

M. PANTALONI

THE 1:1M GEOLOGICAL MAP OF ITALY:
A MILESTONE IN GEOLOGICAL KNOWLEDGE

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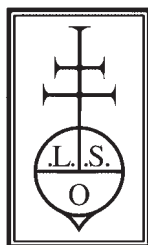
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THE 1:1M GEOLOGICAL MAP OF ITALY: A MILESTONE IN GEOLOGICAL KNOWLEDGE

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ABSTRACT – Since 1873, the Geological Survey of Italy has conducted field research aimed at the realization of the official detailed scale geological map of the country. However, among these maps, the Geological Survey cartographic series also includes the Geological Map of Italy at 1:1,000,000 scale. This map, in addition to its intrinsic scientific significance, also has historical and cultural value; the long time span between the first and the last edition allows us to retrace the evolution of scientific knowledge within Italian geological sciences over 100 years.

GEOLOGICAL CARTOGRAPHY IN PRE-UNIFIED ITALY

The establishment of the Survey in the 19th century opened its doors to modern geology and geological cartography; just as an example, it is worth mentioning some of the Italian scientists who were the first to create geological maps: among them we should remember Giovanni Battista Brocchi, who was appointed inspector of the mines of the Napoleonic Kingdom of Italy. In 1820, he made the first sketch of the geological map of Rome, which was hand-drawn on the topographical base of Giovanni Battista Nolli. The original is kept in the Institute for Environmental Protection and Research (ISPRA) Library. In the meantime, the Papacy also began to believe in this new discipline. Pope Pius IX, who established the Chair of Geology in 1860 in “La Sapienza” University in Rome, assigned the teaching duties

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to Giuseppe Ponzi. He, among other things, was the author of the first geological map of the Papal State, published during the pontificate of Gregory XVI (1831-1846). However, it is difficult to give a full account of the important scientific and cartographic production carried out by Italian geologists in the first half of the 19th century due to the numerous contributors.

Positive consideration for Italian geology was exceptional at the time, so much so that Charles Lyell devoted ample space to the contributions made by his Italian colleagues to the development of the discipline,¹ referring to the book of Nicolaus Steno (a Danish anatomist who worked in Florence and Tuscany), *De Solido intra Solidum Naturaliter contento Dissertationis Prodrromus* (1669) as “this work attests the priority of the Italian school in geological research,”² and by using some geological examples seen in his travels in Italy.

In the 19th century, many European countries began to produce geological maps, which Italian geologists examined carefully, sometimes trying to imitate them. William Smith produced in 1815 the first geological map of England and Wales on his own, which led him to clash with creationists and subsequently to suffer personal economic ruin. France too, thanks to the work of Jean-Baptiste Élie de Beaumont, produced in 1841 the first edition of the geological map of the country at a scale of 1:500,000, which followed the work of Alexandre Brongniart and Georges Cuvier, at the beginning in the 19th century.

The most important scientific meetings that took place in Italy in that period were undoubtedly the Meetings of Italian Scientists, the first of which was held in Pisa in October 1839. During the third Meeting, held in Florence in September 1841, the idea was launched to create a geological map of the entire Italian peninsula, following the production of the maps of England and France. The starting point was from the collection of maps, fossils and minerals of the Grand Duchy of Tuscany. Undoubtedly, one of the most significant effects of these meetings for Italian geologists was the increase in opportunities to meet and exchange opinions and ideas with other scholars, especially from foreign countries. In fact, Leopold von Buch, Élie de Beaumont and others often were taken on visits to the classic locations of Italian geology: the Alps, Mount Vesuvius, and the Apuan Alps.

However, despite the emotional impulse and the commitments made, the realization of the geological map of the peninsula was not concluded. However, some works were developed on personal initiatives, such as that

¹ LYELL, 1830-33 (in particular see vol. 1, 1830, pp. 21-74).

² Ivi, pp. 27-28.

of Giacinto Ottavio Provana di Collegno, who presented at the Meeting held in Milan in 1844 his geological map of Italy at the scale 1:2,000,000 (Fig. 1, refer to Colour Plate Section, plate XIII).³

The need for a geological map of the peninsula had already encouraged King Carlo Alberto di Savoia to entrust Angelo Sismonda with the task of producing the *Carta geologica degli Stati di Terraferma*, but he finished his work only in 1866.

