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MESOZOIC PALEOTECTONIC EVOLUTION OF THE RAGUSA ZONE (SOUTHEASTERN SICILY)

The Ragusa zone is a gently deformed sector of the African continental margin which during late Neogene times played the rôle of the foreland of south-verging décollement nappes. In the field, mainly Tertiary carbonate rocks and mafic volcanites are exposed, but the subsurface has been extensively investigated by oil exploration and several boreholes crossed thick Mesozoic-Tertiary sequences. Upper Triassic dolomites are the deepest horizon which has been reached by drilling, so that no data are available on the beginning of the Alpine history in Southern Sicily.

Our research reveals that this crustal sector underwent during the Mesozoic the typical evolution of a sunken continental margin, showing close similarities with many other paleogeographic domains located along the periadriatic sector of the African continental margin. Most of these domains, however, have been strongly deformed during the Alpine compression, so that any paleotectonic reconstruction preliminarily needs an accurate palinspastic restoration. In the Ragusa zone, on the contrary, shape and dimension of the original paleogeographic domains are still preserved, since no significant crustal shortening has modified the area. Such suitable conditions, together with the abundance of available data coming from oil exploration, allowed us to reconstruct depositional environments and their differentation in space and time induced by the paleotectonic activity to a real scale.

During Late Triassic the Ragusa zone was characterized by sedimentary environments comparable with modern tidal flats. An intertidal algal flat uniformely extended over the whole area during Norian time, while a more complex depositional setting developed in the upper part of the Rhetian (fig. 60) and two main paleogeographic domains individualized: the Siracusa belt and the Ragusa belt. The first was characterized by shallow-marine conditions with an open circulation; the second appears as a sheltered sedimentary environment with a complex system of channels and ponds bordered northwards and eastwards by beach ridges.

In early Hettangian time (fig. 51) a severe phase of synsedimentary faulting dissected the Triassic platform; the faulting was accompanied by fissural mafic volcanism (fig. 53). A continuous moderate subsidence compensated by deposition allowed the persistence of shallow-water conditions in the Siracusa belt; a strongly subsiding basin, on the contrary, established to the south, where thousands of metres of turbiditic deposits accumulated (fig. 61).

During the Sinemurian-Lotharingian, the inner edge of the Siracusa carbonate-platform was activated by WSW-ENE and NW-SE faults, and a prism of shelf-derived resediments accumulated along the steep slopes (figs. 62,63). During middle Liassic, tension faults dissected also the carbonate-platform body, producing sinking of blocks; at the end of Domerian time the entire Siracusa platform was drowned below the photic zone (fig. 64).

In the Toarcian-Bathonian time span the tectonic activity did not play an important rôle and WSW-ENE and NW-SE persisting trends are still manifested by the facies boundaries and by the orientation of the most subsiding areas.

By the end of Middle Jurassic a renewal of the synsedimentary tectonics was accompanied by new submarine volcanic activity, and isolated edifices developed in correspondence of the intersections of the main faults (figs. 54,55). During Late Jurassic times, the sedimentation was controlled by a moderate subsidence of the whole area and by modifications of the bottom topography induced by the growth of volcanic sea-mounts (fig. 65).

At the beginning of the Tithonian the volcanic activity ceased and no signs of synsedimentary tectonics are recognizable for a long time. The facies distribution, however, (figs. 66, 67) still reflects the physiography resulting from the Middle-Upper Jurassic modifications of the bottom relief. From Tithonian until Turonian time, the whole Ragusa zone underwent only moderate subsidence which caused a gradual expansion of the basinal areas appearing at this time as a gently slanting depression in the central part of the studied region (figs. 56, 57).

During Senonian tensional faults once again dissected the Ragusa zone. Isolated volcanic edifices developed at the intersections of the main faults, as it was the case during Middle-Upper Jurassic (fig. 59). Some of them reached the photic zone, as indicated by rudistid reefs on their top. The synsedimentary tectonic activity increased during Late Senonian, until spectacular gravity-slide phenomena occurred during Paleocene and Eocene times.

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* G. Giunta and V. Liguori partecipated in the first step of this work, by sampling cores and cuttings and by contributing to a preliminar examination of logs and thin sections.
Consiglio Nazionale delle Ricerche. Progetto Finalizzato Geodinamica, contribution n° 298.

Geological outline

The Gela-Catania line, marking the front of south-verging décollement nappes, divides Sicily into two structural regions (fig. 1): a northern folded belt, consisting of a pile of thrust sheets, and a southern stable area where weakly deformed Tertiary deposits and mafic volcanites are exposed (see SERVIZIO GEOLOGICO D'ITALIA, 1976). In this paper the latter is named the Ragusa zone.

The deformed belt is considered as the easternmost segment of the south-verging Neogene Maghrebian chain (SCANDONE *et al.*, 1974; AMODIO MORELLI *et al.*, 1978), whilst the Ragusa zone is interpreted as a gently deformed sector of the African continental margin (FINETTI and MORELLI, 1973; SCANDONE *et al.*, 1974; BARBERI *et al.*, 1974). The latter played the rôle of the foreland during Tertiary times, when the front of the Alpine compression reached the most external domains, and the

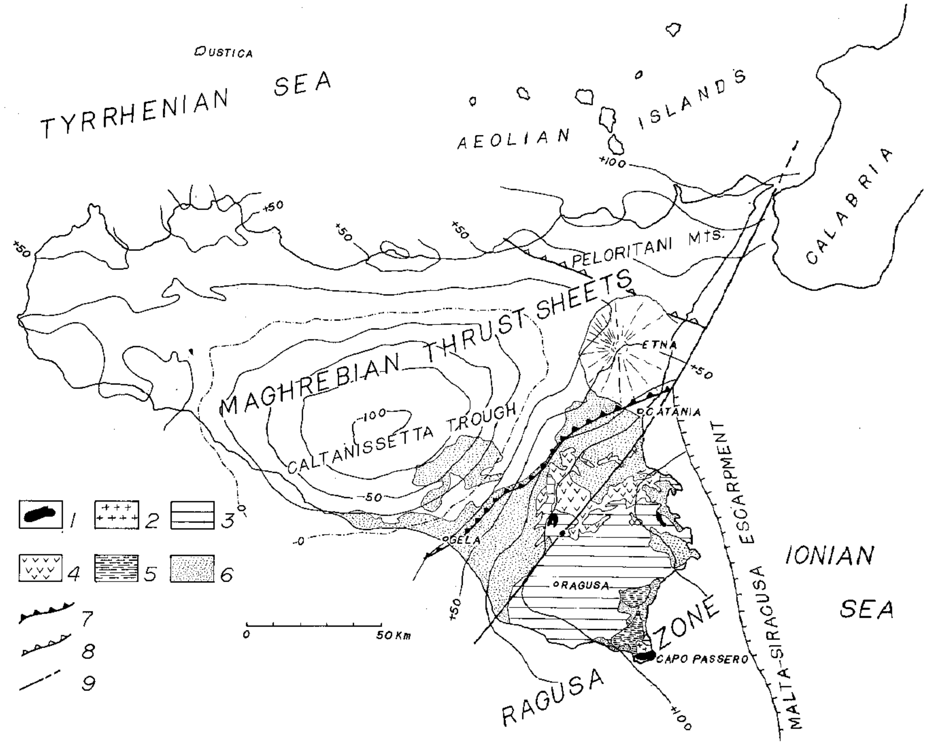


FIG. 1 — Structural sketch of Sicily. The Gela-Catania line marks the front of allochthonous sheets which overthrust the Ragusa foreland during Pliocene time. The large negative anomalies (Caltanissetta trough) correspond to the axis of the uppermost Miocene-Pliocene foredeep, today buried beneath the front of the chain. 1) Upper Cretaceous limestones; 2) Upper Cretaceous mafic volcanites; 3) Paleogene and Neogene calcarenites and marls; 4) Neogene mafic volcanites of the Iblei Mountains; 5) Messinian-Lower Pliocene deposits; 6) « neoauthochtonous » Upper Pliocene-Quaternary deposits; 7) front of the south-verging Neogene Maghrebian nappes; 8) front of the south-verging Paleogene Peloritani nappes; 9) main faults. Bouguer gravity anomalies from AGIP (1978).

— Schema strutturale semplificato della Sicilia. La linea Gela-Catania segna il fronte della catena, che nel Pliocene raggiunge il margine settentrionale della zona ragusana. L'area marcata da forti anomalie negative (fossa di Caltanissetta) corrisponde all'asse dell'avanfossa miocenico superiore-pliocenica, oggi sepolta sotto le coltri alloctone della catena. 1) calcari del Cretaceo superiore; 2) vulcaniti basiche del Cretaceo superiore; 3) calcareniti e marne paleogeniche e neogeniche; 4) vulcaniti basiche neogeniche dei Monti Iblei; 5) depositi del Messiniano e del Pliocene inferiore; 6) depositi neoautoctoni del Pliocene superiore-Quaternario; 7) fronte delle falde neogeniche maghrebidi, a vergenza meridionale; 8) fronte delle falde paleogeniche dei Monti Peloritani, a vergenza meridionale; 9) faglie principali. Le anomalie di Bouguer sono tratte dalla Carta Gravimetrica della Sicilia, AGIP (1978) edita dal Servizio Geologico d'Italia.

frontal part of the chain overthrust the northern margin of the Ragusa zone (fig. 2). The last severe phase of orogenic transport occurred after early Pliocene times; the amount of horizontal displacement of the front of the chain was of several tens of kilometres. The sediments filling the inner (northern) portion of the Upper Miocene-lower Pliocene foredeep were also involved in the orogenic transport; the greatest part of the foredeep northern margin of the Ragusa zone, with throws increasing towards the NW, that is, towards the front of the chain. The sinking obviously continued also beneath the outer margin of the chain, in that the thickness of the allocthonous sheets already reaches 3 kilometres at about 15 kilometres behind the front. The same trend is recognizable by off-shore seismic reflection profiles.

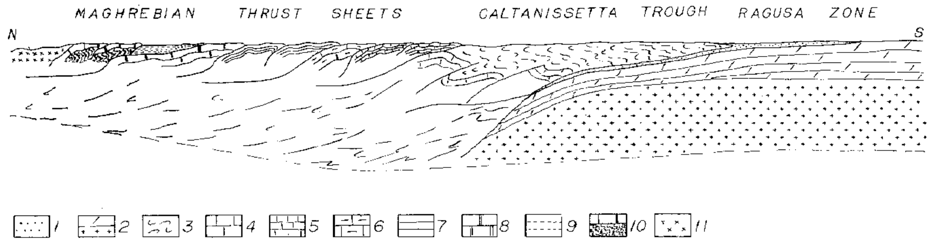
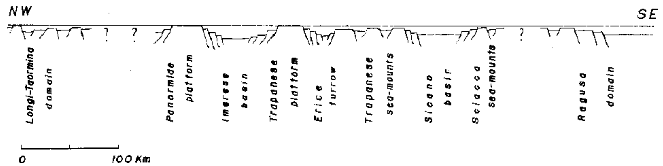


FIG. 2 — Idealized cross-section of Sicily showing the southern foreland dipping beneath the allochthonous sheets of the chain. The estimated crustal thickness of the stable area, including the sedimentary cover, is at around 30 kilometres. The basement of the Ragusa zone is a typical continental crust; a crustal mélange is hypotized under the thrust sheets of the chain. Roots are thinned in the north, towards the Tyrrhenian Sea. 1) Pliocene and Quaternary deposits of the Ragusa zone; 2) basement and Mesozoic-Tertiary sedimentary cover of the Ragusa zone; 3) chaotic « Argille Varicolori » nappes, « external flysch » and Upper Miocene-Pliocene allochthous deposits; 4) parautochthonous (?) Sciacca zone; 5) Sicanian units; 6) Trapanese units; 7) Imerese units; 8) Panormide units; 9) Sicilide units; 10) Longi-Taormina, Fondachelli and Mandanici units; 11) Aspromonte units.

— Sezione shematica attraverso la Sicilia mostrante l'avampaese ragusano immergente sotto le coltri della catena. Lo spessore crostale dell'area stabile, comprensivo della copertura sedimentaria mesozoico-terziaria, è intorno ai 30 chilometri. Per le caratteristiche geofisiche il basamento della zona ragusana è interpretato come una tipica crosta continentale; sotto le coltri della catena, invece, è ipotizzata la presenza di un mélange crostale con assottigliamento delle radici verso nord, in direzione del Mar Tirreno. 1) depositi pliocenici e quaternari della zona ragusana; 2) basamento e copertura sedimentaria mesozoico-terziaria della zona ragusana; 3) coltri di « Argille Varicolori » caotiche, flysch esterni e depositi alloctoni del Miocene superiore-Pliocene; 4) zona parautoctona (?) di Sciacca; 5) unità sicane; 6) unità trapanesi; 7) unità imeresi; 8) unità panormidi; 9) unità sicilidi; 10) unità di Longi-Taormina, Fondachelli e Mandanici; 11) unità dell'Aspromonte.

FIG. 3 — Palinspastic cross-section through Sicily at Late Jurassic time. From SCANDONE et al. (1974) with slight modifications.

— Sezione palinspastica attraverso la Sicilia, riferita al Giurassico superiore. Da SCANDONE et al. (1974) con lievi modifiche.



deposits, on the contrary, was tectonically buried beneath the outer margin of the chain. This compressional phase was responsible for a gentle folding of the sedimentary sequence in the Ragusa zone. During Late Pliocene-Pleistocene time the area was affected by tensional faulting with tilting of blocks; at the same time, huge olistostromes were gliding towards the Ragusa zone from the mobile front of the chain. The fault systems have both SW-NE and NW-SE directions. The SW-NE trending system caused sinking along the

Problems concerning the original spatial relationships between the continental domains involved in the orogenic transport and the Ragusa zone are not yet completely resolved. However, it seems likely that the Ragusa zone was connected northwards with the Sciacca zone. From a N-S palinspastic cross section (fig. 3) it can be seen that a dissected continental margin hundreds of kilometres wide (restored by smoothing out the thrust sheets of the chain) separated the Ragusa zone from those realms which during Late Jurassic faced the Tethys Ocean (SCANDONE *et al.*, 1974; AMODIO MORELLI *et al.*, 1978; CATALANO and D'ARGENIO, 1978). It is more difficult to define where and how far the Ragusa zone extended eastwards, towards the Ionian Sea. It undoubtedly reached the Siracusa-Malta escarpment (CHAYES *et al.*, 1979) but we do not know if it continued even further east, beneath the Neogene-Quaternary sediments of the Messina abyssal plain.

The Ragusa zone has been extensively investigated by oil exploration. The crystalline basement has never been reached by drilling; however the geophysical characteristics point to a typical continental crust (CASSINIS *et al.*, 1969; GIESE and MORELLI, 1973). A thick Mesozoic-Tertiary sedimentary cover, on the contrary, was penetrated by several boreholes. The Mesozoic sequence is made of Upper Triassic shallow water dolomites overlain by Jurassic and Cretaceous basinal deposits; volcanic episodes occur throughout the whole sequence. At the surface, only scattered and small outcrops of Upper Cretaceous carbonates and basalts are exposed. The Tertiary terranes consist of basinal to shallow-water calcarenites and subordinate marls and clays. These sediments interfinger with mafic volcanites in the Mt. Iblei region.

Our research on the Ragusa zone shows that, during Mesozoic time, this crustal sector underwent the typical evolution of a passive, Atlantic-type continental margin, showing close similarities with many other paleogeographic domains located along the periadriatic sector of the African continental margin (BERNOULLI and JENKYNS, 1974; BERNOULLI *et al.*, 1979). Most of these domains, however, have been strongly deformed during the Alpine compression, so that any paleotectonic reconstruction preliminarily needs an accurate palinspastic restoration. By contrast, in the Ragusa zone, shape and dimension of the original paleogeographic domains are still preserved, since the area was not significantly shortened. These favourable conditions, together with the abundance of available data coming from oil exploration, allow a precise reconstruction of the paleotectonic and sedimentary evolution of this crustal sector during Mesozoic time-span. An additional accurate analysis on the Tertiary deposits, however, would be necessary to obtain a complete picture of the evolution of the Ragusa foreland. In any case, we think that the term « Ragusa Platform » used by many geologists should be abandoned. The « Ragusa Platform » was often considered as part of the Apulia Platform, which is characterized by a thick sequence of shallow-water carbonates. Although these zone played an analogous rôle in the orogenic history of the Calabrian Arc (both of them, together with the north-western part of the Ionian Sea, were part of the foreland of the Maghrebian-Apennine chain), nevertheless they underwent a very different paleotectonic evolution during Mesozoic times. To try to connect them directly (see, e.g. CAIRE, 1970) would mean to oversimplify the problem of the nature of the crust under the Ionian Sea. Another over-simplification is the assumption that the pelagic facies of the Jurassic deposits of the Ragusa zone prove their closeness to an oceanic Ionian area (HSÜ, 1977). Indeed, Triassic and Jurassic sea-ways founded on thinned continental crust were common features in the circum-Mediterranean region also within domains hundreds of kilometres far from oceanic realms (SCANDONE, 1975; LAUBSCHER and BERNOULLI, 1977).

Stratigraphy and facies analysis

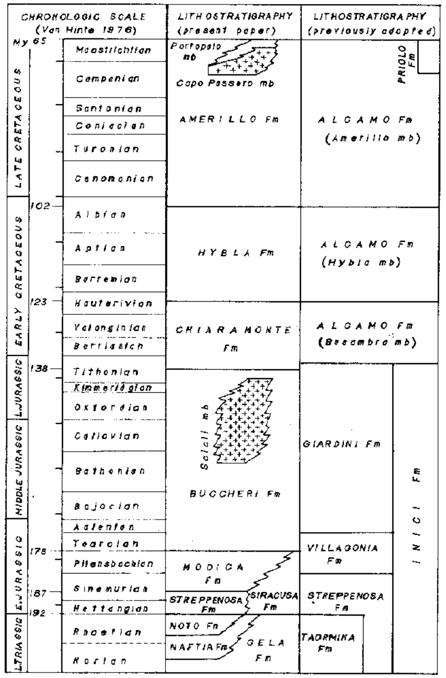
Introduction

Petroleum geologists usually distinguish two kinds of sequence in the Mesozoic of the Ragusa zone: the « Siracusa facies » and the « Ragusa facies » (ENI, 1969). The first type of sequence would be represented by Upper Triassic-Upper Cretaceous bioclastic carbonates; the second one by Upper Triassic shallow-water dolomites, Upper Triassic-lower Liassic « Black Shales » and by middle Liassic-Upper Cretaceous carbonates and marls, the latter indicating open-marine depositional conditions.

A revision of a large number of cores and cuttings from most of the selected boreholes (figure in Plate 5), together with a re-interpretation of the electric logs, improved the knowledge of the Mesozoic paleotectonic evolution in Southern Sicily. We shall also distinguish a Siracusa belt and a Ragusa belt, eventhough merely during Late Triassic-middle Liassic time-span when two well-defined paleogeographic zones were actually developed in the studied region. The distinction was particularly evident during the Hettangian-Sinemurian, when a strongly subsiding basin, developed in the southern part of the area (Ragusa belt), was bordered northwards and eastwards by a persistent shallow-water carbonate platform (Siracusa belt). The differences became shaded towards the end of the middle Liassic, when the carbonate platform sunk below the photic zone.

The lithostratigraphic nomenclature usually applied in Sicily by petroleum geologists comes from RIGO and BARBIERI (1959) and SCHMIDT DI FRIEDBERG (1965). We have been obliged to abandon most of the traditional formational names, as they were derived from three different lithostratigraphic groups: the Longi-Taormina, the Trapanese and the Ragusa groups. The first two groups belong to paleogeographic realms (fig. 3) characterized by paleotectonic evolution and orogenic history very different from those of the Ragusa zone, and are today represented in distinct thrust sheets of the chain (fig. 2). Moreover, some new lithostratigraphic units are introduced. The comparative Table 1 presents both the traditionally adopted nomenclature and that proposed in this paper, as well as the age range of the single formations.

The aim of this paper is to outline the Mesozoic evolution of South-Eastern Sicily by correlating depositional environments, paleotectonic activity and distribution of the volcanism. A description of the single lithostratigraphic units, electric logs (Plates 1,2) and columnar sections (Plates 2-4) of some selected boreholes, isopach (figs. 50-59) and facies distribution (figs. 60-67) maps, and restored cross-sections (Plate 5) are reported. Future research will be directed towards a better knowledge of the volcanism, by defining the petrological and geochemical characteristics of the products, as well as by investigating the relationships between the synsedimentary faulting and the volcanic activity.



TAB. 1 — Synopsis of the Mesozoic rock-units in the Ragusa zone.

— Quadro sinottico delle unità litostratigrafiche mesozoiche della zona ragusana.

Gela Formation (Norian-Rhetian)

The Triassic dolomites reached by drilling in the Ragusa zone are subdivided in this paper into two lithostratigraphic units: the Gela Formation and the Naftia Formation. These dolomites have usually been included by petroleum geologists into the Taormina Formation (see RIGO and BARBERI, 1959). This name should not be used in the Ragusa zone, since it derives from dolomites belonging to the Longi-Taormina Unit of AMODIO MORELLI *et al.* (1978).

Synonymies: Taormina Formation *p.p.* of RIGO and BARBIERI (1959)
Source of name: Gela well N° 32, located NE of Gela
Geographic coordinates: Lat. 37° 05' 06" N; Long. 1° 50' 48" E
Operating Company: AGIP Mineraria
Date of drilling: 7/11/59 - 19/4/60
Total depth: 3596.30 metres
Ground elevation: 19.0 metres

The Gela Formation was crossed in the type-well from 3380 metres to the final depth of the drilling. The lower boundary is unknown, as in the whole Ragusa zone, whereas the upper boundary is defined by the base of the Naftia Formation. This boundary is gradational. A detailed description of the Triassic dolomites drilled in the type-well is available in MATTAVELLI *et al.* (1969). The authors distinguish three facies: Stromatolitic Dolomite, Tan Dolomite and White Dolomite. We attributed the first lithofacies to the Gela Formation and the latter ones to the Naftia Formation.

Besides the type-well, the Gela Formation was recognized in the wells Catania 10, Francofonte 1 Giarratana 1, Licodia 1, Melilli 1, Naftia 1, Noto 1, Noto 2, Ragusa 1, Ragusa 45, Siracusa 1, Vittoria 1, and Vizzini 1. The sequence entirely consists of white dolomites and dolomitic limestones of tidal flat environment; sporadic layers of mafic volcanites (alkalic basalts, CRISTOFOLINI, 1966) were also drilled in the Gela 32, Licodia 1, Noto 1, Ragusa 45 and Vizzini 1 wells. In the Ragusa belt, the Gela dolomites are overlain by Norian-Rhetian dolomites and evaporites of the Naftia Formation. The age is probably Norian; the thickness is at least 3000 metres (Ragusa 45). In the Siracusa belt, on the contrary, the Gela Formation is overlain by lower-middle Liassic limestones of the Siracusa Formation. Micropaleontological data suggest a Norian-Rhetian age in this area; the thickness of the Rhetian portion is around 800 metres (Siracusa 1).

The *Norian* part of the Gela Formation is everywhere represented by a monotonous sequence of

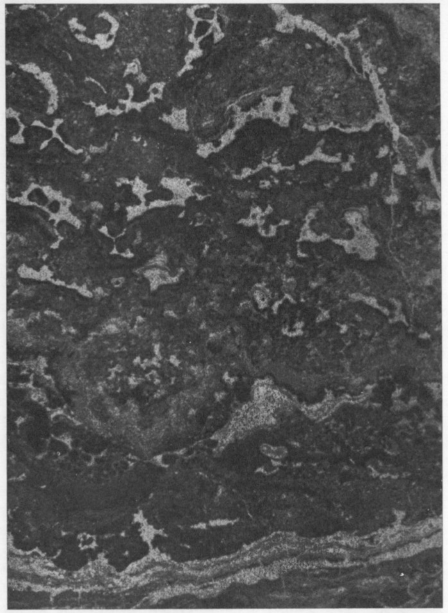


FIG. 4 — Algal loferitic dolomite from the Norian part of the Gela Formation. Fenestrae of varying shapes and dimensions are filled with sparry dolomite and only locally with fine-grained bioclastic packstone/grainstone showing inverse grading. Giarratana well N° 1, 1697 m; thin section, x 6.

— Dolomia loferitica algale proveniente dalla parte norica della Formazione Gela. Le cavità, di varie dimensioni e forma, sono generalmente riempite da un mosaico di dolosparite e localmente da un packstone/grainstone bioclastico a gradazione inversa. Pozzo Giarratana 1, 1697 m; sezione sottile, x 6.

white loferitic dolomites (fig. 4) which characteristically appear banded by algal layers varying in thickness from a few centimetres to some decimetres. The algal levels are frequently represented by stromatolite horizons (fig. 5) and, in some places, by layers with well preserved *Cyanophyceae* probable *Cayeuxia*) occurring both as nodular and crustose growth forms. Ostracods, *Lagenidae* and arenaceous Foraminifera (*Aulotortus*, *Ammodiscidae*) are sometimes trapped within the algal films. The algal layers alternate with bioclastic ones. These latter are represented by wackestones/packstones with peloids, lumps, small oncoids, rounded intraclasts, badly-preserved arenaceous

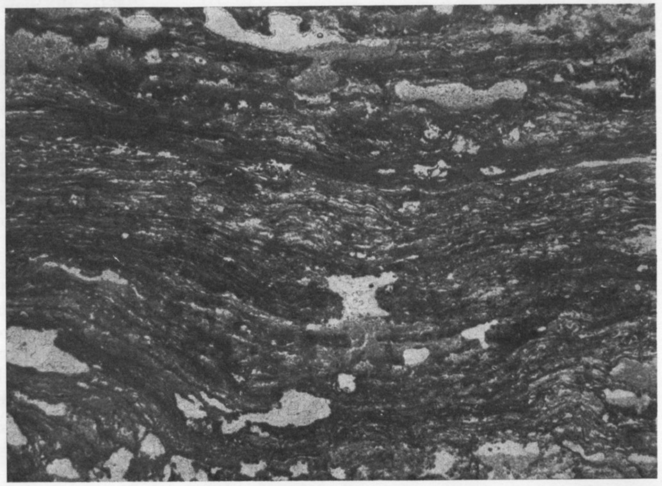


FIG. 5 — Algal stromatolite from the Norian dolomites of the Gela Formation. Presence of laminoid fenestrae with geopetal internal sediment and/or drusy dolomite infillings. Licodia well N° 1, 1530 m; thin section, x 6.

