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Lithostratigraphy of Sicily

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Foreword

The extended, well-documented and richly illustrated monograph dedicated to *Lithostratigraphy of Sicily*, written by Luca Basilone from the University of Palermo, deserves a special presentation. It displays the results of over ten years of fieldwork carried out under the expert and careful guidance of Raimondo Catalano and from related detailed sedimentologic, micropaleontologic and microfacies analysis. The work is pertinent in particular to several geological sheets of the new geologic map at the scale 1:50,000 of the Italian CARG project, but it has a much broader context, that extends well beyond the sheets boundaries.

Indeed, Sicily, the largest island of the Mediterranean, is situated just in the middle of this small ocean basin that is surrounded and crossed by a series of mountain ranges created during the Alpine orogeny. In terms of plate tectonics, Sicily is dissected by a W-E-directed plate boundary that separates the two major plates Eurasia and Africa, the latter subject to a counterclockwise rotation.

Collisional mountain ranges are developed on the northern border of the island and terminate towards ENE with the Peloritani Mountains (Calabrian arc with a metamorphic basal unit). Westward, the complex chain is SSE vergent and displays a thickness of up to 15 km. Three units are distinguished, as follows: Peloritani units, Sicilidi units and Maghrebian units. The collision is related to the Alpine orogeny and is Paleogene–Miocene in age. The western Mediterranean (remnant of the Mesozoic Tethys) was entirely consumed ("lost ocean") after the Alpine orogeny, and the Balearic basin was created by the counterclockwise rotation of the Corsica/Sardinia block. This happened in late Oligocene/early Miocene time. The counterclockwise rotation of the Italian peninsula initiated during the Messinian salinity crisis and is still active today.

But well before the conceptual model of plate tectonics was formulated in the late 1960s of last century, the rich fossil faunas of various ages attracted the attention of local palaeontologists, first of all Gemmellaro (from 1872). The existence of the highest active volcano in Europe was another strong attraction of Sicily for geologists and volcanologists even in the early days of science. Finally, mining geology with special reference to the exploitation of the Gessoso–Solfifera Formation played an important role starting from the second half of the eighteenth century (Mottura, 1871, Baldacci, 1886) and, more recently, are documented by the prominent work of Ogniben (1957) and Decima (1975).

Oil exploration started in Sicily during World War II, soon after the American troops disembarked near Gela on 10 July 1943. Gela proved to be an important oil field, and the influence of Hollis Hedberg, who was vice-chair of Gulf Oil Co. at that time, is strongly felt in the modern, practical approach to lithostratigraphy (Schmidt di Friedberg, 1964–65), predating the publication of the International Guide of Stratigraphic Nomenclature. Meanwhile, structural geologists concentrated their efforts in deciphering the northern chains (Broquet, Mascle, Caflisch) where richly fossiliferous Mesozoic successions are exposed and document important facies changes.

A new interest in Sicilian geology derived from the first deep-sea exploration of the Mediterranean by the R/V GLOMAR CHALLENGER in 1970 and the unexpected discovery that evaporites quite similar to those outcropping in Sicily (Gessoso–Solfifera Formation) were present in the sub-bottom of the Balearic, Tyrrhenian, Ionian and Levantine basin, directly underlying the Trubi formation. As a follow-up of the discovery, a conceptual model for a deep-sea desiccation model was formulated and the "Messinian salinity crisis" became a major subject of multidisciplinary, interdisciplinary, high-resolution multinational researches that greatly contributed to improve the late Neogene stratigraphy notwithstanding the inherent difficulties deriving from the complicated geodynamic situation. Indeed, the investigations carried out on the outcrops bordering the Sicily channel from Capo Bianco through Capo Rossello to Falconara and Gela originated astrocyclostratigraphy (of Hilgen, 1991 and the Utrecht school) and are considered the template for the Pliocene timescale (MB. Cita and colleagues). But some aspects of the model (s) are still controversial, after over forty years and over 1000 publications, as the role and precise location of the sills separating the various subbasins, the timing of the desiccation phase, the speed of the final filling, the source of the "lago mare".

In the monograph compiled by Luca Basilone 71 formations are described, of which 43 have already been formalized. Ten are emended in the present paper, and ten more are proposed as new. The seven sinthems follow the usage adopted by CARG for the sediments that represent the youngest deposits that cover the substrate, are non-marine in origin, are usually unfossiliferous and thus difficult to date (as alluvial fan, beach rock, cemented debris, eluvial deposits). Sinthems in principle should be bounded by erosional surfaces of regional significance.

The lithostratigraphy of the Sicilian rocks described by Luca Basilone is based on outcrops and also on subsurface data derived by borehole stratigraphy calibrated by the interpretation of seismic reflection profiles.

The monograph is open to new and future integrations useful to improve our knowledge of the Sicilian geology.

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Preface

The paper introduces the fundamentals of the lithostratigraphy of Sicily, as acquired from recent researches. This note aims at illustrating stratigraphic terminology, the geological lexicon and the main stratigraphic subdivisions that are not familiar to Sicilian geologists.

The work carried out consists in a series of sheets describing the main features of Sicilian lithostratigraphic units. Each of the 77 worksheets describes the lithological characteristics, sedimentological and laboratory features, thickness, depositional environments and regional geographic distribution of the Sicilian formations according to the standard stratigraphic procedure and nomenclature rules provided by the International Commission on Stratigraphy (ICS).

Most of the many previously defined formations are revised and amended here, and several new formations are proposed for their formalization. The seven systems follow the usage adopted by Carg for the sediments that represent the youngest continental and marine deposits that cover the substrate that are bounded by erosional surfaces of regional significance.

