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ATLANTE GEOCHIMICO-AMBIENTALE D'ITALIA

Geochemical Environmental Atlas of Italy

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1. INTRODUCTION

The Geochemical Atlas of Italy addresses the need for a large scale geochemical mapping based on FOREGS procedures. The aim of the Geochemical Atlas of Italy is to define background/baseline chemical element values on a national scale and it will help government decision makers in defining trigger and action limits on a local scale, bearing in mind the complex spatial variability of Italian geology. As regards the Geochemical Atlas of Italy, data of Italian topsoil (T), subsoil (C), stream water (W), stream sediment (S) and floodplain sediment (F), have been extracted from the FOREGS database and supplemented with new sampling data from 8 additional sites.

The italian territory has been divided into 27 sampling cells (Fig. 1.1) on the basis of the Global Terrestrial Network (GTN), a sampling grid of 160 km x 160 km cells which covers the entire surface of the Earth, according to the establishments of the Global Geochemical Baseline project (IGCP 360) (*Darnley et al., 1995*).

During field activities and sample preparation, FOREGS procedures (*Salminen et al., 1998*) were strictly followed. The geochemical data used for the FOREGS project and the new data from subcells of southern Italy have been processed using ArcView GIS™ and a new Multifractal IDW method available in the software GeoDAS™ (*Cheng et al., 2003; Lima et al., 2003*). Interpolated maps have been overlayed by dots and have been classified by statistic graphs, for a total production of 348 maps. Data show that, even, on a large scale, the distribution of elements reflects the major geo-lithological Italy structures.

Landscape view of an area in the Cilento Natural Park (Southern Italy - Cell N27E09)

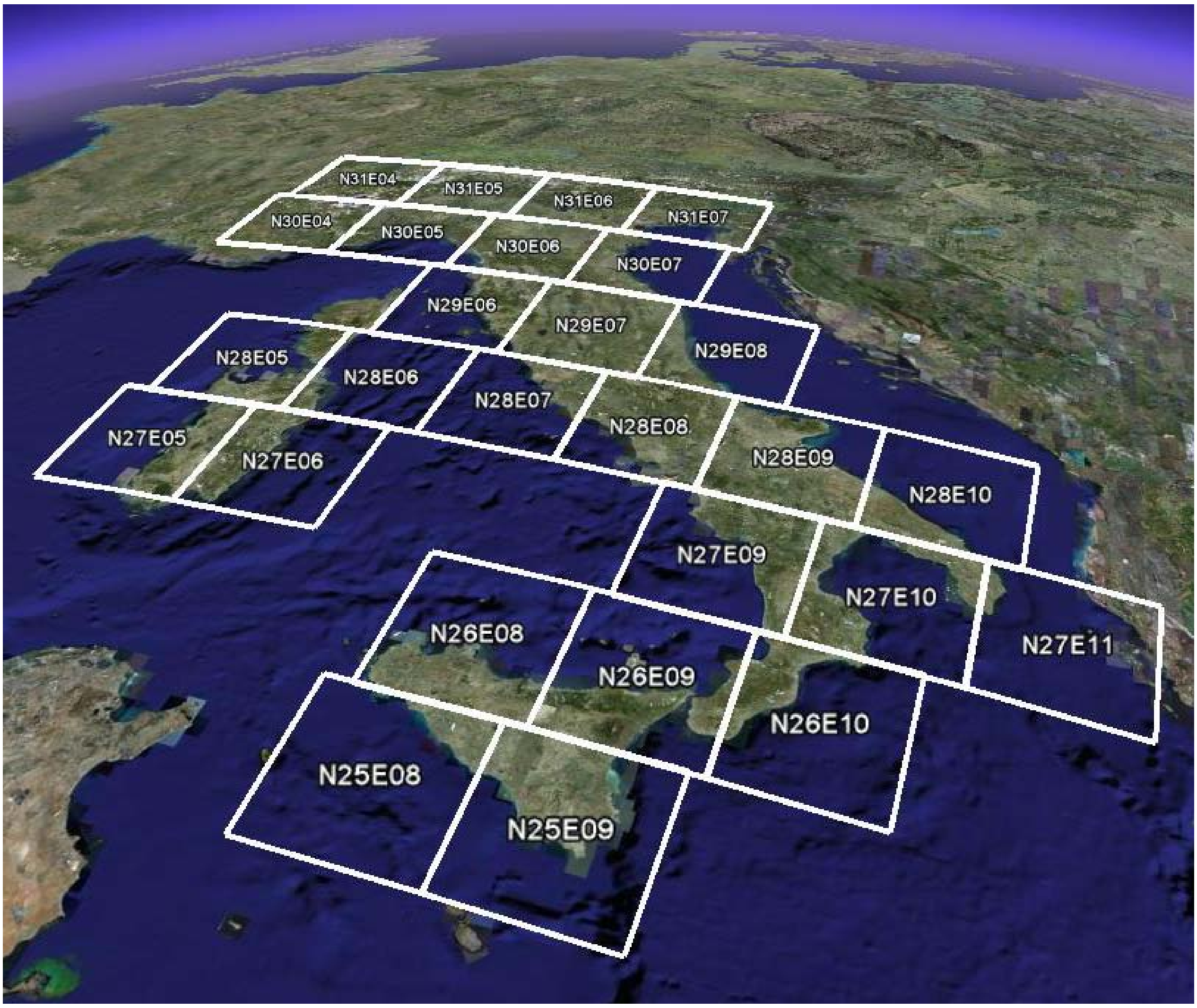

Fig 1.1 Satellite view of Italy overlayed by the GTN reference grid (Darnley et al., 1995).

2. ITALY

2.1 Introduction

The territory of the Italian Republic covers 301,278 sq km. It lies between the northern latitudes of 47º05'29'' and 35º39'26'', and the eastern longitudes from Greenwich of 6º37'32'' and 18º31'13''

2.2 Climate and Vegetation

2.2.1 Climatic zone

Despite its geographical position at the centre of the temperate zone, Italy has variable climatic characteristics. This is due to the presence of both the Mediterranean sea, whose warm waters mitigate thermal extremes, and the Alpine arc, which forms a barrier against the cold north winds. Italy is also subject to both wet and moderate atmospheric currents from the Atlantic Ocean and dry and cold ones from eastern Europe. The Apennine chain too, comparing the wet winds from the Tyrrhenian sea, causes considerable climatic differences between the opposite sides of the peninsula. The differences in temperature between the winter and summer months are more marked in the northern regions than in the south and along the coasts. The mean temperatures for the month of January in the Po Plain fluctuate around zero, while in the Alpine valleys the thermometer can drop to -20º C and snow can remain on the ground for many weeks. In the southern regions, the mean temperatures for January are around 10º C, with the exception of the inland mountainous zones. Mean summer temperatures throughout the whole of Italy rise to 24º-25º C for July, although they are lower in the highest zones. Rainfall distribution also varies considerably, due to the influence of both mountains and prevailing winds. The highest values are registered in the Alpine arc (over 3,000 mm pa in the Lepontine and Julian Alps) and on the Apennines (over 3,000 mm pa in the Apuan Alps). The plains, however, including that of the Po, receive scarce precipitation. Generally it is less than 800-900 mm pa but in the southern regions of the peninsula (Apulia and southern Sicily) it falls below 600 mm pa. The great internal Alpine valleys and the coastal plains of the Tyrrhenian (Maremma) and Sardinia also receive little rain.

Altogether, six large climatic regions can be distinguished, mainly characterized by mountain influence.

1) The **Alpine region** (N30E04, N31E04, N31E05, N31E06) strongly influenced by altitude, with long cold winters and short cool summers with an elevated day-time temperature range; precipitation is more intense in the spring and autumn months, especially in the pre-Alpine belt.

2) The **Po plain region** (N31E05, N31E06, N31E07, N30E06), with continental conditions, consisting of cold and sometimes snowy winters and warm and sultry summers. Precipitation is greatest in the spring and autumn months when the climate becomes milder. However, around the pre-Alpine lakes fog is frequent in the winter, due to the wetness of the land.

3) The **Adriatic region** (N31E07, N30E07, N29E08). Because of the inability of the Adriatic's shallow waters to trap summer heat, the climate has a continental character, that is, winters dominated by cold north-east winds (bora).

4) The **Apennine region** (N30E06, N29E06, N29E07, N28E08, N28E09), also with continental tendencies and cold snowy winters; precipitation is more intense on the Tyrrhenian slopes and is abundant in all seasons apart from the summer.

5) The **Ligurian-Tyrrhenian region** (N30E04, N30E05, N30E06, N29E06,

N28E07), with a maritime climate and heavy and frequent precipitation, lower in the summer and distributed irregularly; the winters are cool and the annual temperature range narrow.

6) The **Mediterranean region** (N28E05, N28E06, N28E07, N28E08, N27E05, N27E06, N27E09, N27E10, N26E08, N26E09, N26E10, N25E08, N25E09), also with a limited annual temperature range; precipitation is frequent, especially in winter, and the summers are hot and dry. The interior and the mountain zones of the islands and Calabria also have an Apennine type climate due to the altitude.

2.2.2 Vegetation zone

Due to the thousands of years of intense exploitation by human beings the original vegetation cover has been greatly altered, as have been the high mountain zones of the Alps and Apennines, which were subject to systematic deforestation until the end of the last century. Despite attempts to protect the mountains, which began at the beginning of this century, many of Italy's mountain regions still remain without tree cover and are therefore susceptible to hydrogeological disaster, especially in the zones with particularly unstable rock types. At the present time little more than a fifth (21.2%) of Italy is covered by trees, which altogether occupy an area of about 64 sq km. In the strictly floral category, the Italian territory includes unites Mediterranean and central European species. When these are combined with morphological and altimetrical influences there is a varied floral landscape, that is due to climatic conditions rather than soil types. Thus it is possible to identify at least four principal floral regions.

1) The **Alpine region** (N30E04, N31E04, N31E05, N31E06), divided into bands according to height, with oaks and other broad-leaved trees prevailing in the lower areas and valley bottoms, followed up to about 1,000 m by chestnuts and then beeches followed still higher up, but not beyond 2,000 m., by a mixture of needle-leaved trees (firs, larches and Scotch pines); the summit areas are dominated by meadows and pastures with shrub vegetation (rhododendrons and dwarf pines) or, on the margins of permanent snow (circa 2,400-2,800 m.), by Alpine tundra with mosses and lichens. Olives and cypresses grow around the around the southern shores of the major Alpine lakes, and on the hills at the edges of the Adige plain.

2) The **Apennine region** (N31E07, N30E07, N30E06, N29E06, N29E07, N28E08, N28E09), similar in character and sequence to the Alpine but with the presence of temperate species in the valley bottoms and a lesser spread of conifers in the upper levels.

3) A **Po region** (N31E05, N31E06, N31E07, N30E06), dominated by broad-leaved trees (willows, alders, poplars and oaks), which still form small woods but only along the river banks, while on the upper plain there survive extensive stretches of the original heath with American acacias, heathers and brooms and, along the Adriatic coast, some forests of maritime pine.

4) The **Mediterranean region** (N30E05, N30E06, N29E06, N28E05, N28E06, N28E07, N28E08, N27E05, N27E06, N27E09, N27E10, N26E08, N26E09, N26E10, N25E08, N25E09), covering the Ligurian and Tyrrhenian coasts as well as those of the central and southern Adriatic and the islands, dominated by a mixture of maritime pine and evergreen undergrowth (with olives, cypresses, corks, etc.) derived from the spoliation of the original ilex groves.

2.3 Geological Framework

2.3.1 Geology

The complexity of its geological history combined with the wide variety of its substratum rock types, often dislocated by numerous fault-lines, folding and thrusting of the rocky Units by orogenic forces, have contributed to Italy's extremely diverse morphology. Less than a quarter (23%) of its total territory is formed by plains, while mountainous areas occupy over a third of its surface (35%). And, over two-fifths (42%) consists of hill zones. Italy's maximum height above sea level corresponds with the summit of Mont Bianco, 4,810 m., on the border with France. In the far eastern section of the Po valley there are some zones which are slightly below the sea level and which are often subject to subsidence phenomena. However, physically, the Italian territory, generally speaking, consists can be considered to consist of the following regional units, characterized by a certain morphological and at times climatic similarity: the Alpine system and Po-Venetian Plain in the continental section; the Apennine system and anti-Apennine reliefs in the peninsula section; and the large islands of Sicily and Sardinia.

Italy is a country whose variegate characteristics are strictly controlled by its peculiar geology (*Doglioni & Flores, 1997*), whose main lineaments reflect the constraints of the Alpidic structural setting . From a geographical and geological point of view it is useful to distinguish between former European basement (Sardinia), Alps (Northern & Southern), Apennines, bigger (Po plain, Tavoliere delle Puglie) and smaller plains, the variegated volcanic districts, including also many islands groups.

The Italian crust is continental, apart from in the Tyrrhenian abyssal plain and the Ionian sea. Its maximum thickness occurs in the Alpine chain (about 50÷60 km), and its minimum along the Tuscan and Latium coastal belt.

The pre-Alpine Basement is well exposed in the Alps, in the island of Sardinia, and locally in Calabria and Sicily. It consists of variously metamorphosed sedimentary successions, associated to minor Caledonian and far more widespread Variscan magmatites.

Post-Variscan stratigraphy in Italy from the Permian to Cretaceous, exhibit the typical characteristics of a passive margin, reflecting the geodynamic evolution of the Central Mediterranean. Sedimentary sequences both in the Alps and the Apennines record the rifting and drifting history of the Tethys margins. Italy was part of the passive margin of the western and northern Adriatic plate during the opening of the western Tethys.