— Stromatolite algale proveniente dalle dolomie noriche della Formazione Gela. Sono ben sviluppate strutture fenestrali a disposizione parallela, con le cavità riempite da sedimento geopetale e/o da un mosaico di dolosparite. Pozzo Licodia 1, 1530 m; sezione sottile, x 6.

FIG. 6 — Calcrete deposit from the upper part of the Gela dolomites in the Ragusa belt. Vadose pisolites and fragments of laminated crusts are cemented by a sparry dolomite mosaic. Francofonte well N° 1, 1576 m; thin section, x 9.

— Deposito calcretico della parte alta della Formazione Gela nel dominio ragusano. I vuoti tra le pisoliti vadose e i frammenti di croste carbonatiche sono parzialmente riempiti da cristalli euedrali di dolomite. Pozzo Francofonte 1, 1576 m; sezione sottile, x 9.

Foraminifera (*Ataxophragmiidae*, *Ammodiscidae*), ostracods, gastropods, pelecypods, fragments of *Cyanophyceae* and *Aeolisaccus*-like forms. Fragments of stromatolites are also present as clasts in occasional intraformational breccias. Uniformity and nature of sedimentary features testify homogeneous intertidal conditions over the whole study area.

The upper part of the Gela Formation in the Ragusa belt is characterized by widely developed calcrete levels (fig. 6) which suggest a progressive change from intertidal to supratidal conditions.

The *Rhetian* portion of the Gela Formation, present only in the Siracusa belt, is represented by porous white dolomites and dolomitic limestones (thickness: about 200 metres) followed by white calcarenites (thickness: about 600 metres). The lower part of the sequence is constituted by an irregular alternance of:

— algal mat dolomites and *Thaumatoporella* boundstones displaying small irregular fenestrae;

— bioclastic packstones with *Thaumatoporella* remains and associated *Dasycladaceae*, *Involutina*, *Tolypammina* (?), bivalve fragments, fully micritized bioclasts and rare small *Frondicularia*. The *Thaumatoporella* thalli and part of the calcite-micrite matrix appear patchily recrystallized into sparite;

— bioclastic wackestones with small gastropods, *Involutina*, *Meandrospira*, *Trochammina*, *Ammodiscidae*, scattered ostracods and *Lagenidae*. Bioclasts are characteristically preserved as moulds geopetally filled by dolomicritic sediment (fig. 7).

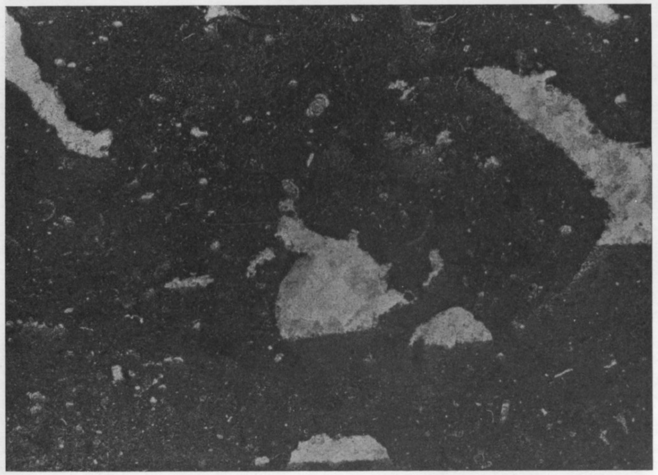


FIG. 7 — Porous dolomite from the Rhaetian part of Gela Formation. Bioclastic wackestone with early diagenetic vugs and fossil moulds (gastropods and some Foraminifera) showing geopetal filling. The upper part of the large cavities is only partly filled with sparry dolomite. Siracusa well N° 1, 3000 m; thin section, x 9.

— Dolomia porosa proveniente dalla parte retica della Formazione Gela. Wackestone bioclastico con cavità da diagenesi precoce e da dissoluzione riempite geopetalmente da un fine sedimento peloidico. La parte alta delle cavità più grandi è riempita solo parzialmente da cristalli di dolomite. Pozzo Siracusa 1, 3000 m; sezione sottile, x 9.

The overlying calcarenites are more or less recrystallized bioclastic packstones and grainstones with rounded algal remains (chiefly *Dasycladaceae*), *Triasina*, *Involutina*, *Frondicularia* cf. *woodwardi*, ostracods, *Aeolisaccus*-like forms and large fragments of gastropods, bivalves and echinoderms. Bioclasts are frequently micritized; in some places they appear also as moulds filled with blocky calcite (fig. 8).

The sedimentary features in the lower part of the Rhetian sequence suggest persistence of intertidal conditions. Shallow subtidal conditions with open marine circulation were reached higher up in the section at the transition from the dolomites to the calcarenites.

Naftia Formation (*Norian p.p.-Rhetian*)

We propose the term Naftia Formation for a sequence of brownish dolomites associated with evaporites which overlie the Gela Formation everywhere in the Ragusa belt. The wide extent and the distinctive sedimentary features justify in our opinion, the introduction of a new formation.

Synonymies: Taormina Formation *p.p.* of RIGO and BARBIERI (1959)
Source of name: Naftia well N° 1, located SSW of Ramacca
Geographic Coordinates: Lat. 37° 19' 38" N; Long. 2° 13' 34" E
Operating Company: AGIP Mineraria
Date of drilling: 18/11/57 - 23/3/58
Total depth: 2052.70 metres
Ground elevation: 114 metres

The Naftia Formation was crossed in the type-well between 1750 and 1930 metres. The lower boundary with the Gela Formation is gradational; the upper one with the Noto Formation is sharp.

Besides the type-well, the Naftia Formation has been recognized in the wells: Acate 1, Acate 2, Acate 3, Avola 1, Belliscala 1, Buccheri 1, Buccheri 2, Chiaramonte 1, Comiso 1, Comiso 2, Comiso 3, Cono 1, Francofonte 1, Francofonte 2, Frigintini 1, Gela 1, Gela 32, Giarratana 1, Grammichele 1, Licodia 1, Margherita 1, Mineo 1, Modica 1, Modica 2, Monterosso S1, Naftia 2, Noto 1, Noto 2, Palazzolo 1, Piazza Armerina 1, Ponte Dirillo 1, Ponte Olivo 1, Pozzillo 1, Ragusa 1, Ragusa 45, S. Matteo 1, S. Croce Camerina 2, Santo Pietro 1, Sigona Grande 1, Streppenosa 1, Troitta 1, Vittoria 1, Vittoria 2, Vittoria 3 and Vizzini 1.

The sequence consists of dolomites with anhydrite lenses and nodules (Tan Dolomite facies and White Dolomite facies of the Taormina Formation in MATTAVELLI *et al.*, 1969), originated in a supratidal-intertidal zone with sporadic evaporitic episodes. The age is Norian *p.p.* - Rhetian *p.p.* In the drillings which reach the lower boundary (Francofonte 1, Gela 32, Giarratana 1, Licodia 1, Naftia 1, Noto 1, Noto 2, Ragusa 1, Ragusa 45 and Vittoria 1) the thickness is 80 metres on average. The maximum thickness (180 metres) was reached in the Naftia well N° 1. The lower boundary is the top of the Gela Formation, the upper one the base of the Noto Formation. Only in the Pozzillo well N° 1 the Naftia Formation is conformably overlain by lower-middle Liassic limestones of the Siracusa Formation; the stratigraphic position suggests that the Naftia Formation includes here the whole Rhetian. Another peculiar case is exhibited by the Vizzini well N° 1 where evaporites and dolomites were drilled for about 2000 metres. The anomalous thickness indicates that supratidal conditions began earlier in this zone, so that the Norian

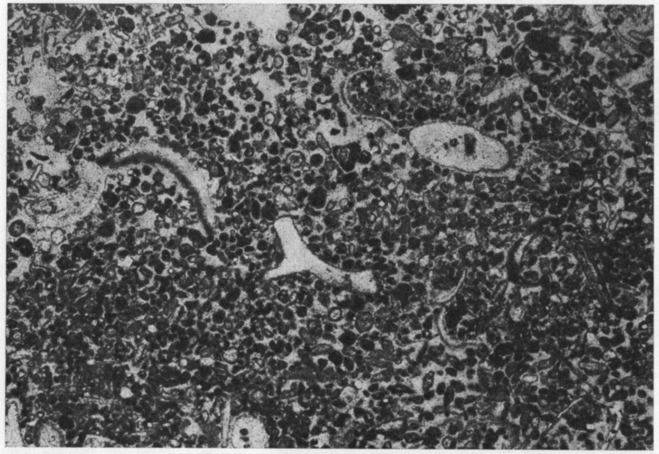


FIG. 8 — Calcarenite from the Rhetian part of the Gela Formation. Bioclastic packstone with ill-sorted, partly worn and partly angular fragments of gastropods and bivalves, abundant *Involutina*, more or less micritized bioclasts and lithoclasts and small arenaceous Foraminifera. Most of the bioclasts are preserved as moulds completely or partly filled with sparry calcite. The matrix is in large part recrystallized into sparite or microsparite. Incipient dolomization is manifested by scattered dolomite rhombs. Siracusa well N° 1, 2240 m; thin section, x 9.

— Calcarenite bioclastica della parte retica della Formazione Gela. Packstone bioclastico con frammenti di gasteropodi e bivalvi, frequenti esemplari di *Involutina*, bioclasti e litoclasti micritizzati e arrotondati, piccoli foraminiferi arenacei. La gran parte dei bioclasti si presenta disciolta, e le cavità sono completamente o parzialmente riempite da calcite spatica. La matrice micritica è in gran parte ricristallizzata in sparite o microsparite. Una debole dolomitizzazione è messa in evidenza da piccoli cristalli euedrali di dolomite dispersi nel sedimento. Pozzo Siracusa 1, 2240 m; sezione sottile, x 9.

FIG. 9 — Algal mat dolomite from the Naftia Formation. The darker laminae are made up of horizontally grown algal filaments and fine-grained sediment trapped in the algal film; the light discontinuous layers show radial filaments. Laminoid fenestrae are generated mainly by internal solution of the latter. Noto well N° 1, 2673 m; thin section, x 18.

— Dolomia con feltri algali abbastanza ben conservati, proveniente dalla Formazione Naftia. Le lamine più scure risultano costituite da filamenti algali orizzontali e da un fine sedimento intrappolato nella mucillagine; i livelli grigio chiari, discontinui, mostrano filamenti a prevalente disposizione radiale. Le strutture fenestrali laminoidi sono generate soprattutto dalla dissoluzione di questi ultimi. Pozzo Noto 1, 2673 m; sezione sottile, x 18.

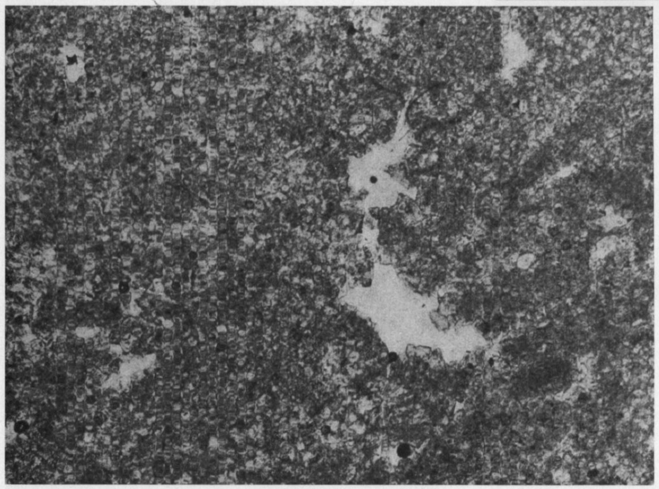


FIG. 10 — Whitish porous dolomite from the Naftia Formation. The original texture has been completely destroyed and the rock appears as an irregular dolomite mosaic with shaded dolomicritic patches. Unfilled solution cavities are lined with euhedral dolomite rhombs. Naftia well N° 2, 1052 m; thin section, x 18.

— Dolomia porosa biancastra della Formazione Naftia. La tessitura originaria è stata completamente distrutta dalla ricristallizzazione, e la roccia si presenta come un mosaico irregolare di dolomite con tracce sfumate di granuli relitti. Le cavità da dissoluzione, non completamente riempite, sono tappezzate da cristalli euedrali di dolomite. Pozzo Naftia 2, 1052 m; sezione sottile, x 18.

algal dolomites of the Gela Formation were here laterally replaced by evaporitic deposits.

In the Ragusa belt the sequence is made up of alternating brownish algal dolomites (more frequent in the lower part) and crystalline, often porous, grey and whitish dolomites associated with dolomitic breccias. The first lithotype consists of algal mat dolomites (fig. 9) with layers of oncoidal and/or bioclastic packstones. The algal mat appears to be constituted by an alternance of dense laminae rich in very fine-grained detrital grains and looser layers showing horizontally grown algal filaments as well as vertical and locally flabellate bundles (see MONTY, 1976). The grey and whitish dolomites are dolosparites or peloidal dolomicrosparites with mere shadows of organic (?) remains (fig. 10). The associated breccias are coarse wackestones with light angular dolosparite elements of varying dimensions included in a darker dolomicrosparite matrix.

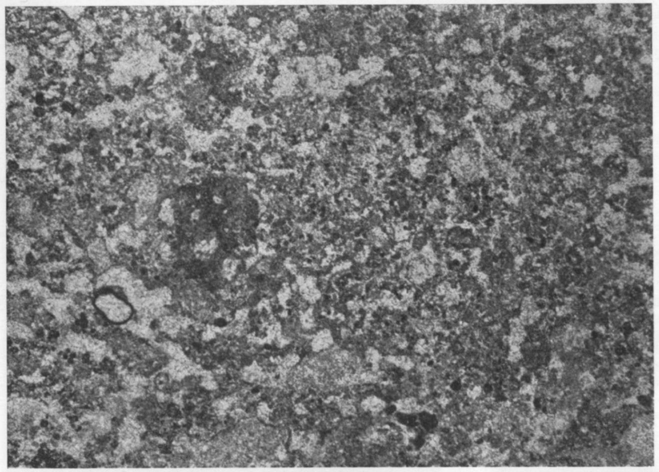


FIG. 11 — White dolomite from the Naftia Formation. Peloidal packstone with shaded *Thaumatoporella* remains. The thalli, preserved merely as moulds, appear as light patches of dolosparite and dolomicrosparite. Giarratana well N° 1, 1684 m; thin section, x 16.

— Dolomia bianca della Formazione Naftia. Packstone con numerosi fantasmi di *Thaumatoporella*. I talli, quasi completamente disciolti, appaiono nella foto come plaghe irregolari più chiare occupate da dolosparite e dolomicrosparite. Pozzo Giarratana 1, 1684 m; sezione sottile, x 16.

FIG. 12 — White calcarenite from the Naftia Formation. A cracked dark loferite layer (algal mat?) is overlain by a bio-lithoclastic packstone with *Involutina* and rare *Ammodiscidae*. The bioclasts are characteristically preserved as moulds. The dolomicrite matrix appears locally recrystallized into dolosparite. Naftia well N° 1, 1822 m; thin section, x 6.

— Doloarenite bianca della Formazione Naftia. Un livello loferitico scuro (feltro algale?) con fratture da disseccamento è ricoperto da un packstone bio-litoclastico con *Involutina* a rari *Ammodiscidi*. Le cavità da dissoluzione dei bioclasti si presentano riempite da sparite e, più raramente, da un fine sedimento geopetale. La matrice dolomicritica è localmente ricristallizzata in dolosparite. Pozzo Naftia 1, 1822 m; sezione sottile, x 6.

In the marginal areas of the Ragusa belt, towards the Siracusa belt, additional lithologies appear; they include whitish dolomites consisting of:

— recrystallized peloidal wackestones and packstones characterized by abundant *Thaumatoporella* remains and scattered *Ataxophragmiidae* (fig. 11). This lithotype occurs mainly in the lower part of the sequence;

— faintly laminated peloidal packstones with small ooids and oolites, *Ammodiscidae*, scattered fragments of bivalves, *Aeolisaccus*-like forms and rounded intraclasts. The matrix is recrystallized into microsparite and sparite;

— bioclastic packstones with abundant *Involutina* and some *Triasina* (?), *Ammodiscidae*, small arenaceous Foraminifera, *Aeolisaccus*-like forms, fragments of brachiopods, pelecypods and gastropods (fig. 12).

The above described lithologies wich, as concerns their fossil contents, display close similarities with the Rhetian part of the Gela Formation, mark the lateral transition from the mainly supratidal deposits of the Naftia Formation to the subtidal ones of the upper portion of the Gela Formation.

Noto Formation (*Rhetian*)

According to the petroleum geologists the Triassic dolomites of the Ragusa belt are overlain by an Upper Triassic-lower Liassic sequence of black shales, named the Streppenosa Formation. In reality, the Streppenosa Formation *Auct.* includes two lithostratigraphic units having different ages and different depositional meaning. We call the lower one the Noto Formation and the upper one the Streppenosa Formation. Their identification is possible in almost all the wells which reached these units, since the electric logs show quite different patterns. The Noto Formation partially corresponds to the « *Estheria* or *Posidonia* zone » of the Streppenosa Formation *Auct.* (see, e.g., Buccheri 1, Margherita 1, Monterosso S1, Ragusa 1 and Streppenosa 1).

Synonymies: Taormina Formation *p.p.* and Streppenosa Formation *p.p.* of RIGO and BARBIERI (1959); « Black Shale » *p.p.* of some petroleum geologists
Source of name: Noto well N° 2, located E of Rosolini
Geographic coordinates: Lat. 36°48' 59" N; Long. 2° 34' 43" E
Operating Company: AGIP Mineraria
Date of drilling: 8/10/57 - 23/8/58
Total depth: 3200 metres
Ground elevation: 22 metres

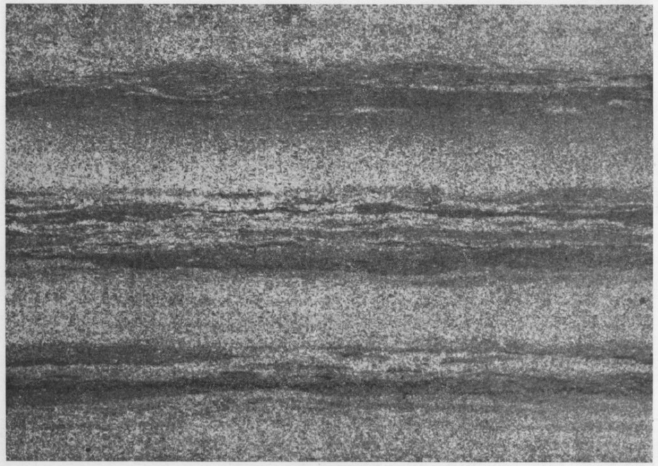
In the type-well the Noto Formation was crossed between 2862 and 3076 metres. The lower boundary with the Naftia Formation and the upper one with the Streppenosa Formation are sharp (Plate 3).

The Noto Formation is developed everywhere in the Ragusa belt; to the east, in the Siracusa belt, it is laterally replaced by the Rhetian part of the Gela Formation. The thickness ranges from some tens of metres to about 300 metres (fig. 50).

The sequence consists of tidal flat carbonates deposited in a channeled belt (*sensu* SHINN *et al.*, 1969). We can distinguish (fig. 60) a central area characterized by thin-bedded dark dolomites and dolomitic limestones interlayered with black shales, and a marginal area which consists of two narrow, WSW-ENE and NW-SE trending zones, characterized by whitish and tan porous dolomitic calcarenites. Sporadic volcanites were found in the Naftia 2, Noto 1, Santo Pietro 1 and Vittoria 1 wells.

FIG. 13 — Laminated dolomitic limestone from the Noto Formation. Millimetric alternance of light calcite-microsparite with subordinate dolomicrosparite and dark dolomicrite layers. The thicker light-coloured layers are single beds showing in some places normal micrograding in crystal size. They are intercalate with lenticular and wavy composite bed-sets. Noto well N° 1, 2596 m; thin section, x 15.

— Calcare dolomitico laminato della Formazione Noto. Alternanza millimetrica di letti chiari costituiti da microsparite calcitica e subordinatamente dolomitica, e di letti scuri dolomicritici. Letti chiari più spessi mostrano talora microgradazione evidenziata dalla progressiva riduzione delle dimensioni dei cristalli verso l'alto e si alternano a sets di lamine più sottili con microstratificazione lenticolare ed ondulata. Pozzo Noto 1, 2596 m; sezione sottile, x 15.



In the central area the most common lithotypes are represented by thinly laminated dolomitic limestones and dolomites, dark fine-grained dolomitic limestones and flaser dolomites.

The laminated dolomitic limestones display rythmic repetitions of microsequences consisting of alternating layers of ligth calcite microsparite and dark dololutite rich in organic matter and clay minerals (fig. 13). The layering is frequently evidenced by solution seams; the thickness of the layers is usually less than 2 mm, but in some places it may reach a few centimetres. Within single layers, small-scale plane-parallel bedding and all the transitional types from flaser to lenticular bedding through wavy bedding are present. Well preserved fore-set laminae are sometimes displayed in the flaser and lenticular beds. Slumping at the microscopic scale, microfaults, small sedimentary dykes (fig. 14), mud cracks and associated collapse breccias with several generations of superimposed brecciation (fig. 15) are common features. Normal grading in crystal size, faint lamination and bioturbation are often displayed in the thickest beds. In places, where the recrystallization is less pervasive, it is possible to recognize that the sediment consists of very fine-grained peloidal wackestones with small dolomicritic flakes (fig. 14). The bioclasts include *Thaumatoporella* fragments, *Lagenidae*, shadows of arenaceous Foraminifera, rare thin-shelled ostracods and algal filaments.

The grey dolomitic limestones are very fine-grained bioclastic wackestones with dispersed platy chips of dark dolomicrite. The components include peloids, *Lagenidae*, thin-shelled ostracods, ghosts of arenaceous Foraminifera and silty bio-detritus. Iron-bearing minerals, sometimes concentrated in streaks, are very common. The sediment locally shows normal micrograding and a faint thinly-spaced parallel-lamination. In places, vugs are developed; they are either geopetally filled with micrite or unfilled. Associated lithologies include lithoclastic wackestones with angular or flattened dark micritic elements floating in a matrix

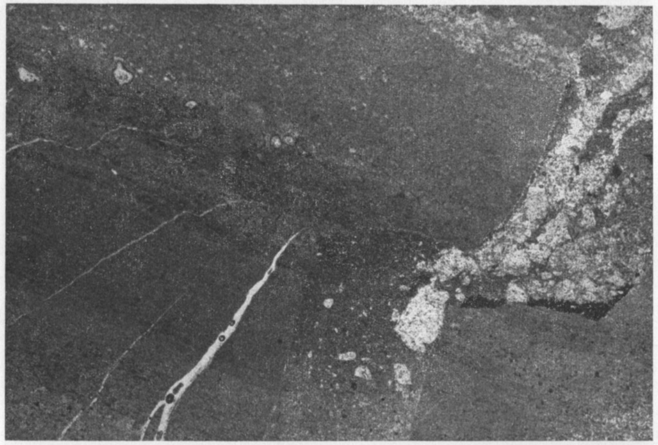


FIG. 14 — Laminated dolomitic limestone from the Noto Formation. Sedimentary dyke in a laminated peloidal wackestone with *Thaumatoporella* remains. The fissure is filled by a silt-sized dolomitic sediment with angular clasts deriving from a crumbled sparry-calcite cement related to a previously generated fracture. Naftia well N° 2, 903 m; thin section, x 6.

— Calcare dolomitico laminato della Formazione Noto. Filone sedimentario che traversa un wackestone peloidico a laminazione parallela con resti di *Thaumatoporella*. La fessura è riempita da un sedimento detritico fine di natura dolomitica con clasti angolosi di calcite spatica legati a una frattura di precedente generazione. Pozzo Naftia 2, 903 m; sezione sottile, x 6.

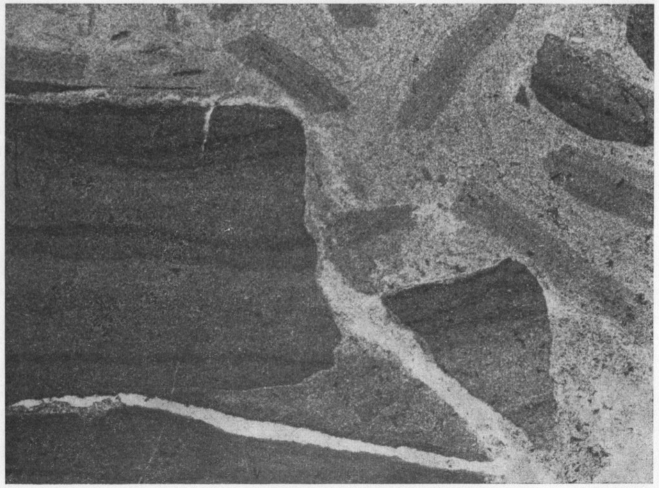


FIG. 15 — Synsedimentary breccia in laminated dolomitic limestone from the Noto Formation. A fissure in the laminated lime sediment is filled with platy and blocky lithoclasts set in a lighter dolomicrosparite matrix. Later fissures are filled with sparite. Gela well N° 32, 3191 m; thin section, x 10.

— Breccia intraformazionale nei calcari dolomitici laminati della Formazione Noto. Una fessura nel deposito laminitico è riempita da litoclasti immersi in una matrice dolomicrosparitica. Fessure di successiva generazione sono riempite da sparite. Pozzo Gela 32, 3191 m; sezione sottile, x 10.

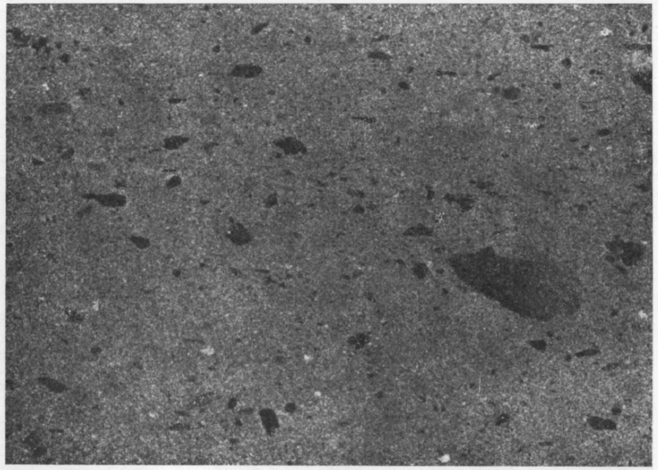


FIG. 16 — Grey dolomitic limestone from the Noto Formation. Lithoclastic wackestone with angular elements of dark micrite floating in a lighter microsparite matrix with ghosts of (?) bioclastic material. Ponte Dirillo well N° 1, 2956 m; thin section, x 15.