The description of the units is based on data collected during recent years through the analysis of several sedimentary successions outcropping in Sicily and by the reinterpretation of hydrocarbon exploration well logs. Lithostratigraphic methods, facies analysis and physical stratigraphy accompanied by biostratigraphy and numerical age-dating coming from the literature have been used to define the outcropping carbonate and terrigenous rock bodies. The acquisition and elaboration of the stratigraphic data have been also integrated with information obtained from a careful review of literature existing on stratigraphy, lithostratigraphy, palaeontology and tectonics since the late nineteenth century.

In the present paper, the rocks outcropping along the large belt extending from the North to the South of Sicily, as represented in the large-scale field map provided in Fig. 1.1, are schematically illustrated. A general background feature has been summarized based on the recently available stratigraphy of the Sicilian Fold and Thrust Belt (FTB) and its foreland and is illustrated in the schematic diagrams of Figs. 1.6, 1.7, 2.1, 2.2, 2.7, 2.22 and 2.72, which show the lateral (heteropic)-to-vertical relationships of the Permo-Triassic clastics, the Mesozoic–Paleogene carbonates and the Miocene–Pleistocene clastic–evaporite–carbonate deposits. These schemes are supported by recent biostratigraphic and chronostratigraphic studies developed in Sicily. Furthermore, a conceptual scheme (Fig. 2.97) that shows the geometric relationships of the Quaternary marine and continental deposits, recently defined as unconformity-bounded stratigraphic units (UBSUs), is also presented.

Sicilian successions consist of carbonate and clastic deposits spanning the Permian-to-Quaternary time interval and can be subdivided into two main rock assemblages. The Palaeozoic-to-Palaeogene clastics and carbonates represent the sedimentary cover of the original ancient passive continental margin (i.e. African margin) of the "Mesozoic Tethyan realm". After the detachment from their basement, the geological bodies were deformed and are, at present, exposed in the Sicilian FTB to form a stack of tectonic units. The Miocene-to-Pleistocene rocks assemblage, consisting of clastic, evaporite and carbonate deposits, represent the sedimentary cover of the thrust-top basins developing during the orogeny phases and forming the present Alpine collisional continental margin. Finally, the Pleistocene–Holocene rocks assemblage, consisting of marine and continental deposits, fills the basins that are mostly located in the northern Sicily coastal belt and its offshore. They were formed in an extensional regime related to the opening of the Tyrrhenian Sea.

Palermo, Italy Luca Basilone

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Contents

*New units

°Amended units

Synonyms

AB 4	Enna marls
Ancient flysch	Mufara Formation
Amerillo unit	Amerillo Formation
Arenaceous-glauconitic Lower Miocene	Corleone calcarenites
Barbara and San Cataldo unit	Terravecchia formation
Barracù formation	Amerillo Formation
Bellolampo limestone	Inici Formation
Biancone Veneto	Lattimusa
Blue clays	Monte Narbone Formation
Bluish clays	Enna marls
Bonifato formation	San Cipirello marls
Bonifato pp formation	Corleone calcarenites
Brancaleone formation	*Exogira* marls
Busambra member	Lattimusa
Butera formation	Agrigento Formation
Calabianca unit	Lattimusa
Calcare Massiccio	Inici Formation
Calcareous molassa post nappe	Terravecchia formation
Calpionellid limestone	Lattimusa
Carnian flysch	Mufara Formation
Casale limestone	Inici Formation
Carrozza Formation	Baucina Formation
Cefalù Formation	Pellegrino Formation
Cenomanian African facies	*Exogira* marls
Cherty limestone	Scillato Formation
Chiarastella unit	Scillato Formation
Chiaromonte formation	Lattimusa
Clayey-arenaceous flysch	Lercara complex
Clayey limestone unit	Mufara Formation
Clays and brown sandstones	Numidian flysch

Collesano Formation	Numidian flysch
Concretionated limestone	Calcare di base member of Cattolica Formation
Coral limestone	Baucina Formation
Coral and sponge biolitites	Cozzo di Lupo Formation
Cozzo Terravecchia formation	Terravecchia Formation
Crystalline limestone	Inici Formation
Cuminello formation	Caltavuturo Formation
Ellipsactinie and *Nerinea* biolitites	Piano Battaglia reef limestone
Entrochi limestone	Crinoidal limestone
Eo-miocene flysch	Caltavuturo Formation
Facies astiana	Agrigento Formation
Facies piacenziana	Monte Narbone Formation
Flysch antico	Lercara complex
Fusulinid limestone	Sosio limestone
Garbata formation	Tavernola Formation
Gela formation	Sciacca Formation
Gessoso–Solfifera Formation	Gessoso-solfifero group
Giardinello formation	Caltavuturo Formation
Giardini Formation	Buccheri Formation
Gibellina formation	Ciminna Formation
Globigerina clays	San Cipirello marls
Grey and black cherty limestone	Scillato Formation
Gypsum series	Gessoso-solfifero Group
Halobids limestone	Mufara Formation
Hybla member	Hybla Formation
Jurassic detritic-organogen limestone	Inici Formation
Kungurian Flysch	Cozzo S Filippo sandstone
Leptaena beds	Crinoidal limestone
Lower and upper scaly clays	Varicoloured clays
Lower Scillato formation	Mufara Formation
Marly limestone unit	Caltavuturo Formation
Megalodontid limestone	Capo Rama Formation
Mesozoic calcareous-dolomitic reef	Cozzo di Lupo Formation
Messinian evaporites	Gessoso-solfifero Group
Messinian reef of Salemi	Baucina Formation
Mirabella formation	Scillato Formation
Monte Balatelle formation	Amerillo Formation
Monte dei Cervi formation	Crisanti Formation
Naftia formation	Sciacca Formation
Nerinee and Diceratids limestone	Pizzo Manolfo limestone
Norian-Rhaetian dolostone	Fanusi Formation
Olistostroma	Varicoloured clays