The inversion and relative motion between Europe and Adriatic plates began during Cretaceous and generated compression at the western margin or dextral transpression at the northern margin of the Adriatic plate.

The spatial and temporal evolution of the Alps and later of Apennines during the Tertiary is recorded by clastic sediments, flysch and molasses which overlaid the earlier passive margin sequences.

From Triassic to Recent, several magmatic episodes with different geodynamic significance occurred in Italy. The most significant are: the middle Triassic calc-alkaline and the Eocene-Oligocene riolitic-trachitic and basaltic, both effusive and subvolcanic magmatisms of the Central-Eastern Southern Alps; the Tertiary calc-alkalic magmatism, which marked the Oligo-Miocene rifts in Sardinia; the Plio-Quaternary volcanism with variable character, occurring, in Sardinia, in several districts of Central and Southern Italy and in the Aeolian islands.

2.3.2 Lithological description of sampled GRN cells

The evolution of the geology of Italy spans from the early Paleozoic orogens throughout the Mesozoic opening of the Tethys oceans to the later closure of these oceanic embayments during the Alpine and Apenninic subductions. All these phenomena are reflected in the lithological characteristics of the different Italian regions. We will present here a short summary of these variable characteristics.

The alpine regions, from Piedmont, Lombardy, Trentino-Alto Adige, Veneto to Friuli, where the samples of the N31 cells (E05-E06-E07) have been taken, are characterized by a combination of lithologies comprising the metamorphic-magmatic rocks of the basaments of the different Alpine thrust sheets, the extensive Permo-Triassic to Oligocene-Miocene sedimentary covers and the widespread sediments of the foreland plains (Po-Adige-Piave river plain).

In Piedmont region the most northerly lithologies are the pre-Triassic crystalline rocks, and in part Mesozoic ophiolitic-sedimentary series, comprised in the Penninic tectonic Units, separated by the Canavese and Centovalli Lineaments (westernmost part of the Insubric Line) from the southern Late- to post-Variscan magmatites and associated calcareous-dolomitic and terrigenous Anisian to Eocene sediments. More to the south there are late orogenic molasses and the alluvial deposits of the Po plain.

In the Liguria region the ophiolite deposits, associated to deep sea sediments, both of Jurassic age are common.

In the easternmost regions, from Lombardy to Friuli, the sub-latitudinal Tonale-Giudicarie-Pusteria-Gail Lineament (easternmost part of the Insubric Line) separates, to the North, the rocky crystalline Units of the Austroalpine Complex, from the sequences of the Southalpine Complex. The Austroalpine Units consist of various Paleozoic sedimentary and volcano sedimentary poly-metamorphosed series, locally with autochthonous strips of Mesozoic sedimentary cover, that exhibits only the effects of the Alpine tectono-metamorphic cycle. In the northernmost Lombardy and Trentino Alto Adige areas some strips of the Penninic Units outcrop in tectonic windows across the Austroalpine belt.

The Southalpine Complex includes:

1) a Variscan crystalline basement, mostly outcropping along the Insubric Line, made up of prevailing paragneisses in Lombardy and of phillites in Trentino–Alto Adige and Veneto, in both cases with intercalated minor quartzites, porphyroid-gneiss and metabasites;

2) a wide sedimentary Permo-Miocene unmetamorphosed sedimentary cover, several thousand meters thick, consisting of both shallow water carbonates and basinal deposit, with major calcareous-dolomitic sequences in the Dolomites.

Late- to post-Variscan granitic-granodioritic bodies are intruded along the Insubric Line, as well as in the Southalpine crystalline basement (mainly in the Trentino-Alto Adige region) as plutonic and epi-plutonic masses; very large effusive, often ignimbritic deposits evolving from andesite-dacite to riolite (Piattaforma Porfirica Atesina) are products of the same magmatic event. Across the southern sedimentary covers are also widely present sub-volcanic and effusive calc-alkaline to shoshonitic products of the Ladinian-Carnian magmatism. At the edge or in the near Po-Adige plain, outcrop abundant alkali-basaltic rocks (Lessini-Berici Mountains) and sub-volcanic trachi-andesitic to riolitic bodies (Euganei Hills) of the Eocene-Oligocene age.

In the N30E06 cell, comprising almost the whole of the Tuscan region, there are quite distinct complexes, which include both the Liguridi Units, consisting of flyschoid successions, often associated to ophiolites, and the successions of terrains of the Tuscany thrust sheets. These consist of a carbonate platform as well as of pelagic sediments, with their related flysch deposits. The deeper tectonic unit are the crystalline (parautocthonous) deposits of the Apuane metamorphic carbonates.

The same tectonic situation, but with strongly variable lithological types, is found in cell N29E07, comprising southern Tuscany and parts of the Umbria-Marche-Latio-Abruzzo regions. Here the pelagic successions of the Umbria-Marche domain are quite important and they are accompanied by their late-orogenic flysch deposits, grading toward Abruzzi to carbonate platform deposits. Along the Tyrrhenian coastal belt, there occur the thick volcanic deposits of the Southern Tuscan-Roman province with high-K magmas, whose volcanoes were emplaced along grabens with an Apenninic trend.

Sardinia is composed of 4 cells, two in the north of the island (N28E05-N28E06), and two in the south (N27E05-N27E06). In the island outcrop most of the Paleozoic lithotypes recorded in Italy. In the north, high grade metamorphic rocks of Variscan age prevail (amphibolites and migmatites), associated to syn- to post-kynematic granites. Tertiary volcanites of calc-alkalic character occur both in the north and in the south of the island, often in association with Tertiary continental sediments. In the southern part of the island, the metamorphic character of the Paleozoic Thrust Complexes is lower. In the South-West of the island, the Cambrian and Ordovician platform carbonates of the External Zones, hosted important base metal ores resources.

The central-southern cells N28E08-09-010, also share many common lithological characteristics. They comprise the Southern Latium-Campania and the uppermost Apulia district. Common lithologies are the widespread Mesozoic platform carbonates (limestone>dolomite) and their associated silicoclastic flysch deposits. Upper Tertiary post-orogenic pelitic successions and marine to continental Pleistocene deposits are also present, mostly in easternmost Campania and Abruzzi regions. In the southernmost Campania the pelagic deposits of the Lagonegro Units, mostly Mesozoic in age, start to occur. They consist of pelagic carbonates with chert nodules, evolving to radiolarite sequences. Volcanic rocks with potassic character occur mostly in the Campania region, forming the Roccamonfina, Vesuvius and Phlegrean Fields complexes.

Another volcanic center is the Vulture complex, between Apulia and Lucania.

The two cells N27E09 and N27E010 cover the terrains between southern Campania, Lucania, Calabria and the southernmost extremity of Apulia. In the latter region carbonate sequences of foreland environment prevail. In Campania-Lucania and northern Calabria the most characteristic deposits are Mesozoic carbonate platform sediments, with an age equivalent to the basinal Lagonegro sequences. Tertiary flysch deposits are also present, some of which, the most internal, can be compared with those outcropping in the north-western Italian regions: the Liguridi flysch successions. In cell N27E010, the successions of the Taranto gulf area correspond to thick silicoclastic deposits belonging to post-orogenic foredeep accumulations.

In the next three cells N26E08-09-010 the lithologies outcropping in southern Calabria and Northern Sicily are given. In Southern Calabria occur mostly heavy metamorphic and magmatic types, produced through both Hercynian and Alpine orogenetic cycles. The same lithologies have been recorded in the easternmost area of Sicily, the Peloritani Mountains. In northern Sicily the successions are generally sedimentary, Mesozoic to Tertiary in age and similar to those of the carbonate platforms of southern continental Italy. Several flysch deposits also occur, among which the Numidian flysch, a very mature Tertiary sandstone. In Eastern Sicily the most important volcanic complexes are related to the Aetna, whose basaltic effusions cover a great part of the Catania province. Further north, the Aeolian arc volcanism, mostly bearing a calc-alkaline character is present.

In the southern cells of Sicily, N25E08-09 the most extensive formations consist again of carbonates and late-orogenic flysch deposits, as well as of the Iblei basaltic rocks. The volcanic island of Pantelleria belongs to the same cells.

2.4 Mineralisations Of Italian territory

The ore mineralisation (Cu, Zn, Pb, Hg, Sb, As, Ag, Sn, W, Mo, Au, Ag, Mn, Ni, Co, Cr, Ti, PGM, REE etc.) and the industrial minerals deposits (fluorite, barite, feldspar, alkaline-magnesic salts, talc, asbestos, clays, coal, hydrocarbons, bitumen etc.), present in the lithosphere, generally constitute some small or tiny-sized geological bodies. Nonetheless, their geochemical impact, besides the economic importance, is enormous: in fact they are some "singular" and quite uncommon rocks, characterized by very high concentrations of elements that are normally accessory or traces in the common rocks of the earth's crust. Their deposits formed within specific "metallotects", generated by specific geodynamic or environmental contexts, owing to particular chemical-physical processes during magmatic, sedimentary or metamorphic events. Despite their small sizes, these mineralisation can decisively influence the geochemical landscape of the host region: this impact, when the mineralisation occurs in swarms across wide areas, is as accentuated and extreme as it gives rise to some real metallogenic provinces.

The various types of industrial minerals and ore deposits mark the territory with their geochemical signature, determined by a natural spectrum of indicator and pathfinder elements. It is a specific basic spectrum determining and characterizing the mineralisation as well as the genetic context, the processes and the formation environments.

The appearance of false geochemical spectra generally indicates the presence or the overlapping of "ungeological" processes.

The potential of primary and secondary geochemical dispersion characterizing the mineralisation can enlarge and extend, sometimes enormously, their impact on territory. The secondary dispersion processes, through the matched actions of weathering and of mechanical and chemical dispersion can influence, sometimes very extensively, the geochemistry of soils, stream sediments, stream water and floodplain sediments.

The "Carta Mineraria d'Italia 1:1.000.000" of the Italian Geological Survey (*Stampanoni, 1973*) and its explanatory notes (*Castaldo and Stampanoni, 1975*) were the base for drafting the chapter and the dressing of the Italian Territory Mineralisation

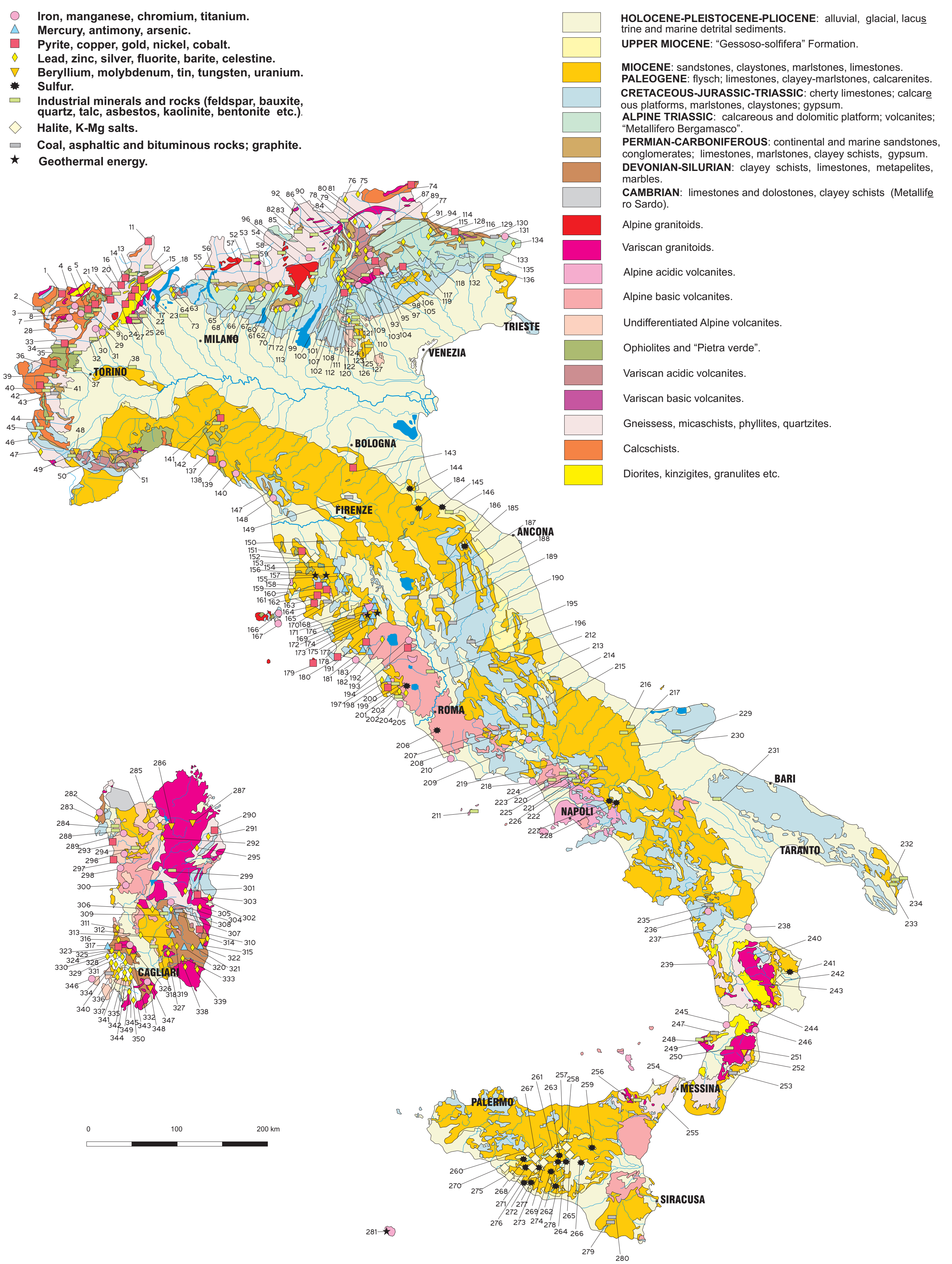

Fig. 2.1 Mineralisation Map of the Italian Territory (after *Castaldo and Stampanoni, 1975*)

Map (Fig. 2.1). Refer to these Authors for major information: the original numbering is reported on the deposits to facilitate the readers. A new concise bibliography updated the metallogenic situation of some areas with particular importance: e.g. the scheelite deposits in the Alpine Arc and in the Calabrian-Peloritan Complex, the Au and different ore mineralisation in Sardinia and in various other areas.