What was missing for the realization of this undertaking was above all economic support, but also the lack of coordination between the still-numerous local governments, accurate topographical basemaps for the surveys, and reliable processes of typographic reproduction. Above all, there was a lack of ambiguity regarding scientific methods and intentions.

In pre-unified Italy, only the Veneto, Lombardy and the Kingdom of Sardinia had started geological surveys, derived from different economic needs. Alberto Ferrero Della Marmora published, thanks to his determination and personal inherited wealth, a pioneering but valuable *Carte geologique de l'Île de Sardaigne* on a scale of 1:500,000 (1851).

Grand Duke Leopold II also wanted to start a cartographic project for the Grand Duchy of Tuscany, calling upon Leopoldo Pilla as the Chair of Geology at the University of Pisa. Pilla, undoubtedly one of the most capable Italian geologists of that time, author of numerous studies of volcanology and of a stunning volume *Studi di geologia, ovvero conoscenze elementari delle Scienze della Terra*, was driven by the spirit of the Italian Risorgimento. In fact, he participated with some students of the University of Pisa in the insurrectional uprisings and died in the battle of Curtatone in May, 1848.

The project of the Geological map of the Grand Duchy of Tuscany was then taken up by Iginò Cocchi, who proposed the establishment of a private association aimed at the geological survey of the Grand Duchy for mining and economic purposes.

Besides the economic difficulties, also problematical were the political events of the years 1848-49, which blocked both the realization of the *Carta geologica degli Stati di Terraferma* of Sismonda and Cocchi's project for Tuscany. However, the process of transformation of geology in Italy, from a naturalistic science to an indispensable tool for economic development and territorial planning, was now under way. Therefore, having overcome the deep-rooted cultural resistance, geology began to become a widespread topic even outside a restricted circle of scientists.

³ CORSI, 2003.

As a proof, we should mention the works on the geology and paleontology of Lombardy published, at his own expense, by the Abbot Antonio Stoppani (Lecco, 1824-1891). By virtue of his teaching and divulgation skills, Stoppani is considered the 'father of Italian geology,' so much so that the volume *Il Bel Paese* (1876) still remains in the collective memory of the people today. According to some, that work was fundamental for spreading geological knowledge of the newborn nation among the Italian people.

Regarding the project of realizing a geological map of the entire Italian territory, things did not seem to change radically, despite the intervention of the aforementioned Igino Cocchi and the interventions of Quintino Sella and Felice Giordano, who were the most stubborn supporters for the establishment of a central body aimed precisely at the production of the geological map of the country. The restrictions involved with analogous map produced for France by Élie De Beaumont and Dufrenoy were too strict: the risk was that, as happened in France, the realization of the geological map of the entire country by the national authorities thus had left the task of doing the detailed cartography to the local councils.

GEOLOGY IN THE KINGDOM OF ITALY

Immediately after the unification of Italy in March 1861, due to the initiative of Quintino Sella, the project for the realization of the geological map of the Kingdom started. The Ministry of Agriculture, Industry and Trade (MAIC), from which the Corp of Mines was supported, issued a Royal Decree in July 1861 setting up an Advisory Council for the realization of the geological map.

In April 1866, the MAIC established a geological section within the Corp of Mines, prior to the founding of the Royal Geological Committee, in December 1867, and prior to creation of the Royal Geological Survey, in June 1873.⁴ Igino Cocchi, Giuseppe Meneghini and Giuseppe Scarabelli chaired the geological section. Igino Cocchi was convinced that an institutional structure could revive the great tradition of Italian geological studies.⁵ He was also conscious that Italy was the only major European country that lacked a geological map.

These expectations were realized in 1867 on the occasion of the Universal Exhibition in Paris, during which a special Italian Royal Commission,

⁴ PANTALONI, 2014.