Olistostroma Napola	Terravecchia Formation
Oolitic limestone	Inici Formation
Palma formation	Trubi
Permian flysch	Cozzo S Filippo sandstone
Permian of Sosio	Sosio limestone
Pettineo formation	Reitano Formation
Pietra di Salomone limestone	Sosio limestone
Pizzo Canna limestone	Piano Battaglia reef limestone
Portella Arena formation	Mufara Formation
Radiolaritic and calcareous-spongholitic formations	Crisanti Formation
Recattivo reef limestone	Landro member of the Terravecchia formation
Red Unit	Buccheri Formation
Reef Cretaceous limestone	Pellegrino Formation
Reefoid unit	Cozzo di Lupo Formation
Reefoide unit pp	Inici Formation
Rhaetian dolostone	Fanusi Formation
Rosignano limestone	Baucina Formation
Rosso Ammonitico	Buccheri Formation
Rudistid limestone	Pellegrino Formation
Saheliano cycle deposits	Terravecchia Formation
San Calogero Flysch	Cozzo S Filippo sandstone
Scaglia	Amerillo Formation
Scaly clays	Varicoloured clays
Segesta formation	Sciacca Formation
Siliceous limestone unit	Crisanti Formation
Siliceous schists and calcareous intercalations	Crisanti Formation
Siracusa formation	Inici Formation
Solfifera formation	Gessoso-solfifero group
Sosio Megablocks	Sosio limestone
Stromatolitic dolostone	Sciacca Formation
Taormina formation	Sciacca Formation
Tithonian detritic-organogen limestone	Piano Battaglia reef limestone
Tortonian parautocton	Castellana Sicula Formation
Tortonian semialloctonhous	Castellana Sicula Formation
Trapani and Alcamo limestone	Bonifato Formation
Triassic limestone	Cozzo di Lupo Formation
Trias dolomitized limestone	Scillato Formation
Troina-Tusa flysch	Troina sandstone
Troina formation	Troina sandstone
Troina sandstone formation	Troina sandstone
Trubi member	Trubi
Tufi palombini	Trubi

Tufo calcareous of the Congerie Zone	Pasquasia Formation
Tufo fossiliferous and yellow sands	Baucina Formation
Tufo with Pecten	Baucina Formation
Ultradetritic zone	Pellegrino Formation
Upper dolostone	Fanusi Formation
Upper Miocene (pp)	Terravecchia Formation
Upper Triassic carbonate platform deposits	Sciacca Formation
Vacuolar-organogen limestone	Baucina Formation
Variegated clays	Varicoloured clays
Villagonia formation	Inici Formation
Vizzini pp formation	Sciacca Formation

Acronyms

AFL	Capo Plaia synthem
AMM	Amerillo Formation
AMM_m	Calcareous megabreccias of the Amerillo Formation
AMM_a	Red scaglia of the Amerillo Formation
AMM_b	White scaglia of the Amerillo Formation
AMM_d	Ichnites limestone of the Amerillo Formation
AUC	Calcarenites and marls of Sauci
AVF	Varicoloured clays
AVF_a	Exogyra marls
AVF_b	Caprinid breccias
β	Basalts
BAU	Baucina formation
BAU_a	*Porites* reef limestone of the Baucina formation
BAU_b	Forereef limestone of the Baucina formation
BAX	Bauxites of Spinasanta
BCH	Buccheri Formation
BCH_1	Lower Rosso Ammonitico member of the Buccheri Formation
BCH_2	Radiolarite member of the Buccheri Formation
BCH_3	Upper Rosso Ammonitico member of the Buccheri Formation
BCO	Monte Bosco formation
BLC	Marly arenaceous Belice formation
BLT	Polisano synthem
BON	Bonifato formation
CAL	Caltavuturo Formation
CAL_a	Nummulitid breccias of the Caltavuturo Formation
CCR	Corleone calcarenites
CDR	Brachiopod limestone
CII	Ciminna formation
CIP	San Cipirello marls

CZP	Cozzo di Lupo formation
CRI	Crisanti Formation
CRI_1	Radiolarite member of the Crisanti Formation
CRI_2	*Ellipsactinia* breccias member of the Crisanti Formation
CRI_3	Spongholitic member of the Crisanti Formation
CRI_4	Rudistid breccias member of the Crisanti Formation
CTI	Pizzo Manolfo limestone
FRM	Capo Rama formation
FUN	Fanusi formation
FYN	Numidian flysch
FYN_2	Portella Colla member of the Numidian flysch
FYN_5	Geraci Siculo member of the Numidian flysch
GS	Gessoso-solfifero group
GPQ	Pasquasia Formation
GPQ_1	Gessarenites member of the Pasquasia Formation
GPQ_2	Marly gypsum member of the Pasquasia Formation
GPQ_3	*Congerie* limestone member of the Pasquasia Formation
GPQ_4	Fanglomerates member of the Pasquasia Formation
GPQ_5	Arenazzolo member of the Pasquasia Formation
GTL	Cattolica Formation
GTL_1	Calcare di base member of the Cattolica Formation
GTL_2	Selenitic member of the Cattolica Formation
GTL_3	Salt member of the Cattolica Formation
GRT	Gratteri formation
HIO	Mischio
HYB	Hybla Formation
INI	Inici Formation
IMR	Imera synthem
ITO	Marabito limestone
LER	Lercara complex
LER_a	Cozzo San Filippo sandstone
LER_b	Sosio limestone
LTM	Lattimusa
LUO	Monte Luziano formation
MCD	Crinoidal limestone
MCD_a	Altofonte breccias
LEG	Pellegrino formation
MUF	Mufara Formation
MRS	Marsala synthem
PNB	Piano Battaglia reef limestone
PNB_a	Reef lithofacies of the Piano Battaglia reef limestone
PNB_b	Forereef lithofacies of the Piano Battaglia reef limestone
POZ	Polizzi Formation
RDE	Cardellia marls