— Calcare dolomitico grigio della Formazione Noto. Wackestone litoclastico con elementi angolosi di micrite scura immersi in una matrice microsparitica più chiara con fantasmi organici (?). Pozzo Ponte Dirillo 1, 2956 m; sezione sottile x 15.

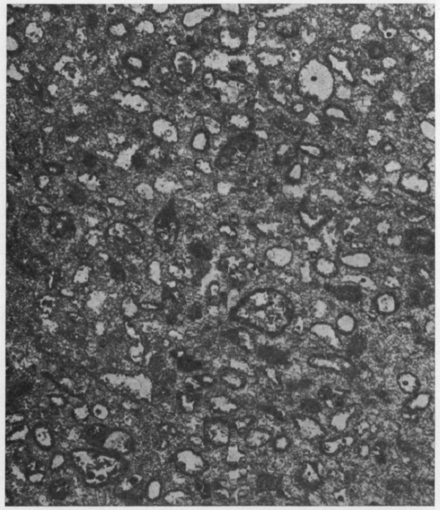


FIG. 17 — Porous dolomitic calcarenite from the Noto Formation. Recrystallized bioclastic packstone with rounded allochems mainly consisting of organic remains. Rare *Involutina*, small bivalves, badly preserved arenaceous Foraminifera and completely micritized grains are recognizable. The bioclasts are generally preserved as unfilled solution-moulds rimmed by calcite-dolomite micrite. The cavities are internally lined by small euhedral crystals of dolomite. Naftia well N° 1, 1740 m; thin section, x 16.

— Calcarenite dolomitica porosa della Formazione Noto. Packstone bioclastico ricristallizzato con allochimici arrotondati costituiti soprattutto da resti organici circondati da un bordo di micrite calcitico-dolomitica. Si riconoscono rare *Involutina*, piccoli bivalvi, foraminiferi arenacei mal conservati e granuli completamente micritizzati. Le cavità derivanti dalla dissoluzione dei bioclasti sono rivestite internamente da piccoli cristalli euedrali di dolomite. Pozzo Naftia 1, 1740 m; sezione sottile, x 16.

of peloidal microsparite (fig. 16). The clasts are fragments of reworked early-lithified lime sediment whose original texture, however, has been obliterated by micritization.

The flaser dolomites form beds having a thickness of some centimetres; they appear as dolomicrosparites with flames of dark dolomicrite. In places, where recrystallization did not destroy the original structure, relics of small current ripples are preserved in the microdolosparite and the flames are seen to represent mud flaser in ripple troughs.

The described lithologies are indicative of several geomorphic sub-environments, as ponds, channels and levees. Our available data are scattered and do not allow a detailed facies reconstruction of such a complex depositional environment where, moreover, tides, episodical floods and temporary exposure caused an ever more intricate interfingering of facies boundaries through time.

At the borders of the channeled area, towards the Siracusa belt, whitish and tan porous dolomitic calcarenites, which we interpret as beach ridge deposits, are widely developed. They consist of:
— ooidal and bioclastic packstones and grainstones (figs. 17, 18, 19) with fragments of small gastropods and brachiopods, large bivalves (including probable *Estheria*), ghosts of arenaceous Foraminifera (*Trochamminidae*, *Ammodiscidae*), entirely micritized grains, small oolites and a few allochems coated by algal rims. Cross-lamination is a quite frequent sedimentary structure;
— bioclastic packstones with *Thaumatoporella* remains. Early diagenetic solution vugs, unfilled and only lined with euhedral crystals of dolomite, frequently occur in these facies.

Additional finer lithologies, mainly developed in the upper part of the sequence, are represented by tan dolomitic limestones consisting of:
— more or less recrystallized peloidal packstones

FIG. 18 — Porous dolomitized calcarenite from the Noto Formation. Grainstone with fragments of pelecypods and micritized rounded grains. Allochems are in part coated with algal rinds. Both original interparticle voids incompletely filled by fibrous calcite and unfilled solution voids are present. Euhedral dolomite rhombs appear concentrated in patches. Palazzolo well N° 1, 2300 m; thin section, x 14.

— Calcarenite dolomitica porosa della Formazione Noto. Grainstone con frammenti di lamellibranchi e granuli micritizzati talora circondati da un rivestimento algale. Sono presenti sia cavità intergranulari riempite solo parzialmente da calcite fibrosa, sia cavità da dissoluzione rimaste vuote. Vistosi fenomeni di ricristallizzazione sono messi in evidenza dalla presenza di plaghe più chiare occupate da grossi cristalli euedrali di dolomite. Pozzo Palazzolo 1, 2300 m; sezione sottile, x 14.

and fine- grained bioclastic wackestones with small ooids, coprolites, arenaceous Foraminifera (*Ammodiscidae*), ostracods, scattered bivalves, *Aeolisaccus*-like forms and fragments of *Thaumatoporella*;
— bioclastic packstones with thin-shelled ostracods, frequently displaying parallel lamination.

Sequences constituted by laminated fine-grained sediments (central part of the channeled belt) and dolomitic calcarenites (beach ridge deposits) have been recognized in the Gela 1, Gela 32, Troitta 1, Giarratana 1 and Rigolizia 1 wells; they testify complex interfingering between the two facies.

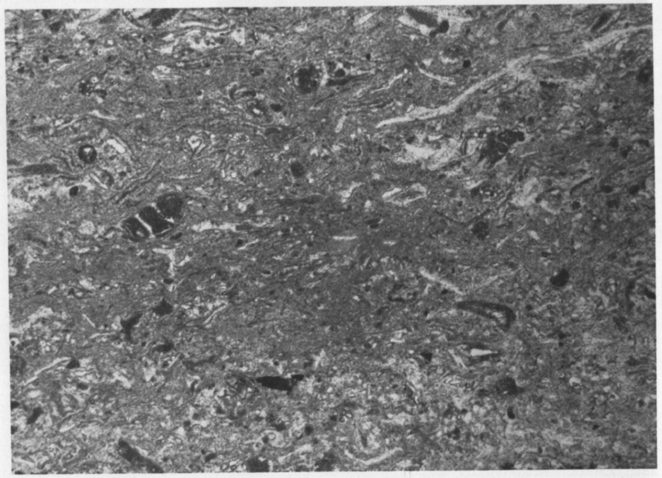


FIG. 19 — Dolomitic limestone from the Noto Formation. Bioclastic packstone with bivalves (including probable *Estheria*), small gastropods and micritized allochems. Gastropods are filled with a dark calcite-dolomite micrite. Most of the shell fragments are preserved as moulds which are partly or entirely filled with calcite sparite or microsparite and a minor amount of dolomite. Pervasive dolomitization, moreover, is manifested by diffuse fine-grained dolomite crystals. Mineo well N° 1, 2062 m; thin section, x 9.

— Calcare dolomitico della Formazione Noto. Packstone bioclastico con bivalvi (probabilmente comprendenti *Estheria*), piccoli gasteropodi e allochimici micritizzati. I gasteropodi sono riempiti da un fine sedimento scuro di natura calcitico-dolomitica. La maggior parte dei gusci dei bivalvi risulta disciolta e in seguito riempita da sparite o microsparite calcitica con subordinata dolomite. Ulteriori fenomeni di dolomitizzazione sono messi in evidenza da diffusi piccoli cristalli di dolomite. Pozzo Mineo 1, 2062 m; sezione sottile, x 9.

Some porous saccharoidal dolomites, consisting of coarse dolosparite with intercrystalline voids filled with iron-bearing minerals, were found in the Mineo 1, Naftia 1 and Sigona Grande 1 wells. The occurrence of this lithotype, which is identical to the saccharoidal dolomites of the Naftia Formation, suggests lateral transitions to the evaporitic conditions which still persisted at that time in the Pozzillo area.

Siracusa Formation (Hettangian- ? Domerian)

The peritidal white limestones of lower-middle Liassic age, which were crossed by drilling in the whole Siracusa belt, have generally been included into the Inici Formation. We are obliged to propose a new name, since the Inici Formation was established in a tectonic unit belonging to the Trapanese domain.

Synonymies: Inici Formation of SCHMIDT DI FRIEDBERG (1965); Melilli Formation of some petroleum geologists (see, e.g. Avola well N° 1, RAP-SIS 1963)
Source of name: Siracusa well N° 1, located S of Canicattini Bagni
Geographic coordinates: Lat. 37° 00' 05" N; Long. 2° 38' 48" E
Operating Company: Società Idrocarburi Siracusana
Date of drilling: 21/7/56 - 13/3/57
Total depth: 3447.2 metres
Ground elevation: 325.45 metres

In the type-well the Siracusa Formation was crossed between 1530 and 2200 metres. It is underlain by the Gela Formation and overlain by the Modica Formation; the boundaries are not evident from the electric log.

In the other wells the lower boundary is represented by the top of the Gela Formation, except in the Pozzillo well N° 1 where the Siracusa limestones are underlain by dolomites and evaporites of the Naftia Formation. The upper boundary is made by nodular pelagic limestones of the Buccheri Formation. The age of the Siracusa Formation is assumed to be lower Liassic in the type-well, as the unit overlies Rhetian dolomites and dolomitic limestones with *Triasina* (Gela Formation), and underlies lime coarse resediments with microfacies indicative of middle Liassic age (Modica Formation). In the other wells we have no direct data on the age of the upper boundary, since the contact between the shallow-water Siracusa limestones and the overlying deeper-marine nodular limestones of the Buccheri Formation is presumably marked by submarine sedimentary gaps. The occurrence of resediments with penecontemporaneously-displaced neritic materials up to the upper part of the Modica Formation suggests that platform conditions persisted somewhere until Domerian. The thickness

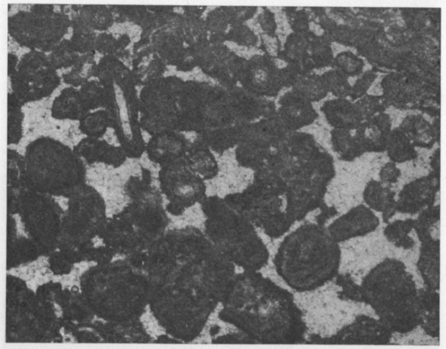


FIG. 20 — White limestone from the Siracusa Formation. Bioclastic packstone/grainstone with small oncoids and lumps, algal coated skeletal debris and rare oolites. Most of the grains appear micritized; the matrix is almost entirely recrystallized into sparry calcite. San Demetrio well N° 1, 1014 m; thin section, x 19.

— Calcare bianco della Formazione Siracusa. Packstone/grainstone bioclastico con piccoli oncoidi, lumps, resti organici con rivestimenti algali e rare ooliti. La maggior parte dei granuli è micritizzata; la matrice è quasi interamente ricristallizzata in calcite spatica. Pozzo S. Demetrio 1, 1014 m; sezione sottile, x 19.

of the Siracusa Formation is 700-800 metres, except in the Pozzillo well N° 1 where it is only 350 metres.

The sequence consists everywhere of whitish limestones and subordinate dolomitic limestones indicative of an open marine platform. Sporadic intercalations of mafic volcanites were found in the Catania well N° 10. The limestones are represented by oncoidal and ooidal grainstones/packstones and by bioclastic packstones/grainstones with lumps, rounded intraclasts, coated fragments of pelecypods and gastropods, algal remains (*Thaumatoporella*, *Cayeuxia*), bored echinodermal plates, arenaceous Foraminifera (*Ataxophragmiidae*, *Textulariidae*, *Nubeculariidae*, *Lituolidae*), *Lagenidae*, *Lenticulina*, ostracods and *Aeolisaccus*; the organic debris frequently display heavy micritization phenomena (fig. 20). In some places interparticle voids and occasional fenestrae are filled with geopetal micrite. The diagenetic and sedimentary features of these lithologies point to a shallow water depositional environment in a subtidal to intertidal zone.

Streppenosa Formation (Hettangian-Sinemurian s.str.)

A re-definition of the Streppenosa Formation is necessary, since the Streppenosa Formation of RIGO

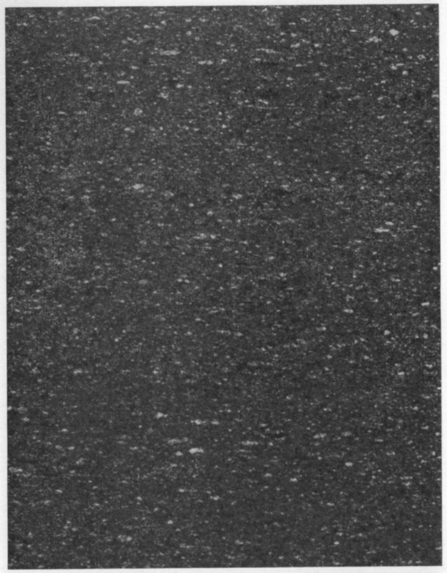


FIG. 21 — Clayey limestone from the Streppenosa Formation. Fine-grained wackestone with biogenic silt and rare badly-preserved Radiolaria and thin sponge spicules. Iron-bearing minerals are concentrated in streaks. Marzamemi well N° 1, 2850 m; thin section, x 20.

— Calcare marnoso della Formazione Streppenosa. Wackestone a grana fine con silt biogenico e rari radiolari e spicole di spugna mal conservati. Sono riconoscibili minerali di ferro concentrati in piccole chiazze scure. Pozzo Marzamemi 1, 2850 m; sezione sottile, x 20.

and BARBIERI (1959) includes Upper Triassic lithologies which we attribute to the Noto Formation. Petroleum geologists divide the Streppenosa Formation (or « Black Shale » Unit) into three zones: « Barren Zone », « Dwarfed Fauna Zone » and « *Estheria* or *Posidonia* Zone ». The formation, as it has been defined in this paper, includes the first two zones; the « *Estheria* or *Posidonia* Zone », in turn, is attributed to the Noto Formation.

Synonymies: Streppenosa Formation *p.p.* of RIGO and BARBIERI (1959); « Black Shales » *p.p. Auct.*
Source of name: Streppenosa well N° 1, located W of Modica
Geographic coordinates: Lat. 36° 50' 43" N; Long. 2° 15' 54" E
Operating Company: GULF Italia
Date of drilling: 22/8/57 - 7/3/58
Total depth: 2891 metres
Ground elevation: 395 metres

In the type-well the Streppenosa Formation was crossed between 2130 and 2436 metres. The lower boundary with the Noto Formation and the upper one with the Modica Formation are sharp (Plate 3).

The Streppenosa Formation widely extends in the subsurface of the Ragusa belt; in the Siracusa belt it is heteropic with the lower part of the Siracusa Formation. The lower and the upper boundaries are made everywhere by the Noto and by the Modica formations. The age is most probably Hettangian-Sinemurian *s.str.*, as the Streppenosa Formation stratigraphically overlies Rhetian deposits (Noto Formation) and underlies Lotharingian deposits (see BARBIERI, 1964) of the Modica Formation. The thickness ranges (fig. 51) from few tens of metres to more than 2900 metres (see Pachino well N° 4, where the drill penetrated the sequence for 2920 metres without reaching the base).

In the Streppenosa Formation the following three kinds of sequence can be distinguished (figs. 61, 62):

basinal sequence, characterized by a thick pile of calcareous resediments which accumulated in a strongly subsiding basin to the south. The main lithologies are grey-greenish dolomitic and marly limestones with black shale interlayers (*Facies 1*). Intercalations of mafic volcanites are frequent, particularly in the southern part of the Ragusa belt (fig. 53). The limestones are very fine-grained bioclastic wackestones (fig. 21) with scattered and badly preserved Radiolaria, sponge spicules, *Lagenidae*, ostracods, rare peloids, scarce terrigenous-volcanogenic silt and dark minerals. These are either scattered or concentrated in discontinuous streaks. Sedimentary structures (D-E intervals of the BOUMA sequence and frequent *Chondrites*-type burrowing) suggest deposition from low-flow-regime turbidity currents. Coarser turbiditic layers mainly occur in the lower part of the sequence and in the southern part of the basin. In these resediments the lower part of the single beds is made up of dolomitized calcarenites with well developed B-C BOUMA intervals, which grade upwards into micaceous calcisiltites and silty marls. Calcarenites and calcisiltites consist of pelagic and shallow-water carbonate material with a minor amount of terrigenous and volcanogenic sand and silt. The carbonate components include ooids, small rounded intraclasts, coprolites, peloids, fragments of echinoderms, brachiopods, algae (*Thaumatoporella*), and arenaceous Foraminifera (*Ataxophragmiidae*, *Am-*

modiscidae) generally preserved as ghosts (fig. 22). The terrigenous component, more frequent in the upper, fine-grained parts of the turbiditic layers, is represented by quartz, white mica and feldspars (fig. 23). The primary micrite matrix is generally recrystallized into microsparite or sparite, mainly where the carbonate component prevails. Pressure-

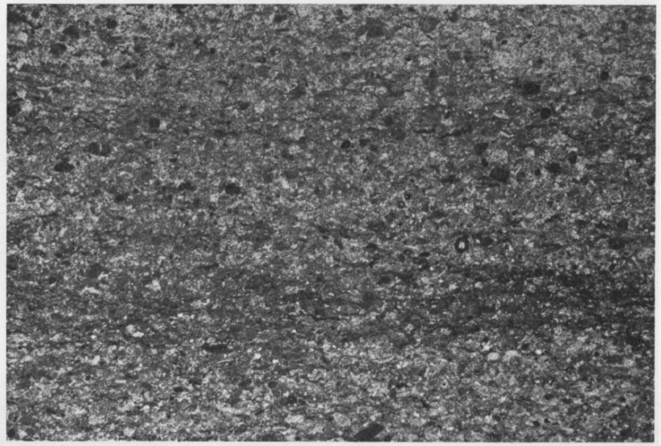


FIG. 22 — Fine-grained calcarenite from a turbidite layer of the Streppenosa Formation. Bioclastic wackestone/packstone with rounded dark micritic grains, peloids, badly preserved arenaceous Foraminifera and ostracods, dispersed in a fine biodetritus with small amount of terrigenous silt; a faint lamination is recognizable. The micrite matrix is recrystallized into microsparite; scattered small dolomite rhombs and pressure-solution phenomena are also present. S. Croce Camerina well N° 2, 2453 m; thin section, x 9.

— Calcarenite a grana fine proveniente da uno strato torbiditico della Formazione Streppenosa. Wackestone/packstone bioclastico con granuli micritici scuri arrotondati, peloidi, foraminiferi arenacei mal conservati e ostracodi, dispersi in un fine detrito biogenico con piccole quantità di silt terrigeno; è riconoscibile una debole laminazione parallela. La matrice è quasi del tutto ricristallizzata in microsparite. Sono sviluppati fenomeni di dolomitizzazione e di pressione-dissoluzione. Pozzo S. Croce Camerina 2, 2453 m; sezione sottile, x 9.

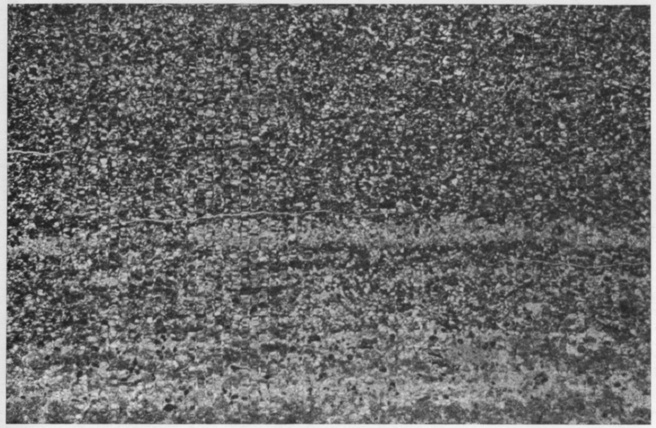


FIG. 23 — Terrigenous calcisiltite from the upper part of the turbidite layer of fig. 22. Laminated siltite with white mica, quartz, feldspars, biotite, chlorite and dark minerals in a lime micrite matrix. S. Croce Camerina well N° 2, 2453 m; thin section, x 12.

— Calcisiltite micacea proveniente dalla parte alta dello stesso strato torbiditico illustrato in fig. 22. Siltite a laminazione piano-parallela con mica bianca, quarzo, feldspati, biotite, clorite e minerali opachi in una matrice carbonatica a grana fine. Pozzo S. Croce Camerina 2, 2453 m; sezione sottile, x 12,

solution phenomena and dolomitization manifested by scattered dolomite rhombs are common diagenetic features.

In the S. Croce Camerina 2, Scicli 1 and Scicli 2 wells some pebbly mudstones and breccias were also found. The elements of the pebbly mudstones are made up of pinkish lime wackestones with large radiolarian tests and small gastropod and ammonite remains associated with a minor amount of *Globochaete* and *Lagenidae*. The matrix is a finely « clotted » micrite with dispersed terrigenous-volcanogenic silt and isolated *Schizosphaerella* valves. The latter are mainly recognizable in the microsparite which geopetally fills small diagenetic vugs and fossil moulds. The soft clasts are floating in a marly matrix which appears as a fine-grained bioclastic wackestone richer in terrigenous-volcanogenic silt; the bioclasts are represented only by badly preserved ostracods, small fragments of echinoderms, sponge spicules and *Lagenidae* (fig. 24). The occurrence of these clasts, which display sedimentary and diagenetic features indicative of condensed pelagic deposition, testifies the existence of local and probably shortlived submarine hills within the basinal area. The elements of the breccia, on the contrary, consist of a more or less recrystallized peloidal wackestone with few and badly preserved coprolites, ostracods, echinoderm fragments, arenaceous Foraminifera and *Aeolisaccus*. The elements have angular shapes and are dispersed in a dark matrix constituted by a mixture of fine-grained biodetritus and terrigenous-volcanogenic silt;

condensed sequence, consisting of dark grey nodular marly limestones and marls with associated glauconitic calcarenites (*Facies* 2), deposited over a more stable area with smooth submarine topography north and east of the subsiding basin.

The fine-grained lithologies consist of bioturbated peloidal wackestones/packstones with scattered small ostracods, rare sponge spicules, *Ammodiscidae*, *Lagenidae*, *Spirillina*, echinoderm ossicles, *Aeolisaccus*, *Globochaete*, dispersed unidentified bioclastic material and terrigenous-volcanogenic silt. The matrix reveals a « clotted » texture. These lithotypes constitute also the angular elements of the intraformational breccias found in the Mineo 1 and Mineo 2 wells, which probably are related to a moderate synsedimentary tectonic activity.

The coarse-grained lithologies (fig. 25) are represented by nodular bioclastic packstones with bivalves, gastropods, ammonites, echinoderm fragments, thick-shelled ostracods, abundant arenaceous Foraminifera (*Nubeculariidae*, *Ammodiscidae*), sponge spicules and *Aeolisaccus*. This facies (figs. 26, 27) is characterized by:

— considerable amount of authigenic pyrite and glauconite; these minerals occur either dispersed in the sediment as small grains or concentrated within micro and macrofossils;

— extensive leaching of the aragonite, as testified by dissolution of the ammonite skeletons;

— geopetal filling of the macrofossil tests with micrite rich in *Schizosphaerella*;

— extensive bioturbation, boring and organic encrustation of shell fragments;

composite sequence with condensed hemipelagic deposits of Facies 2 overlain by a prism of shelf-derived coarse resediments (*Facies* 3) extending along WSW-ENE active faults bordering the Siracusa belt to the south. The resediments, constituted by grey-brownish calcarenites and lime breccias, accumulated by different types of mass flow. Interbedded (hemi)pelagic sediments are represented by dark grey marls and clays.

The coarse-grained lithologies usually appear as grain supported sediments with variable matrix contents, and grainstone/packstone textures may be displayed also in the same thin section (fig. 28). The grains are represented by lithoclasts, oncoids, lumps, oolites, unidentified micritized allochems, worn fragments of echinoderms, gastropods and pelecypods, algal remains (*Thaumatoporella*, *Cyanophyceae*), peloids, *Aeolisaccus*, badly preserved arenaceous Foraminifera (*Ataxophragmiidae*, *Textulariidae*, *Ammodiscidae*, *Lituolidae*), ostracods and terrigenous silt. The matrix, where it is present, is frequently recrystallized into a dark sparite. Ex-

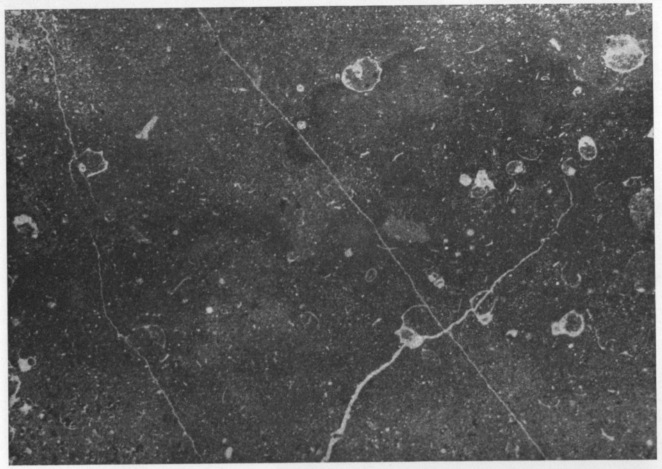


FIG. 24 — Pebbly mudstone from the Streppenosa Formation. Soft clasts consist of bioclastic wackestone with small gastropods and Radiolaria dispersed in a fine shell debris. Gastropods appear typically filled with « clotted » geopetal micrite and sparry calcite. The matrix of the pebbles is a fine-grained wackestone consisting of biodetritus and terrigenous silt. S. Croce Camerina well N° 2, 2480 m; thin section, x 9.

— Pebbly mudstone della Formazione Streppenosa. I clasti, a contorno sfumato, sono costituiti da un wackstone bioclastico con piccoli gesteropodi riempiti geopetalmente da micrite, radiolari e silt biogenico. La matrice dei clasti è data da un wackestone a grana fine con biodetrito e silt terrigeno. Pozzo S. Croce Camerina 2, 2480 m; sezione sottile, x 9.