2.4.1 The mineralization of the Western Alps

Southalpine Complex

I. The *Strona Ceneri-Serie dei Laghi Zone* is an Early Palaeozoic sequence of gneisses, biotite-muscovite micaschists and quartzites with Late Variscan volcanic calcalkaline plutonic and effusive rocks. The magmatic activity generated several pyrite, arsenopyrite and Pb, Zn, Cu ± Ag sulphide veins, scattered between Orta Lake and Maggiore Lake (Di Colbertaldo, 1967). The Gignese-Motto Piombino [23], Nocco, Brovello etc. are the main ore bodies, located within the micaschists; easternmost, the polymetallic fluorite and barite veins of Brusimpiano [63] and Valvassera [64] lie within the "Porfidi di Lugano".

II. The *Ivrea-Verbano diorite-kinzigite Zone* is a high-grade sequence including a Mafic complex and a Kinzigite Fm (paragneisses, marbles, amphibolites and granulitic peridotites). The Mafic complex hosts Ni, Cu, (± PGE), Fe-Cr and Fe-Ti mineralisation. Different cupriferous, manganesiferous and Fe-Ba occurences are related to the Kinzigite Fm (*Omenetto and Brigo, 1974; Bigioggero et al., 1979*):

a) the ore deposits of the Mafic complex are mainly *liquid-magmatic mineralisation of Cu, Ni, Co (and PGE)* with nodules, veinlets and sometimes layered lenses of pyrrhotite, pentlandite, chalcopyrite and minor pyrite, bravoite, sperrylite, chromite: they are linked to pre-Variscan basic and ultrabasic granulitic rocks (*Ferrario et al., 1982*). The most important mineralisation are Alvani-Campello Monti [17], Gula-Fobello [22], Val Barbina-Scopello [24], Cruvino-Bruzolo [36]: other occurrences outcrop in Val Sesia and its tributary valleys (e.g. Balmuccia, Vocca, Valmaggia, Fei di Doccio, Locarno and Parone, Sella Bassa, Alpe Cevia, Cravagliana, Meula) and in Strona Valley (e.g., Alvani, Pennino Grande and Croso dell'Acqua). La Balma, Campello Monti, Val Maggia, Fei di Doccio are PGE-bearing mineralisation connected with cumulus ultramafic dykes. Some Fe-Cr spinel occurrences lie in peridotite bodies (Balmuccia, Alpe Campo); titanomagnetite-ilmenite ores occur at Meula;

b) *cupriferous mineralisation* "Kieslager" type, with pyrrhotite, chalcopyrite and minor pyrite, bravoite, galena, molibdenite, magnetite etc. are connected with the belt of metabasites, gnisseses and quartzites (Kinzigite Fm), extended from Strona to Ossola Valleys: the main ore deposits are Nibbio, Migiandone [18] and Ornavasso (Ossola Valley), Alpe Frera, Val di Mengo and Alpe Collo. The Kinzigite Fm also includes some Fe, Cu, (Au) stratiform ores, intercalated within pelitic rocks [e.g., Fonte Amara; Mn (carbonate and silicate) ± Fe, Cu, (Au) mineralisation (e.g., Ravinella)] linked to a quartzite horizon; numerous occurrences of Fe oxides and sulphides with barite, scattered along a 100 km level of marbles, outcrop from Ascona to Coggiola (e.g., Ascona, Porto Ronco, Gridone, Candoglia, Sambughetto etc.).

III. Sedimentary cover. Some deposits of illitic-montmorillonitic clays (e.g. Zizzano [38]) occur in the Monferrato area; they are embedded within the "Calcari da Cemento" Fm (Middle Eocene). Various *fireclays* deposits (caolinite, halloisite, quartz, K-feldspar, Fe and Al hydroxides) are located within the Plio-Pleistocene sediments of the piedmont zone of Vercelli province: they originated by weathering, in a hot damp climate, of Villafranchiano lagoonal and deltaic deposits (sands, clays, conglomerates with clasts of Permian rhyolites and granitoids): the major deposits are S. Grato-Boca [26], Lozzolo-Roasio [27] and Villa del Bosco [25].

Austroalpine

I. The *Sesia-Lanzo Zone* includes an Early Palaeozoic metasedimentary series (paragneisses, micaschists and marbles) and some granodiorite plutonic bodies (Vico and Traversella). Some pyrometasomatic deposits, genetically connected with the granodiorite intrusions, lie within the marbles layers. The ferriferous and polymetallic characters prevail in the Traversella [30] and Montajeu-Gias del Gallo ore deposits (magnetite, pyrrhotite, pyrite with Cu, Zn, As, Sb, Bi sulphides and sulphosalts, scheelite and sometimes uraninite). Pyrite, viceversa, dominates in Brosso, Baio and Bore [31] ore bodies (pyrite, hematite, Cu, Pb, As, Sb sulphides and sulphosalts, fluorite and boron-silicates). Bariasso-Aquila [29] (Tavagnasco) is a hydrothermal stockwork mineralisation with quartz, siderite and Fe, Pb, Zn, Cu etc. sulphides.

II. The *Fobello and Rimella Schists* includes phyllites, amphybolites and chlorite-epidote phyllonitic gneisses, interested by an extensive shear zone. They host various lenticular ore bodies produced by local hydrothermal-geothermal concentrations of quartz, carbonates, auriferous pyrite and arsenopyrite, sphalerite, chalcopyrite, galena, scheelite and native gold (e.g., Val Toppa [15], Vogogna, Cortitti and Guia).

Penninic Domain

The metalliferous occurrences are widespread in the Pennine nappes.

The *Antigorio-Crodo Series* (granitoid gneisses with micaschists and marbles of Lower Penninic) hosts numerous quartz veins with auriferous pyrite and arsenopyrite and minor chalcopyrite, e.g., the group of Maglioggio-Alfenza-Faella [11] in the Micascisti di Crodo.

The *"Brianzonese Zone"* hosts, within the Carboniferous phyllitic-arenaceous schists (Aosta Valley), some polymetallic sulphide mineralisation (Promise [3]) and some anthracite seams (e.g., La Thuile and Morgex [2]). The tuffitic metasediments of Upper Permian, outcropping in the Cuneo province, contain various lenses of sericite-graphite phyllites pechblende-rich, pyrite and minor Pb, Cu, Zn, As, Sb sulphides (e.g., Grange Serre [46] in Preit Valley, Rio Freddo [48] near Peveragno and Bric Colmé [50], south of Mondovì). The Oligocene marly-arenaceous sequence in Tanaro Valley hosts various seams of lignite (Bagnasco [51]).

In the *Monte Rosa Nappe,* numerous "complex" pegmatites (orthoclase, microcline, plagioclase, quartz, micas, tourmaline, beryl, garnet, accessory Fe, Cu, Pb, Zn, As, Bi sulphides and minerals of Ti, U, Nb, Ta, REE etc.) occur in the Domodossola-Val Vigezzo area (e.g., Piano Lavonchio-Siauler-Eglio-Craveggia [12]); they are embedded in the augengneisses sequence and in the contiguous "Orselina Series" (paragneisses, micaschists, amphybolites and calcschists). Similar pegmatitic bodies occur in Antrona Valley (Alpe Mondei-Montescheno [13]) within the Camughera-Moncucco Complex (paragneisses, micaschists and talc-steatitic amphybolites). Feldspar, quartz and muscovite pegmatites outcrop in Sesia Valley (e.g., Mud di Mezzo [20] near Alagna). A widespread scheelite metallogenesis occurs in the Sesia, Quarazza, Anzasca, Sermenza, Ossola and Vigezzo Valleys, as well as in the Arcesa-Brusson Crystalline in Ayas Valley. The primary scheelite areas are strata-bound connected to a Pre-Ordovician meta-volcano-sedimentary horizon (*Omenetto and Brigo, 1981*), in which the most of them occur scattered in amphybolites and in quartz-calcsilicate fels with apatite, but also mobilized as veinlets, along foliation planes, cracks and fissures of Alpine age, within aplitic gneisses and augengneisses. The mobilized scheelite reached sometimes the Calcschists-Ophiolites Complex (e.g., in Ayas Valley) and locally produced massive concentrations with auriferous pyrite in chloritic-amphybolitic lenses at the tectonic contact belt between the Pennine Mt Rosa nappe and the Sesia-Lanzo Austroalpine Complex (e.g., Rima, Carcoforo, Bannio Anzino).

Various auriferous mineralisation occurs in lenticular and vein bodies, sometimes conformable, within the micaschists, paragneisses and quartzites and more frequently in veinlets filling the lithoclases in augengneisses: the ore minerals include auriferous pyrite and arsenopyrite, minor galena, sphalerite, chalcopyrite, argentiferous sulphosalts, native gold etc. (Moroni, 1977), with an abundant gangue of quartz and minor carbonates. The most important auriferous deposits are situated in Anzasca Valley near Pestarena (Cani, Agaré-Miretti) and Lavanchetto (Quarazzola-Col Badile) [16], in Antrona Valley (Mottone-Mee [14]), in Sesia Valley near Alagna (Kreas [19], Mud and Jazza) as well as in Ayas Valley (Arceza-Brusson [5], Arbaz-Orbeillaz, Targnod).

In the *Gran Paradiso Massif* numerous veins and lenses of quartz ± siderite, sulphides, sulphosalts and native gold intersect the augengneisses and the paragneisses in Locana Valley (Bellagarda and Cuccagna). Various outcrops with primary and mobilized scheelite occur within a lithostratigraphic context like the Mt Rosa nappe (mainly in Locana, Noaschetta, Col Nivolet, Savaranche, Nontey, Valleille Valleys). Some strata-bound mineralisation with Fe, Cu, Pb, Zn, Sb sulphides (e.g., La Reale [28] and Rio del Rancio near Campiglia Soana) is indicated in the "Scisti grafitosi del Pessinetto".

The *Dora Maira Massif* hosts numerous talc and graphite deposits; some little outcrops with scheelite in amphybolites occur in Germanasca Valley. Many white talc deposits (with magnetite, dolomite, quartz and silicates) are connected to hydrothermal metasomatism of carbonatic layers, interbedded in the Permian-Carboniferous Dronero Complex (paragneisses with micaschists, prasinites and marbles). The main deposits are: Grange Martinetto and Rolando in Sangone Valley; La Roussa [39] in Chisone Valley; Malzas-Sapatlé [42] and Fontane-Crosetto [41] in Germanasca Valley (Biasio et al., 1995); Grange Subiaschi in Pellice Valley. Some graphite deposits (e.g., Icla-Brutta Comba [43]) are interbedded in the "Pinerolo graphitic micaschists" (Carboniferous).

In the *Gran S. Bernardo Crystalline Nappe* various scheelite occurrences are present, both disseminated in aplitic gneisses and mobilized in veinlets in the augengneisses (Bognanco, Brevettola-Antrona Valleys); in Valdivedro the mobilized scheelite reaches the Calcschists-Ophiolitic Nappe.

The *"Calcschists Ophiolitic Nappe"* (Jurassic-Cretaceous) includes different ore bodies, hosted in the basic and ultrabasic lithotypes in which magnetite, chromite and Fe sulphides are commonly disseminated. The most interesting areas are:

I. bodies and lenses of magnetite and minor hematite, pyrite, chalcopyrite, pyrrhotite, occurring in the serpentinite outcrops of Aosta Valley: the main ore deposit is Cogne [7]; minor bodies occur isolated or in swarms in Mt Avic area [8] (e.g., Lago Gelato, Valmeriana, Ponton, Bella Lana etc.);

II. exhalative-sedimentary cupriferous deposits with pyrite and chalcopyrite and accessory magnetite, pyrrhotite, sphalerite, bornite, linneite etc. are frequent between the Pinerolo area and the Sesia Valley. They are lenticular ore bodies, embedded in amphybolites, metagabbros and prasinites, highly deformed during the tectonic-metamorphic Alpine cycle. Lots of them occur in the Aosta Valley as Preslong-Ollomont [1], Hérin-Champdepraz [6], Chuc and Servette (St. Marcel), Efra, Fenis, Petit Monde (Torgnon), Salsa-Schelbete (Gressoney). Some others occur in upper Chisone Valley (Beth-Ghinivert [40]), in Lanzo Valley (Fragné-Chialamberto [33]), in Susa Valley (Salbertrand), in Soana Valley (Caramia) and in Valsesia near Alagna (T. Otro [21]);

III. Ni, Fe, Co sulphur-arsenide veinlets (smaltite, safflorite, rammelsbergite and other sulphides and sulphosalts with gangue of quartz, siderite, calcite): they locally intersect the metabasites near Cruvino [36] in Susa Valley, Bessanetto and Punta Corna, between the Lanzo and the upper Ala Valleys;

IV. manganesiferous lenses (braunite ± hematite): they are located at the transition between quartz prasinites-serpentineschists and calcschists (e.g., Praborna [4] (Aosta Valley), Alagna-Otro (Sesia Valley) and Ceres (Lanzo Valley);

V. asbestiferous mineralisation connected with serpentinized ultramaphitic bodies (Belluso et al., 1995): they are frequent in Aosta, Soana and Lanzo Valleys. The asbestiferous bodies, rising from the serpentinites transformation, are located along Alpine shear zones. The asbestos is accompanied by minor magnetite, carbonates, garnets and accessory nickeliferous minerals (pentlandite, heazlewoodite, josephinite, native Fe-Ni) with about 0.2% of Ni (Rossetti and Zucchetti, 1988). The major deposit is S. Vittore-Balangero [35], characterized by a thick swarm of asbestiferous lenses within the ultrabasic Lanza massif; some other important deposits are Settarme Chassant [10], in the left side of Aosta Valley, and Auriol-Sampeyre [44] in Varaita Valley;

VI. grey-greenish talc mineralisation, due to the Alpine geothermal-hydrothermal metasomatism on serpentinites (Sandrone, 1995), is generally of small entity but numerous. Mure et Mt. Blanc-Issogne [9] in Aosta Valley, Viù and Cantoira [34] in Valle Grande di Lanzo, Prazzo and Canosio [45] in Maira Valley, are the most important deposits. The talc quality is poor owing to the presence of serpentine, chlorite and amphiboles;

VII. microcrystalline magnesite with opal, dolomite, quartz and clayey minerals; it occurs as stockwork of veinlets due to weathering on serpentinized ultrabasites. The major occurrences are Mt. Calvo-Caselette [37] and Valdellatorre–Givoletto in Susa Valley and Torre Cives-Bettolino [32] near Baldissero (Canavese).