REI	Reitano Formation
RFR	Raffo Rosso synthem
RND	Crinoidal limestone
SCT	Scillato Formation
SIA	Sciacca Formation
SIC	Castellana Sicula formation
SIT	Barcarello synthem
SNP	Buonfornello synthem
SOR	Monte Soro flysch
TAV	Tavernola Formation
TAV_a	*Lucina* limestone of the Tavernola Formation
TRB	Trubi
TRB_1	Lascari member of Trubi
TRP	Tripoli
TRV	Terravecchia Formation
TRV_1	Conglomerate member of the Terravecchia Formation
TRV_2	Sandstone member of the Terravecchia Formation
TRV_3	Pelitic member of the Terravecchia Formation
TUT	Tusa tuffites
VSI	Valdesi formation

Chapter 1
Introduction to the Geology of Sicily

Abstract This introductive section regards a synthetic description of the regional geological setting of the Sicily island. The main stratigraphy and regional distribution of the Sicilian rock units and the paleogeography and paleo-tectonics of the Permo-Mesozoic carbonates is included. Furthermore, an overview on the stratigraphic classification principles is provided to facilitate the reader in understanding the terminology used in the main body of text.

Sicily, located between the Calabrian Arc and the chains of North Africa is considered a key area for an understanding of the very complex geological history of the Central Mediterranean. It is characterised by different rocks, a large variety of sedimentary sequences, volcanism and tectonic structures developed during the Paleozoic–Quaternary time interval (Fig. 1.1). Metamorphic, igneous and sedimentary rocks pertaining to different geological domains (Europe, Africa and Tethys) and widely outcropping in Sicily have promoted several geological research projects since the end of the 1800s, which have had a strong impact on the description and definition both of the Sicilian regional geological setting and sedimentary sequences.

The complexity of the sedimentary successions lies in the understanding of their manner, time and place of formation and therefore must be analysed by considering various aspects and according to different criteria (see Bosellini et al. 1989). The simplest and most immediate way to differentiate the rocks of a sedimentary succession is by taking account of their lithological differences. This method allows a sedimentary body within a given area and in a specific stratigraphic sequence to be distinguished and defined. This method, which requires specific criteria based on physical observations, is defined as the lithostratigraphic classification.

Generally, the advancement of geological knowledge, which includes the stratigraphic knowledge of the Sicilian sedimentary sequences, has always corresponded to historical moments of human progress, during which significant economic and social benefits were produced. At the end of the 1800s, the progress of geological research in Italy was accelerated by the realization of the Geological Map of Italy at 1:100,000 scale (proposed by the Royal Italian Geological

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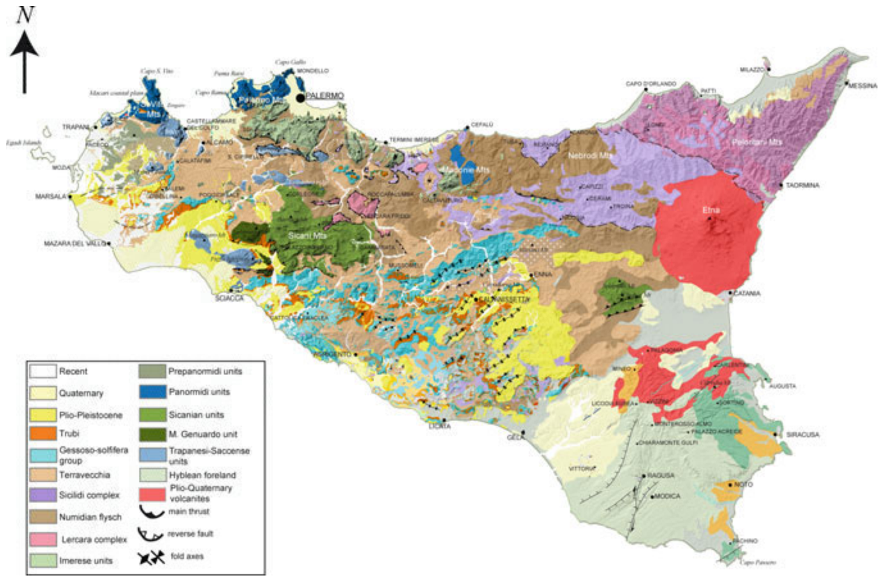

Fig. 1.1 Simplified geological map of Sicily (from Catalano et al. 2004a) showing the distribution of the main lithotectonic assemblages and their tectonic relationships

Committee), which in Sicily was responsible for producing the first regional geological map of the new Kingdom of Italy. It consists of 27 Geological Sheets and was performed by the eminent field geologists S. Mottura, R. Travaglia and L. Baldacci, under the scientific supervision of G. G. Gemmellaro.