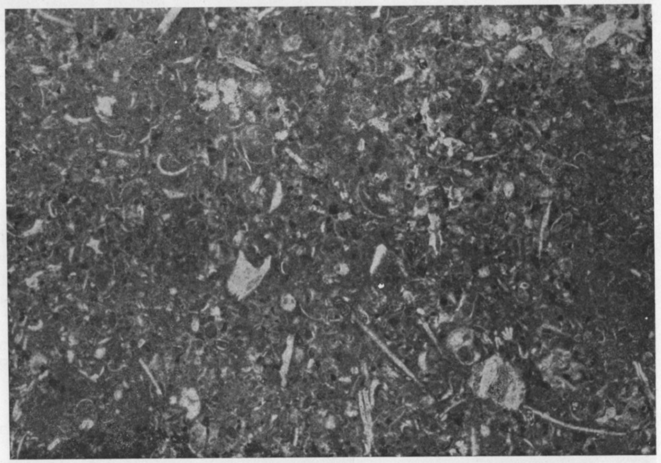


FIG. 25 — Nodular glauconitic limestone from the Streppenosa Formation. Bioclastic packstone/wackestone with worn fragments of small gastropods, pelecypods and echinoderms, associated with ostracods, *Ammodiscidae*, attached benthonic Foraminifera and sponge spicules. Presence of dispersed glauconite grains. Mineo well N° 2, 2686 m; thin section, x 15.

— Calcare glauconitico nodulare della Formazione Streppenosa. Packstone/wackestone bioclastico con frammenti di lamellibranchi, piccoli gesteropodi ed echinodermi, in associazione con ostracodi, ammodiscidi, Foraminiferi bentonici incrostanti e spicole di spugna. Sono riconoscibili granuli dispersi di glauconite. Pozzo Mineo 2, 2686 m; sezione sottile, x 15.

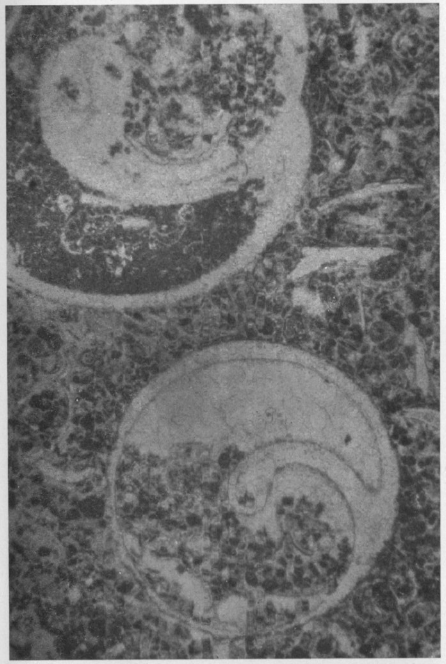


FIG. 26 — Nodular glauconitic limestone from the Streppenosa Formation. Bioclastic packstone with gastropods, shell debris, rounded micritic grains and arenaceous Foraminifera. The micrite matrix is recrystallized into microsparite. The shell of the geopetally-filled gastropod appears bored and encrusted by *Nubeculariidae*, as well as most of the large shell fragments. Shelter effects are recognizable in the sediment filling the gastropod in the lower part of the photograph. Ponte Dirillo well N° 1, 2855 m; thin section AGIP n° 10, x 15.

— Calcare glauconitico della Formazione Streppenosa. Packstone bioclastico con gasteropodi, frammenti di gusci indeterminati, granuli micritici arrotondati e foraminiferi arenacei. La matrice micritica è ricristallizzata in microsparite. Il guscio del gasteropode riempito geopetalmente appare perforato e incrostato da nubecularidi. Questi ultimi incrostano anche la maggior parte dei frammenti organici più grandi. Nel sedimento che riempie il gasteropode nella parte inferiore della foto sono anche riconoscibili effetti di protezione. Pozzo Ponte Dirillo 1, 2855 m; sezione sottile AGIP n° 10, x 15.

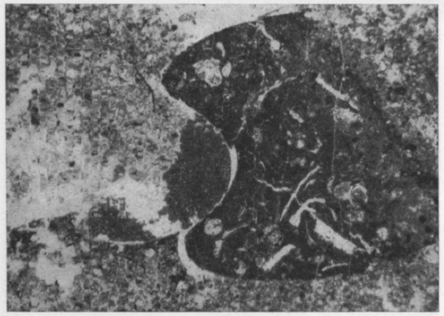


FIG. 27 — Nodular glauconitic limestone from the Streppenosa Formation. Ammonite remain, filled partly with a bioclastic wackstone with tiny gastropods, *Lagenidae* and ostracods, and partly with a fine-grained sediment. The ammonite remain, which shows almost complete removal of the shell material, represents a fragment of exhumed «Steinkern» encrusted by iron-bearing minerals and glauconite before the final burial. Ponte Dirillo well N° 1, 2855 m; thin section AGIP n° 6, x 11.

— Calcare glauconitico nodulare della Formazione Streppenosa. Frammento di ammonite con il guscio riempito in parte da un wackestone bioclastico con piccoli gasteropodi, lagenidi e ostracodi, e in parte da un fine sedimento micritico. Si tratta di un frammento di modello interno riesumato dopo una diagenesi precoce e incrostato da minerali di ferro e da glauconite prima del definitivo seppellimento. Pozzo Ponte Dirillo 1, 2855 m; sezione sottile AGIP n° 6, x 11.

tensive dolomitization and syntaxial overgrowth on echinodermal plates are common diagenetic features; sometimes the dolomitization obliterates the primary texture of the sediment, as well as the nature and the amount of the original matrix. Fine-grained resediments may be occasionally intercalated within the calcarenites and breccias. They are bioclastic wackestones with small *Lagenidae*, peloids, ostracods, sponge spicules, small arenaceous Foraminifera and Radiolaria.

Modica Formation (*Lotharingian-Domerian*)

RIGO and BARBIERI (1959) include the Liassic basinal deposits overlying the Streppenosa Formation into the middle-upper Liassic Villagonia Formation. The latter, however, was established in the Peloritani Mountains, in a sequence belonging to the Longi-Taormina Unit of AMODIO MORELLI *et al.* (1978).

Synonymies: Villagonia Formation of RIGO and BARBIERI (1959)
Source of name: Modica well N° 1, located north of Modica
Geographic coordinates: Lat. 33° 53' 14" N; Long. 2° 19' 33" E
Operating Company: AGIP Mineraria
Date of drilling: 12/4/56 - 13/2/57
Total depth: 3060.30 metres
Ground elevation: 550 metres

In the type-well the Modica Formation was crossed from 2170 to 2523 metres. The boundary with the underlying Streppenosa Formation is gradational, while the upper contact with the Buccheri Formation is sharp (Plate 3).

The unit extends in the subsurface of the whole Ragusa belt, and has been found only locally (Siracusa 1) in the Siracusa belt. As in the type-well, in the whole Ragusa belt the lower boundary coincides with the top of the Streppenosa Formation and only in the Siracusa well N° 1 with the top of the Siracusa Formation. The upper boundary is marked in the whole area by the base of the Buccheri Formation. The Modica Formation is Lotharingian-Domerian in age (see BARBIERI, 1964), and is heteropic with the upper part of the Siracusa Formation; the thickness ranges from some tens of metres to about 500 metres (fig. 52). The following three kinds of sequence with different areal distributions can be distinguished (fig. 63):

basinal sequence, entirely consisting of fine-grained carbonate sediments which we interpret as peri-platform ooze (see SCHLAGER and JAMES, 1978). These deposits (*Facies 1*), occurring in the southern part of the Ragusa belt, include light grey cherty limestones and mottled marly limestones alternating with grey-greenish marls and clays. Grey micaceous calcisiltites with *Chondrites*-type burrows are present mainly in the lowermost part of the sequence. Moreover, sporadic basalts and hyaloclastite levels were found in some boreholes (fig. 53). The limestones appear as fine-grained bioclastic wackestones with Radiolaria (frequently preserved as moulds geopetally filled with microsparite), sponge spicules, thin-shelled ostracods, rare ammonite remains, scattered *Globochaete* and *Stomiosphera*, algal filaments, *Lagenidae*, *Involutina*, *Spirillina*, small echinoderm fragments, a few, badly preserved, arenaceous Foraminifera and subordinate

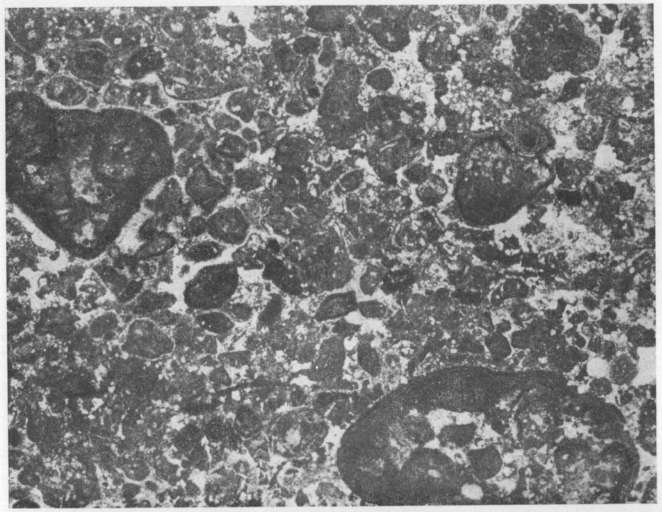


FIG. 28 — Coarse calcarenite from the Streppenosa Formation. Litho-bioclastic grainstone /packstone with rounded lithoclasts of shallow-water origin, ooids, algal remains and other unidentified allochem grains. All the allochems show extensive micritization. Local free-matrix interparticle voids have been entirely or partly filled with fibrous calcite. A faint dolomitization is manifested by the presence of scattered dolomite rhombs. Naftia well N° 1, 1695 m; thin section, x 16.

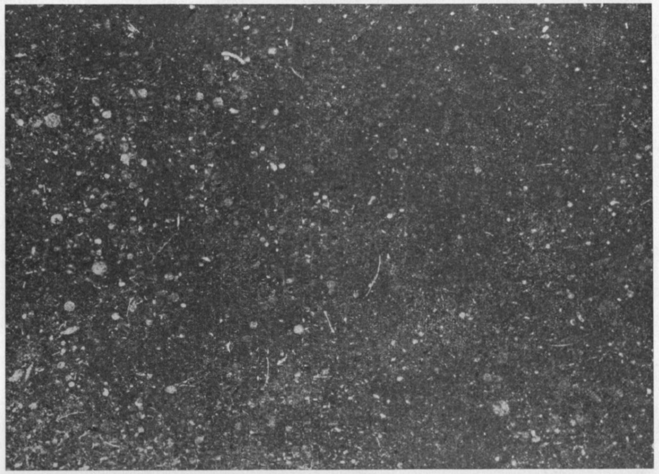
— Calcarenite grossolana della Formazione Streppenosa. Grainstone/packstone lito-bioclastico con elementi arrotondati di origine neritica, ooidi, resti algali ed altri allochimici non determinati. I granuli mostrano fenomeni di intensa micritizzazione. Locali vuoti intergranulari originariamente privi di matrice sono stati riempiti in tutto o in parte da calcite fibrosa. La presenza di romboedri dispersi di dolomite testimonia una debole dolomitizzazione. Pozzo Naftia 1, 1695 m; sezione sottile, x 16.

terrigenous silt (fig. 29). The micrite matrix contains numerous schizosphaerellids, particularly evident (even in thin section) where the surrounding micrite is replaced by neomorphic microsparite. In some places, closely-packed *Schizosphaerella* valves give a « clotted » appearence to the matrix (1). These deposits, consisting of a mixture of fine-grained pelagic and neritic materials, are thought to be in large part redeposited. The absence of any trace of sedimentary structures, except a sporadic faint lamination, may result from intensive bioturbation. The existence of subaqueous gravity movements is, anyhow, supported by some layers of undoubtable turbidite origin (usually D-E and C-E beds) and by some pebbly mudstones (e.g. S. Croce Camerina 2). In the latter the lithoclasts, represented by a bioclastic wackestone displaying « subsolution » features (see Facies 2), prove the existence of submarine hills, seats of condensed deposition, also within the basinal area;

composite sequence consisting of red nodular ammonite-bearing limestones (*Facies* 2) overlain by light grey and greenish limestones and marls referable to the Facies 1. The nodular limestones presumably mark local and shortlived submarine hills inherited from the Sinemurian physiography. They are bioclastic wackestones (fig. 30). with ammonite

FIG. 29 — Bioturbated marly limestone from the Modica Formation. Very fine-grained bioclastic wackestone with Radiolaria, sponge spicules, thin-shelled bivalves and *Globochaete*, associated with a variable amount of biogenic and terrigenous silt. The irregular distribution of the microshells is determined by extensive bioturbation. Scicli well N° 1, 2376 m; thin section, x 15.

— Calcare marnoso bioturbato della Formazione Modica. Wackestone bioclastico a grana fine con Radiolari, spicole di spugna, frammenti di sottili gusci di lamellibranchi e *Globochaete*, associati a biodetrito e a silt terrigeno. La distribuzione irregolare dei microfossili testimonia una intensa bioturbazione del sedimento. Pozzo Scicli 1, 2376 m; sezione sottile, x 15.



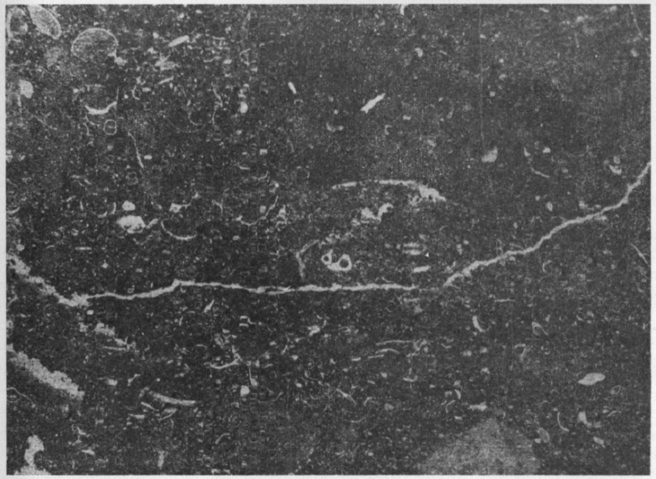


FIG. 30 — Red nodular limestone from the Modica Formation. Faintly nodular bioclastic wackestone with ammonite remains, fragments of pelecypods and gastropods, ostracods, *Involutina liassica*, Radiolaria, *Lagenidae* and unidentified shell debris. The matrix is a micrite with « clotted » texture. Presence of early diagenetic vugs and fractures filled with geopetal microsparite. Palazzolo well N° 1, 2120 m; thin section, x 6.

— Calcare nodulare rosso della Formazione Modica. Wackestone bioclastico a struttura debolmente nodulare con resti di ammoniti, frammenti di lamellibranchi e gasteropodi, ostracodi, *Involutina liassica*, radiolari, lagenidi e biodetrito. La matrice è una micrite a tessitura grumosa. Presenza di cavità e fratture di diagenesi precoce riempite geopetalmente da microsparite. Pozzo Palazzolo 1, 2120 m; sezione sottile, x 6.

(1) Similar « clotted » or « pelletted » textures are described in Jurassic deposits of the Tuscan realm by KÄLIN *et al.* (1979).

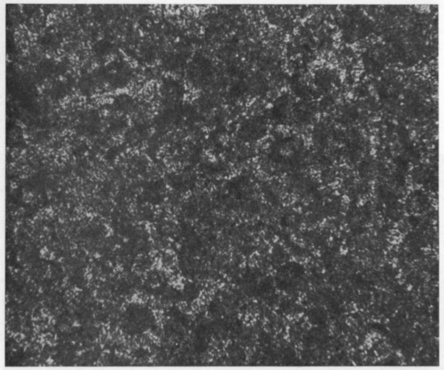


FIG. 31 — Red nodular limestone from the Modica Formation. The « clotted » appearance of the micrite results from a close framework of *Schizosphaerella* valves. The latter are particularly evident where the micrite underwent aggrading neomorphism phenomena. Naftia well N° 2, 807 m; thin section, x 180.

— Calcare rosso nodulare della Formazione Modica. L'aspetto grumoso della matrice è dovuto all'abbondanza di valve di *Schizosphaerella*. Queste ultime sono particolarmente evidenti laddove la micrite ha subito deboli processi di ricristallizzazione. Pozzo Naftia 2, 807 m; sezione sottile, x 180.

remains, large Radiolaria, bivalve fragments, thick-shelled ostracods, well preserved *Lagenidae* (*Frondicularia exagona*), *Involutina liassica*, *Spirillina*, *Lenticulina*, echinoderm fragments, *Stomiosphaera*, aptychi, small brachiopods and gastropods and rare arenaceous Foraminifera (*Ammodiscidae*). The matrix is a *Schizosphaerella*-rich micrite with a « clotted » appearence (fig. 31); *Schizosphaerella* valves are particularly abundant and well preserved in the microsparite which occurs as geopetal infill within early diagenetic vugs and fossil moulds The deposits of Facies 2 display all the sedimentary and diagenetic features typical of the Tethyan ammonite-bearing nodular limestones (Rosso Ammonitico *Auct.*, see SCHLAGER, 1974; JENKYNS, 1974). These include:

— intensive bioturbation and oxidation of the sediment;

— boring and FeO encrustations of shell fragments;

— extensive leaching of the aragonitic ammonite tests;

— early cementation testified, for instance, by small diagenetic vugs and thin fissures filled with « clotted » microsparite;

proximal basinal sequence made up of coarse-grained lime resediments containing shelf-derived particles and skeletal debris (*Facies* 3). These resediments form a wedge, 100 to 350 metres thick, along the margins of the Ragusa belt. The wedge thins towards the central part of the Ragusa belt by interfingering with more distal turbidites which, in turn, grade into the basinal deposits of the Facies 1.

This type of sequence has been found in the Rabbito 1, Cammarata 1, Ponte Olivo 1, Caltagirone 1, Naftia 1, Siracusa 1 and Avola 1 wells. In some holes (Caltagirone 1, Cammarata 1 and Naftia 1) these resediments, interpreted by petroleum geologists as shallow-water carbonates, were included in the Inici Formation (Siracusa Formation in this paper). The lithologies comprise light cream cherty calcarenites and calcareous breccias with marly intercalations. It is difficult to trace in this area the boundary between the Streppenosa and the Modica formations, since their lithologies are very similar. The Streppenosa Formation, however, differs from the Modica Formation by the presence of dark grey marly and clayey interlayers, by the occurrence of terrigenous sand or silt and by diffuse strong dolomitization.

The coarse-grained lithologies consist of ooidal and bio/lithoclastic packstones with small rounded intraclasts, fragments of calcareous algae (*Thaumatoporella* and *Cyanophyceae*), ooids, coated or entirely micritized particles, bored echinodermal plates, worn fragments of bivalves, arenaceous Foraminifera (*Ataxophragmiidae*, *Ammodiscidae*, *Textulariidae*, *Lituolidae*, *Ophthalmidiidae*), *Aeolisaccus* and a few *Lagenidae*, Radiolaria, sponge spicules and ostracods (fig. 32). Syntaxial overgrowth on echinoderm ossicles and aggrading neomorphism are very common features in this facies.

The grain size of these resediments decreases towards the centre of the basin and merely fine-grained turbidites occur south of the Rabbito-Naftia area. The deposits consist of bioclastic wackestones with Radiolaria, sponge spicules, *Lagenidae*, ostracods, thin-shelled bivalves, echinoderm particles, *Globochaete*, *Stomiosphaera* and a variable amount of arenaceous Foraminifera (*Ammodiscidae*, *Ataxophragmiidae*, *Textulariidae*, *Vidalina martana*), *Aeolisaccus*, algal filaments, lumps and small micritized grains. The « clotted » appearance of the sediment is due to the presence of tightly-packed minute *Schizosphaerella* valves and clusters of radiating calcite fibres. The latter (? algal precipitates, see MONTY, 1976) appear in thin section much lighter than the surrounding micrite matrix. Parallel lamination and extensive biogenic reworking are common sedimentary structures.

Some levels of pebbly mudstones with soft clasts consisting of pinkish limestones were found in the Gela 1 and Ponte Dirillo 1 wells. The calcareous elements, identical to the condensed pelagic limestones of the previoulsly described Facies 2, suggest that a scarcely subsiding area with aligned submarine hills persisted south of the Rabbito-Naftia slope (fig. 63).

Buccheri Formation (*Toarcian-lower Tithonian*)

The Buccheri Formation roughly corresponds to the Giardini Formation of petroleum geologists. The introduction of a new formational name has been necessary since the Giardini Formation was established by RIGO and BARBIERI (1959) in the Peloritani Mountains where a Jurassic sequence

belonging to the Longi-Taormina Unit of AMODIO MORELLI *et al.* (1978) is exposed.

Synonymies: Giardini Formation of RIGO and BARBIERI (1959); « Red Unit » of some petroleum geologists (see e.g. Chiaramonte well N° 1, GULF Italia 1955; Comiso well N° 1, Mediterranean Oil Company 1955; Francofonte well N° 2, Società Idrocarburi Francofonte 1958)

Source of name: Buccheri well N° 2, located NE of Buccheri village

Geographic coordinates: Lat. 37° 09' 01" N; Long. 2° 25' 48" E

Operating Company: GULF Italia

Date of drilling: 13/1/58 - 28/2/58

Total depth: 1472 metres

Ground elevation: 561 metres

Buccheri Formation is generally made by the top of the Modica Formation except in the Pozzillo 1, Catania 10, S. Demetrio 1 and Melilli 1 wells where the Buccheri Formation disconformably overlies the Siracusa Formation. The formational boundary is quite evident in most of the logs, as it coincides with a sudden increase in the clay contents. The upper boundary with the Chiaramonte Formation, on the contrary, is not evident from the electric logs; we, thus, defined the upper boundary by the occurrence of the first calpionellids (beginning of the *Crassicollaria* zone, ALLEMANN *et al.*, 1970).

Many boreholes crossed mafic volcanites which occur both as basaltic and hyaloclastitic layers intercalated in the sedimentary sequence and/or as huge massive bodies forming isolated submarine

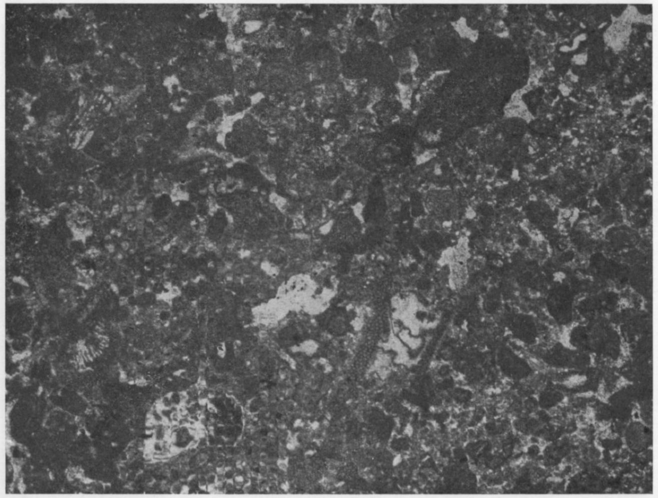


FIG. 32 — Calcarenite from the Modica Formation. Bio-lithoclastic packstone with *Thaumatoporella* fragments, rounded micritized grains, arenaceous Foraminifera and echinodermal particles. The micrite matrix is partly recrystallized into microsparite or sparite. Rabbito well N° 1, 4475 m; thin section, x 18.

— Calcarenite della Formazione Modica. Packstone bio-litoclastico con resti di *Thaumatoporella*, granuli micritizzati, foraminiferi arenacei e frammenti di echinodermi. La matrice micritica è parzialmente ricristallizzata in microsparite o sparite. Pozzo Rabbito 1, 4475 m; sezione sottile, x 18.

In the type-well the Buccheri Formation was crossed between 1096 and 1224 metres. The lower boundary with the Modica Formation is sharp, the upper one with the Chiaramonte Formation is gradational (Plate 3). By analyzing the cutting succession it was possible to divide the Buccheri Formation into three intervals, recorded also by the electric log pattern:

— *upper interval* (from 1096 to 1120 metres), consisting of red nodular marly limestones with *Saccocoma*, *Stomiosphaera* and *Globochaete*;

— *middle interval* (from 1120 to 1166 metres), made up of Radiolaria-bearing cherty limestones and siliceous limestones;

— *lower interval* (from 1166 to 1224 metres), characterized by reddish and greenish marls with pelagic bivalve lumachelles.

As in the type-well, the lower boundary of the volcanoes (fig. 55). We propose the term « *Scicli* Member » of the Buccheri Formation for these volcanic sea-mounts.

Source of name: Scicli well N° 2, located NW of Scicli

Geographic coordinates: Lat. 36° 46' 57" N; Long. 2° 15' 17" E

Operating Company: AGIP Mineraria

Date of drilling: 28/10/61 - 1/2/62

Total depth: 3309 metres

Ground elevation: 225 metres

In the Scicli well N° 2 the volcanic edifice was crossed between 729 and 1420 metres. It overlies Middle Jurassic basinal marls and marly limestones with volcanic intercalations, and is followed by condensed nodular limestones of Upper Jurassic age. The volcanic edifice was responsible here for the sudden change of sedimentation from basinal to typical sea-mount depositional conditions.

The Buccheri Formation extends over the whole Ragusa zone, but displays considerable lateral variations in thickness (fig. 54) and facies (figs. 64, 65). These variations are related both to the inheritance of the relief caused by the early Liassic synsedimentary tectonics and to the Middle-Upper Jurassic volcanic activity.

Although the available data are scattered, in the areas with scarce volcanic activity it is possible to recognize two types of sequence:

complete sequence, in which the succession of the microfacies (pelagic bivalves-Radiolaria-*Saccocoma*) allows the same tripartition as in the type-well; the total thickness of the formation ranges from 50-100 to 650 metres. Each of the above distinguished three intervals displays lateral variations in thickness and facies. The available data do not allow a precise age assignment, nor a reliable evaluation of the thicknesses.

The preservational characteristics of the skeletons (ammonites-pelagic bivalves-Radiolaria) in the sequence reflect a progressive increase in carbonate dissolution untill Callovian. Towards the end of the Upper Jurassic a depression of the solution levels is testified by the preservation, once again of carbonate particles (*Saccocoma*).