⁵ CORSI, 2003.

on behalf of the MAIC, presented the state of geological knowledge of the country. During the Paris Exhibition, among other things, the Italian government presented a geological map and a volume with statistical information.⁶ In Paris, Cocchi presented two copies of a geological map of Central and Northern Italy at 1:600,000 scale that, unfortunately, has never been found.

To reach this goal, during the previous year, a project to collect geological information across the entire newborn Kingdom started through the involvement of the Prefectures that, in turn, requested scientific reports from the different Technical Lyceums, or to well-known local scientists.⁷ In contrast – for regions such as Sardinia, Liguria and the Papal State – existing geological maps or scientific papers were used. In the archive of the Geological Survey of Italy, preserved in the ISPRA Library in Rome, all the original manuscripts are housed, as well as published or unpublished geological maps created by the most important authors. This material, catalogued, transcribed, studied and in part digitized, allowed us to reconstruct the state of geological knowledge of Italy a few years after its unification. Such a study highlights dramatic differences among the various Italian provinces, with main interests varying from pure academic study to applied knowledge for geological resources. Thus, as a whole, the analysis emphasizes the enormous cultural and economic interests related to the development of geosciences in Italy.

THE GEOLOGICAL MAP OF ITALY AT 1:1,000,000 SCALE

Only after the establishment of the Royal Geological Committee and the founding of the Royal Geological Survey in 1873,⁸ was the project for the realization of the 1:100,000 scale Geological Map of Italy started. Following the publication of some “strategic” geological sheets, work began on the 1st edition of the Italian Geological Map at the scale of 1:1,000,000, which was finally published in 1881, in time for the 2nd International Congress of Geology (IGC) held in Bologna.

The proposal for the realization of the map by the Royal Geological Survey came from Antonio Stoppani.⁹ Due to the gaps in field geological surveys, part of the information was deduced from existing regional geo-

⁶ MAESTRI (éd.), 1867.

⁷ PANTALONI, CONSOLE, PETTI, 2017.

⁸ PANTALONI, 2014.

⁹ DE STEFANI, 1882, p. 165.

logical maps. Due to the diversity of criteria and methods of representation, it became necessary to carry out researches and studies in the field in order to harmonize these aspects.

Since no geological field surveys had yet been carried out, the map was produced by drawing up general, regional and partial geological maps that existed at the time; the result therefore suffered from numerous problems in uniformity of the representation. Therefore, this map represented the first comparison and discussion both on the general order of the geological succession, pending a general convention, and on the methods of representation. The topographic base used for this summary map was a map at a scale of one decimetre per degree (1:1.111.111) used for the representation of the railway network.

This 1st edition of the Geological Map of Italy at one million scale, however, partially contains the results of the studies concerning the comparison between the chronological scheme derived from the stratigraphy of the succession of Central Europe (the *Germanic facies*), to those derived from the observations on the *Italian Meso-Cenozoic facies*. This problem, addressed but not solved in this map, heavily affected the development of Italian stratigraphy for more than 50 years. Particularly interesting was the interpretation of the age of the intrusive units (*ancient sedimentary granites, eruptive granites, etc.*).

During the 2nd IGC in Bologna in 1881 two main themes were discussed. For geological mapping the possibility of the adoption of a common system of symbols and colours was considered. The topic of geological nomenclature, relating to stratigraphical classification and unification of nomenclature, involved inquiry into the value and significance of petrological and paleontological characters.

Regarding the first theme, unification of the colours of the chronostratigraphic legend was proposed, based on the Italian 1:1 million geological map (Fig. 2, refer to Colour Plate Section, plate XIV).¹⁰ Therefore, this map represented the base for the initial comparison and discussion of the general order of the stratigraphic succession. There was general agreement about that, as well as the methods of representation. It was, for the Italian geologists, the main success of their work.

A critical note presented by the paleontologist Carlo De Stefani at the meeting of the Italian Geological Society highlighted some interesting observations, to be taken into consideration for the realization of the following edition.¹¹

¹⁰ GIORDANO, 1882.

¹¹ DE STEFANI, 1882.