Since the nineteenth century, several stratigraphic, structural and palaeontological research studies were conducted in Sicily and adjacent regions (G. G. Gemmellaro 1872, 1878, 1880, 1886, 1887–1899, 1902, 1904; Seguenza 1873–1882, 1873, 1880, 1882; Ciofalo 1878, 1909; Capellini 1880–1881; Baldacci 1884, 1886; Di Stefano 1886, 1900a, 1900b, 1903; Carapezza and Tagliarini 1894; De Amicis 1895; Mottura 1871, 1910; Checchia Rispoli 1903, 1905, 1909a, b, 1910, 1911a, 1911b, c, 1936; Silvestri 1904; M. Gemmellaro 1912, 1921, 1922; Arambourg 1925; Renz 1925; Di Salvo 1933; Tricomi 1939; Fabiani 1925, 1926, 1929a, b, 1933, 1941; Fabiani and Ruiz 1932a, b; Ruiz 1928; Floridia 1931; Borghi 1937; Trevisan 1935, 1937a, b; Fabiani and Trevisan 1940; De Stefani 1948, 1952, 1954; Beneo 1950; Moretti 1954; Petrocchi and Bruschi 1954; Jacobacci 1954; Warmann and Arkell 1954; Gaffurini 1954; Crescenzi and Gaffurini 1955; Coggi and Bruschi 1955; Baggio 1956; Ogniben 1957, 1960, 1963a, b; Gianotti 1958; Gianotti and Petrocchi 1960; Ruggieri 1961; Sgrosso 1986; D'Argenio and Scandone 1970). These studies, defining with precise observations the lithological characteristics of the outcropping stratigraphic units, their lateral-vertical relationships, their dating by means of the recognition and definition of numerous new fossil species and their cartographic representation, led to the coining of several new stratigraphic terms (e.g. "cherty limestone", "lattimusa", "scisti silicei", "gessoso-solfifera", etc.) that form the historical lexicon of Sicilian geology. Many of these scientific papers have been collected by Floridia (1950, 1956) in a miscellaneous collection (*Floridia miscellanea*), currently archived in the library of the School of Science of the University of Palermo, and they were later implemented by Stramondo (1962) in his work. These collections are useful manuals for the consultation of the historic geological bibliography of Sicily.

Later, in the '50s and '60s, with the development of oil exploration in Sicily, the analysis of cuttings and cores collected from the deep exploration boreholes provided new data on the Sicilian rock successions. In this view, a reorganization of the Sicilian formations was necessary in order to use a common terminology to describe the outcropping and buried lithologies. Several petroleum geologists, such as E. Beneo, P. Schmidt of Friedberg, F. Barbieri, C. Giannini, P. Petrocchi, were involved in the lithostratigraphic classification of Sicilian rock successions, following internationally consolidated methods and criteria (Hedberg 1954).

Lithostratigraphic units were defined by Rigo and Barbieri (1959) from the study of outcropping sections in Eastern Sicily. In Central-Western Sicily, in studying mostly the Madonie and Nebrodi Mountains, the lithostratigraphic classification was improved by Ogniben (1955, 1957, 1960, 1963a, b, 1964), Schmidt di Friedberg et al. (1960), Ceretti (1960, 1962, 1965), Ceretti and Ciabatti (1965), Marchetti (1956, 1960), Flores (1959), Accordi (1958, 1959), Colacicchi (1958, 1960), Campisi (1958, 1960).

The collection of the Sicilian formational units, according to the rules and procedures proposed by the newly-born ICS (Hedberg 1954) and edited in the first edition of the International Stratigraphic Guide (Hedberg 1976), was summarized in the papers of Schmidt di Friedberg (1964–1965), Rigo and Barbieri (1959) and Patacca et al. (1979). The latter, studying the buried Mesozoic-Paleogene carbonate successions of the Hyblean Plateau, amended the several previously defined units and tentatively completed the previous classification. Subsequently, the geological research was aimed mainly at producing field data and there was a proliferation of several geological maps at various scale based on the new Sicilian lithostratigraphic nomenclature (Beneo 1956; Beneo et al. 1956; Motta 1957, 1958; Caflisch 1966; Montanari 1966; Broquet 1968; Truillet 1968; Duèe 1969; Lentini and Vezzani 1974; Grasso et al. 1978, 1998, 2004; Catalano and Montanari 1979; Mascle 1979; Abate et al. 1988a, b, 1991a, b, 1996; Bommarito 1981, 1982; Di Stefano and Vitale 1993; D'Angelo and Vernuccio 1994, 1995; Bommarito et al. 1995; Mauz and Renda 1991, 1995; Grasso 1997; Lentini et al. 2000; Basilone 2012).

Since the '70s, the application of facies analysis to the Mesozoic carbonates, widely outcropping in Central-Western Sicily, has provided a new approach to the stratigraphic classification by considering also the paleoenvironmental significance of the rock bodies and the paleogeographic setting (Catalano et al. 1973, 1974a, b, c; Catalano and Abate 1974; Abate et al. 1977, 1982a; Grasso et al. 1978; Catalano and D'Argenio 1978, 1982a, b; Di Stefano 1981a, b, 1990). In this view, a large amount of stratigraphic data has provided new definitions and descriptions of the outcropping lithological units. However, at the same time, these studies have produced several new synonyms and descriptive generalizations (either for local variations in the lithological content or due to the lack of regional geological knowledge), inducing terminological and conceptual confusion that have complicated the regional lithostratigraphic classification and nomenclature.

A reorganization of the old Sicilian lithostratigraphic classification began when, with the start of the CARG project, lithostratigraphy and relative units were chosen as the preferred method to classify the outcropping geological bodies and produce 1:50,000-scale geological maps.

Coordinated by the CIS, a synthetic scheme to uniform the Eastern and Western Sicilian lithostratigraphic classification and nomenclature—with the purpose of offer an unambiguous read of the 1:50,000 geological maps—was developed. This lithostratigraphic scheme, proposed by Basilone et al. (2001) at the Meeting of the CIS hosted by the University of Palermo, was accepted and used to reorganize the Sicilian formations and their cartographic representation. Some of the results are reported in the Italian Formations Catalogue (Cita et al. 2007a, b), available online at www.accordo-carg.it, where several worksheets describing the Sicilian lithostratigraphic units used in the published CARG maps are included (Carbone et al. 2010, 2011a, b; Catalano et al. 2010a, b, c, 2011a, b, 2013a, b; Grasso et al. 2010; Tortorici et al. 2010; Di Stefano et al. 2011; Basilone 2012), available online at www.isprambiente.gov.it/MEDIA/carg/sicilia.