The lower interval is characterized by the abundance of pelagic bivalves (*Bositra buchi* or *Posidonia alpina Auct.*). The sedimentary features and the fossils occurring throughout this interval, suggest a correlation with *Posidonia*-bearing marls and limestones (e.g. Marne a *Posidonia Auct.*) widely developed in the Jurassic periadriatic domains. The age ranges probably from the upper Liassic (Toarcian, see Barbieri, 1964) to the Bathonian. Two kinds of facies (fig. 64) may be distinguished:

— basinal resediments (*Facies* 1), chiefly occurring in the southern part of the study area; the major lithologies comprise grey-greenish marls and marly limestones. The latter appear as fine-grained bioclastic packstones/wackestones (fig. 33) with abundant pelagic bivalves, Radiolaria, sponge spicules, ostracods, *Lagenidae*, *Spirillina*, *Lenticulina*, fragments of echinoderms, badly preserved *Globochaete*, *Stomiosphaera*, aptychi and arenaceous Foraminifera (*Ophthalmidiidae*); Radiolaria become more frequent towards the upper part of the lower interval. Small amounts of terrigenous silt (quartz, feldspars and white mica) are mixed with the skeletal material. The matrix is a micrite which appears vaguely « clotted » by the presence of isolated *Schizosphaerella* valves. These deposits display a discontinuous faint lamination evidenced by the isoorientation of shell debris, burrowing and sporadic grading; they are thought to represent distal turbidites;

— more or less condensed basinal deposits (*Facies* 2), developed over a more stable area with smooth topography, located around the former subsiding basin. They are represented by red-greenish marls and clayey marls often displaying nodular structure, with intercalations of thin lumachella-layers. The latter consist of pelagic-bivalve packstones/wackestones with scattered *Globochaete*, aptychi, skeletal debris and rare partly-dissolved ammonite skeletons. The matrix is a clay-rich « clotted » micrite. These shell beds, only a few centimetres thick, originated by both turbidite currents and bottom currents (2). The turbidite layers (fig. 34), probably caused by dilute low-velocity currents, always display grading and parallel lamination, and sometimes a vague current cross-lamination. The bottom current deposits, on the contrary, are characterized by lenticular and discontinuous layers showing sharp boundaries; the bivalves often occur in glomerate clusters, and sheltered cavities are a quite common feature. Also some pelagic-bivalve packstones (e.g. Rabbito 1), displaying ill-defined sets of small-scale ripple cross-laminae (fig. 35), may be possibly referred to bottom current deposits. The « normal » sedimentation between shell beds is represented by mottled marlstones appearing as « pelletted » wackestones with bivalve debris, badly preserved Radio-

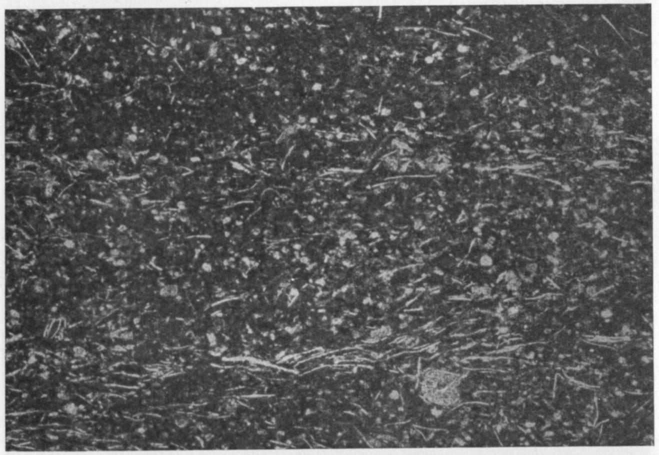


Fig. 33 — Grey-greenish marly limestone from the lower interval of the Buccheri Formation. Bioclastic packstone/wackestone with thin-shelled pelagic bivalves, echinoderm fragments, Radiolaria and rare sponge spicules. A thin parallel lamination is evidenced by isoorientation of the shell debris. Noto well N° 1, 1769; thin section, x 20.

— Calcare marnoso grigio-verde dell'intervallo inferiore della Formazione Buccheri. Packstone /wackestone bioclastico con lamellibranchi pelagici, frammenti di echinodermi, radiolari e rare spicole di spugna. Una sottile laminazione parallela è messa in evidenza dalla isoorientazione dei frammenti di gusci. Pozzo Noto 1, 1769 m; sezione sottile, x 20.

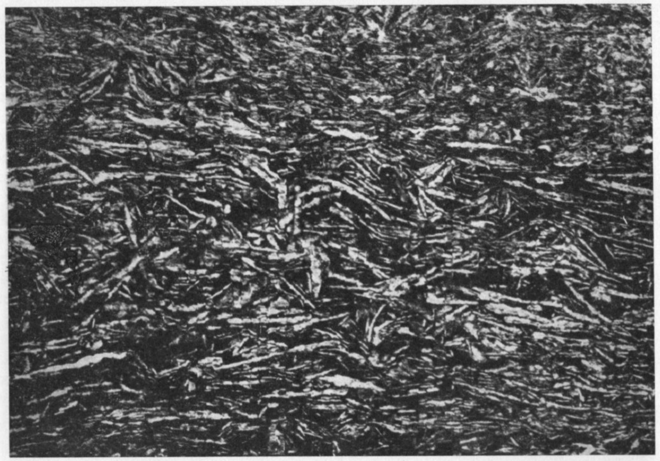


Fig. 34 — Red nodular marly limestone from the lower interval of the Buccheri Formation. Pelagic-bivalve packstone showing normal grading due to an upwards decrease in size of the shell fragments. Naftia well N° 2, 708 m; thin section, x 24.

— Calcare marnoso rosso nodulare dell'intervallo inferiore della Formazione Buccheri. Packstone a bivalvi pelagici mostrante una gradazione determinata dalla riduzione delle dimensioni verso l'alto dei frammenti di gusci. Pozzo Naftia 2, 708 m; sezione sottile, x 24.

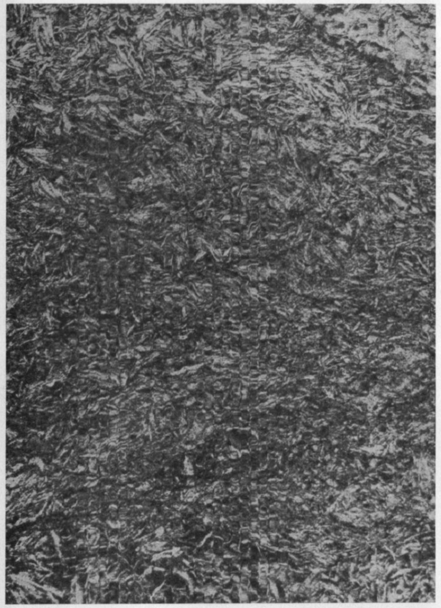


Fig. 35 — Red nodular marly limestone from the lower interval of the Buccheri Formation. Pelagic-bivalve packstone with vague cross-laminae shown by different orientation of the shells, varying contents in micrite matrix and different degree of the shell fragmentation. The orientation of the laminae is locally outlined by pressure-solution strands. Rabbito well N° 1, 4178 m, thin section, x 12.

— Calcare marnoso rosso nodulare dell'intervallo inferiore della Formazione Buccheri. Packstone a lamellibranchi pelagici con una mal definita laminazione obliqua. I singoli sets di lamine mostrano diversa orientazione e differente grado di frammentazione dei gusci, e posseggono inoltre un diverso contenuto in matrice micritica. L'andamento delle lamine è a luoghi sottolineato da una sottile trama ferruginosa dovuta a processi di pressione-dissoluzione. Pozzo Rabbito 1, 4178 m; sezione sottile, x 12.

(2) For a detailed description of these kinds of deposit see Kälin *et al.* (1979).

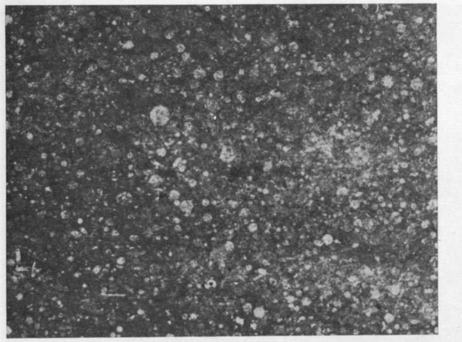


FIG. 36 — Greenish siliceous limestone from the middle interval of the Buccheri Formation. Radiolarian packstone. As a result of a strong bioturbation the radiolarian tests are irregularly distributed and concentrated as nests. Scicli well N° 1, 1955 m; thin section, x 16.

— Calcare siliceo verdastro dell'intervallo medio della Formazione Buccheri. Packstone a radiolari. La distribuzione irregolare dei gusci è dovuta ad una intensa bioturbazione del sedimento. Pozzo Scicli 1, 1955 m; sezione sottile, x 16.

laria, *Lagenidae* and thin-shelled ostracods. The bioclasts are dispersed in a fine-grained compound of biodetritus and volcanogenic silt.

The middle interval, probably Callovian-Kimmeridgian in age, is represented everywhere by light grey and greenish siliceous cherty limestones and calcareous radiolarites with red and green marly interbeds. Similar lithofacies are widespread in Jurassic deeper-marine sequences of the southern continental margin of the Tethys (e.g. « scisti diasprigni » or « calcari diasprini » *Auct.* of the Umbrian realm). The calcareous-siliceous beds consist of radiolarian wackestones/packstones (fig. 36) with rare and badly preserved *Spirillina*, *Globochaete*, *Stomiosphaera*, and variable amounts of silt -sized biodetritus. Radiolaria (mainly spumellinids) are commonly preserved as moulds filled by fibrous calcedony or microcrystalline quartz. The calcimicrite matrix is patchily replaced by silica. Some relics of parallel lamination preserved in unburrowed parts of the sediment suggest a deposition from slowly-moving dilute turbidity flows. In the uppermost part of the middle interval, the limestones become less siliceous; Radiolaria are commonly replaced by microsparite or sparite and *Saccocoma* fragments appear for the first time. The cutting succession from the Grammichele 1 and Monterosso S1 wells shows that sometimes bioclastic wackestones with pelagic bivalves and *Globigerina helvetojurassica* may be associated with the calcareous radiolarites.

The upper interval is characterized by abundant *Saccocoma* ossicles; the age is probably uppermost Kimmeridgian-lower Tithonian. As in the lower interval, two facies may be distinguished, represented by:

— fine-grained resediments with pelagic components (*Facies* 1), accumulated in a small depression located in the southern part of the study area which acted as a sediment trap. This facies is represented by light cream cherty limestones alternating with reddish and greenish marls. The calcareous beds consist of fine-grained bioclastic wackestones with *Saccocoma* fragments, *Stomiosphaera*, well preserved *Globochaete*, Radiolaria, sponge spicules, *Lagenidae*, *Spirillina*, *Lenticulina*, thin-shelled ostracods and abundant silty biodetritus (fig. 37). These deposits, which usually display both parallel lamination and bioturbation, suggest redeposition by low-flow-regime turbidity currents. In the Pachino well

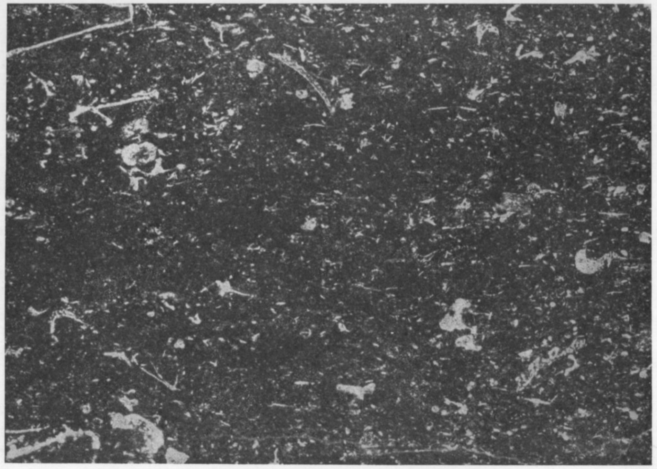


FIG. 37 — Greenish marly limestone from the upper interval of the Buccheri Formation. Bioclastic wackestone with *Saccocoma*, aptychi and shell debris. Parallelly oriented skeletal fragments in the mud-supported sediment suggest deposition by low density-low velocity currents. Pachino well N° 4, 1321 m; thin section, x 16.

— Calcare marnoso verdastro dell'intervallo superiore della Formazione Buccheri. Wackestone bioclastico con *Saccocoma*, aptici e frammenti di gusci. L'orientazione dei frammenti organici, in un sedimento a matrice prevalente, suggerisce deposizione da correnti torbide di bassa energia. Pozzo Pachino 4, 1321 m; sezione sottile, x 16.

N° 4 soft-sediment deformation structures were found in some levels (fig. 38);

— condensed pelagic deposits (*Facies* 2), developed north and east of the previous basinal deposits. They consist of red-greenish mottled marls and

FIG. 38 — Pebbly mudstone from the upper interval of the Buccheri Formation. The soft clast is a bioclastic wackestone with Radiolaria and *Saccocoma*. The matrix mainly consists of biogenic bioclasts with lighter-coloured streaks richer in clay minerals derived from volcanogenic material. Pachino well N° 4, 1319 m; thin section, x 7.

— Pebbly mudstone proveniente dall'intervallo superiore della Formazione Buccheri. Il clasto, dal contorno sfumato, è costituito da un wackestone bioclastico con radiolari e *Saccocoma*. La matrice è data sopratutto da un tritume biogenico con sottili bande discontinue più chiare ricche in minerali argillosi derivanti da alterazione di materiale vulcanogenico. Pozzo Pachino 4, 1319 m; sezione sottile, x 7.

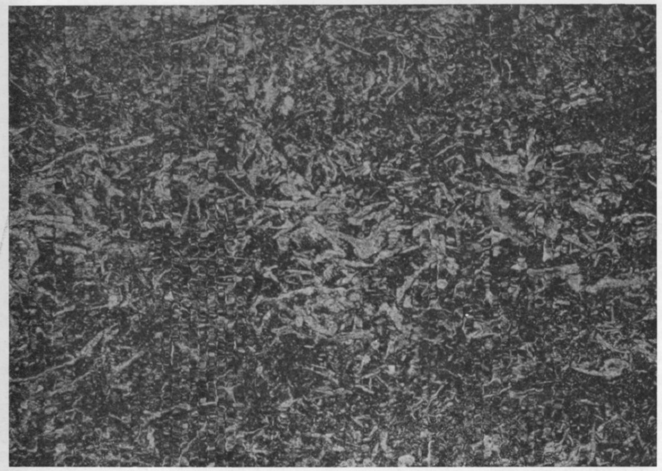


FIG. 39 — Reddish nodular limestone from the upper interval of the Buccheri Formation. *Saccocoma* packstone. Giarratana well N° 1, 1206 m; thin section, x 15.

— Calcare rosso nodulare proveniente dalljintervallo superiore delle Formazione Buccheri. Packstone a *Saccocoma*. Pozzo Giarratana 1, 1206 m; sezione sottile, x 15.

marly limestones often displaying nodular texture. The latter are *Saccocoma* wackestones/packstones with *Globochaete*, *Stomiosphaera* and aptychi, associated with rare *Lagenidae*, *Spirillina*, *Lenticulina* and Radiolaria. (fig. 39). The presence of lenticular and discontinuous thin layers of *Saccocoma* packstones suggests sporadic activity of winnowing bottom currents;

condensed and incomplete sequence, with maximum thickness of 30 metres, developed in the marginal areas corresponding to morphological highs (Cammarata 1, Pozzillo 1, Catania 10, S. Demetrio 1, Melilli 1 and, probably, Naftia 1, Sigona Grande 1 and Ponte Olivo 1). This sequence consists of nodular pinkish limestones and is characterized, mainly in the lower part of the formation, by sedimentary gaps related to submarine erosion and/or non-deposition. In this type of sequence the upper Liassic and part of the Middle Jurassic seem to lack everywhere. The upper part of the Middle Jurassic (probably Callovian) has been recognized only in the Catania well N° 10. It is represented by pelagic-bivalve packstones with scattered *Globigerina helvetojurassica* and a few areanaceous Foraminifera, *Lenticulina*, *Lagenidae* and echinodermal plates. The upper Jurassic, represented by nodular pinkish limestones with *Globigerina helvetojurassica* (*Facies* 3) and by overlying red nodular marly limestones with *Saccocoma*, appears, on the contrary, widely developed. The pinkish limestones of Facies 3 are heteropic with the upper part of the Radiolaria-bearing siliceous limestones and with the lower part of the *Saccocoma*-bearing red marls of the above described complete sequence (middle and upper intervals). They consist of bioclastic packstones with *Globigerina helvetojurassica*, *Saccocoma*, large Radiolaria, ammonite remains, belemnites, echinodermal fragments, thin-shelled bivalves, abundant and well preserved *Globochaete* and *Stomiosphaera*, aptychi, *Spirillina*, *Lagenidae*, *Lenticulina*, rare arenaceous Foraminifera (*Ammodiscidae*), ostracods and small gastropods. This lithology commonly displays all the sedimentary and diagenetic features (e.g. strong bioturbation and boring, differential carbonate dissolution, early cementation etc.) typical of the condensed pelagic deposits. The overlying red nodular marly limestones are very similar to the Facies 2 of the upper interval in the complete sequences. They are characterized by thin *Saccocoma* lumachelles which also in this case are interpreted as a kind of lag deposits caused by winnowing of bottom currents during periods of slow accumulation.

In the areas where widespread magmatic activity occurred (fig. 55), the Buccheri Formation displays significant vertical variations in facies obviously related to sudden or gradual modifications of the sea-bottom topography. The most striking facies variations occurred in correspondence to the volcanic sea-mounts (fig. 64, 65). In the Streppenosa 1 and Scicli 2 holes, for instance, the lower part of the sequence exhibits typical basinal characteristics, while the upper part which overlies the sea-mount is represented by condensed lime deposits (fig. 40). The latter, consisting of nodular packstones/wackestones with *Globigerina helvetojurassica* and *Saccocoma*, bear a strong resemblance to the previously described deposits of the incomplete sequence. Gradual change from basinal to condensed pelagic deposits on morphological highs may occur also not in obvious relations with volcanic edifices. Such variations have been recognized both in deeper basinal areas (Ragusa well N° 1, fig. 41) and in more stable areas characterized by thin incomplete sequences (Vittoria well N° 1). These sea-floor modifications testify local upwelling possibly related to the magmatic activity. In the Vittoria well N° 2, however, the sequence consists of condensed nodular limestones and marls followed by a close alternation of mafic volcanites and condensed pelagic deposits. The sedimentary succession and the characteristics of the sediments suggest here the existence of local and smooth submarine hills even before the first intense volcanic activity.

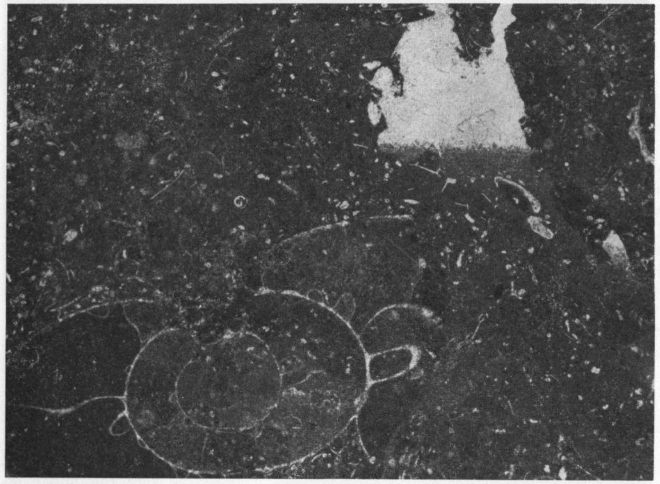


FIG. 40 — Red nodular limestone from the Buccheri Formation. Bioclastic wackestone with ammonite remains, aptychi, Radiolaria, *Globochaete*, *Saccocoma* and ostracods. The ammonite skeleton, already filled with early lithified sediment hardly distinguishable from the embedding matrix, was exhumed and reworked, as is shown by boring and mechanical corrosion. The aragonite test was dissolved after final burial, since geopetal sediment in the shell mould is oriented the same way up as in the nearby vugs of the matrix. Scicli well N° 2, 695 m; thin section, x 15.

— Calcare rosso nodulare della Formazione Buccheri. Wackestone bioclastico con resti di ammoniti, aptici, radiolari, *Globochaete*, *Saccocoma* e ostracodi. L'ammonite, già riempita da un sedimento precocemente litificato, difficilmente distinguibile dalla matrice circostante, è stata riesumata e rimaneggiata sul fondo, come è dimostrato dalla presenza di corrosione meccanica e organica. La dissoluzione del guscio aragonitico è avvenuta dopo il seppellimento finale, dal momento che il sedimento che riempie la sottile cavità del guscio ha la stessa orientazione geopetale di quello che riempie i vuoti da diagenesi precoce nella matrice. Pozzo Scicli 2, 695 m; sezione sottile, x 15.

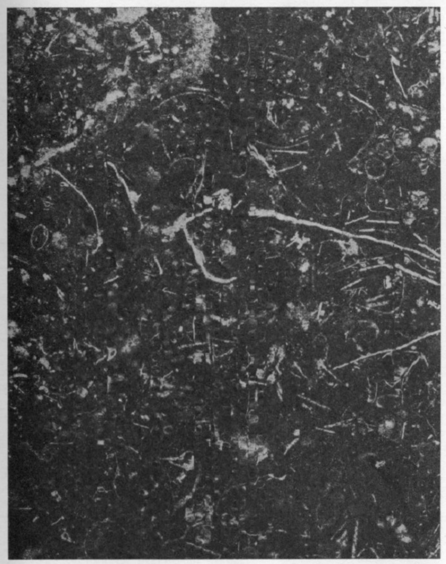


FIG. 41 — Red nodular limestone from the Buccheri Formation. Bioclastic wackestone with *Saccocoma*, *Globigerina helvetojurassica*, Radiolaria, *Globochaete*, debris of thin-shelled bivalves and ostracods. The matrix is a micrite displaying « clotted » texture. Large radiolarian and globigerinid tests are frequently filled with geopetal microsparite. Ragusa well N° 1, 912 m; thin section, x 14.

— Calcare rosso nodulare della Formazione Buccheri. Wackestone bioclastico con *Saccocoma*, *Globigerina helvetojurassica*, radiolari, *Globochaete*, ostracodi e frammenti di lamellibranchi pelagici. La matrice è costituita da una micrite a tessitura grumosa. I gusci dei radiolari di maggiori dimensioni e quelli dei globigerinidi sono spesso riempiti da microsparite geopetale. Pozzo Ragusa 1, 912 m; sezione sottile, x 14.

Chiaramonte Formation (upper Tithonian-lower Hauterivian)

Petroleum geologists called the Busambra Member of the Alcamo Formation a sequence of Tithonian-Neocomian white cherty limestones which in the Ragusa zone are underlain by the Giardini Formation (Buccheri Formation in this paper) and overlain by the Hybla Member of the Alcamo Formation (Hybla Formation in this paper). We propose a new type-locality in the Ragusa zone, since the Busambra type-section (RIGO and BARBIERI, 1959) belongs to a tectonic unit of the Trapanese realm. Moreover, the wide extend in the whole Ragusa zone and the characteristics of these deposits justify, in our opinion, the establishment of a formational unit rather than a member.

Synonymies: Busambra Member of the Alcamo Formation (RIGO and BARBIERI, 1959); « lattimusa » *Auct.*; Kumeta Unit of some petroleum geologists (see, e.g., Avola 1, RAP-SIS 1963)
Source of name: Chiaramonte well N° 1, located north of Chiaramonte Gulfi village
Geographic coordinates: Lat. 37° 01' 40" N; Long. 2° 16' 25" E
Operating Company: GULF Italia
Date of drilling: 16/7/55 - 3/11/55
Total depth: 2242 metres
Ground elevation: 840 metres

In the type-well the unit was drilled from 1340 to 1590 metres. The lower boundary with the Buccheri Formation is gradational, the upper one with the Hybla Formation is sharp and well evidenced by the electric log (Plate 3). The sequence consists of calpionellid-bearing white cherty limestones with marly intercalations upwards increasing in frequence. This type of lithofacies is widespread in the Upper Jurassic-Lower Cretaceous deeper marine sequences of the Tethyan realm (e.g. « maiolica » or « biancone » *Auct.*).

The Chiaramonte Formation was found in the whole Ragusa zone, except in the Catania well N° 10 where mafic volcanites of unknown age, followed by Pliocene deposits, overlie the Buccheri Formation. The upper boundary with the Hybla Formation corresponds to a sudden change in lithology, which happened simultaneously over the whole Ragusa zone. The boundary is picked out by a sharp upwards decrease of the resistivity values in all the electric logs. The Buccheri-Chiaramonte contact, on the contrary, is gradational and does not display the same characteristics everywhere. Therefore, we adopted a biostratigraphic criterium, that is, the first appearance of calpionellids to fix the lower formational boundary. This criterium does not strictly obey the rules for the definition of formations, but allowed us to evidence significant facies and thickness variations within the Upper Jurassic-Lower Cretaceous deposits. The thickness (fig. 56) ranges from 10-20 metres to 350 metres. In the Chiaramonte Formation three kinds of sequence are distinguished:

thick basinal sequence, consisting of fine resediments with pelagic components (*Facies* 1). It accumulated in the central part of the Ragusa zone which apparently was a morphological depression during late Tithonian and Early Cretaceous time (fig. 66). The main lithologies comprise white cherty limestones and greenish marly interlayers. The limestones are fine-grained bioclastic wackestones (fig. 42) with calpionellids, Radiolaria, *Spirillina*, *Lagenidae*, *Lenticulina*, *Globochaete* and calcispheres, mixed with considerable amounts of silt-sized biodetritus. The matrix appears to consist in large part of *Nannoconus*. The age ranges from the upper Tithonian (beginning of the *Crassicollaria* zone of ALLEMANN *et al.*, 1970) to the lower Hauterivian. The Tithonian part is characterized by abundant and well preserved *Crassicollaria*, *Calpionella alpina*, *Tintinnopsella carpathica*, *Stomiosphaera* and *Globochaete*, associated with a few and badly preserved *Saccocoma* particles and aptychi; the Hauterivian part of the sequence contains only Radiolaria and few *Spirillina*. The described sediments commonly show vague parallel lamination and bioturbation;

composite sequence, made up of condensed pelagic deposits (*Facies* 2) in the lower part and of basinal sediments in the upper part. This type of succession indicates a progressive widening of the central basinal area during Early Cretaceous time. The lithotypes are represented by pinkish nodular limestones followed by light cherty limestones and marly limestones with greenish marly interbeds. The nodular limestones (fig. 43) are

FIG. 42 — Whitish limestone from the Chiaramonte Formation. Fine-grained bioclastic wackestone with small Radiolaria, calpionellids (chiefly *Calpionella alpina*) and biogenic silt. Radiolaria are replaced by sparite or microsparite. Faint current-lamination is outlined by oriented elongate bioclasts. Marzamemi well N° 1, 955 m; thin section, x 18.