Following the insights suggested by De Stefani, a 2nd edition of the 1:1 million scale geological map was realized in 1889 and, as stated in the title, “it was compiled based on surveys carried out by the engineers of the Royal Corps of Mines and published works of Italian and foreign geologists.”

This map, completely revised and updated with respect to the previous one, shows the enormous scientific progress made in those few years. The map included the distinction of intrusive units, such as the distinction between Central Gneiss, Granites and Sienites. Important innovations were introduced in describing the Western Alps, in those years the focus of studies by Secondo Franchi, Ettore Mattiolo, Vittorio Novarese, Augusto Stella and Domenico Zaccagna. In the map, a Permian age was suggested for the Crystalline Schists cropping out in Sicily and Calabria, and an evaporitic series (*serie gessoso-solfifera*) was recognized. Progress was also made by the geological surveys of Sicily for the realization of the 1:100,000 scale geological map.

In addition, in 1891 De Stefani published in the Bulletin of the Italian Geological Society a series of observations, some of them quite significant, on the map published 3 years earlier.¹² He overlooked the not-yet-reached agreement on the “ordering of the succession,” but made several criticisms, some of them of lexical order (e.g., disapproving of the use of the term Cretaceous) and others related to the distinction of the units in the legend (e.g., the distinction between central Gneiss and Granites and Sienites).

He praised the innovations introduced in the western Alpine area, although he was very conservative with respect to the Permian attribution for the crystalline schists in Sicily and Calabria, which modified the previous opinion of “those most learned scientists who are Pareto and Gastaldi.”¹³ He also declared his preference for the previous edition rather than the present one, with regard to incorrect attributions concerning the sedimentary succession of Central-Eastern Italy. He also suggested a Pliocene age for the deposits of the Tiber Valley, and proposed the re-examination of the chalky-sulphur zone, which it was hoped would be eliminated in later editions.

A further innovation was the use of the Geographic map of the Kingdom of Italy at the scale 1:1,000,000 published in 1885 by the Italian Military Geographic Institute (IGMI). Less than a decade after its publication, the entire production was sold out, and soon the need for a new updated edition was stressed.

¹² DE STEFANI, 1891.

¹³ Ivi, p. 94.

The First World War, however, blocked this initiative and it was only in 1925 that the Geological Committee entrusted Vittorio Novarese, engineer-geologist of the Royal Geological Survey, to realize a new edition of the 1:1 million map, with the task of excluding any further field survey, in order to speed up the realization time.

The legend of the map was substantially amended: 21 units were defined for the sedimentary rocks, 11 for volcanic and 5 for crystalline units. The sedimentary succession was distinguished based on geochronological characters, while for the other rock types a petrographic criterion of distinction was used.

The 3rd edition of the map was published in 1931 and the novelties introduced resulted from the many advances and innovations made in field surveying, especially in the differentiation of the Alpine chain. It is worth remembering those relating to the distinction of Mesozoic calcschists in the Western Alps, to which Novarese dedicated a large part of his works. The controversies of parallelism between the *Germanic facies* and the *Alpine facies* were finally resolved, which led to the division of the Mesozoic into six different units. In the Alps, the Permian sedimentary part of the succession was distinguished from that of igneous origin and the problem of “scaly clays” (*argille scagliose*) was addressed, at least in the Northern Apennines.

The major innovations, as pointed out by Novarese,¹⁴ derived from the result of the systematic survey carried out in a large part of the Italian territory by the Royal Geological Survey. In fact, by the date of completion of the 3rd edition of the map, the Royal Geological Survey produced 130 sheets of the 1:100,000 scale Geological map. Another 50 sheets had already been produced, the drafts and partial or regional maps using different scales. The analysis of these maps contributed to the development of the 1:1 million map that was integrated with elements derived from new publications and studies.

The information regarding border regions of the map was derived from the 2nd edition of the Geological Map of France at 1,000,000 scale made in 1905,¹⁵ from the Geological Map of Switzerland at 500,000 scale made in 1911,¹⁶ and from maps made by the Vienna Geological Institute for the Eastern part of the country. From a cartographic point of view, a range of colors was adopted as close as possible to that of the International Color

¹⁴ NOVARESE, 1932.