Helvetic Domain

The *Malinvern-Argentera Complex* (Marittime Alps) includes an Early Palaeozoic sequence with paragneisses and granitoid gneisses, anatexites, biotite-amphibolite paragneisses and Late Variscan granitic plutons. Many scheelite, sulphides, barite and fluorite veins occurrences are hosted in this Complex. The scheelite (*Brigo and Frizzo, 1976*) mostly occurs disseminated in the metabasites outcropping in different areas (Stura Valley-Vinadio-Colle della Lombarda, Mollières Valley, Upper Gesso and Rovine Valleys), but sometimes it appears mobilized as metamorphic veinlets with Fe, Cu, As sulphides (Baraccone). The polymetallic veins (Fe, Pb, Zn, Cu, As, Sb, Bi etc. sulphides with barite and fluorite gangue), are connected to the Late Variscan magmatic activity. Fluorite and barite predominate in Pietraporzio (barite) and in Rio Ciardola (fluorite) veins. The sulphides are widespread in other ore bodies (e.g., Ruà-Vinadio Terme [47], Ferriere Valley, Palla Valley, Bergemoletto, Terme di Valdieri etc.).

2.4.2 Mineralisation of the Central-Eastern Alps

Southalpine Complex

The Southalpine Complex of the Central-Eastern Alps includes: I) a *metamorphic basement*, mainly constituted by an Early Palaeozoic terrigenous metasedimentary series with acidic and basic metavolcanites with a Variscan metamorphic overprint of variable grade; II) a *Late Variscan calcalkaline volcano-plutonic complex*; III) a thick *Permian-Caenozoic cover* including carbonatic and p.p. terrigenous sediments, and the products of the Middle Trias and Eocene-Oligocene igneous events.

I. The *metamorphic basement* outcropping in Trentino-Veneto area (“Agordino-Valsuganese belt” - *Frizzo, 2004*) hosts some important exhalative-sedimentary deposits, embedded in the Ordovician-Silurian sequence of quartz phyllites with minor porphyroid-genisses, prasinites and chloritoschists. The lenticular ore bodies of massive sulphides (pyrite, arsenopyrite, marcasite, chalcopyrite, sphalerite, galena, Bi, Sb, Ag sulfosalts with accessory stannite, cassiterite, gold) are kilometric in extent. Vetriolo [110], Calceranica [112] and Sella Valley in Valsugana, Terre Rosse in Val Cismon, Valle Imperina [119] in the Agordino, are the most important. Northernmost, within the Bressanone Quartz Phyllites Fm, sporadic occurrences of disseminated Fe, Cu, Pb, Zn sulphides ± ilmenite (*Brigo, 1971*) are present, linked to a graphitic phyllite horizon outcropping among the Funes Valley, Luson and Dobbiaco. Disseminated polymetallic sulphide ores occur also within a chloritoschist horizon, interbedded in the quartz phyllites in Sarentino area. Similar stratiform mineralisation are present in the Edolo Schists (Upper Camonica Valley), e.g., Buca dell’Oro, sometimes accompanied by mobilized Fe, Zn, Cu, Pb, Sb, As-bearing veins (Carona, Berzo-Demo, Forno d’Allione etc. - *Frizzo and Omenetto, 1974*).

The Paleocarnic Range hosts two different strata-bound mineralisation: the older are stratiform oolitic ferrous-manganesiferous (± Ba, Cu) deposits within the carbonate-terrigenous sequence of “Kokkalke-Eisenkalke” (Lower Silurian), outcropping from Mt. Cocco [131], in the Fella Valley, to Mt. Croce Carnico Pass, in the Austrian side. The others are polymetallic cupriferous ores (Cu-tetraedrite, Zn, Hg, Sb, Pb, Ag, Ni etc., with calcite, quartz, barite and fluorite gangue) within the Middle-Upper Devonian carbonatic platform stretching about a hundred kilometres between the Visdende Valley and the Tarvisio area. The ore deposits are characterized by veinlets, lenses and columnar bodies: Mt. Avanza [128], Comeglians [129], Timau, Mt. Cavallo are the main.

II. The *Late Variscan calcalkaline volcano-plutonic complex* generated lots of ore deposits. Various hydrothermal polymetallic veins are connected to granitic-granodioritic intrusions. Some of these are cupriferous; others are characterized by Zn, Pb, Cu, Ag, Sb, As, Bi sulphides, Au with quartz, fluorite and barite gangue. In the northern sector of the basement the "Diorite di Chiusa" intrusive complex generated, between Isarco and Sarentino Valleys, the ore deposits of Corvara [79], Rio Danza [80], Mt. Fondoli [81], Terlano [84], the magnetite-pyrrhotite mineralisation of Maso del Nido and numerous polymetallic veinlets scattered between the Rio Sega and the Pennes Valley. Some of minor polymetallic veins, scattered between the Sarentino and lower Pusteria Valley, are linked to the granitic pluton of Bressanone. Sourhernmost, in Valsugana, the Cima d'Asta-Roncegno plutonic-epiplutonic complex produced an extensive swarm of cupriferous and polymetallic ore deposits: e.g., Nogarè-Quadrate [101], Valar-Pergine [108], Vignola [111], Cinquevalli, Palù del Fersina, Caoria [104], the magnetite-pyrrhotite deposit of Pamera [109] and the quartz ± pyrite vein with base metal sulphides and gold of Cima d'Orno [102].

The thick volcanic sequence of the Piattaforma Porfirica Atesina hosts: the Pb, Zn, Ag stratiform deposit of Tregiovo [86], linked to a lens of lacustrine sediments interbedded in the upper rhyolitic-ignimbritic units; the Hg (cinnabar, pyrite, marcasite) ore deposit of Vallalta-Sagron Mis [106] (Gosaldo), linked to ignimbrites and tuffites; some veins of barite, e.g., Mt. Zaccon in Valsugana. Some barite veins are also hosted in the volcano-sedimentary succession of the Collio Basin in Rendena (Marigole-Pice [113]) and Lower Camonica Valleys. The numerous veins of fluorite, barite and Pb, Zn, Ag sulphides, e.g., Vallarsa [89], Castelvecchio [90], Case a Prato [91], Prestavel [93], crossing the Piattaforma Porfirica Atesina, are probably due (Bakos et al., 1972) to the Middle Triassic hydrothermal event.

Various metasomatic *albitite bodies,* hosted in the metamorphic basement, are coeval to Late-Variscan magmatic activities: e.g., Giustino [96] in Rendena Valley and some others scattered along the northern edge of the Southalpine basement (e.g., Baitello in Upper Camonica Valley, Val Caldenave [103], Val Varrone etc.).

The uraniferous deposits of Novazza [57] in Goglio Valley (Bergamo) and of Vedello Valley (Sondrio) are also related to the Late Variscan magmatic event (*Omenetto and Brigo, 1974*).

III. The *Permian-Caenozoic cover* includes various types of mineralisation.

Some *uraniferous deposits* (uraninite, pyrite, galena, sphalerite etc.) are connected with some lenses of grey carbonaceous sandstones of the Arenarie di Val Gardena Fm (Middle-Upper Permian), especially in Rendena Valley (e.g., Bocenago-Palastro [99], Daone and Dalgone Valleys); significant concentrations of U are present elsewhere in Trentino and in the Vicentinian Alps. Some Pb-Zn mineralisation, also lie within the Arenarie di Val Gardena Fm, for instance between Andriano and Nalles in Alto Adige (Rio del Bavaro).

The *manganesiferous siderite* ± *barite* ore deposits of the Lombardy Valleys (*Cortecci and Frizzo, 1993*) are particularly numerous and important. They are both metasomatic-stratiform deposits, settled in the lower and middle carbonatic units of the Servino Fm (Scitian), and subvertical veins crossing the below Verrucano Lombardo Fm and crystalline basement. They occur in two characteristic Fe-Mn-Ba sublatitudinal belts: the northern belt hosts the stratiform mineralisation of Manina [58], Barisella-Fondi [59], Meraldo-Vivione [60], Gardena [61], M. Elto [62], Lava etc. and the veins of Ruola Faedo-Faidallo-Baitello [56], Scaletta, Inferno, Masoni-Poblino, M. Lorio, etc. The southern belt hosts the stratiform deposits of Pisogne (e.g., Fusio, Fura, Gottardo-Rizzolo [70], Gale etc.) and of the Trompia Valley (Pezzaze, Alfredo-S.Aloisio [72]), as well as the veins of Vivazzo, Regina, Pineto, etc. Some mineralisation with manganesiferous siderite ± barite also lie within the basal units of the Werfen Fm in Trentino and in Bellunese region; in comparison with those of Lombardy they are richer of Pb, Zn, Ag sulphides and sulfosalts ± stibnite etc. (e.g., Faedo [97], Agli Orti [98], Doss delle Grave [100] and

Roncogno [107] in the argentiferous complex of Mt. Calisio-Trento and easternmost, Transacqua [105], Valle del Mis, Colle S. Lucia-Fursil-Belluno).

The *"Alpine type" Pb-Zn deposits* (Pb, Zn, Cd, Ag with Sb, Mo etc.) characteristic of the Anisian and Ladinian-Carnian calcareous-dolomitic platforms are connected with paleogeographic and paleogeodynamic events and sometimes with the Middle Triassic magmatism. In the Varese region the Pb-Zn mineralisation of Besano-La Nave are hosted within dolomicrites and bituminous marls of the Anisian "Scisti di Besano". In the Alps of the Bergamo province (*Omenetto, 1966*) Paglio Pignolino-Dossena [65], Gorno [66], Presolana [67] etc. are very important ore deposits within the Lower Middle Carnian Metallifero Bergamasco and Breno Formation. In the Belluno and Carnia areas (*Di Colbertaldo, 1968; Brigo et al., 1977; Köppel, 1983; Frizzo et al., 1999*) the ore deposits of Salafossa [116], Grigna-Ferrera-Pian da Barco [114], Argentiera [115], Col Piombin-Passo Giau [117], M. Rite-Valle Inferna [118], Val d'Aupa [133] and Raibl [134] are linked to platforms ranging from Anisian to Carnian.

The products of the *Ladinian-Carnian calcalkaline magmatism* are widespread within the Central-Eastern Alps. They include lavas, ignimbrites, tuffites from rhyolites-rhyodacites to latiandesites-latibasalts and monzonites, and locally (Vicentinian Alps and Predazzo-Monzoni) subvolcanic and plutonic bodies. Between the Camonica and Trompia Valleys the Arenarie di Val Sabbia and the Metallifero Bergamasco Formations, heteropic with the volcanites, show high geochemical concentrations of Pb, Zn, Cu, Sb, Ni, Co, Ba, F etc. but only few poor mineralization. A Middle Triassic granitoid deep plutonism produced the imposing veins cluster of fluorite ± Pb, Zn, Ag of Torgola [71] and Pezzaze-Stese (*Frizzo, 1997*). The Middle Triassic magmatism of the Vicentinian Alps generated most of the polymetallic veins and pyrometasomatic ores (Fe, Pb, Zn, Cu, Ag sulphides and traces of Bi, Au, johannsenite, ilvaite, barite, as Mt. Civillina, Valle dei Mercanti, Mt. Castello [122]), as well as lots of caolinitic (e.g., Colle Xomo, Pianegonda) and illitic-smectitic deposits (e.g., Zanconi [120], Riolo-Valle dei Mercanti [121], Pozzani [123]).

The volcano-plutonic complex of Predazzo-Monzoni produced some magnetite deposits (S. Maria di Viezzena [94]), stockwork with chalcopyrite, scheelite and molybdenite (Bedovina-Mt. Mulat [95]), as well as, in relation with granitic bodies, some minor Sn, Cu, As, Au ores and Pb, Zn, Ag veins. Widespread polymetallic anomalies characterize the Ladinian volcanites of the Belluno and Friuli regions (Pietra Verde and Porfidi di Rio Freddo Formations).

The fluorite mineralisation of Camissinone [68], hosted in fractures of Dolomia Principale (Norian), is the only one subsequent the Middle Trias.