— Calcare biancastro della Formazione Chiaramonte. Wackestone bioclastico a grana fine con piccoli radiolari, tintinnidi (sopratutto *Calpionella alpina*) e silt biogenico. I gusci dei radiolari sono diagenizzati in sparite o microsparite. Una debole laminazione da corrente è messa in evidenza dalla presenza di sottili bioclasti orientati. Pozzo Marzamemi 1, 955 m; sezione sottile, x 18.

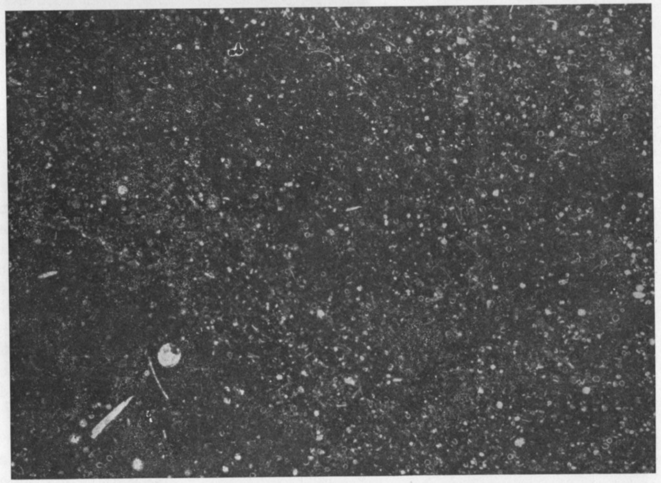


FIG. 43 — Pinkish nodular limestone from the Chiaramonte Formation. Nodular bioclastic wackestone with calpionellids (chiefly *Calpionella alpina* and *Calpionella elliptica*), Radiolaria and silty biodetritus. Nodules, less rich in fossils than the surrounding matrix, are locally evidenced by pressure-solution. Cammarata well N° 1, 3657 m; thin section, x 15.

— Calcare nodulare rosato della Formazione Chiaramonte. Wackestone bioclastico nodulare con tintinnidi (sopratutto *Calpionella alpina e Calpionella elliptica*), radiolari e silt biogenico. I noduli, meno ricchi in fossili della circostante matrice, sono localmente messi in evidenza da fenomeni di pressione-dissoluzione. Pozzo Cammarata 1, 3657 m; sezione sottile, x 15.

bioclastic wackestone/packstones with calpionellids, well preserved *Stomiosphaera*, *Globochaete*, aptychi, ammonites, large Radiolaria, *Saccocoma* (only in the lower part), *Lagenidae*, *Spirillina*, sponge spicules, rare thin-shelled ostracods and unidentified biodetritus. The matrix appears as a *Nannoconus*-rich micrite. Like all the previously described nodular limestones, also these lithotypes display sedimentary and diagenetic features typical of condensed pelagic deposits on swells. The nodular structure is in some places produced by penecontemporaneous remobilization of unevenly lithified sediment (e.g. pebbly mudstones in Mineo 1, fig. 44). The age of these deposits ranges from upper Tithonian to Berriasian *p.p.* (*Crassicollaria* zone and *Calpionella* zone of ALLEMANN *et al.*, 1970). The overlying cherty limestones are fine-grained bioclastic mudstones/wackestones with calpionellids, Radiolaria, rare *Spirillina* and fine biodetritus dispersed in a *Nannoconus*-bearing matrix. Sometimes, a faint lamination pointed out by iso-orientation of the bioclasts suggests episodic current activity. The age ranges from Berriasian *p.p.* (beginning of the *Calpionellopsis* zone of ALLEMANN *et al.*, 1970) to lower Hauterivian;

thin condensed sequence, entirely constituted by red-pinkish nodular limestones showing close similarities with the underlying nodular deposits of the Buccheri Formation. This sequence is developed over marginal parts of the study area which represented persisting morphological highs (fig. 67).

Hybla Formation (*upper Hauterivian-Albian p.p.*)

This formation corresponds to the Hybla Member of the Alcamo Formation, established by RIGO and BARBIERI (1959) in the Ragusa well N° 11. The distinctive lithology, always well recorded on the electric log patterns, as well as the thickness and the wide extent justify, in our opinion, the rank of formation.

Synonymies: Hybla Member of the Alcamo Formation (RIGO and BARBIERI, 1959); Calabianca Unit of some petroleum geologists (see, e.g. Avola 1, RAP-SIS 1963)

Source of name: see RIGO and BARBIERI, 1959

Type well: Ragusa well N° 11

Geographic coordinates: Lat. 36° 53' 46" N; Long. 2° 17' 12" E

Operating Company: GULF Italia

Date of drilling: 29/1/56 - 23/3/57

Total depth: 2890.88 metres

FIG. 44 — Pebbly mudstone from the Chiaramonte Formation. The clasts are bioclastic wackestones with Radiolaria, *Saccocoma*, *Stomiosphaera*, aptychi, *Crassicollaria* and shell fragments; the matrix is a retextured bioclastic packstone with the same fossil assemblage as the soft clasts. Mineo well N° 1, 1747 m; thin section, x 16.

— Pebbly mudstone della Formazione Chiaramonte. I clasti sono costituiti da un wackestone bioclastico con radiolari, *Saccocoma*, *Stomiosphaera*, aptici, *Crassicollaria* e frammenti di molluschi; la matrice, riccamente fossilifera, è un packstone bioclastico ritessiturato con una associazione di microfossili analoga a quella presente negli elementi. Pozzo Mineo 1, 1747 m; sezione sottile, x 16.

In the type-well the formation was drilled from 349 to 632 metres. The lower boundary with the Chiaramonte Formation and the upper one with the Amerillo Formation are sharp (see RIGO and BARBIERI, 1959, fig. 6).

The Hybla Formation has been found in the whole Ragusa zone. The thickness ranges from 10-20 metres to 300 metres (fig. 57). The unit is everywhere underlain by the Chiaramonte Formation and overlain by the Amerillo Formation. The sequence consists of dark grey-greenish burrowed (*Chondrites*-type) clays and clayey marls rich in organic matter. Occasional thin intercalations of whitish marly limestones are also present. Some « tuffaceous marls » (?hyaloclastites) have been reported in the log descriptions of the Chiaramonte 1, Grammichele 1, Palazzolo 1 and Piazza Armerina 1 wells; we have no additional data since no samples were available. The calcareous beds appear as very fine-grained wackestones (fig. 45) with rare Radiolaria, *Spirillina*, globigerinids, *Lagenidae*, *Lenticulina*, thin-shelled ostracods, biodetritus and volcanogenic silt. The matrix is a micrite rich in nannoplankton. The age of the Hybla Formation ranges from upper Hauterivian to Albian *p.p.* In the lower part of the sequence the fossil assemblage is chiefly constituted by Radiolaria with few small globigerinids (*Globigerina hauterivica-infracretacea* type). This interval corresponds to the « *Hedbergella* » *hoterivica* zone of VAN HINTE (1976). The uppermost part of the sequence, which is characterized by the presence of *Hedbergella trochoidea* and by the appearance of the early *Rotalipora* forms, includes the *Ticinella breggensis* zone of VAN HINTE (1976). Thin parallel-lamination always found in the calcareous beds

and underlying Tertiary calcarenites attributed to the Ragusa Formation.

The Monterosso S1 well is located NW of Monterosso Almo village:

Geographic coordinates: Lat. 37° 05' 58" N; Long. 2° 12' 45" E
Operating Company: GULF Italia
Date of drilling: 1/2/58 - 7/3/58
Total depth: 1210 metres
Ground elevation: 449 metres

The drilling started in the Upper Cretaceous cherty limestones; the lower boundary with the Hybla Formation was reached at a depth of 183 metres. The contact is sharp, as in the whole Ragusa zone.

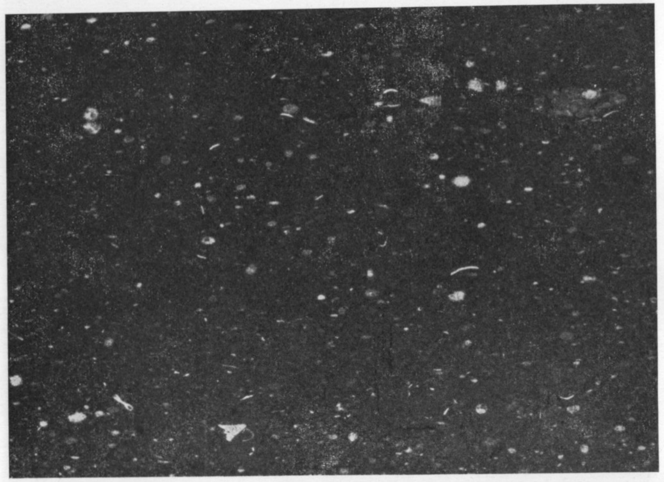


FIG. 45 — Greenish marly limestone from the Hybla Formation. Very fine-grained bioclastic wackestone with Radiolaria, few *Spirillina*, small fragments of echinoderms and biodetritus. Mineo well N° 2, 2218 m; thin section, x 18.

— Calcare marnoso verdastro della Formazione Hybla. Wackestone bioclastico a grana fine con radiolari, *Spirillina*, piccoli frammenti di echinodermi e biodetrito. Pozzo Mineo 2, 2218 m; sezione sottile, x 18.

of the Hybla Formation suggests basinal deposition controlled by current activity. The general characteristics of the Hybla Formation, whose counterparts (e.g. « scisti a fucoidi » *Auct.* of the Umbrian realm) are well known in other parts of the periadriatic domains, denote temporary reducing conditions at the sea floor.

Amerillo Formation (Albian p.p. - Maastrichtian)

This formation corresponds to the Amerillo Member of the Alcamo Formation established by RIGO and BARBIERI (1959) in the Amerillo valley. The lower part of the unit, badly exposed in this section, was defined by the authors in the Monterosso S1 well. The unit, widely developed in the Ragusa zone, is represented by white cherty limestones stratigraphically overlying the Hybla marls

The upper part of the unit is exposed along the Vizzini-Monterosso road. RIGO and BARBIERI (1959) fixed the boundary between the Amerillo cherty limestones and the overlying Ragusa calcarenites in correspondence to a ruditic level interpreted as a transgressive conglomerate. This « conglomerate », in reality, is one of the many slump breccias occurring in the uppermost part of the Amerillo Formation.

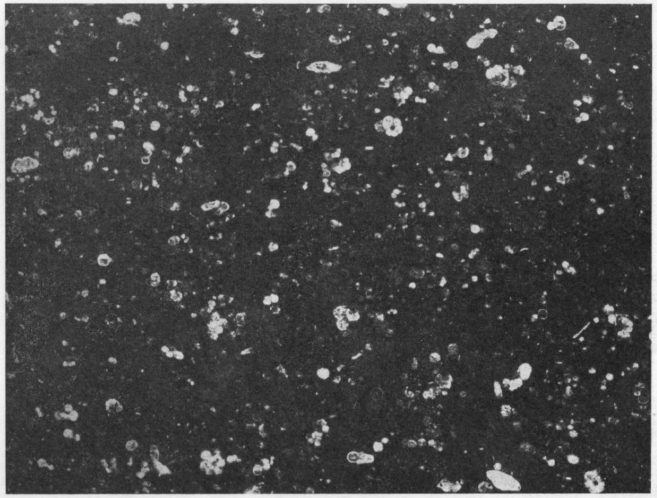
In the whole Ragusa zone, the Amerillo Formation may be divided into two intervals. The thickness of the formation varies from 20-50 metres to about 800 metres (fig. 58). It is interesting to observe that the lower interval occupies only a small part of the sequence, reaching a maximum of one hundred metres in the thickest sections. The *lower interval* (Cenomanian-Turonian) is represented by fine-grained foraminiferal wackestones/

mudstones (fig. 46) with *Rotalipora*, *Globotruncana*, globigerinids, *Heterohelicidae*, *Pithonella*, *Lagenidae* and *Stomiosphaera*. Bioturbation is the only sedimentary structure displayed in these (hemi)pelagic deposits.
The *upper interval* (Senonian) mainly consists of

These deposits, often displying parallel lamination and bioturbation, are interpreted as incomplete BOUMA cycles. Sometimes, C-E BOUMA sequences have been observed. The biogenic material in these layers consists of small Radiolaria, sponge spicules, *Pithonella*, *Stomiosphaera*, globigerinids, *Heteroheli-*

FIG. 46 — White limestone from the Amerillo Formation. Foraminiferal wackestone with globigerinids, *Rotalipora appenninica*, *Planomalina buxtorfi* and *Globotruncana renzi*. S. Croce Camerina well N° 2, 1318 m; thin section, x 16.

— Calcare bianco della Formazione Amerillo. Wackestone a foraminiferi planctonici con globigerinidi, *Rotalipora appennìnica*, *Planomalina buxtorfi* e *Globotruncana renzi*. Pozzo S. Croce Camerina 2, 1318 m; sezione sottile, x 16.



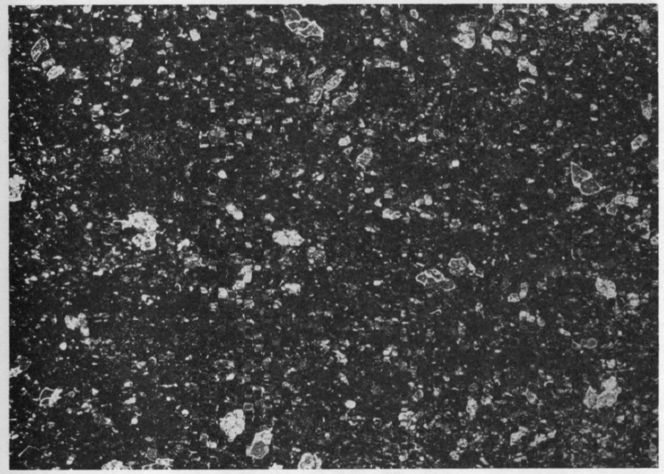


FIG. 47 — White limestone from Amerillo Formation. Bioclastic wackestone with *Globotruncana* and globigerinids mixed with large amounts of undetermined biodetritus. Modica well N° 1, 994 m; thin section, x 16.

— Calcare bianco della Formazione Amerillo. Wackestone bioclastico a *Globotruncana*, globigerinidi e abbondante biodetrito. Pozzo Modica 1, 994 m; sezione sottile, x 16.

turbiditic resediments with pelagic components. Turbidites with both pelagic and shallow-water materials were found chiefly in the upper part of the sequence. The lithologies include bioclastic wackestones (fig. 47) with *Globotruncana*, *Heterohelicidae*, globigerinids and unidentified biodetritus.

cidae, benthonic Foraminifera, scattered *Globotruncana* and reworked *Rotalipora* with admixed unidentified biodetritus and volcanogenic silt (fig. 48). In places, the base of turbidite beds is made by irregular thin layers of foraminiferal packstones/wackestones probably representing the A interval of the BOUMA sequence (fig. 49). In some wells, resediments with shallow-water components (*Orbitoides*, *Omphalocyclus*, rudistid fragments and arenaceous Foraminifera) were also found.

A sudden change in sedimentation occurred everywhere by the Maastrichtian-Paleocene boundary, where the upper boundary of the Amerillo Formation ought to be placed, since the transition to the overlying Ragusa Formation is very gradual. We suggest to place the formational boundary at the base of the Maastrichtian-Paleocene channelized deposits since they mark a sudden increase in the

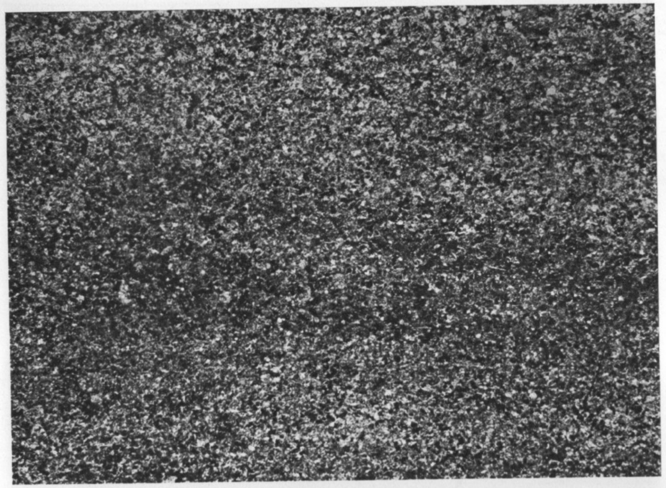


FIG 48 — White calcisiltite from the Amerillo Formation. Fine-grained bioclastic packstone displaying cross-lamination (C interval of a turbidite layer). Bioclasts chiefly consist of *Pithonella* and *Stomiosphaera* with mixed globigerinids, benthonic Foraminifera and biogenic silt. S. Croce Camerina well N° 2, 1181 m; thin section, x 9.

— Calcisiltite bianca della Formazione Amerillo. Packstone bioclastico a grana fine con laminazione incrociata (intervallo C di un livello torbiditico). I bioclasti sono costituiti sopratutto da *Pithonella* e *Stomiosphaera*, associate a globigerinidi, foraminiferi bentonici e silt biogenico. Pozzo S. Croce Camerina 2, 1181 m; sezione sottile, x 9.

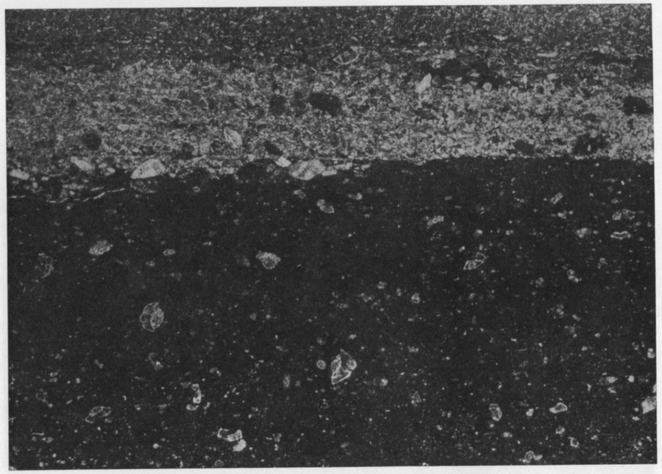


FIG. 49 — White limestone from the Amerillo Formation. Bioclastic wackestone with *Globotruncana*, overlain by graded bioclastic packstone with planktonic Foraminifera, *Inoceramus* prisms and volcanogenic silt. Note the erosional contact at the base of the turbidite layer. Noto well N° 1, 764 m; thin section, x 9.

— Calcare bianco della Formazione Amerillo. Wackestone bioclastico con *Globotruncana* sormontato da un packstone bioclastico, gradato, a foraminiferi planctonici e bentonici, prismi di inocerami e silt vulcanogenico. Si osservi il contatto erosionale alla base del sottile livello torbiditico. Pozzo Noto 1, 764 m; sezione sottile, x 9.

synsedimentary tectonic activity over the whole Ragusa zone. and the former basinal deposits are overlain by slope deposits. This part cf the sequence is characterized by fine-grained turbidites revealing more complete BOUMA sequences, as well as by slumps, slides and subordinate coarse gravity-flow deposits. Good outcrops are present, for instance, along the Vizzini-Monterosso road. We were undecided

Mafic volcanites were drilled in the Amerillo Formation, mainly in the upper part. As in the Buccheri Formation, they occur both as layers intercalated within the sedimentary sequence and as huge massive bodies forming isolated volcanic

edifices (fig. 59). Some volcanic sea-mounts reached the sea level (Melilli 1, Portopalo 1 and Pachino 4), as testified by the presence of shallow-water sediments on top. We propose the introduction of two members: the Capo Passero Volcanite and the Portopalo Limestone, these names having been already used in the geological literature (COLACICCHI, 1963).

The Capo Passero volcanites are alkalic undersaturated basalts ranging in age from 81 to 71 MY (K/Ar ages, 71 MY being the most reliable value, BARBERI *et al.*, 1974). We chose the Pachino well N° 4 as type-well, since it penetrated a volcanic sea-mount for about 600 metres (between 297 and 885.50 metres) and crossed the upper contact with rudistid limestones and the lower one with *Globotruncana* cherty limestones.
Synonymies: Tephrite of Capo Passero (COLACICCHI, 1963)
Geographic coordinates: Lat. 36° 41' 49'' N; Long. 2° 36' 20'' E
Operating Company: AGIP Mineraria
Date of drilling: 2/10/59 - 22/7/60
Total depth: 5003 metres
Ground elevation: 22 metres

The Portopalo Limestone is well exposed along the cliff north and south of Portopalo village, farther south of Pachino. Here a reef complex made up of rudistid limestones rich in large Foraminifera, algae etc. overlies the Capo Passero basalts and is disconformably overlain by the Eocene Cozzo Cugni calcarenites (COLACICCHI, 1963; TREVISAN, 1936). The thickness is about 40 metres. COLACICCHI described interfingerings betwwen shallow-water limestones and pillow lavas at Isola di Capo Passero.

Paleotectonic evolution

The Upper Triassic dolomites of the Ragusa zone are the deepest horizon which has been explored in Southern Sicily. Therefore, no data on the beginning of the Alpine history are available in this area. Middle Triassic tensional tectonics, widespread in the whole Mediterranean area, caused, north of the Ragusa zone, opening of early sea-ways, seats of pelagic deposition and volcanic activity (SCANDONE, 1975). We cannot say whether and how much this phase affected Southern Sicily; the considerable thickness of the Norian deposits, however, suggests crustal thinning probably related to the Middle Triassic tensional tectonics.

In the following sections we shall sketch the Mesozoic history of the Ragusa zone by pointing out the most significant stages of the paleotectonic evolution.

The Upper Triassic peritidal platform

Sedimentary environments comparable with modern tidal flats characterized Southern Sicily during Late Triassic times. An intertidal algal flat extended over the whole Ragusa zone during Norian. In the upper part of the Rhetian a facies differentiation, suggesting a more complex depositional setting is recognized (fig. 60). Two main paleogeographic domains can be distinguished: the Siracusa belt and the Ragusa belt. The first was characterized by shallow-water (intertidal-subtidal) conditions with open circulation; the second appears as a sheltered sedimentary environment with a complex system of tidal channels and ponds bordered northwards and eastwards by beach ridges. Supratidal dolomites and evaporites (Naftia Formation), stratigraphically intervening between the Norian algal dolomites (Gela Formation) and the Rhetian tidal-channel deposits (Noto Formation), mark in the Ragusa belt a general regression. Supratidal conditions did not reach the Siracusa belt where shallow-water calcarenites indicative of subtidal zone followed during Rhetian time typical deposits of intertidal environment.

Signs of synsedimentary tectonic activity during Late Triassic are indicated by the occurrence of some mafic volcanites. Their areal distribution, however, appears random since the available data are not homogeneous. Indeed, the Upper Triassic dolomites were crossed for thousands of metres in some boreholes and only for some hundred metres in others.

The dissection of the Triassic platform

A severe phase of synsedimentary tectonic activity dissected the Triassic platform in early Hettangian time (fig. 51). The WSW-ENE and NW-SE trending faults appear to follow the Rhetian facies boundaries. The faulting was accompanied by fissural basaltic volcanism. Fig. 53 shows that along the main active faults 1/5 or more of the sequence is made of lava flows and hyaloclastites. The study area appears at this time clearly divided into two paleogeographic realms (fig. 61). In the Siracusa belt subsidence was balanced by deposition, allowing the persistence of shallow-water conditions; the sedimentation rate reached maximal values of about 80 m/MY. In the Ragusa belt, on the contrary, a sudden sinking brought the sea floor below the photic zone and deeper marine conditions set up. Here a subsiding basin characterized by at least about 3000 metres of turbiditic deposits and by a high overall sedimentation rate (600 m/MY) established to the south (fig. 51). Towards the Siracusa belt, this basin was bordered by a scarcely subsiding flat area where condensed sequences with low overall sedimentation rate (only 10-15 m/MY) were deposited. The sedimentary and diagenetic features of the shallow-water deposits suggest open circulation and well-oxigenated conditions in the Siracusa belt. By contrast, dysaerobic conditions are recorded by the Hettangian-Sinemurian sediments of the Ragusa belt which display typical characteristics of an enclosed basin. A southern landmass is assumed as source area of the terrigeneous sand which accumulated in the southern basin.

During Sinemurian-Lotharingian the inner edge of the Siracusa platform was activated by WSW-ENE and by subsequent NW-SE faults. The synsedimentary tectonic activity persisted until Domerian and a prism of shelf-derived resediments accumulated along steep slopes (figs. 62, 63).

In the Ragusa belt the Sinemurian-Lotharingian boundary coincides with a considerable change in the depositional conditions, manifested by a sudden decrease in the depositional rate (fig. 52), interruption of the supply of terrigenous material from the southern continental area and by increase in the water oxigenation. In the southern basin the deposition rate during Lotharingian-Domerian time was around 55m/MY; this moderate value, compared with the 600 m/MY of the Hettangian-Sinemurian deposits, suggests a reduction also in the subsidence rate.

Throughout the Lotharingian, the basinal facies gradually spread towards the Siracusa platform, invading zones previously covered by fine-grained shelf-derived resediments, as well as the last submarine hills which still persisted in the scarcely subsiding areas of the Ragusa belt.

Sinking and starvation of the Siracusa platform

During Hettangian-Lotharingian time pronounced subsidence accompanied by synsedimentary faulting played an important rôle in the Ragusa belt, while moderate and more uniform subsidence occurred in the Siracusa platform. Only during middle Liassic the Siracusa platform was affected by faulting. The eastern margin first « collapsed », as shown by Lotharingian shallow-water limestones stratigraphically overlain by middle Liassic coarse resediments. At the end of Domerian the entire Siracusa platform sunk below the photic zone and the distinction between the Siracusa and Ragusa belts became less evident. The main paleogeographic lineaments during Toarcian time are shown in fig. 64.

The tectonic activity did not play an important rôle in the Toarcian-Bathonian time span. WSW-ENE and NW-SE persisting trends, however, are manifested by the facies pattern and by the preferred orientation of basin axes (fig. 54). In the area previously corresponding to the Ragusa belt, the deposition rate was about 15 m/MY in the southern basin and only around 3 m/MY in the marginal areas. The top of the sunken and starved Siracusa platform is still recognizable at this time, and appears as a belt characterized by non-deposition or submarine erosion. The sudden decrease of the deposition rate accompanied by a simultaneous increase in the clay/carbonate ratio in the sediment is interpreted as resulting from an interplay of two factors: drastic reduction of the lime-mud imput partly related to the starvation of the platform areas, and increasing in the carbonate dissolution at the sea floor. Obviously, these factors were not controlled by mere local conditions, since the abrupt sedimentation change at the beginning of the Toarcian time is a common feature in many basinal sequences of the Tethyan realm.