¹⁵ MICHEL-LEVY, TERMIER, 1905.

¹⁶ HEIM, SCHMIDT, 1911.

Code, adapting it to local needs. Compared to the previous edition, the symbolic representation of the mineral deposits (lignite, rock salt, etc.) was eliminated because in the meantime the Royal Mining Corps had begun the realization of a distinct Mining Map of Italy at 1:500,000 scale where this information was included.¹⁷ The topographical base used was the same as that of 1885, only being modified with the addition of the area of South Tyrol up to the northern border of the Vetta d'Italia.

Federico Sacco, states that "in this period the much-desired Geological Map of Italy to the millionth was published, which naturally required the Geological Survey to do an intense work of preparation, coordination and execution."¹⁸ With this sentence, Sacco was recognizing not only the work of Novarese, but also that of the cartographers F. Cozzolino and A. Di Pasquale. Thirty years later, in 1961, under the direction of Enzo Beneo, the Geological Survey of Italy produced the 4th edition of the 1:1 million map, which was a simple re-edition of the 1931 map. In this version a better definition of the units of the legend was introduced: for the sedimentary units the lithological description, the depositional environment and, in some cases, the corresponding geological formations were introduced. To this edition, however, should be given the merit of re-proposing after 30 years the geological map of the entire Italian country, at a time when the geological sciences, even in Italy, were evolving very rapidly.¹⁹ On the occasion of the 150th anniversary of the Unification of Italy, in 2011, the Geological Survey of Italy published the 5th edition of the Geological Map at 1:1,000,000 scale (Fig. 3, refer to Colour Plate Section, plate XV).

Due to the long time interval that had elapsed since the previous 4th edition (1961), makes this edition a representative element of the scientific progress made by the geological sciences. Its realization involved many researchers and this work had been carried out through the analysis and synthesis of the progress that had been achieved in the Italian geological cartography project (CARG project), as well as new data arising from the enormous amount of scientific work that had been published in recent years. The aim of the work was to spread within the scientific field, but also within educational institutions, the geological knowledge of the territory. The aim of this map was in fact to present a synthesis of modern geological knowledge of the country to a very wide audience of scholars, teachers, students and enthusiasts.

¹⁷ CORPO REALE DELLE MINIERE, 1926-1935.

¹⁸ SACCO, 1938, p. 382.

¹⁹ CASTELLARIN, COLACICCHI, PRATURLON, 2011.

The legend of the map follows the division of the rocks according to their origin (sedimentary, metamorphic, intrusive and effusive), and then according to lithology, age, depositional environment, orogenic cycle, and degree of metamorphism. With the help of a Structural scheme that represents the major orogenic domains, the result is a geological map in which, in addition to the “conventional” lithological characterization, structural features are included, providing a valid aid to the understanding of the geological and geodynamic history of the Italian peninsula.

The realization of the 5th edition (2011) of the map has been carried out using digital techniques;²⁰ this has allowed us to experiment with numerical acquisition techniques and to make simplifications that take into account the scale of representation and also the user for whom the map itself was designed.

The topographic base is derived from the overlapping and simplification of the 6 sheets of the 1:1,000,000 scale map published in 2006 by the Italian Military Geographic Institute (*Istituto Geografico Militare – IGMI*). The bathymetric data provided by the Hydrographic Institute of the Italian Navy has also been included. For the drafting criteria, the chromatic reference manual was adopted, created specifically for the CARG project and set according to international cartographic standards. This complex work was completed with the realization of a specific database in which each polygon of the geological map has been associated with a string type attribute (“*sigla*”), which briefly describes its geological characteristics and is used to label the legend blocks.²¹ This edition also takes a huge step forward in terms of mapping: the use of GIS and of the digital printing process which allows the management of many different colors and the representation of small surfaces, facilitating several possible reading keys.

ITALY – GEOLOGY IN RELIEF: BACK TO THE FUTURE

The tradition of “geological relief maps” in Italy dates back to the first decades of the 20th century, when both the Royal Geological Survey and the Military Geographic Institute realized some geological relief maps of specific areas of the Italian territory, for educational purposes or for museum exhibitions. This tradition, which has led to the creation of dozens of beautiful geological relief maps, had been lost over time, perhaps due to the high cost of the models and the loss of specific skills.