The aim of this book is to offer as complete an overview as possible on the lithostratigraphy of Sicily, taking into account the multiplicity of existing formational and terminological variability developed over more than a century of studies and publications. The new stratigraphic methods and the required use of formations as mapping units have prompted the acquisition of new lithostratigraphic data, the review of the previous units and their comparison with the new collected data, enabling the definition of some new lithostratigraphic units.

The results have been summarized in 77 worksheets containing the most important information regarding the lithological, sedimentological and microfacies characteristics, the measured thicknesses, areal extent and the regional aspects, the paleoenvironmental, paleogeographic and paleo-tectonics setting, compiled according to standard procedures and nomenclature (Salvador 1994).

The worksheets are grouped in a generally chronological order and the complete list is shown in table of contents. In each chronologic group the worksheets of the described formations are organized in alphabetic order. The Permo-Triassic units, consisting of mainly clastic and carbonate sequences, represent the oldest deposits outcropping in Sicily that originated during the early stages of the Southern Tethyan continental rifting; the Mesozoic-Cenozoic carbonate units, consisting of shallow- and deep-water carbonate, clastic-carbonate and siliceous deposits, were formed along the continental margin during the opening stages of the Tethys Ocean. They represent the sedimentary sequences of the various stratigraphic successions differentiated in the field along the Sicilian outcrops that were considered the infilling sequences of the several Meso-Cenozoic paleogeographic domains that were structured, since the Triassic, along the Sicilian sector of the Southern Tethyan continental margin. The deposits of the Sicilide Complex (Tethyan units) and the

Tertiary clastics (Numidian flysch) are grouped separately. The Miocene and the Plio-Pleistocene units, consisting of clastics, evaporites and pelagic carbonates, representing the sedimentary cover of the wedge-top basins formed during the construction of the Sicilian FTB, are described in different chapters. The Quaternary units, consisting of the most recent continental and marine deposits, are classified as Unconformity-Bounded Stratigraphic Units (UBSUs) and were deposited mainly along the coastal belts of the island of Sicily.

The worksheets are accompanied by several illustrations showing the main lithological, textural and paleontological characteristics of the rock units from outcrop and microscope observations and by several synoptic sketches, supported by the updated biostratigraphic and chronostratigraphic data, which display the lateral (heteropic)-vertical stratigraphic distribution of the described units.

The nomenclature used here follows the directives of the International Nomenclature Codes listed in the International Stratigraphic Guide (ISG, Salvador 1994). For easier reading of the individual worksheet, it should be noted that the units in upper case in the text have been validated, while the units in lower case are informal or as yet unvalidated units. Finally, as suggested by the ISG, the historical names have been maintained (e.g., Lattimusa, Tripoli, Inici, etc.).

An introductive section about the synthetic regional geological setting of Sicily, the main stratigraphy and regional distribution of the Sicilian rock units and the paleogeography and paleo-tectonics of the Permo-Mesozoic carbonates is included. Furthermore, an overview on the stratigraphic classification principles is provided to facilitate the reader in understanding the terminology used in the main body of text.

1.1 Sicily Regional Geological Setting

As a premise, a brief introduction about the regional geological setting of Sicily is necessary to understand the stratigraphic framework described in the following.

Sicily is part of the western central Mediterranean and is developing along the African-European plate boundary. It is a segment linking the African Maghrebides with the Southern Apennines across the Calabrian accretionary wedge (Fig. 1.2). The chain and its submerged western and northern extensions are partly located between the Sardinia block and the Pelagian-Ionian sector and partly beneath the central southern Tyrrhenian Sea (Fig. 1.3).

In this sector of the Mediterranean area, the main compressional movements, after the Paleogene Alpine orogeny, began with the latest Oligocene-Early Miocene counter-clockwise rotation of Corsica-Sardinia, believed to represent a volcanic arc and its collision with the African continental margin. Thrusting occurred in connection with the westward subduction of the Adriatic and Ionian lithosphere beneath the Corsica-Sardinia block. At present-day, a north-dipping Benioff zone, as deep as 400 km, located west of Calabria and the Apennines and the related calc-alkaline volcanism in the Aeolian Islands, indicates a westward subduction

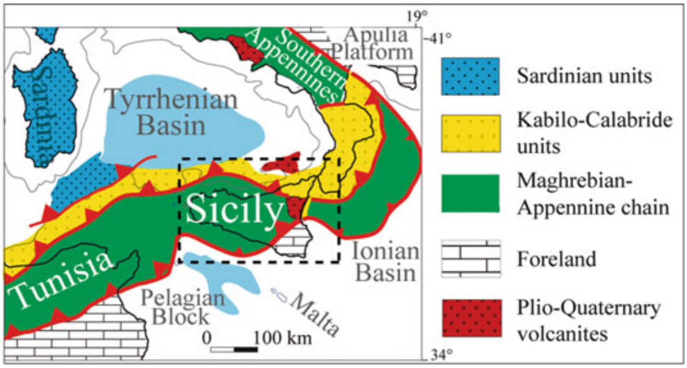

Fig. 1.2 Schematic structural map of Central Mediterranean (from Catalano et al. 2013c)