The Middle-Upper Jurassic volcanism

By the end of the Middle Jurassic renewed synsedimentary tectonics caused widespread submarine volcanic activity, which persisted until early Kimmeridgian (fig. 55). Isolated edifices built up in correspondence to the intersections of the main faults, but the available data do not allow us to localize the single faults which accounted for the volcanic activity, although a network of WSW-ENE and NW-SE lineaments clearly appears in the isopach map of the Buccheri Formation (fig. 54).

During Late Jurassic the sedimentation was strongly influenced by modifications of the bottom physiography induced by the building up of volcanic edifices (fig. 65). The Scicli sea-mount, for instance, was responsible for a sudden change from basinal to sea-mount condensed facies. Probably renewed increase in imput of lime-mud (pelagic organisms) allowed condensed deposition also over the areas previously characterized by submarine sedimentary gaps.

Temporary tectonic quiescence

At the beginning of the Tithonian the volcanic activity ceased completely and no signs of synsedimentary tectonics are recognizable for a long time. The facies distribution (figs. 66, 67) and the isopach patterns (figs. 56, 57) reflect new physiographic conditions resulting from the Middle-Upper Jurassic modifications of the bottom relief.

From Tithonian until Turonian times the whole Ragusa zone underwent only moderate subsidence manifested by a gradual expansion of the basinal areas; the latter presumably appeared at this time as a gently slanting depression in the central part of the study region. Condensed pelagic deposits surrounding the central depression progressively migrated towards the outer margin of the area, until clayey basinal resediments uniformely deposited during Hauterivian. The lithologies testify reducing conditions at the sea-floor, with repeated episodes of stagnation. These dysaerobic conditions seem to be related to a general oxigen depletion which happened at this time (RYAN and CITA, 1977), rather than to a local lack of sea-floor ventilation. The maximal deposition rate of the Hauterivian-Albian clayey deposits is around 14 m/MY. In late Albian time normal conditions of oxigenation again set in; the sedimentation rate reached maximal values around 8 m/MY during Cenomanian-Turonian time. Sporadic mafic volcanites are interpreted as the first signs of a renewed synsedimentary tectonic activity.

The Upper Cretaceous tectonic activity and volcanism

During Senonian the Ragusa zone was again dissected by tensional faults. The isopach map (fig. 58) reveals a new network of SW-NE and WNW-ESE trending faults, and the existence of active subsidence in the Noto-Chiaramonte area. The tectonic instability is suggested also by the high accumulation rate (30 m/MY) of the basinal deposits, which mainly consisted of lime turbidites. Isolated volcanic edifices (fig. 59) developed at the intersections of main faults, as it was the case in the Middle-Upper Jurassic. Some of them (e.g. Pachino area and Melilli well N° 1) reached the photic zone and rudistid reefs grew on top.

By the end of Late Cretaceous the synsedimentary tectonic activity increased, as it is testified by the wide occurrence of slumps and other mass flow deposits. More striking evidences of tectonic instability are finally provided by evidence of large downslope displacements of carbonate sand accompanied by spectacular gravity-slides in most of the Paleocene and Eocene sequences of the area.

Acknowledgments - The authors are very grateful to O. Kälin for reading the manuscript and making helpful suggestions, and to C. Gratziu for collaboration in the microphotographs. AGIP Mineraria and Corpo Regionale delle Miniere-Servizio Idrocarburi of Sicily made available logs, cores and cuttings. Some drawings were made by R. Tosi.

SOMMARIO

La zona ibleo-ragusana costituisce oggi una zona relativamente stabile che funge da avampaese del settore siciliano della catena maghrebide. Il sottosuolo di questa regione è stato ampiamente esplorato per ricerche di idrocarburi, e numerosi pozzi hanno attraversato sequenze complete dal Miocene al Trias superiore. In superficie affiorano essenzialmente terreni neogenici, e i termini mesozoici sono limitati a pochi e ristretti affioramenti di vulcaniti e calcari del Cretaceo superiore.

Nella letteratura geologica vengono generalmente distinte una *facies siracusana* e una *facies ragusana*; la prima sarebbe caratterizzata da una sedimentazione detritico-organogena continua dal Trias al Cretaceo superiore, la seconda da una successione di dolomie neritiche triassiche, di « Black Shales » del Trias sup.-Lias e quindi di sedimenti di mare aperto in tutto il resto del Mesozoico (ENI, Enciclopedia del Petrolio, 1969). Il quadro da noi ricostruito rivela una maggiore complessità e si discosta alquanto dagli schemi tradizionalmente accettati per la Sicilia meridionale.

In questa nota vengono esposti i risultati di uno studio di revisione di circa 70 pozzi, per la gran parte dei quali si disponeva di campioni di carote e cuttings. In alcuni pozzi la campionatura molto fitta ha permesso sia una dettagliata ricostruzione delle successioni e delle relative facies, sia un'ottima taratura dei logs elettrici che ha facilitato la correlazione con pozzi per i quali si disponeva di pochi campioni.

La nomenclatura litostratigrafica comunemente usata in Sicilia dai geologi del petrolio deriva da Rigo e Barbieri (1959) e da Schmidt Di Friedberg (1965). Siamo stati costretti ad abbandonare la gran parte dei nomi formazionali tradizionali poiché molti di essi derivavano da unità della catena, e ad introdurre nuove formazioni dal momento che alcune unità litostratigrafiche comprendevano tipi litologici di età e significato deposizionale differenti. Nella tabella 1 sono riportate la nomenclatura tradizionalmente adottata e quella proposta in questo lavoro, con l'età delle singole formazioni.

Le nostre ricerche nella zona di Ragusa mostrano che questo settore crostale ha subito durante il Mesozoico una tipica evoluzione di margine continentale in via di sprofondamento, molto simile a quella di altri domini paleogeografici situati lungo il settore periadriatico del margine continentale africano. La gran parte di questi domini, tuttavia, è stata fortemente deformata durante la compressione alpina cosicché qualunque ricostruzione paleotettonica necessita preliminarmente di accurate ricostruzioni palinspastiche. Nella zona di Ragusa, invece, forma e dimensioni degli originari domini paleogeografici sono ancora conservate, dal momento che questa area non è stata modificata da accorciamenti crostali significativi. Queste condizioni strutturali favorevoli, congiuntamente all'abbondanza di dati derivanti dall'esplorazione petrolifera, permettono di studiare a scala reale ambienti deposizionali e relative modificazioni spazio-temporali indotte dalla subsidenza, dalla dissezione ad opera di faglie e dal vulcanismo.

Anche noi distinguiamo un dominio siracusano e un dominio ragusano, anche se soltanto relativamente all'intervallo di tempo Trias superiore-Lias medio, quando la regione studiata si presentava effettivamente divisa in due ben distinte zone paleogeografiche. Questa distinzione diventa meno evidente alla fine del Lias medio quando la piattaforma carbonatica siracusana sprofonda al di sotto della zona fotica.

Le dolomie del Trias superiore della zona di Ragusa sono l'orizzonte più vecchio esplorato in Sicilia meridionale; pertanto non si hanno dati sull'inizio della storia alpina in quest'area. La tettonica tensiva del Trias medio determinò a nord di Ragusa l'apertura di bacini precoci sedi di deposizione pelagica e di attività vulcanica. Non siamo in grado di dire se e quanto questa fase abbia interessato la Sicilia meridionale; lo spessore considerevole dei depositi norici suggerisce comunque processi di assottigliamento crostale in atto, probabilmente legati alla fase tettonica medio-triassica. Tracceremo la storia mesozoica della zona di Ragusa a partire dal Norico cercando di mettere in evidenza gli stadi più significativi della sua evoluzione paleotettonica.

Un ambiente comparabile con le attuali pianure tidali caratterizza nel Trias superiore la Sicilia meridionale. Durante il Norico tutta la zona si presenta come una uniforme, piatta area intertidale ricoperta da depositi algali (sopratutto stromatoliti). Al passaggio Norico-Retico cominciano a delinearsi due elementi paleogeografici: il dominio ragusano, in cui si depositano dolomie sopratidali ed evaporiti, e il dominio siracusano caratterizzato invece dapprima da depositi intertidali e poi da depositi subtidali di mare aperto. Nella parte alta del Retico la differenza tra i due domini si accentua: il dominio siracusano presenta ancora caratteri di deposizione di mare aperto, il dominio ragusano, invece, appare come un complesso sistema deposizionale con canali e lagune costiere di ambiente ristretto bordate a nord e a est da barre.

Una energica fase di tettonica sinsedimentaria smembra la piattaforma triassica nell'Hettangiano. L'andamento delle faglie segue le linee già tracciate dai limiti di facies retici. Il fagliamento è accompagnato da un vulcanismo basaltico di tipo fissurale. La zona di Ragusa appare in questo tempo più chiaramente suddivisa in due domini paleogeografici. Nel dominio siracusano la subsidenza è compensata dalla sedimentazione cosicché permangono ancora condizioni di mare basso. Nel dominio ragusano invece un rapido sprofondamento dell'area genera un bacino fortemente subsidente in cui si accumulano migliaia di metri di depositi torbiditici. Il bacino è bordato a nord, verso il dominio siracusano, da un'area piatta scarsamente subsidente sede di deposizione condensata. La velocità di sedimentazione raggiunge i 600 m/MA nel bacino merdionale e soltanto 10-15 m/MA nelle aree marginali. Nel dominio siracusano velocità di subsidenza e velocità di sedimentazione raggiungono valori massimi di circa 80 m/MA. Le caratteristiche deposizionali e diagenetiche dei depositi suggeriscono condizioni ben ossigenate nel dominio siracusano e condizioni disaerobiche nel dominio ragusano.

Durante il Sinemuriano-Lotaringiano il bordo interno della piattaforma siracusana è tagliata da faglie con an-

damento WSW-ENE e NW-SE. L'attività tettonica sinsedimentaria continua fino al Domeriano consentendo l'accumulo di risedimenti grossolani a componente neritica al piede delle scarpate.

Il limite Sinemuriano-Lotaringiano marca nel dominio ragusano un notevole cambio delle condizioni sedimentarie che si manifestano soprattutto in una improvvisa riduzione della velocità di deposizione, in una interruzione dell'apporto terrigeno dai quadranti meridionali e in un'aumento dell'ossigenazione delle acque sul fondo.

Nel bacino meridionale la velocità di sedimentazione durante il Lotaringiano-Domeriano è di circa 55m/MA, valori molto bassi se comparati con i 600 m/MA dei depositi hettangiano-sinemuriani.

Nella parte alta del Lotaringiano le facies bacinali si espandono gradualmente verso la piattaforma siracusana invadendo zone in precedenza coperte da risedimenti a componente neritica, nonché le zone residue di alto morfologico.

Nel Lias medio faglie sinsedimentarie smembrano anche il corpo centrale della piattaforma carbonatica. Il margine orientale sprofonda per primo e i calcari neritici lotaringiani sono in tal modo ricoperti da risedimenti grossolani del Lias medio. Alla fine del Domeriano l'intera zona siracusana sprofonda al di sotto della zona fotica e la distinzione tra dominio ragusano e dominio siracusano diventa di nuovo sfumata.

L'attività paleotettonica non gioca un ruolo importante in tutto l'intervallo Toarciano-Batoniano anche se lineamenti WSW-ENE e NW-SE sono messi ancora in evidenza dall'andamento delle facies e dall'allungamento delle aree di maggiore subsidenza. Nelle aree corrispondenti in precedenza al dominio ragusano la velocità di sedimentazione è di circa 15m/MA nel bacino meridionale e di soli 3m/MA nelle aree marginali. Il tetto della piattaforma siracusana annegata è ancora riconoscibile e appare come un'area non subsidente caratterizzata da lacune sottomarine.

Verso la fine del Dogger una ripresa della tettonica sinsedimentaria genera una considerevole attività vulcanica sottomarina che persiste fino al Kimmeridgiano inferiore. In corrispondenza dell'intersezione delle faglie principali si sviluppano singoli edifici vulcanici. Nel Malm la sedimentazione è essenzialmente controllata da una moderata subsidenza e dalle modificazioni fisiografiche del fondo determinate dallo sviluppo degli edifici vulcanici. Il *sea-mount* di Scicli, ad esempio si sviluppa in corrispondenza di un'area relativamente profonda dove si andavano accumulando risedimenti bacinali ed è ricoperto da depositi pelagici condensati.

All'inizio del Titonico l'attività vulcanica cessa del tutto e non vi sono tracce di attività tettonica sinsedimentaria per lungo tempo. La distribuzione delle facies e l'andamento delle isopache riflettono le condizioni fisiografiche ereditate in precedenza.

Dal Titonico fino al Turoniano la zona di Ragusa è soggetta soltanto ad una moderata subsidenza che si manifesta con una graduale espansione dell'area bacinale corrispondente, in questo tempo, a una poco pronunciata depressione nella parte centrale della zona. La migrazione delle facies verso le aree più esterne porta nell'Hauteriviano a una sedimentazione relativamente uniforme di depositi argillosi su tutta l'area; i caratteri di questi depositi riflettono condizioni riducenti sul fondo.

A partire dalla parte alta dell'Albiano le condizioni di ossigenazione si normalizzano. Nel Cenomaniano-Turoniano la velocità di sedimentazione raggiunge valori massimi di 8mM/A. Sporadiche vulcaniti basiche costituiscono i primi segni della ripresa dell'attività tettonica sinsedimentaria nel Cretaceo superiore.

Nel Senoniano la zona di Ragusa è tagliata ancora una volta da faglie, questa volta con andamenti SW-NE e WNW-ESE; l'instabilità tettonica dell'area è suggerita anche dalla relativamente alta velocità di sedimentazione (30 m/MA) rispetto ai valori precedenti (8 m/MA); i depositi sono costituiti in questo periodo soprattutto da torbiditi a componente pelagica. All'intersezione delle faglie principali si sviluppano edifici vulcanici, analogamente a quanto si era verificato nel Giurassico medio-superiore. Alcuni *sea-mounts* raggiungono la zona fotica e scogliere a rudiste si impiantano sulla loro sommità.

Alla fine del Cretaceo l'attività sinsedimentaria cresce ulteriormente, come è testimoniata dalla frequenza di *slumpings* e di altri fenomeni gravitativi. Evidenze ancora maggiori di instabilità tettonica sono date dalla presenza di risedimenti grossolani accompagnati da spettacolari fenomeni di scivolamenti gravitativi nella gran parte delle sequenze paleoceniche ed eoceniche affioranti nella zona ragusana.

Il nostro lavoro era volto alla ricostruzione paleogeografica mesozoica e pertanto non sono stati studiati i depositi terziari, l'analisi dei quali consentirebbe di ricavare il quadro completo dell'evoluzione dell'avampaese ibleo-ragusano. Ci sembra comunque che il termine « piattaforma ibleo-ragusana » usato per quest'area da molti autori debba essere definitivamente abbandonato, trattandosi di un settore di margine continentale con evoluzione paleotettonica e conseguente storia sedimentaria estremamente complessa, comparabile, come già accennato, più con alcuni settori del margine periadriatico coinvolti nella deformazione alpina che non con certe aree di avampaese tipicamente di piattaforma, come la Puglia alla quale la zona ibleo-ragusana è stata spesso assimilata. Qui una monotona successione di carbonati di mare basso dal Trias al Cretaceo testimoniano una storia evolutiva del tutto differente.

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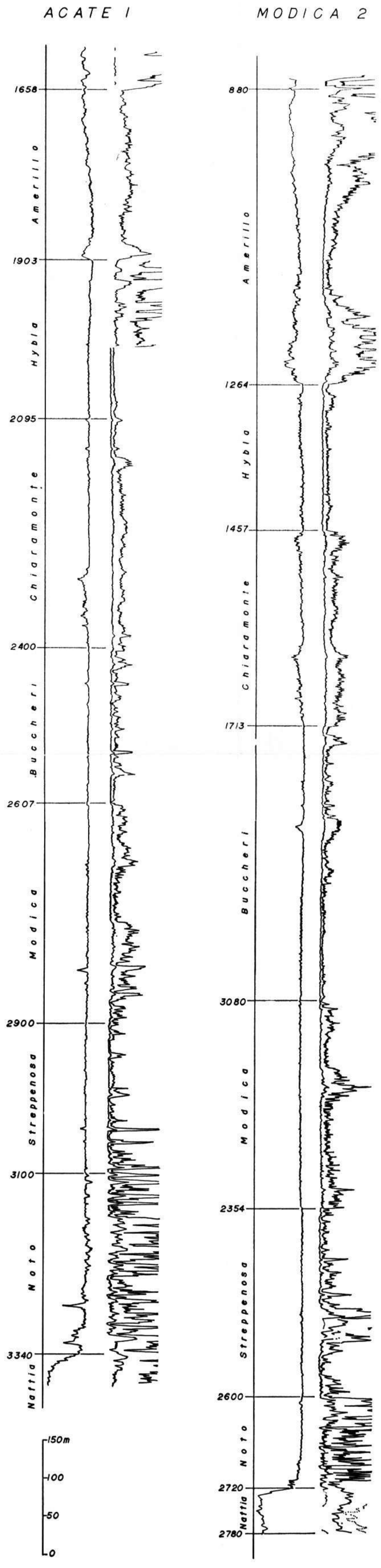
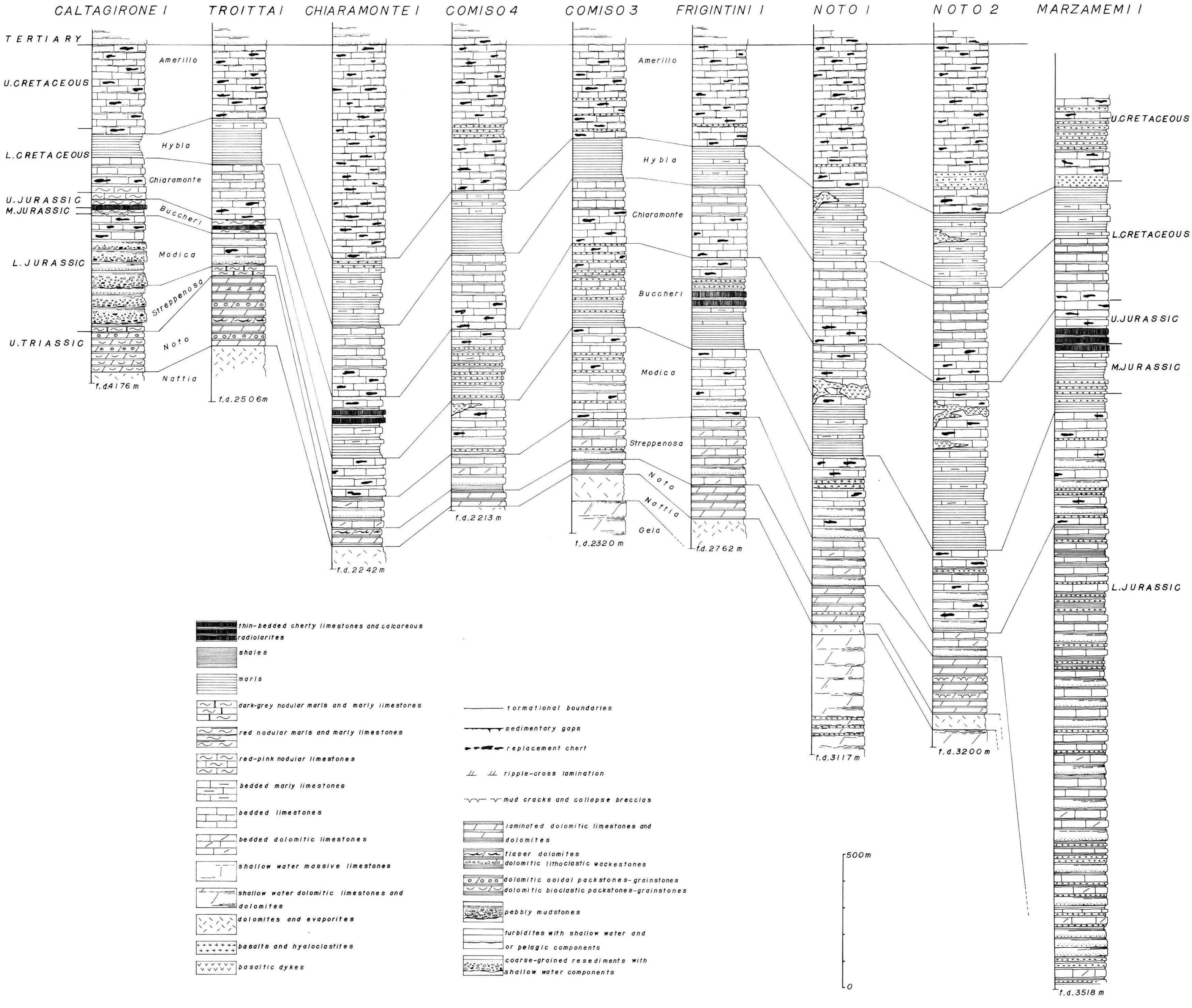
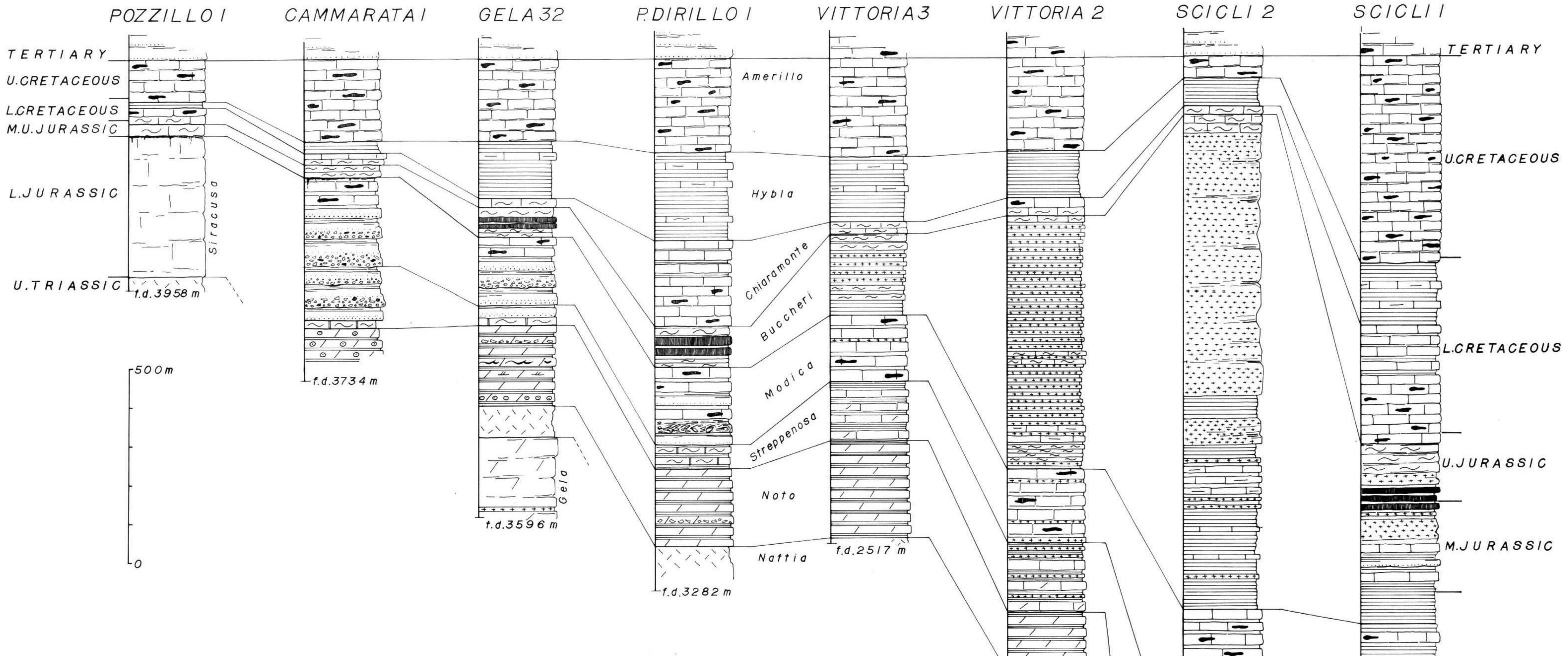
Plate I



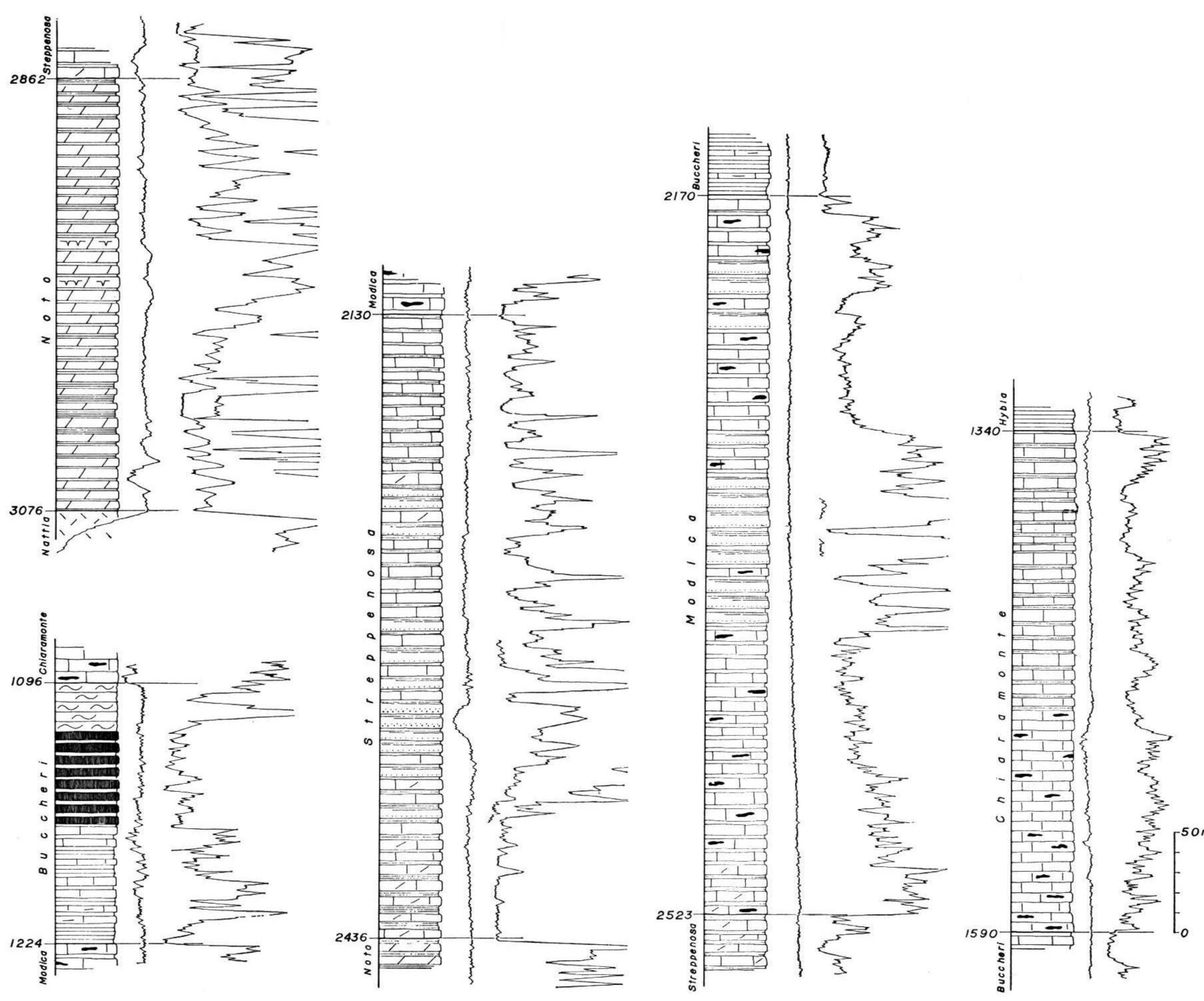
SP-resistivity log response of the Mesozoic rock units in the Ragusa Zone. Selected examples