²⁰ PANTALONI, TACCHIA, VITALE, 2009.

²¹ CIPOLLONI, PANTALONI, VENTURA et al., 2009.

Today, this tradition has been revived through the realization of a new relief geological map of the entire Italian territory at 1:1,250,000 scale, believing that a synthetic scale map is an important tool for scientific information and geological dissemination.

Italy – geology in relief represents the first example of reproduction of the geological characteristics of the entire Italian territory on a 3D support, following a didactic and popular approach aimed at the dissemination of scientific content, representing the only example in the world of reproduction of geological characters on a national scale on a three-dimensional support.²²

The data used to create this innovative geological 3D relief map derive from the re-elaboration of the 5th edition of the Geological Map of Italy, from various synthetic geological maps and from the geological maps at 1:50,000 scale produced within the Italian geological cartography project.

Developing this model, particular care was taken to apply strategies and tools useful for education and dissemination, with the goal to enabling potential users to fully understand the high scientific content of this particular cartographic product. For this reason, the chronostratigraphic legend has been arranged in a “self-referential” way, thus ensuring a rapid identification of rock successions and their main features.

For its innovative characters and the accuracy in reproduction of the relief on a 3D model, this model represents a very effective tool of geological education and knowledge about the shapes of the Earth, allowing the correlation between geomorphological characters and their relations with geological substrate (Fig. 4, refer to Colour Plate Section, plate XVI).

CONCLUSIONS

The study of synthetic scale geological maps allows us to reconstruct the scientific and technological evolution that always has gone hand-in-hand with the social and cultural development of a country.

The history of the Geological Survey of Italy reflects the social and economic changes that our country has gone through over this long period of time. Despite the difficulties, the Geological Survey has always played a decisive role in the development and dissemination of geological sciences as a way to add to the knowledge of the territory.

Geologists and engineers in the staff of the Survey have left traces of their studies in numerous geological and geothematic maps and papers and

²² PANTALONI, VENTURINI, BONOMO et al., 2019.

in the large amount of gray literature stored in the archives of the office. Their teachings aided several generations of field geologists in contributing to the widespread dissemination and growth of our discipline. These teachings represent the attitude with which geologists and engineers from the Geological Survey of Italy continue their studies and research to serve the country as part of a complex research institute such as the present Italian Institute for Environmental Protection and Research (ISPRA).

Edition - Year of publication	Geological Map of Italy 1:1.000.000 scale		
	Edited by	Printed by	Note
I - 1881	R. Ufficio Geologico	Stabilimento Litografico Virano e Teano	Geological map in 2 sheets, at a scale of 1:1.111.111
II - 1889	R. Ufficio Geologico	R. Stabilimento C. Virano	Geological map in 2 sheets; revised and corrected edition of the first edition
III - 1929/1931	R. Ufficio Geologico: V. Novarese	Stabilimento L. Salomone	Geological map in 6 sheets
IV - 1961	Servizio Geologico d'Italia: E. Beneo	Litografia Artistica Cartografica, Firenze	Reprint reworked from third edition
V - 2011	Servizio Geologico d'Italia – ISPRA: B. Compagnoni, F. Galluzzo, R. Bonomo, F. Capotorti, C. D'Ambrogi, R. Di Stefano, R. Graziano, L. Martarelli, M.L. Pampaloni, M. Pantaloni, V. Ricci, D. Tacchia, G. Masella, V. Pannuti, R. Ventura, V. Vitale	S.EL.CA., Firenze	Geological map in 1 sheet with Explanatory notes
2018	Università di Bologna, Servizio Geologico d'Italia – ISPRA: C. Venturini, M. Pantaloni	Global Map – S.EL.CA., Firenze	Geological 3D relief map at 1:1,250,000 scale

Table 1 – List of the different editions of the Geological Map of Italy at 1:1.000.000 scale published by the Geological Survey of Italy. Much of the historical cartography is available in digital format on the ISPRA website (www.isprambiente.it).

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