W. & Jacob Ch. (1908) - Chemin de fer international à travers le Mont-Blanc. Projets présentés par le syndicat d'étudesdu tunnel du Mont-Blanc et de ses voies d'accès. I) Rapport géologique sur les projets de tunnels (…) par M.M. Secondo Franchi, W. Kilian et Ch. Jacob, II) Etude géologique de la zone des rampes d'accès d'Aoste aux tunnels du Mont Blanc par M. Secondo Franchi. III) Etude sur la rampe d'accès des tunnels du Mont Blanc entre Oex et Chamonix par W. Kilian et Ch. Jacob. Grenoble le 8 Octobre 1907.

Franchi S., Kilian W. & Lory P. (1908) - Sur les rapports des Schistes lustrés avec les faciès dauphinois et briançonnais du Lias. Bull. Carte Géol. France, XVIII, 119 (1907-1908), 135-141.

Franchi S. & Stella A. (1912) - Foglio 12 M. Bianco in scala 1:100.000 della Carta Geologica d'Italia. R. Ufficio Geologico d'Italia, Roma.

Frasca G. (2018) - Fossiliferous high-pressure metasediments from the Western Alps (Petit-Saint-Bernard Pass, Subbriançonnais Unit, Italy). International Journal of Earth Sciences, 107, 2635—2637.

Issel A., Mazzuoli L. & Zaccagna D. (1887) - Carta geologica delle Riviere Liguri e delle Alpi Marittime alla scala 1:200.000, Club Alpino Italiano, Genova.

Kilian W. & Haug E. (1898) - Sur l'origine des nappes de recouvrement de la région de l'Ubaye. Comp. Rend. Acad. Sc. 14 Février 1898

Lory C. (1858) - Carte géologique du Dauphiné, comprenant les trois départements del'Isère, de la Drôme et des Hautes-Alpes, à l'échelle 1:200,000, Paris, (https://gallica.bnf.fr/ark:/12148/btv1b53085073n).

Lory C. (1860) - Nouveaux détails sur un gisement de nummulites en Maurienne, et considérations sur l'usage des caractères stratigraphiques dans les Alpes. Bulletin de La Société géologique de France, 2e Série, 17, 481-488.

Lory C. (1863) - Carte géologique du Briançonnais (Hautes Alpes), à l'échelle 1:250,000.

Lugeon M. & Argand E. (1905) - Sur les grandes nappes de recouvrement de la zone du Piémont. C.R. Acad. Sci. Paris, 140, 1491-1493.

Malaroda R. (1970) - Carta Geologica del Massiccio dell'Argentera alla scala 1:50.000. Mem. Soc. Geol. It., IX.

Ministère des Travaux Publics de France (1905) - Carte Géologique de la France a l'échelle 1:1,000,000.

Mosca P. & Fioraso G. (2016) - La Carta Geologica delle Alpi Occidentali in scala 1:400.000 del Regio Ufficio Geologico: inestimabile documento della cartografia geologica italiana. In: Console F., Pantaloni M. & Tacchia D. (Eds.), La cartografia del Servizio Geologico d'Italia. Mem. Descr. Carta Geol. It., 100, 61-72.

Novarese V. (1938) - Secondo Franchi. Boll. R. Com. Geol. It., 63, Nota 1, 1-22.

Pantaloni M. (2013) - La storia in una tavoletta di campagna. Published on September 22, 2013 at www. geoitaliani.it

Pantaloni M. (2014) - 15 giugno 1873, nasce il R. Ufficio geologico. 140 anni di geologia in Italia. Geologia Tecnica & Ambientale, 1, 37-44.

Pareto L. (1846) - Cenni geologici sulla Liguria Marittima. Tip. Ferrando, Genova, 105 pp.

Petti F.M., Pantaloni M., Console F. & Fabbi S. (2016) - The contribution to the geological knowledge of Tripolitania and Cyrenaic regions (Libya N-Africa): the first Italian expedition between 1910 and 1914. Rend. Online Soc. Geol. It., Suppl. 1/40. 88° Congresso Società Geologica Italiana, Napoli, 7-9 settembre 2016.

Regio Comitato Geologico (1890) - Boll. R. Com. Geol. d'It, vol. XX, Atti ufficiali, 24.

Regio Comitato Geologico (1911) – Boll. R. Com. Geol. d'It, vol. 24, Atti ufficiali, IX-XXIV

Regio Ufficio Geologico (1908) - Carta Geologica delle Alpi Occidentali in scala 1:400.000. R. Ufficio Geologico d'Italia, Roma.

Regio Ufficio Geologico (1912) - Carta Geologica d'Italia, scala 1:100.000. F. 12 M. Bianco. Roma, Stab. L. Salomone.

Regio Ufficio Geologico (1928) - Carta Geologica d'Italia, scala 1:100.000. F. 102 San Remo. Roma, Stab. L. Salomone.

Ricci B. (1967) - Nuove località fossilifere nei calcescisti dell'Alta Val Grana (Alpi Cozie). Boll. Soc. Geol. It., 86, 97-101.

Sismonda A. (1866) - Carta Geologica di Savoja, Piemonte e Liguria alla scala 1:500.000 dal Governo di S.M. Vittorio Emanuele II Re d'Italia.

Sismonda A. (1867) - Nuove osservazioni geologiche sulle rocce antracitifere delle Alpi. Mem. R. Accademia delle Scienze di Torino, S.II, t. 24, pp. 26.

Spada Sermonti I. (1998) - Franchi, Secondo. Dizionario Biografico degli Italiani, Enciclopedia Treccani, 50, https://www.treccani.it/enciclopedia/secondo-franchi_(Dizionario-Biografico)/.

Stella A. (1933) - Commemorazione del socio corrispondente Secondo Franchi. Atti R: Accad. Lincei, Rend. Classe Sci. Fis. Mat. Nat., 17, 1010-1019.

Sturani C. (1961) - Osservazioni preliminari sui calcescisti fossiliferi dell'alta Valgrana (Alpi Cozie meridionali). Boll. Soc. Geol. It., 80, 225-237.

Termier P. (1925) - Compte rendu d'une excursion géologique dans les hautes vallées de la Dora Riparia, de la Maira et de la Stura, en compagnie de MM. Secondo Franchi, Wilfrid Kilian et Eugène Raguin - Bull. Soc. Geol. France, 25(4), 839-855.

Zaccagna D. (1887) – Sulla geologia delle Alpi occidentali. Boll. R. Com. Geol. It., 18, 346-417.

Zaccagna D. (1892) - Riassunto di osservazioni geologiche fatte sul versante occidentale delle Alpi Graje. Boll. R. Com. Geol. It., 23, 311-404.

Zaccagna D. (1901) - Alcune osservazioni sugli ultimi lavori geologici intorno alle Alpi occidentali. Boll. R. Com. Geol. It., 32, 4-71.

Zaccagna D. (1902) - Alcune osservazioni sugli ultimi lavori geologici intorno alle Alpi occidentali. Boll. R. Com. Geol. It., 33, 149-160.

Zaccagna D. (1903) - Alcune osservazioni sugli ultimi lavori geologici intorno alle Alpi Occidentali. Boll. R. Com. Geol. It., 34, 297-332.