The Tertiary granitoid plutonism (Adamello and Vedrette di Ries) and the Eocene-Oligocene rhyolitic to trachy-andesitic and alkalibasaltic volcanism-subvolcanism (Euganei-Lessini-Berici region) did not produce ore deposits. Various *bentonitic* deposits (e.g., Vegri-Campotamaso [125], Schiavi-S. Urbano [126] etc.) and numerous high geochemical anomalies of Ti, Ni, Co, V, Cr in the soils and alluvial sediments are connected with the alkalibasalts.

Lots of *bitumen, ichthyolitic schists and coal* deposits are present in the sedimentary series of eastern Alps. Here we remember a layer of "boghead" interbedded in the lower Dolomia Principale of Mt. Plauris (Carnia) near Resartico-Resiutta [135]; ichthyolitic bituminous marls (with Pb-Zn occurrences) within the Scisti di Besano Fm (Anisian) near Besano and Bisuschio (VA); ichthyolitic schists (Mollaro [92] with Fe sulphides and minor Cu, V etc.) in the Scisti di Mollaro (Cenomanian-Albian) in Val di Non; in Carnia, bituminous limestones (Cretaceous) near Nimis [136] and various coal deposits as anthracite (Carboniferous) at Cason di Lanza-Mt. Corona [130], northern Pontebba, and bituminous coal (Raiblian) between Tolmezzo and Ovaro, e.g., Claudinico-Corodonis [132]; lignite in Vicenza region (Eocene-Oligocene), e.g., Mt. Pulli [124], Monteviale, Zovencedo, and in Valsugana (Tortonian), e.g., Coalba and Bronzale; lacustrine lignite (Villafranchian) at Valgandino-Leffe [69] (Bergamo).

Austroalpine

The ore mineralisation of Austroalpine Com plex involves only the metamorphic basement, characterized by an Ordovician-Silurian metavolcanic-sedimentary sequence (garnet-biotitie-muscovite paragneisses, micaschists, porfiroid gneisses, amphybolites and marbles), with a polymetamorphic Variscan and Alpine overprint. The stratiform massive sulphides deposits (Fe, Zn, Pb, Cd, Ag, Cu, Sb, As, Ni, Co, Bi) of the S. Martino di Monteneve [76] and Fleres [75] Groups, outcropping between the Passiria Valley and the Brennero Pass, are particularly important. Similar mineralisation (Lasa, Annaberg, Jennewand) occurs in the Venosta Valley basement. Minor cupriferous stratiform deposits (e.g., Rifugio Borromeo) occur in a phyllites with cloritoschists sequence.

Numerous feldspar-bearing pegmatoid ore bodies occur from Martello to Racines Valley (e.g., Martello Valley [83], Le Lame [85]), sometimes with beryl, tourmaline and micas, e.g., Rio Masul [78] and in Giovo Valley.

Tungsten strata-bound occurrences (scheelite with As ± Au disseminated or in veinlets) locally outcrop from Valtellina (Bormio) to upper Pusteria Valley (Dobbiaco-S. Candido). The scheelite prevalently occurs in metabasites, marbles or paragneisses with carbonatic metablastesys, within sequences of dominant quartz phyllites or paragneisses. The most interesting occurrences outcrop in the upper Venosta/Vintschgau (Lasa, Solda, Peder, Martello, Ultimo Valleys) and upper Pusteria right side (Riomolino, Anterselva-Vedrette di Ries, Casies, Croda Rossa and Thurntaler - *Frizzo, 1981*; *Brigo and Omenetto, 1983*). The scheelite of the Thurntaler [77] lies within some lenses of prasinites and chlorite amphybolites interbedded in the quartz phyllites; it is moreover mobilized in Alpine veins stockworks with Fe, Pb, Zn, Cu, As sulphides and Au.

In Peio Valley some magnetite-pyrrhotite ore bodies [88] occur, within layers of marbles with silicates, interbedded in a sequence of paragneisses, quartz amphybolites and orthogneisses.

Alpine veins of arsenopyrite and quartz, with minor Pb, Zn, Cu sulphides and native Au, are frequent in various areas of Austroalpine basement; sometimes the veins reach the basal layers of the Permian-Carboniferous cover.

Penninic Domain

Lots of mineralisation are connected with the ophiolites outcropping in Malenco Valley (Lombardy) and in the Tauri Window (Alto Adige). They are mainly exhalative-sedimentary pyritic-cupriferous deposits, generally of little importance. The major deposits occur in Val di Vizze and especially in Valle Aurina: S. Valentino di Predoi [74] is the most important, characterized by conformable lenses of pyrite and chalcopyrite with magnetite, pyrrhotite, bornite, cubanite, sphalerite, molibdenite, millerite etc., within the metamorphosed ophiolites.

The talc and asbestos deposits are common in Val Malenco. Talc occurs both in subvertical veins, crossing the serpentinites and sometimes the dolomitic marbles or gneisses, and as lenticular bodies along the Pennidic-Austroalpine overthrust plane. The veins are numerous and sometimes extend several kilometres. The most important are the steatite vein of Ponticelli di Riva [52], hosted in the serpentinites, and the two veins of white talc of Bagnada, within dolomitic marbles. Some minor talc mineralisation are present also in the serpentinites of the Vizze Valley (Bolzano).
Various lenticular bodies of chrysotile occur in the serpentinites in the upper Malenco Valley, e.g., at Val Brutta-Dossi Franscia-Bocchetta [53].

2.4.3 Mineralisation and industrial minerals of the Italian Apennines

Ore deposits of Ligurian-Emilian Apennines

The most important ore deposits of the Ligurian-Emilian Apennines are connected with the "Argilloscisti con ofioliti" Complex (Jurassic-Cretaceous) including some strips of oceanic crust (pillow lavas and diabases) and of the mantle (peridotites, lherzolites, dunites, layered gabbros, ultramafites etc.) and a sedimentary sequence of tuffites, clayey schists and limestones with chert and jaspers. In the hinterland, between Chiavari and La Spezia, pillow lavas and diabases host numerous massive *cupriferous sulphides deposits* with pyrite and chalcopyrite, accessory sphalerite and pyrrhotite and sometimes magnetite, e.g., Libiola [138], Gallinaria, Bardeneto, M. Loreto, Casali, Le Cascine. Similar ore deposits (Vigonzano [141]) occur in serpentinites, prasinites and talc bodies (Mt. Albareto [142], Groppallo, Bolgheri, Forno di sotto) in the Apennines of Piacenza. South of Bologna the cupriferous mineralisation of Bisano [143], Sassonero and Gurlano are connected to chaotic breccias of ophiolites and clayey schists. *Chromite* mineralisation with accessory magnetite (Ziona [139]) occurs between serpentinites and gabbros near Bracco. *Manganesiferous* ore bodies (braunite, rhodochrosite, rhodonite, pyrolusite) are linked to the Malm-Tithonian jaspers overlapping the ophiolites: the greatest ones are Gambatesa-Tre Monti [137], Cassagna, Mt. Porcile and southern-easternmost, near La Spezia, Cerchiara [140], Amola, Baccano, Mt. Sorbolo, Gaggiola.

Some minor mineralisation with polymetallic sulphides occur in Savona and Imperia provinces and in the Apennines of Parma and Piacenza. Here some albitite bodies are also present near Varviaro and Menta in Taro Valley.

Ore deposits of Tuscany

Numerous ore deposits are present in Tuscany (*Tanelli, 1983; Ciarapica et al., 1985*), distributed in the deepest structural units, both autochthonous ("Apuan Metamorphic Nucleus") and parautochthonous (Fornovolasco-Panie Unit and Massa-Punta Bianca Unit) as well as in the overlapping allochthonous Units or rather the northern and southern Tuscan Nappes and the Ligurian Nappes.

The Tuscan Nappes, constituted by unmetamorphosed litotypes of "Tuscany series", widely outcrop up to northern Latium: the Norian-Rhaetian calcareous-dolomitic with evaporites successions ("Calcare Cavernoso Fm") have a considerable extent and continuity. The Ligurian Nappes are characterized by ophiolitic bodies with clayeys, limestones, marls and sandstones.

The Tuscany mineralisation was produced by three metallogenic main cycles, respectively: a) Middle Triassic; b) Jurassic; c) Late Alpine (Late Miocene-Pleistocene).

a)Middle Triassic mineralisation

Several ore mineralisation occurs within the "Apuanidi" (Apuan Metamorphic Nucleus and Fornovolasco-Panie Unit) and "Spezidi" (Massa-Punta Bianca Units). They are stratiform and strata-bound ore bodies, including pyrite, polymetallic sulphides, Fe oxides, fluorite, barite etc., hosted in a specific Late Ladinian-Carnian "Metalliferous horizon", underlaying the calcareous platform of Norian-Rhaetian Grezzoni Fm. In the Metamorphic Nucleus and in the Fornovolasco Unit, the Metalliferous horizon is mainly constituted by quartz-sericite-albite sometimes tourmaline phyllites: it represents the transgressive cover on the Variscan basement, including sericite-albite phyllites, quartzites, porphyritic schists and Silurian dolomitic lenses.

Lots of ore deposits (pyrite, polymetallic sulphides and/or Fe oxides, barite etc.), like Bottino di Serravezza [147], M. Ornato, S. Barbara, Mt. Tambura, Argentiera, Gallena, Canale dell'Angina, Valdicastello-Pollone, are linked to tourmaline phyllites: the mineral paragenesis includes argentiferous galena, sphalerite, minor chalcopyrite, abundant Cu, Ag, Bi etc. sulphosalts, quartz, carbonate and sometimes, abundant pyrite and fluorite (e.g., Valdicastello-Pollone). Several exhalative-sedimentary deposits with pyrite, barite, magnetite, hematite, minor siderite, rare sulphosalts, traces of V and W minerals (e.g., Buca della Vena [148], M. Arsiccio, Canale della Radice, Fornovolasco, etc.) occur at the top of Metalliferous horizon, underneath the "Grezzoni" Fm. The protolites and the ore deposits show an Alpine low grade metamorphic overprint (27÷11 My). The stratiform mineralisation are intensely folded, fractured and resealed; it frequently show extensive mobilizations with growth of nodules and veinlets of argentiferous galena, sphalerite, abundant sulphosalts and sometimes native Au with quartz, barite and fluorite gangue. The *Metalliferous horizon* of the Massa Punta Bianca Unit (terrigenous-carbonatic and sometimes evaporitic metasediments with occasional alkali-basalt metavolcanites) contains strata-bound ore deposits with manganesiferous siderite, Fe and Mn oxides, chalcopyrite and minor polymetallic sulphides (Frigido, Strettoia, Bocca di Magra, Mt. Brugiana, P.ta Bianca etc.).

b)Mineralisation in the Ophiolites

A strip of ophiolites and clayey schists (Late Jurassic – Early Cretaceous) hosts the cupriferous pyrite deposits of Montecatini-Val di Cecina [151]. They consist of a "primary" mineralisation, constituted by some irregular bodies and veins of pyrite, chalcopyrite, bornite etc., within pillow lavas, serpentinites and gabbros, and a “supergenic” very rich mineralisation, within two large clayey lenses containing centi-decimetric nodules of chalcocite, bornite and native Cu.

c)Late Alpine mineralisation

The Late Alpine extensional tectonic event, that followed the contractional orogenetic phase, generated, during the Miocene-Quaternary, a horst and graben system with Apennine direction. It enabled the intrusion of granite plutonic bodies (e.g., Isola d’Elba) and of some subvolcanic domes as well as the eruption of ignimbrites (e.g., Mt. Amiata). The magmatism produced lots of pyrometasomatic and hydrothermal ore deposits crossing the whole system of Nappes and lithostratigraphic Units of Tuscany. Moreover, some gypsum, salt and lignite deposits are connected with the terrigenous sediments filling the graben.

The ferriferous deposit of Isola d’Elba are in relation with the Miocene quartz-monzonite intrusion: hematite and minor magnetite with pyrite and accessory galena, sphalerite, arsenopyrite, chalcopyrite, bismutinite of Rio Marina [166] and Ortano constitute a swarm of metasomatic ore bodies and irregular veins within the Verrucano and the Calcare Cavernoso Fm. Magnetite-hematite with minor pyrite bodies are connected to pyrometasomatic calksilicate rocks at Capo Calamita [167] and Ginevro within the dolomitic limestones and the schists of the “Verrucano” Fm.

Stanniferous nodules and veinlets of cassiterite, tourmaline and hematite occur at Mt.Valerio [159] within the Lias-Dogger silicified limestones at the contact with the granite of Botro: a hydrothermal paragenesis with pyrite, sphalerite, chalcopyrite, galena, calcite, siderite and pyrolusite adds to the Sn mineralisation.

Some large deposits of pyrite within minor polymetallic sulphides are linked to some wide skarn and hornfels zones, commonly near granitoid domes. The Campiglia Marittima-Temperino-Valle S. Silvestro [158] ore deposits are a stockwork of veins and nodules of pyrite with pyrrhotite, magnetite and minor base metal sulphides within extensive skarn on Liassic limestones with hedembergite, joahnnsenite, rhodonite, ilvaite, garnet, epidote, calcite, fluorite, quartz. Niccioleta [160] includes different bodies of pyrite with minor magnetite and Zn, Pb, Cu, Sb sulphides: the mineralisation lies within wide silicate skarns developed on anhydritic lenses embedded in the Calcare Cavernoso Fm and in the lower Filladi di Boccheggiano Fm. Similar contexts host other important bodies of pyrite with minor base metals sulphides: Gavorrano-Rigoloccio-Ravi-Montecatini-Valmaggiore [164], Boccheggiano [162a], Campiano [161] as well as the deposits of the Isola del Giglio [179] and Mt. Argentario [180].