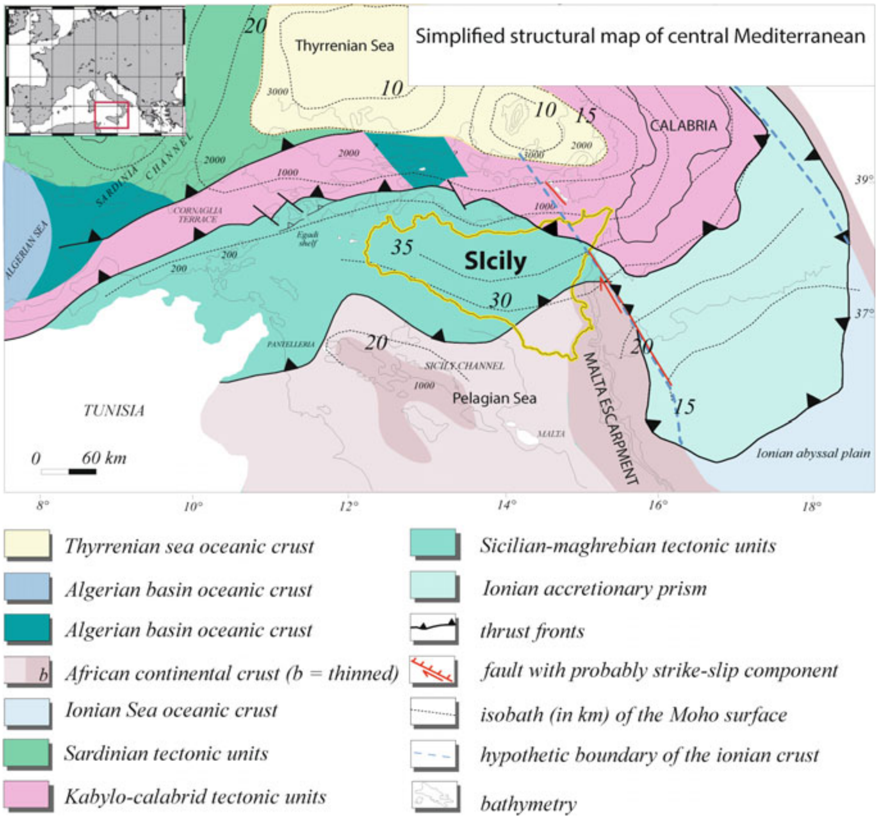

Fig. 1.3 Structural map showing the main tectonic elements of the Central Mediterranean Sea (from Catalano et al. 2013c)

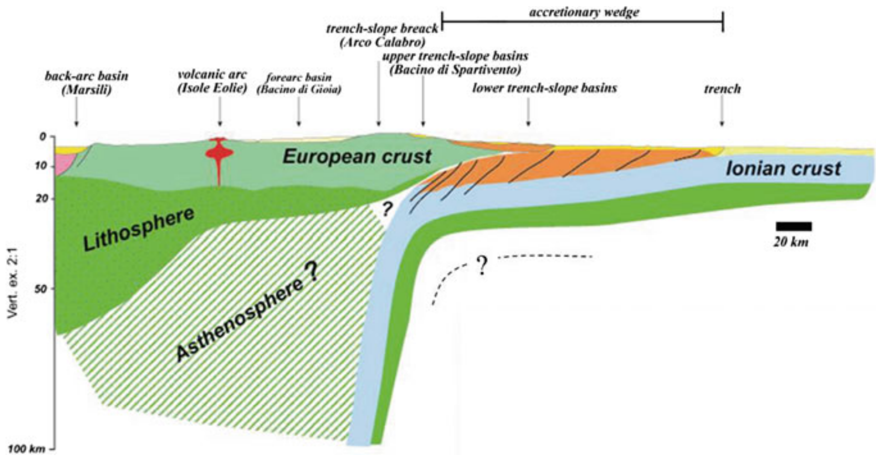

Fig. 1.4 Geological sketch of the Ionian-Thyrrenian subduction system (from Catalano et al. 2013c)

(Fig. 1.4). Subduction and thrusting are contemporaneous with rotations and back arc-type extensions in the Tyrrhenian Sea (Channel et al. 1980; Ghisetti and Vezzani 1984; Finetti and Del Ben 1986; Finetti et al. 1996, 2005; Rehault et al. 1987; Malinverno and Ryan 1986; Catalano et al. 1989a, b; Faccenna et al. 1996; Roure et al. 1990, 2002; Gueguen et al. 1998; Chamot-Rooke et al. 2005; Finetti 2005).

Recent interpretations of several reflection seismic profiles (Bornati et al. 1997; Catalano et al. 1998b, 2000a, 2004a, b, 2008a, b, 2011c, 2013c, d; Bello et al. 2000; Accaino et al. 2011) and the available stratigraphic, paleomagnetic and structural surface data derived from new geological maps (Catalano et al. 2010a, b, 2011a, b, 2013a, b, 2014) as well as those from substantially reinterpreted hydrocarbon exploration well logs (Basilone et al. 2011, 2016a) help to reconstruct the structure of mainland Sicily.

1.1.1 The Collisional Complex of Sicily

Three elements characterised the "collisional" complex of Sicily and adjacent off-shore areas (Fig. 1.3):

- a complex chain of thrust imbricates outcrops in Sicily and is locally more than 15 km thick (Fig. 1.5); it consists (from internal to external) of a "European" element (Peloritani Units with a metamorphic basement) a "Tethyan" element (Sicilide Units) and an African element (Maghrebian-Apennine Units). The tectonic units derived primarily from the deformation of a number of original paleogeographic domains (carbonate basinal and platform successions) that