Some large quartz veins with pyrite and polymetallic sulphides follow, sometimes kilometres long, some stretching faults with Apennine direction crossing the Filladi di Boccheggiano Fm, the Calcare Cavernoso and the Flysch of the Ligurian nappe: the most important are the cupriferous deposit of Boccheggiano [162b], the pyrite and polymetallic argentiferous sulphides veins of Fenice Capanne-Accesa-Serrabottini [163] and some minor mineralisation south of Massa Marittima (e.g., Montieri, Bruscoline, Podere Altini etc.).

The *Hg and Sb deposits* of the Tuscany are recent and often occur near the actual thermal springs and gas leaks (H_2S, CO_2 etc.). Sb and Hg occur in different ore bodies, or in mineralisation characterized by the absolute prevalence of one of the two elements. The antimoniferous deposits usually occur at the tectonic or stratigraphic contact between limestones (usually the Calcare Cavernoso) and an impermeable clayey cover (frequently the Ligurian Flysch). The mineralisation with predominant Hg lies within rocks of different ages: from schists of Apuan Metamorphic Nucleus (Levigliani) or the schists of the Massa Unit (Ripa), to Mio-Pliocene sediments (e.g., Selvena-Morone and Cerreto Piano). Among the *antimoniferous deposits* (stibnite, pyrite and marcasite, minor sphalerite and galena, sometimes cinnabar, and quartz, calcite, barite, celestine and fluorite gangue) the most important are: Tafone [181] and the near cluster of mineralisation of Càpita [182] (Montaùto, Macchia Casella); Cetine di Cotorniano [154]; Spannocchia-Camporedaldi [155]; Casal di Pari [170]; Pereta o Zolfiere [178b].

Among the important *mercuriferous mineralisation* (veins and disseminated cynnabar) there are:

Ripa and Levigliani, Bagni di S. Filippo [168], within Rhaetian dolomitic limestone; Abbadia S. Salvatore [169], Bàgnore [171] and Selvena-Morone [177], within marly limestones and evaporites underlaying an "impermeable" cover, as the Scisti Policromi Fm, the quartz-latite ignimbrites of Mt. Amiata, the Pietraforte Fm and the Flysch of Ligurian Units; Mt. Labbro [174], hosted within fractured jaspers (Malm of Tuscany Serie), covered by clays and marls of the Maiolica Fm (Cretaceous); Carpine, Solforate, Siele, Abetina [175], a swarm of stockwork occurrences within the Pietraforte Fm; Cerreto Piano [178a], two cinnabar mineralisation hosted respectively in the Calcare Cavernoso and within the sandy Pliocene sedimentary series. The Hg mineralisation extends up to northern Latium, e.g., Castagneto della Trinità [198] within the Tolfa trachytes.

The geothermal fields, characterizing the provinces of Pisa and Grosseto, are due to the thermal flows generated by granitoids domes. The convective circuits, involving meteoric waters deeply infiltrating and warming, reascend carrying away gas, steams and geothermal flows, rich of boric acid and various elements. The Late Triassic evaporites, covered by impermeable lithotypes, are usually the "reservoir rocks". The high temperature hydrothermal fluids of the geothermal fields of Larderello and Mt. Amiata (Mt. Gabbro-Lago di Travale [156], Larderello- Castelnuovo-Rio Secco-M. Lago [157], Bàgnore-S. Fiora [172], Piancastagnaio [173]) are used for electric energy production.

Evaporitic gypsum and salt deposits (Buriano–Saline di Volterra [153] and Ponte Ginori [152]) intercalate within the lagoon sands, marlstones, clays and limestones, deposited in the Neogene grabens. Similar sedimentary series host seams of *lignite*, e.g., Ribolla [165], Baccinello-Cana [176] within the Upper Miocene sediments, and Mugello [149], Castelnuovo dei Sabbioni [150] etc. in the Pleistocene "clayey-lignite Complex".

Ferriferous submarine placers characterize the sediments of depth in front of the mining area of Rio Marina. The coastal sandy bars between Ansedonia and Burano-Foce del Chiarone [183] are rich of Fe oxides and heavy minerals, derived by the weathering and erosion of volcanites: magnetite (up to 25%) is mainly concentrate toward the shoreline, with piroxenes, amphiboles, ilmenite, zircon; while quartz-feldspathic sands predominate toward the inland.

2.4.4 Mineralisation of the Central-Southern Italy

Several ore and industrial minerals, linked to Triassic-Quaternary sedimentary and volcanic sequences, characterize the Central-Southern Italy. The principal deposits are bauxite and sulphur, polymetallic veins, uranium occurrences and leucite, clay, carbon and bitumen.

a)Bauxite in calcareous platforms

Numerous bauxite deposits are connected with the Upper Triassic-Miocene calcareous platforms outcropping along wide areas of the Central-Southern Appennine and Apulia. The bauxite ore bodies deposed during Albian-Turonian age on karstic paleosurfaces originated during the Upper-Middle Cretacic emersion or, as in Salento area, between Upper Cretaceous and Neogene. The paleokarstic surfaces developed on the Giurassic and Cretaceous calcareous platforms. They are overlapped by transgressive limestones, locally alternating with lenses and layers of marls, clays and sometimes conglomerates. A lot of oolitic-pisolitic bauxite ± Ti oxides bodies occur: in Lazio, Colle Carovenzi-Pescosolido [208] in Liri Valley, near Sora; in Abruzzo, Casamaina-Puzzilli [213] (L'Aquila) and Mandrilli [215] (Marsica); in Campania, Bocca della Selva [220] and Pecorareccia-Regia Piana [221] (Matese), Mt. Maggiore-Caiazzo-Mt. Fosco [224], Castello di Dragoni [225] and Mt. Grande [226] (Caserta); in Apulia, the wide bauxite deposit of S. Giovanni Rotondo [229] (Gargano), Cavone-Spinazzola [231] (Murge) and various Upper Cretaceous-Neogene clay deposits with bauxite, pisolites, oolites and Ti oxides (e.g., Palmariggi [232], Poggiardo [233] and Otranto [234]) overlapped by Miocene limestones.

b)Sulphur deposits

The Gessoso-Solfifera Fm (Upper Miocene), outcropping along the entire Appennine ridge, hosts lots of sulphur deposits. At the border of Emilia-Marche there are the important deposits of Perticara-Marazzano [184] and Cabernardi [185] (Montefeltro). Southernmost, in Val Cesano, some stratiform and lenticular sulphur bodies, alternating with gypsums and limestones, occur. Several important sulphur deposits are also present in Campania, especially in Irpinia, as Isca della Palata-Stretto di Barba [227] and Bosco della Palata [228].

c)Polymetallic sulphides; fluorite and barite; manganese

Numerous polymetallic sulphide, uranium, fluorite, barite, clays etc. mineralization are connected with the magmatism characteristic of the coastal belt between Southern Tuscany and Vulture region. The calcalkaline Tuscan-Latial magmatism (ignimbrites, lavas and domes from rhyolite to quartz-latite), started in Paleocene, is typical of the Tolfa and Cimini Mountains. Afterwards, the alkaline-potassic magmatism of Latium produced, southward: the lavas and the leucite pyroclastites of Volsini Mountains (Bolsena); the tephrite-leucite lavas and the phonolite-tephrite ignimbrites of Sabatini Mountains (Bracciano); the leucitic-tephrites and the tephrite-phonolite ignimbrites of the Vico volcanic edifice; the sequence of leucite-nepheline lavas, pyroclastites, tuffites and pozzolanas of the Albani Hills complex. The petrologic characteristics of Campania magmatism delineate with the Roccamonfina volcanic complex latites, trachyte-phonolites, trachybasalts, leucobasanites (Campi Flegrei, neighbouring Islands and Vesuvio). Pleistocene trachytic lavas and pyroclastites, hauynites-phonolites and basalts characterize the Vulture.

The calcalkaline Tuscan-Latial magmatism and the alkaline-potassic magmatism of Latium are particularly productive from the metallogenic point of view. Widespread thermomineral springs rich in F as well as several small Quaternary base metals sulphides occurrences with fluorite, minor stibnite, cinnabar and pyrolusite, characterize the Upper Latium volcanites. Fe, Pb, Zn, Ag, Sb, Hg etc. veins are frequent in Tolfa-Cimini area, often hosted within Trias-Oligocene sedimentary sequences: Ponte S. Pietro [191] (Fiora Valley, in the Verrucano phyllites); Roccaccia-Pian Ceraso [200], Edificio del Piombo and Casa Grande (polymetallic sulphides and fluorite), Pian dell'Organo-Sacromonte [197] (barite and celestine), Monte delle Fate-Prato del Casone [203] (fluorite) in the surroundings of the Tolfa. Some other mineralisation are hosted within the volcanites, e.g., Castagneto della Trinità-Allumière [198] (cinnabar) and the lenticular bodies of alunite and caolinite of La Provvidenza-La Bianca [199] and Fosso Eri-Sasso [202] produced by the hydrothermal weathering of rhyolitic ignimbrites. Quaternary exhalative-sedimentary mineralisation (marcasite, pyrite and sulphur of solfatara) are common in the Cimini-Volsini-Vico Complex (e.g., Rovine di Ferento Sud-Macchia Grande [194], Ceriti-Manziana [201], Latera etc) and in the Albani Hills (e.g., Quarto della Solforatella [206]). Numerous fluorite with Ba and Sr carbonates and sulphates and sometimes apatite deposits occur between Rome and the Bolsena and Bracciano Lakes. They are often stratiform-lacustrine deposits, alternating within the Plio-Pleistocene pyroclastites and/or tuffites: e.g., S. Maria di Sala-Acquaforte [192], Lago di Mezzano (fluorite and alunite), Pian Aùta, Pianciano [204], Castel Giuliano, Cornazzano and Villa Santa, Farnesina-M. Mario. Lenses and thin layers of Fe and Mn oxides (mainly pyrolusite), usually alternate with clayey pyroclastites and travertine deposits, particularly frequent soutward and eastward of Bolsena Lake and westward of Bracciano Lake, e.g., Tardane, La Mola, C. Pigotti [193].

d)Uraniferous occurrences

The geochemical concentration of uranium are commonly high within the volcanites of Volsini-Cimini-Vico complex. Enrichments up to 800 ppm of U occur in various lacustrine sediments and around the hydrothermal springs and volcanic gas emissions, like Macchia Grande [194], Legarelle, La Carbonara, Pantane, Poggio di Campo, Perello (Viterbo province).

e)Industrial minerals

The leucite, typical of lavas, ignimbrites and tuffites of the Volsini, Cimini, Sabatini Mountains, Vico and Roccamonfina, locally reaches sometimes interesting concentrations higher than 20÷25%, like at Prataroni-Case Ciotti [196] (Viterbo) and Roccamonfina [223].

Kaolinite deposits, due to hydrothermal and/ or fumarole weathering of volcanites, occur at

Casale di Mezzano (Viterbo), Pantano Fragneto [219] (Caserta) and Pozzuoli. Some bentonite and perlite deposits are in Ponza Island (Le Forna [211]) and at Capo Bianco (perlite).

Bentonite and smectite layers lie within the Daunia Fm, like at Colle Pagliarone [216] and Masseria Ianiri [217] (Molise) and Vignali-Macchia di Lenza-Vetrucco [230] (Foggia).

Bituminous-asphaltic residues often fill the intensely fractured Triassic-Miocene carbonatic and calcareous-marly rocks: those of S. Domenico-Le Fornaci [207] (Frosinone), M. Coliuccio, Filettino, Veroli and Civitella Roveto are the most interesting in Latium, while, among S.Valentino, Lettomanoppello and Pratedonica [214] (Abruzzo), the most important bituminous asphaltic deposits occur in the Miocene marly limestones of Maiella.

Numerous and sometimes important lignitiferous deposits alternate within the Plio-Pleistocene terrigenous sediments (e.g., Gubbio [186], Pietrafitta-Val Nestore [187], Torgiano [188], Bastardo-Giano [189], Morgnano-Spoleto [190]) in Umbria; Ruscio-Leonessa [195] in Latium; Aterno [212] in Abruzzo; Morcone [222] in Tammaro Valley, in Campania; Mercure [235], in Lucania).

f)Coastal placers

Sands with abundant heavy minerals, mainly originated from the volcanites of Latium inland, involve long strips of the Tyrrenian coast: e.g., between Tarquinina and Ladispoli [205] (magnetite, ilmenite, hematite, pyroxenes, amphyboles, zircon, rutile, thorite etc. derived from Sabatini Mountains); between Nettuno and Torre Astura [210] (magnetite, ilmenite, hematite, rutile, zircon, monazite, thorite, uranothorite, gold, garnets, corundum, chromite, cassiterite, anphyboles, pyroxenes etc., especially from Albani Hills); between Torre del Fico and Torre S. Limato [218], near the Garigliano mouth (magnetite, ilmenite, hematite, amphibole, pyroxene, garnet, olivine, staurolite, tourmaline).

2.4.5 Mineralisation of Calabria

The Calabrian-Peloritan Arc

The metamorphic-magmatic Calabrian-Peloritan Arc (*Censi and Ferla, 1982-83; Ferla, 1982-83; Bonardi et al., 1982*) includes an Europe verging domain (Cetraro-Cosenza-Catanzaro belt - M. Gariglione Unit) and a wider Africa verging chain (Longobucco - p.p. Sila Units and the rest of Calabrian-Peloritan Arc, south of Catanzaro plain). The Africa verging chain is constituted by a metamorphic basement overthrust and overturned on its Palaeozoic volcano-sedimentary cover. The piling up of the Africa verging tectonic Units shall be pre-Variscan (*Ferla et al., 1982-83*) or Alpine (*Bonardi et al., 1982*).

The Late Variscan granitoid magmatism shows widespread intrusions in Calabria and only small bodies (Capo Rasocolmo and Capo d'Orlando) in the Peloritani Mountains.

The Volcano-Sedimentary Paleozoic series (Cambrian-Ordovician to Devonian-Carboniferous terrigenous-carbonaceous metasediments with intercalated metavolcanites) characterizes the southern belt of the Peloritan Mountains and wide areas of the Calabria: the Bocchigliero Unit (underlying the Mandatoriccio tectonic Unit), the Sila-Longobucco range and the Stilo Unit of the Serre (Bivongi) and the Aspromonte areas.

The Calabria hosts some minor polymetallic W, Mo occurrences linked to the Late Variscan granitoid plutonism and rare mineralization connected with the matamorphic basement and local limbs of ophiolites. Some sulphur, clayey and coal deposits are registered in the Miocene-Oligocene sedimentary cover.

I. Mineralisation linked to Late Variscan granitoids

Some *albite* deposits are linked to the southern Calabria plutons: Gabrielli [248] and Petti dell'Arena [249] hosted in the granites of Mt. Poro-Capo Vaticano; Fosso dell'Arena [250] in the high aluminiferous granodiorites of Mt. Pecoraro-Serra S. Bruno; others near Luzzi, Acri and S. Domenico (Sorbo).

Disseminated scheelite-molibdenite occur within granodiorites and micrograntes near Bivongi [251] and in S. Todaro-Calatria area within the phyllites at the eastern border of Mt. Pecoraro-Serra S. Bruno pluton.

Lenses and irregular bodies of pyrrhotite and/or magnetite with sphalerite, minor chalcopyrite, galena and fluorite gangue (S. Roberto d'Aspromonte [254] and Cartegì) occur at the north-western slopes of the Aspromonte, at the contact between the granites and the gneisses, amphibolites and marbles.

The Sila pluton generated various sphalerite, galena, pyrite, chalcopyrite, marcasite veins with calcite, quartz, fluorite and barite gangue (e.g., Longobucco [240]). The fluorite (Cerenzia [243]) or the barite (Fiumarella-Mastricarro [244]) predominate in some veins.

Skarn type scheelite mineralisation are linked to the contact aureole between the granodiorites and the Bocchigliero and Mandatoriccio Units rocks, as well as in southern Aspromonte within the Aspromonte Nappe. Some pneumatholitic hydrothermal stockwork veins of Zn, Pb, fluorite, scheelite are sometimes present within similar contexts.

II. Mineralisation of the Ophiolite Unitis

The sequences of argillites, siltites and calcariferous schists with pillow metabasalts, serpentinites and metaultrabasites (Sinni Valley) overlapped by graded sandstones and conglomerates (north-eastern Pollino) constitute local tongues of the ophiolitiferous unit. It hosts various minor cupriferous and some magnetite and/or chromite mineralisation linked to metabasites: the most interesting ore is the manganesiferous deposit of Mormanno [236] (pyrolusite and braunite, Fe oxides and chert/quartz), linked to a limb of clay schists and polychrome jaspers. Some small occurrences of Fe-Cu sulphides (Sangineto, Malvito, S. Agata, Cerzeto etc.) are linked to the ophiolitic tongues outcropping in the Diamante, Terranova, Gimigliano and Malvito areas.

III. Mineralisation of the sedimentary cover

The sedimentary cover includes Lower-Middle Triassic to Plio-Quaternary sedimentary series.

Some ferriferous lenses (goethite and hematite with relict pyrite, chalcopyrite, sphalerite and galena) occur at the transgressive contact between the phyllitic basement and the Mesozoic limestones at Pazzano-Stilo [252]: this is probably a weathered deposit of pyrite with minor base metal sulphides.

Some lignite seams (e.g., Agnana-Antonimina [253], Locri hinterland) intercalate within the Oligocene sequence of sandstones and clayschists, overlapping the crystalline basement. Lignitiferous seams (e.g., Conidoni-Briatico- Zungri [247], Vibo Valentia) also occur within the Tortonian clayey-arenaceous sequence.

The Gessoso Solfifera Fm (Messinian - Upper Miocene) includes, from the bottom to the top, "tripoli", limestones and evaporites. The evaporites contain various sulphur and salt mineralisation. The main sulphur deposit is Comero-Strongoli [241], that exploited a calc-sulphur stratified body embedded between "tripoli" and marls. Among the most interesting salt deposits there are Lungro [237], a salt and clay alternated layers SW of Castrovillari, and Timpa del Salto [242], a deposit 300 m thick in Neto Valley (Crotone). The beach sands of the coastal shores of the Ionian and Tyrrhenian Seas are frequently rich of heavy minerals, particularly Fe and Ti oxides. The most important placers are Rossano-Corigliano [238], at the mouth of the Crati, Cetraro [239], S. Eufemia [245] and Soverato [246].

2.4.6 Mineralisation of Sicily

The metalliferous and industrial mineral deposits of the Sicily are hosted: I) in the *Peloritani metamorphic basement*; II) in the *Gessoso Solfifera Fm* (Messinian), widely outcropping in the Sicily Central Basin; III) in the porous and cataclastic rocks of the *Ragusa Fm* (Lower Miocene-Oligocene) and the *Tellaro Fm* (Upper/Middle Miocene) in the Hyblean Mountains.

I. The *Peloritan metamorphic basement* represents the southward prosecution of the Aspromonte basement. The Palaeozoic Volcano-Sedimentary Series represents the southern belt of the Peloritani Mountains. It hosts only small mineralisation: the most interesting are pyrite ($\pm$ Cu, Zn, Pb) occurrences, linked to Silurian-Devonian black schists, and some Pb, Sb, Cu, Ag, (Hg?) sulphides-bearing veinlets skattered within the phyllite rocks.

The Mandanici Unit is typical of the Peloritani Mountains; it also outcrops in Calabrian Arc but with only small tongues, in the Cardeto Window. It includes a sequence of quartz-carbonate phyllites with alternated tuffitic and transitional-toleiitic metabasalts: three marble horizons mark the sequence.

The Aspromonte Nappe, overlapping the Mandanici Unit, is a thick sequence of high grade paragneisses, including a “variegated” alternance of marbles, Ca-silicate fels, mafic and acidic metavolcanites and minor augengneisses. The phyllite-metavolcanite zones of the Mandanici Unit are highly metalliferous (*Omenetto et al., 1988*). Numerous green tourmaline-scheelite stratiform, folded and/or mobilized ores are connected with sericite-chlorite, quartzite and quartz-phyllite horizons. Accessory apatite, pyrite, arsenopyrite, sphalerite, tethraedrite, stibnite, fluorite, rutile etc. accompany the tourmaline-scheelite, frequently mobilized in veinlets and stockwork, e.g., Tripi and Giampilieri; Vacco and Migliuso in Fiumedinisi area. High grade scheelite (wolframite) ores bodies, with ankerite and quartz gangue, lie with the transition graphite schists-paragonite marbles: the enrichment of scheelite occurs in breccias in the Tripi and south Fiumedinisi areas. Coarse grained scheelite ores occur along the shear-zone at the tectonic contact Mandanici Unit-Aspromonte Nappe in the North Fiumedinisi and Gioiosa areas.

Skarn and skarnoid scheelite mineralisation are also connected with perianathectic, magmatic and retrograde metamorphism within the Aspromonte Nappe both in the north-eastern Peloritan Mountains and southern Aspromonte *(Omenetto et al., 1988*).

The Mandanici Unit also includes: some stratiform magnetite-pyrrhotite (± Cu, Zn sulphides) ore bodies, linked to a chlorite-phyllite horizon below the Upper marbles; many stratiform, veinlet and irregular bodies of Fe, Cu, As, Zn, Pb, Sb sulphides and sulphosalts, native Au and Ag with quartz, calcite and chlorite gangue, are embedded within the phyllites of the Mandanici Unit, particularly in the Fiumedinisi, Nizza di Sicilia and Alì areas. Among the most important are those of Bafia, outcropping between Pomia and Carbone Valleys, and of Tripi [255]; some quartz and fluorite veins with abundant sphalerite and argentiferous galena; minor Fe-Mn carbonates and oxides, barite and accessories polymetallic sulphides and sulphosalts, frequent at the top of the lower marble horizon.

The metamorphic basement also hosts several mineralisation produced by hydrothermal and thermometamorphic Late Variscan magmatism outcropping with small bodies at Capo Rasocolmo and Capo d’Orlando. Various vein and lenticular pegmatitic bodies of feldspar (e.g., Mongiove [256]) occur within the high grade metamorphic Unit, near Patti.

II. The *Gessoso Solfifera Fm* of the Central Sicily Basin is characterized by sedimentary and p.p. magmatic series deposited after the Tortonian tectonic phase. Limestones, marlstones, clays, sandstones and conglomerates predominate at the base (Upper Tortonian – Lower Messinian), followed by marlstones with tripoli, evaporitic limestones, laminar and selenitic gypsum, salts (Gessi di Cattolica). The salt deposits are cut by an unconformity, overlapped by the sequence of laminate gypsum and selenite (Gessi di Pasquasia), covered by terrigenous deposits, gypsarenites, marlstones, limestones (Upper Messinian). Salt and sulphur deposits abound in the “Central Basin”.

Most of *salt deposits* occurs within a 20 km wide belt, extending from Porto Empedocle to Nicosia; some of them touch thickness of hundreds of meters due to refolding. They generally include salt layers with intercalate anhydrite, followed upward by halite and polihalite, K-Mg salts and clays bands on top. The main deposits are Petralia [257], Coffari-Muti [260], Ranieri [267], Cattolica [270], Realmonte [275], Racalmuto-Montedoro [272]. The K-Mg salts (kainite, carnallite and sylvite) characterize the Pasquasia [265], S. Cataldo [269], Racalmuto-Montedoro [272], Corvillo [258], S. Caterina [261] etc. deposits.

The *sulphur deposits*, due to the bacterial-gypsum-hydrocarbon interaction, are usually connected with gypsiferous vacuolated limestones (“Perciuliato”). The sulphur mineralisation are very numerous below the main gypsum horizons, especially along the synclinal and/or anticlinal structures. The most important are Zimbalio-Giangagliano [259], Gessolungo-Juncio [262], Trabonella [263], Giummentaro [264], Floristella [266], Cozzodisi [268], Stretto Cuvello [271], Gibellini [273], La Grasta [274], Ciavolotta [276], Lucia [277], Muculufa [278].

III. The Ragusa Fm, outcropping in the Hyblean region (Siracusa-Ragusa), includes calcareous arenites and marlstones at the base (Oligocene-Lower Miocene); marlstones and marly limestones with intercalated volcanites on top (Middle-Upper Miocene).

The northern slopes of Hyblean Mountains are constituted by biocalcarenites (Palazzolo Fm) and Etna's volcanic products (Pliocene-Holocene). Lots of *asphaltiferous-bituminous* impregnate deposits locally occur within the porous sedimentary rocks of Ragusa Fm and of Tellaro Fm. They represent the residual products of hydrocarbons risen from the deep oilfields, well-known in the Hyblean area along the fractures and faults system and porous rocks. The main asphaltiferous-bituminous deposits are those of Streppenosa-Castelluccio [279], Tabuna [280], Vizzini and Licodia Eubea area.

Some wide clay deposits also occur in Sicily: ceramic clays near Termini Imerese (Palermo), bentonite near Racalbuto (Enna), caolinite in the Lipari Island (Messina).

Carbon dioxide exhalations occur near the Naftia Lake (Catania).

2.4.7 Mineralisation of Sardinia

Many ore and industrial mineral deposits occur within the Cambrian-Holocene Sardinia rocks.

I. Mineralisation linked to the Cambrian Units

The Cambrian is characterized by shallow sea and partly lagoon sediments in SW Sardinia. They include the "Arenarie F.", arenaceous-clayey rocks with alternate limestones; the "Metallifero Fm", a sometimes heteropic sequence of grey "dolomie rigate" and "calcari ceroidi", alternating with calcariferous schists and tuffites; the "Scisti di Cabitza Fm", with predominant clayey schists. The Cambrian Units host different stratabound ore deposits. Highly *oxidized pyritic-zinciferous*, with minor Pb deposits (Fe-ochres and calamine products) occur below the "Metallifero Fm" and within the "Dolomia rigata": e.g., Campo Pisano-Funtana Perda-Seddas Moddizzis group [336] (Iglesiente); Candiazzus [329] and Antas (Fluminese). Pb and Ag are richer in the upper part of the sequences, as at Monteponi-S.Giovanni-M.Agruxau [336], Nebida-Masua-Acquaresi [334], Buggerru [330], Marganai [331]. Significant concentrations of Cu mark the Zn, Pb, Ag deposits of the Sulcis: e.g., Rosas-Truba Niedda-Sa Marchesa [345] and Teulada [350]. Several bodies of barite with minor fluorite and galena occur in Sulcis-Iglesiente areas: e.g., Barega–Arcu Sa Gruxi [337], Corona Sa Craba-Barbusi-Sa Punta Peppixedda [341], Mont'Ega [344], Giuenni-Concas de Sinui-Orbai-P. Filippeddu [342; 343] and Su Benatzu [349]. Barite with minor galena, sphalerite and hematite (e.g., Arenas-Tiny [328]), fills some paleokarstic structures of the Cambrian-Ordovican unconformity.

After the Caledonian orogenic phase and the Upper Silurian erosion, limestones, sandstones, claystones, acidic and basic volcanites deposited during the Devonian-Carboniferous. Sb and W bearing mineralisation (southern Sardinia) and some ferriferous deposits (Nura, NW Sardinia) occur within this sequence.