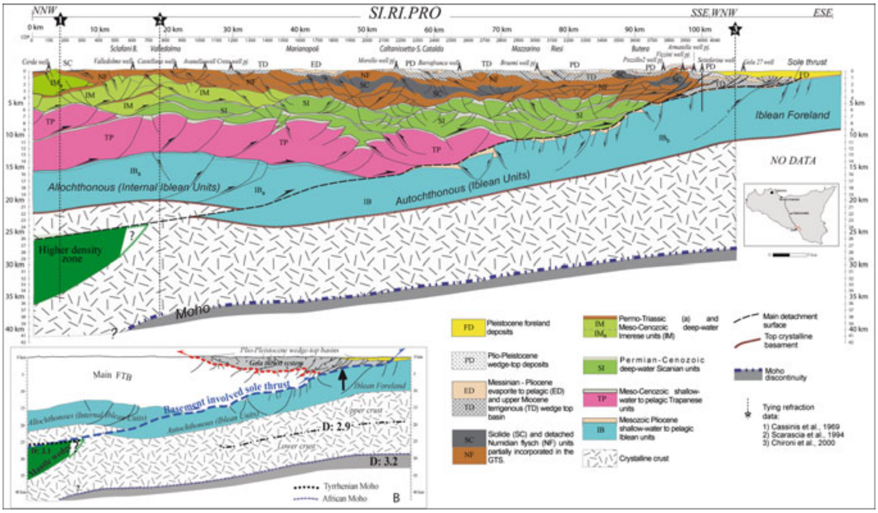

Fig. 1.5 Geological cross-section resulting from the interpretation of the seismic stack section of the SI.RI.PRO. Crustal profile and its southeastern commercial multichannel seismic extension (from Catalano et al. 2013d). The geological cross-section reconstruction benefits from the main geophysical (refraction and gravity) data. Geological sketch illustrating the regional monocline that underlies the whole orogenic wedge (B). The latter includes a basement-involved fault that merges into the overlying allochthonous units. The thrust emanates from the leading edge of the northern basement-involved fault. It carries the leading edge of the units of the overlying orogenic wedge to emerge as a thrust plane that underlies the external units of the GTS. The dark arrow indicates the arching of the basal detachment

developed during the Meso-Cenozoic interval in the Sicilian sector of the African continental margin. The distribution of the main lithotectonic assemblages and their tectonic relationships are illustrated in a general structural map of Sicily (Fig. 1.1);

– a foredeep basin developed between the chain and the foreland area and it extends from the Gela basin to offshore Sicily in the Sicily Channel. The sediments are late Miocene-to-Pleistocene in age and include the Messinian formations of the “Gessoso-Solfifero” Group and the overlying Trubi and Monte Narbone formations. The Gela nappe was displaced in the early Pleistocene;
– a foreland area belonging to the African plate developed in south-eastern Sicily (Hyblean). The sedimentary succession is 7/8 km thick and includes Triassic and Jurassic carbonates indicative of shelf and a slope-to-basin environment; late Jurassic and Cretaceous-to-Miocene pelagic carbonates followed upwards by clastic open platform deposits.

1.2 Main Stratigraphy, Facies Domains and Regional Distribution

Stratigraphic studies carried out in Sicily have highlighted the presence of lithological successions characterised by different sedimentary facies pertaining to relevant sedimentation domains (Ogniben 1960; Caflisch 1966; Broquet 1968, 1970, 1972; Giunta and Liguori 1972, 1973; Lentini and Vezzani 1974; Grasso et al. 1978; Di Geronimo et al. 1978; Catalano and D'Argenio 1978, 1982a, b; Abate et al. 1978, 1982b; Mascle 1970, 1979; Catalano and Montanari 1979; Montanari 1989; Catalano et al. 1989a, b, 1995, 1996, 1998a, 2000a, b, 2004a, 2010a, b, 2011a, b, 2013a, b; Mauz and Renda 1991, 1995, 1996; Agate et al. 1998a, b; Di Stefano 2002; Di Stefano et al. 2002a, b; Nigro and Renda 1999, 2002; Basilone 2009a, b, 2011, 2011b, 2017; Basilone et al. 2010, 2011, 2016a, b, c; Gasparo Morticelli et al. 2017).

The structural model proposed in the '60s evidenced the occurrence of a tectonic edifice superimposed on the so-called autochtonous "Basal Complex" (Ogniben 1960). The latter consists of a stratigraphic sequence also described as "Western Madonie sequence" by Schmidt di Friedberg et al. (1960), "paleo-autochton sequence" by Ceretti and Ciabatti (1965), "Sclafani succession" by Broquet (1968) and corresponds to the present-day Imerese succession (Catalano and D'Argenio 1978).

Broquet et al. (1966) and Broquet (1968, 1972) suggest the existence of a tectonic edifice resulting from the deformation of an original area occupying the southern sector of the belt named Cammarata Zone (the external chain) superimposed by the tectonic units of the Sclafani Zone and Internal Flysch (represented by the Monte Soro flysch and Varicoloured clays), outcropping in the northern and internal sectors of the Sicilian chain.

Facies analysis, physical stratigraphy and biostratigraphy have been used since the '70s to define the outcropping carbonate and terrigenous rock bodies in Sicily. This approach has allowed (Catalano and D'Argenio 1978, 1982a) to define the concept of paleogeographic units (large original rock bodies deposited in specific paleogeographic domains, a group of 'isopic zones' not yet deformed by tectogenesis). As a consequence, the study has envisaged the occurrence of different Paleozoic-Neogene successions representing the sedimentary cover of distinct crustal paleodomains belonging to the "Tethyan" Ocean and the African continental margin.

The lithological successions exposed in Sicily (Fig. 1.1) can be grouped into: (i) passive margin sequences, represented by the Permo-Triassic clastic and the Mesozoic-Cenozoic carbonates, which represent the sedimentary fill of different basins developed along the stretched African continental margin and the Tethys ocean before the onset of orogenic deformation; (ii) the active margin sequences, represented by the terrigenous deposits of the Oligo-Miocene turbiditic sedimentation (Numidian flysch), believed to be the product of the dismantling of the chain during its deformation and by the Mio-Pleistocene rocks, consisting of clastics,