II. Mineralisation connected with the Late Variscan magmatism.

An imposing granitoid magmatism (286 ± 2 Ma - *Dini et al., 2005*) involved various wide Sardinia areas at the end of the Variscan tectonic metamorphic event, producing lots of important ore deposits.

Several feldspatic *pegmatitic bodies* occur in Nuorese (Valle S. Marco-Liscoi) and in Sulcis (Capoterra and Sarroch).

Pneumatolitic Mo, W, Sn, Ni, Co deposits: molibdenite and quartz deposits are Su Seinargiu [348] (Sulcis), Perd'e Pibera-Perda Lada [326] (Arburese), Oschiri [286] and Monti [287] (Logudoro); scheelite and wolframite occur within the Quirra-Perda Maiori [315] deposit (Arburese); the stanniferous deposits of Perdu Cara-M. Mannu [332] and various occurrences with Ni, Co solfoarsenides, arsenopyrite and Pb, Zn, Cu, Ag sulphides are characteristic of the Arburese–Fluminese region.

Pyrometasomatic deposits, sometimes with scheelite and Fe oxides and sulphides, are frequent in Sulcis and Gerrei region. Ferriferous thermomethamorphic deposits (magnetite, carbonates, silicates and sometimes sulphides) occur in Silurian schists, e.g., in Nurra area (Canaglia [282]), in Barbagia (Giacurru-Roccia Perdabila [304] etc.) and in Sulcis region (S. Leone [347]). The talc and steatite deposits in Nuorese (Sa Matta-S. Francesco-Predas Biancas [299]) are probably due to the thermomethamorphic and hydrothermal alterations on Paleozoic rocks.

Various irregular ore bodies set at the contact between granite plutons and wall rocks. The main are Sa Lilla-Parredis [321] in Gerrei, Correboi [301] in Barbagia region, Perda S'Oliu [324] in Fluminese and Arzana [305] in Ogliastra; their typical paragenesis includes galena, sphalerite, chalcopyrite, pyrite, pyrrothite and Fe oxides; also abundant arsenopyrite occurs sometimes (e.g., Baccu Locci [322] in Gerrei and Scivu [323] in Fluminese), or fluorite (e.g., S. Lucia [325], Su Zurfuru-Perda Niedda-Is Murvonis [335]). Mainly cupriferous deposits (chalcopyrite, sphalerite, galena, magnetite etc) are Funtana Raminosa [307], at the contact between Silurian metamorphic rocks and Late Variscan porphyritic domes and dykes, and Talana [302], with granites.

Hydrothermal vein type, lenticular or epigenetic "columnar" mineralisation are abundant and often very important within the Devonian-Silurian and sometimes Cambrian formations. They are generally constituted by Ag-galena, Cd-sphalerite and pyrite with quartz, siderite, ankerite, minor fluorite and barite gangue. The wide Montevecchio-Ingurtosu-Gennamari [316] swarm of veins extends NW of the Arburese pluton. Similar deposits are Sos Enattos and Guzzurra [295] in Nuorese, Su Elzu [292] in Logudoro, Argentiera [283] in Nurra, S'Ortu Becciu [327] in Sarrabus and Genna Olidoni [303] in Ogliastra. The veins are sometimes characterized by dominant fluorite, barite and minor Pb, Zn, Ag, etc. sulphides: e.g., in Gerrei (Silius-Bruncu Mannu-Genna Tres Montis [319]), in Campidano (Sardara [312]), in Sarrabus ("Argentifero" [333], Burcei [338], M. Arbu [339]), in Sulcis (M. Calcinaio), in Barbagia (Correboi and Gennarule [301]), in Logudoro (Punta Lanzinosa), in Sarcidano region (Castello Medusa [306]), Bruncu Molentinu (Sarrabus), Santoru [314], Gianna Aidu Entu [291] in Baronia, Tsurufusu [311] in Arburese and, also with chalcopyrite, Talentinu [310] in Quirra. A vein with dominant siderite occurs at Salaponi [317], in Arburese.

Some swarms of *auriferous veinlets* (arsenopyrite with minor pyrite, galena, stibnite and gold) cut the Silurian meta-volcanosedimentary series in M. Ollasteddu, Flumineddu, Baccu Locci, Baccheruta etc. areas, Northern of Villasalto – S. Vito in SE Sardinia (*Dini et al., 2005*). The auriferous veinlets, ~260 Ma dating, are hosted within Late Variscan fractures, coeval with the calcalkaline basaltic dikes. The same meta-volcanosedimentary series hosts some Sb and sometimes W (scheelite) stratabound and vein type deposits, e.g. Genna Ureu [313] and Ballao-Su Suergiu [320].

III.Mineralisation of the cover sequences

Several minor uraniferous occurrences are skattered in Sulcis (Capoterra).

The post Variscan erosional phase was interrupted by the Late Carboniferous-Permian continental deposition of clastic sediments, acidic volcanites and lacustrine pelites with some coal seams (e.g., anthracite of Corongiu [308] in Barbagia).

The marine sedimentation started in Nurra region, during the Trias, with limestones, marlstones and evaporites, and spread to the rest of Sardinia, during the Jurassic. The "Serie dei Tacchi" marks the transgression in the Barbagia and Sarcidano: this is constituted by a conglomeratic-clayey unit with underside hematite-goethite lenses and layers ("Ferro dei Tacchi") and upward bentonite, kaolinite and refractory clays, exploited near Laconi and Nurallo (e.g., Funtana Mela-Corona Arrubia [309]). Some Pb, Zn stratabound occurrences (e.g., Nurai-M. Albo and Bosano) lie within the Dogger calcareous-dolomitic sequence in the Nuoro province.

After the Middle Cretaceous uplift and the carbonatic platform erosion, some bauxite (e.g., Olmedo [284] in Nurra) and ferruginous deposits (eastern Sardinia) filled the karst cavities.

Wide lignite seams of "Bacino del Sulcis" [340], Cixerri Valley and Narcao lie within the Eocene lacustrine and shallow sea sediments.

The Oligocene-Pleistocene Alpine extensional tectonics promoted the eruption of abundant trachy-andesitic and basaltic volcanites (NW Sardinia). In the central belt of the island trachy-andesitic lavas alternate with continental terrigenous deposits, overlapped by Miocene transgressive marlstones, sandstones, organogenous limestones and tuffites, followed by Pliocene coastal and terrigenous lagoon deposits.

The Tertiary volcanites generated some cupriferous (± Pb, Zn etc.) deposits (Calabona [293] in Logudoro area, Torpè-Canale Barisone [290] and

Capo Marargiu-Bosano [297] in Alghero area) and various manganesiferous mineralisation at Chiaramonti [285], Padru [289], Montresta [296], Tres Nuraghes [298], Isole S. Pietro [346] and S. Antioco. A hematite vein with quartz occurs in M. Ferru [300].

The pervasive hydrothermal-geothermal convective cells within the Tertiary volcanites produced several large bentonite clays deposits (e.g., Pedra de Fogu [288], Meilogu and Mt. Oliena in Sulcis) and kaolinite (e.g., Castello di Bonvei-Rio Badu de Ludu [294], Serrenti-Furtei in Campidano, Mt. Porceddu [318] etc.). The kaolinite bodies are characterized by widespread disseminated pyrite grains and by local silicification pipes, rich in pyrite, sulphides and sulphosalts of Cu, As, Sb, Zn etc., sometimes highly auriferous and argentiferous (e.g., Furtei).

An important perlite deposit lie witihin the Mt. Arci volcanic complex (Oristano area).

The Quaternary sediments filling the Fossa del Campidano host some eluvial barite deposits and various magnetite, ilmenite, cassiterite etc. placers.

2.5 Human activities

2.5.1 Industry

Initially concentrated in the vicinity of large cities, busy ports or sources of energy and raw materials, with the declining importance of agriculture, industry moved nearer smaller centers with adequate infrastructures, before spreading right into the country competing with agriculture for land and changing the face of the countryside.

However this is not the case in every part of the country, and in fact in both the North and South the most highly industrialized and urbanized areas are mainly in the densely populated regions. The traditional industrial triangle (Lombardy-Liguria-Piedmont) has now spread to include practically the whole of the Po Valley (N31E04, N31E05, N31E06, N31E07, N30E04, N30E05, N30E06, N30E07), with highest concentrations along the foot of the Prealps, Preapennines and the Adriatic coast (Trieste, Marghera, Ravenna etc.) as well as the large alpine valleys (Adige, Valcamonica). Industry in Tuscany and Umbria (N29E06, N29E07, N29E08), is concentrated on the plains near the Arno and Tiber river basins; in the Marche region it spreads over the whole region, scattered throughout the network of valleys. Industry in Latium and Abruzzo (N29E08, N28E07)is concentrated in the intermontane valleys and along the coasts as well as round the main cities. The distribution of industry in Southern Italy, however, follows an irregular pattern, with excessive concentration in certain coastal zones (such as the Caserta-Naples-Caserta belt) (N28E08) or in a number of geographically favorable positions (the Bari-Taranto-Brindisi triangle) (N28E09, N28E10, N27E10, N27E11). Industrial areas on the two main islands of Sicily and Sardinia are generally peripheral and close to harbors.

The structure of industrial production and the service industries is characterized by the prevalence of small and medium-sized companies, employing, however, only 70% of the workforce, 30% being monopolized by large companies.

The country's economic revival in the immediate post-war period was essentially sustained by the development and expansion of the basic industries, particularly the steel industry, itself conditioned by the importation of raw materials such as ores, scrap iron and coal.

Mechanical engineering production is extremely varied and includes car-manufacture, shipbuilding, aerospace, as well as the manufacturers of simple tools. Component manufacturing is also well developed and closely linked to companies producing durable goods not easily classified in any one sector (for example, non-metallic materials used in the car industry: rubber, glass, plastics etc).

The chemical industry is closely linked to mining and quarrying and uses prevalently liquid (oil) and gaseous hydrocarbons (methane) from which an immense range of materials is produced (rubber, plastics, synthetic resins, synthetic fibres, fertilizers etc.), apart from traditional utilization like heating fuel, engine fuel etc.).

Textiles are the oldest Italian industry, widespread throughout the peninsula and frequently linked to the rural community which provided plentiful low cost labor.

Other specific sectors include the food industry, the building industry, the manufacture of paper and allied materials, tobacco (utilizing some national raw materials), footwear, leather and rubber articles, while jewellery and hand-crafted products such as pottery, glass, wood and wrought-iron, provide employment for large numbers, with a generally standardized output for the tourist trade.

2.5.2 Agriculture

In spite of the variety of morphological condi tions and the extent of mountainous terrain, only 12% of Italian territory (buildings, roads, wasteland, waters etc.) is actually unproductive. Apart from the large extent of forest (c. 21%), abandoned and rough ground and service areas (c. 9%), the surface effectively destined for annual or stable permanent cultivation amounts to little more than 58% of the entire country.

The variety of climatic and morphological conditions together with the heterogeneous nature of the soil are factors which have mainly influenced, together with the force of tradition, agriculture in Italy. Wheat and maize are the major cereal crops though barley is now increasingly grown, while rice is a specialized crop exported in large quantities. Olives and citrus tree fruits are the commonest and best known which, together with vineyards, make the country a leader in this sector in the Mediterranean and in Europe. Other fruit is also important, particularly apples and peaches, and sugar beet is a crop for industrial utilization, supplying the sugar refining industry. Horticultural produce, most importantly tomatoes, is widely cultivated. Floriculture is now expanding rapidly, favored by the mild climate and widespread greenhouse cultivation. Certain other characteristic products, e.g. mushrooms and truffles, are found in significant quantities, as well as wild strawberries, raspberries and the like, now also grown under cover. Of localized importance is the product of certain trees such as chestnut and hazel, whose fruits are utilized principally by the confectionery and bakery industries.

Livestock breeding is a traditional agricultural activity. Methods are somewhat backward except in the Po Valley, and the contribution to national demand for meat is insufficient. Certain old customs, such as transhumance in the Apennines, are now dying out. However, in the North, high altitude alpine pastures are still grazed in the summer. Pig breeding and poultry are presently expanding but the once large number of horses and other pack animals has dropped sharply. Quality animal products are salami and cheese, though imported raw materials are also utilized in their production. In spite of the extensive coastlines and ancient traditions, the fishing industry in Italy is of relatively minor importance.

2.5.3 Energy and mining resources

With a few exceptions the geological characteristics of Italian territory do not comprise high deposits of industrially useful mineral resources, and only four regions (Sardinia, Tuscany, Sicily and Trentino-Alto Adige) (N31E07, N27E05, N27E06, N26E09) have a mineral content of any interest. The only fuel found in any quantity particularly in the Po Valley and in the nearly Adriatic off shore, is natural gas (methane) though there is consistent exploitation of geothermal resources. There is widespread extraction of lithoids and incohesive sediments (gravel, sand and clay) from alluvial plains; numerous quarries are scattered throughout the country, sometimes responsible for ruining the landscape and disturbing the stability of sloping ground. Considerable use is also made of underground waters, both thermal and mineral.

The lack of fossil coal led to the building of a number of hydroelectric power stations last century, mainly in alpine valleys, though also in several sites in the Apennines. More power stations were later built in various other regions. After the last war, however, industrial expansion had to utilize power generated by coal or hydrocarbon power stations. At present a quarter of the electricity produced is obtained from water resources and three quarters from thermal sources. The few nuclear power plants in the Po plain and Latium, were closed several years ago.

What is certain, however, is that present energy production cannot cover domestic requirements, and it is necessary to import electricity directly from transalpine countries.

For energy purposes, Italy is obliged to supplement its shortage of hydrocarbons by large-scale importation to supply the numerous refining centres sited generally close to the principal ports. Hydrocarbon supplies are also channeled by oil and gas pipelines from Europe, Russia and Africa.