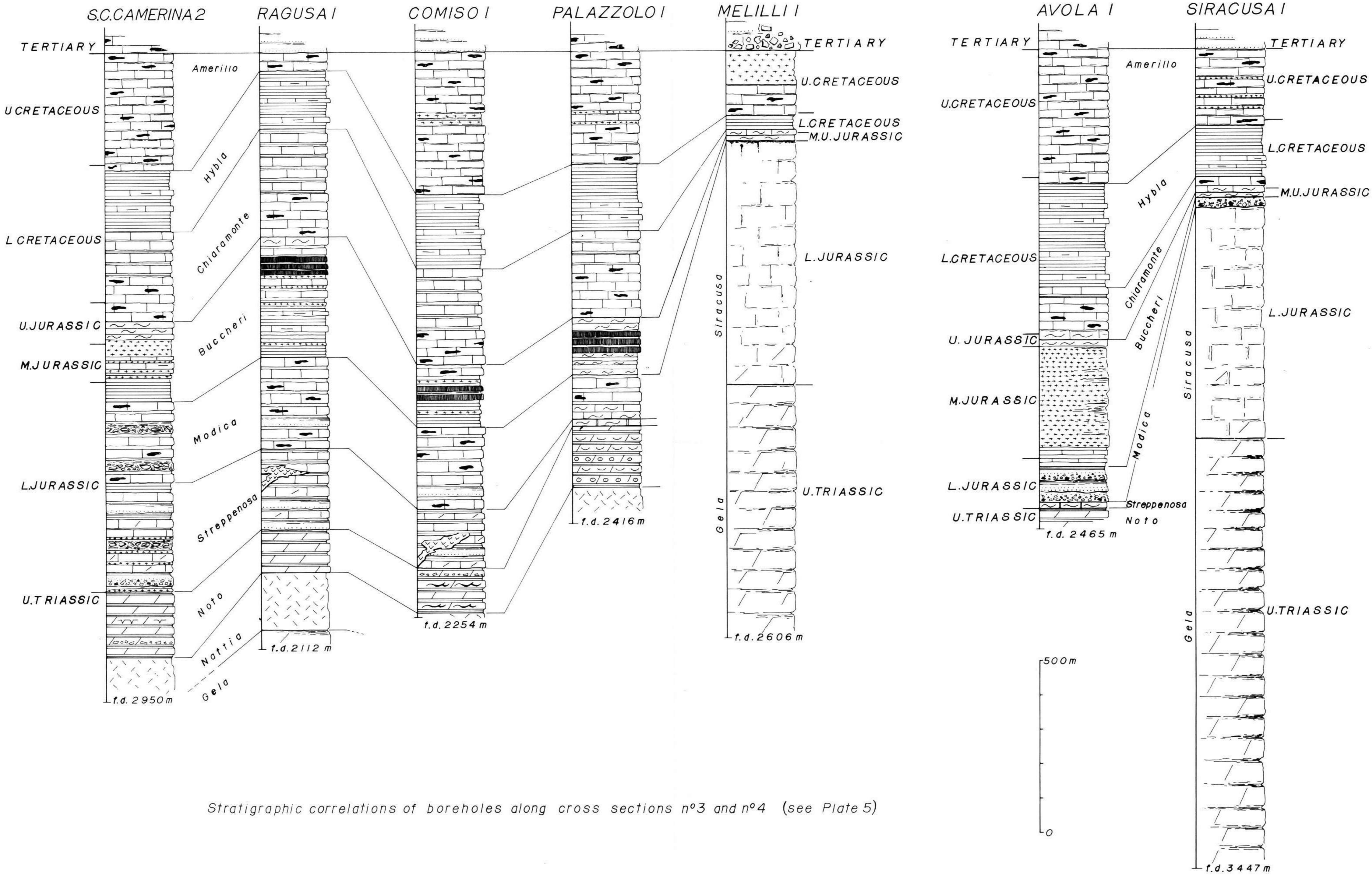
Stratigraphic correlations of boreholes along cross section n° I (see Plate 5)



Stratigraphic correlations of boreholes along cross section n° 2 (see Plate 5)



Columnar sections and electric logs of some Mesozoic formations in the type-wells



Stratigraphic correlations of boreholes along cross sections n°3 and n°4 (see Plate 5)

Restored schematic sections across the Ragusa Zone (Upper Cretaceous)

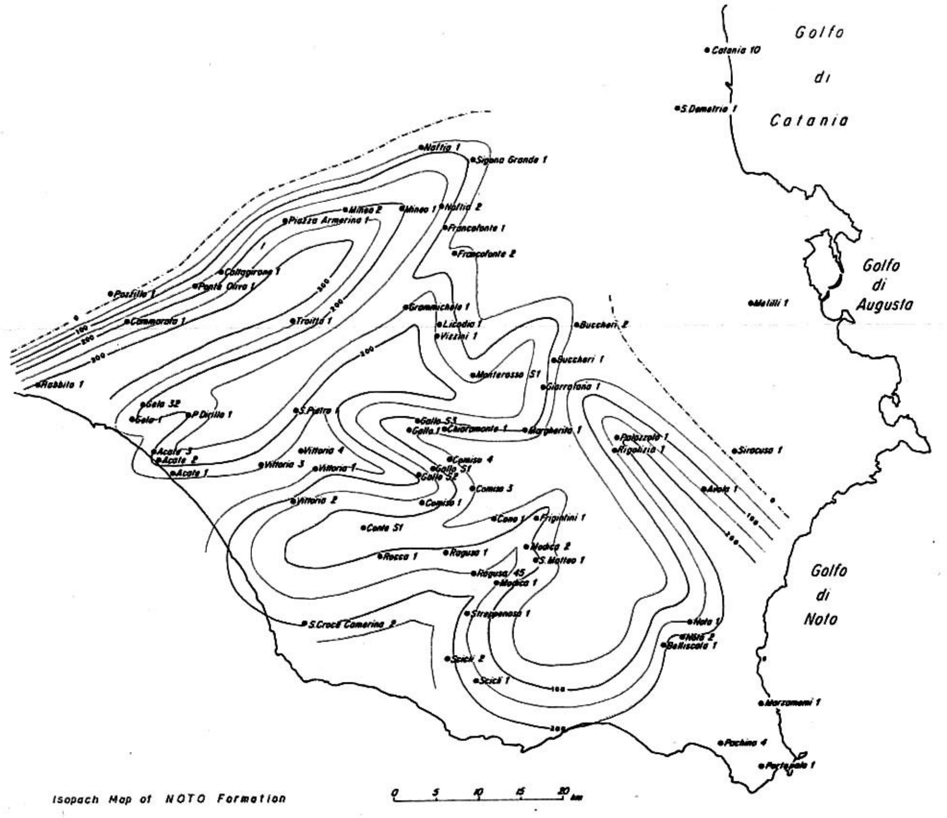


FIG. 50

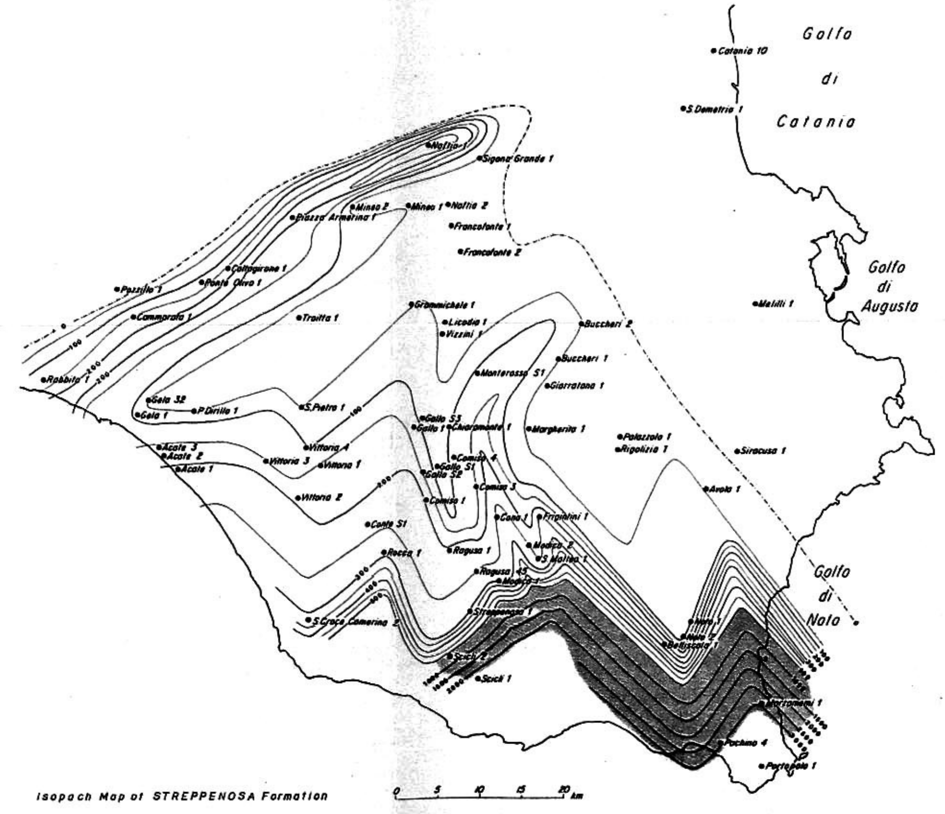


FIG. 51

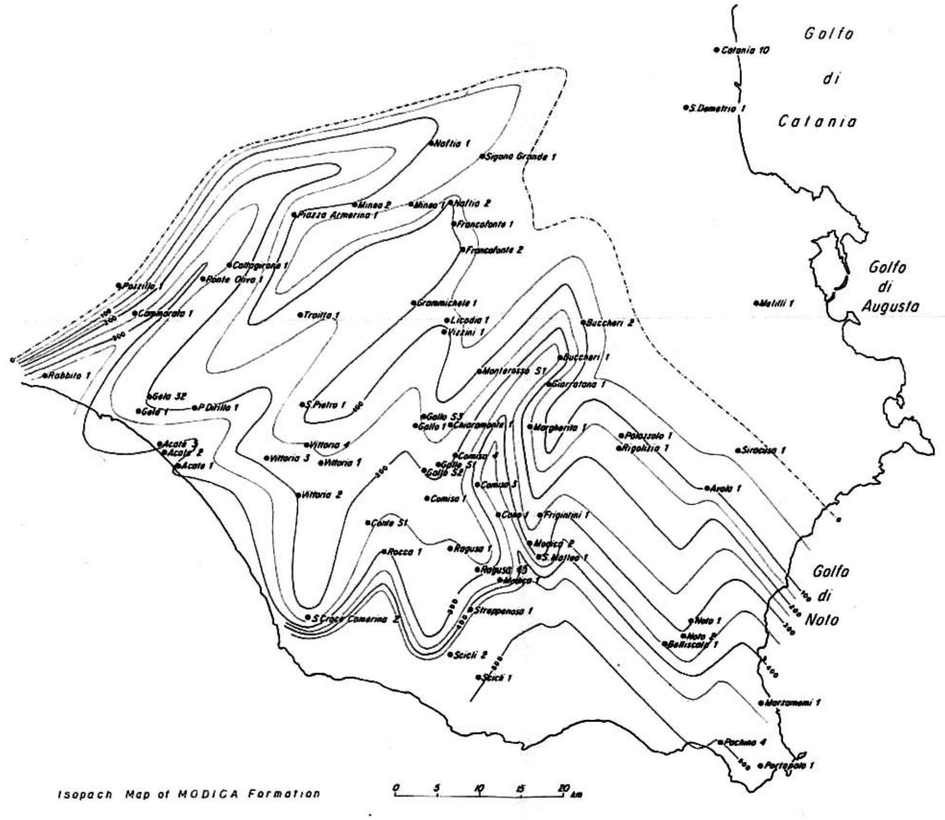


FIG. 52

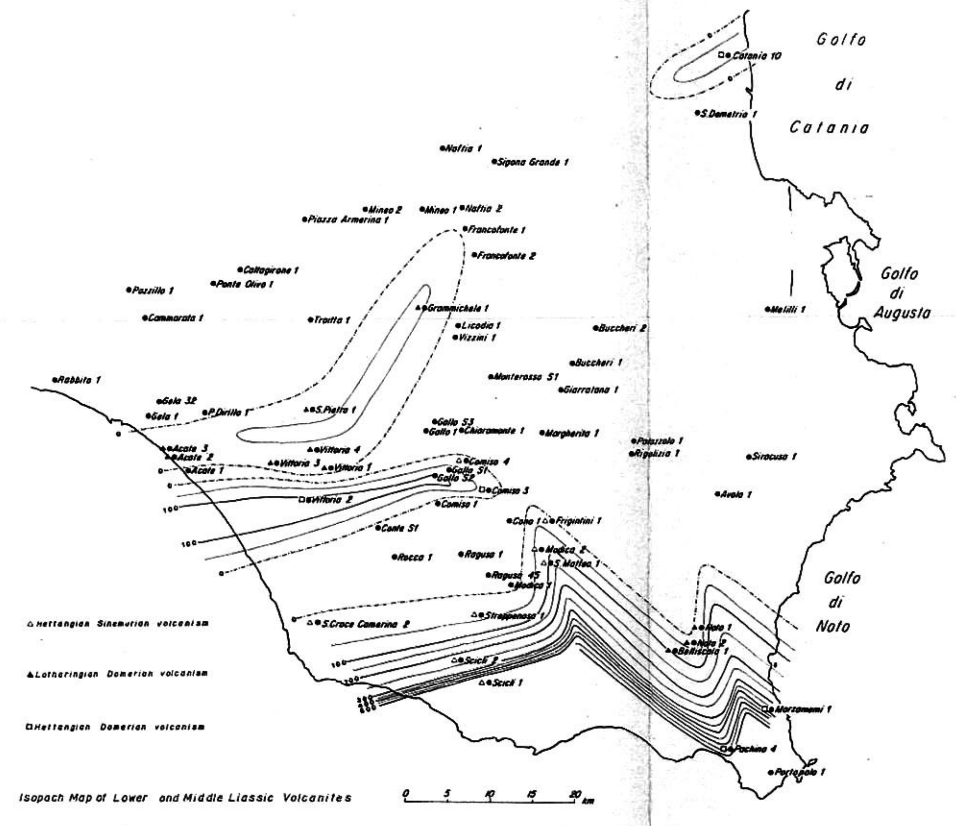


FIG. 53

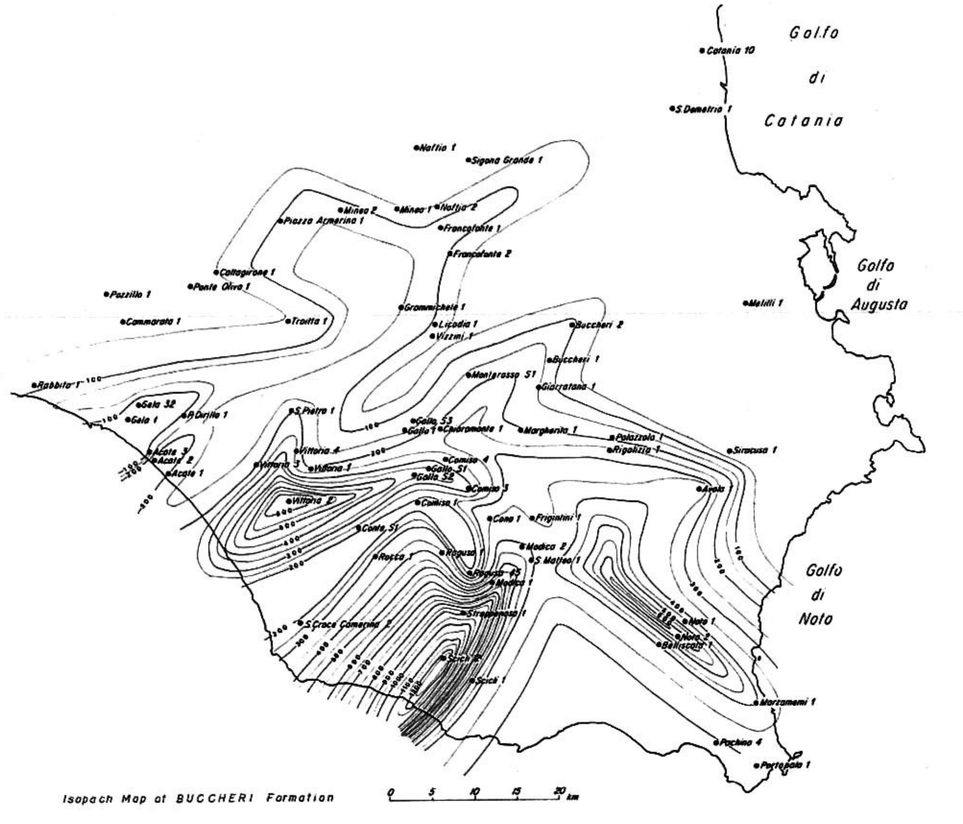


FIG. 54

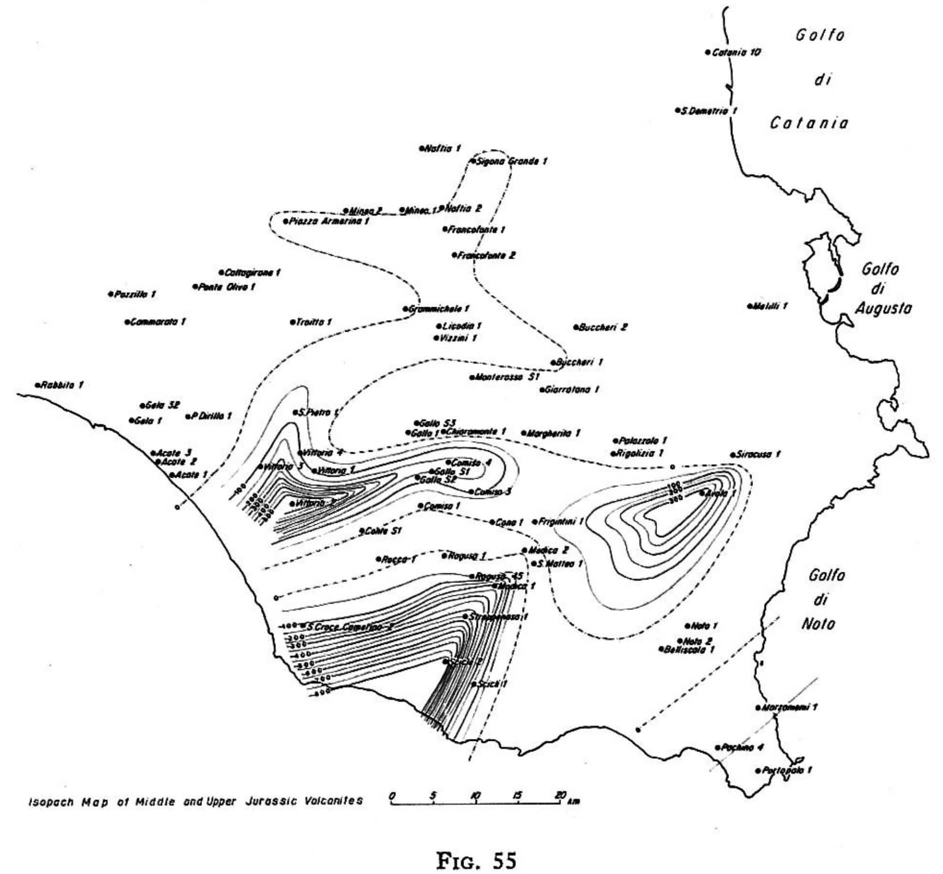


FIG. 55

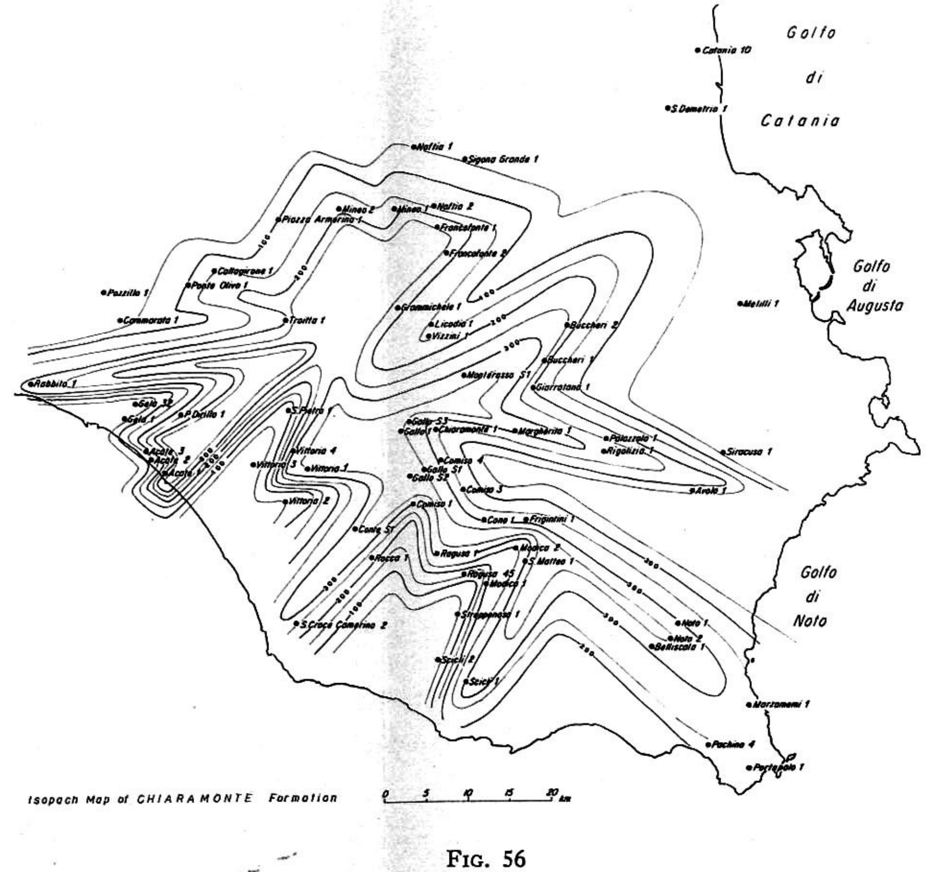


FIG. 56

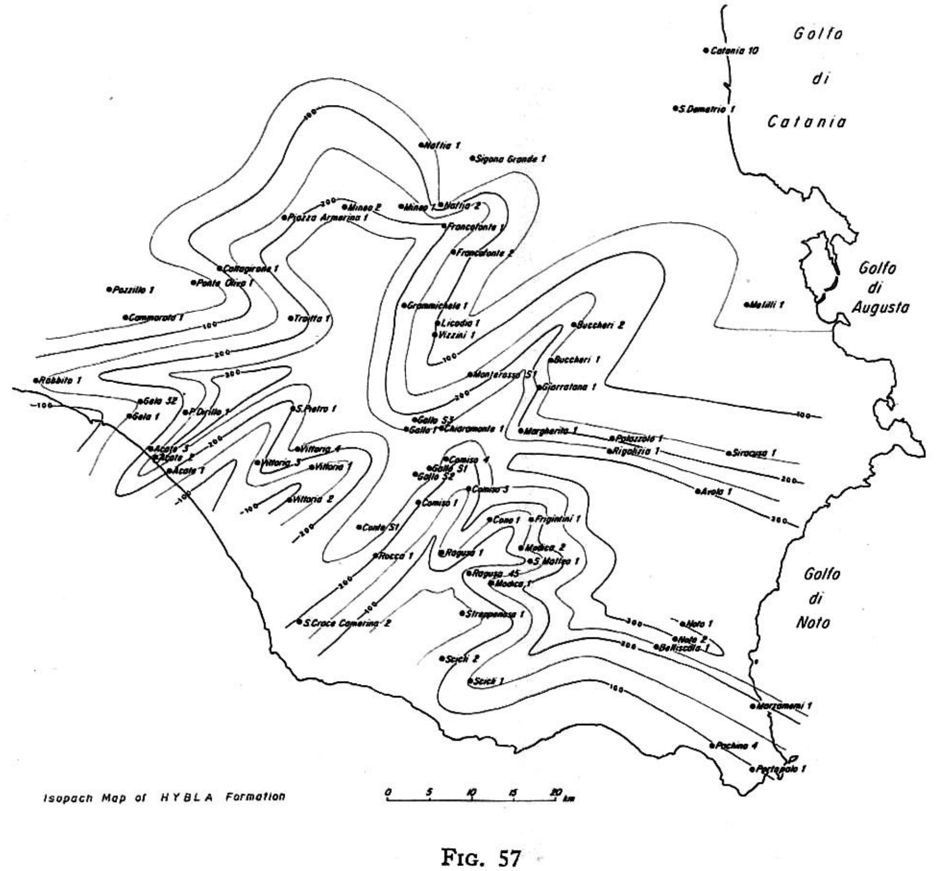


FIG. 57

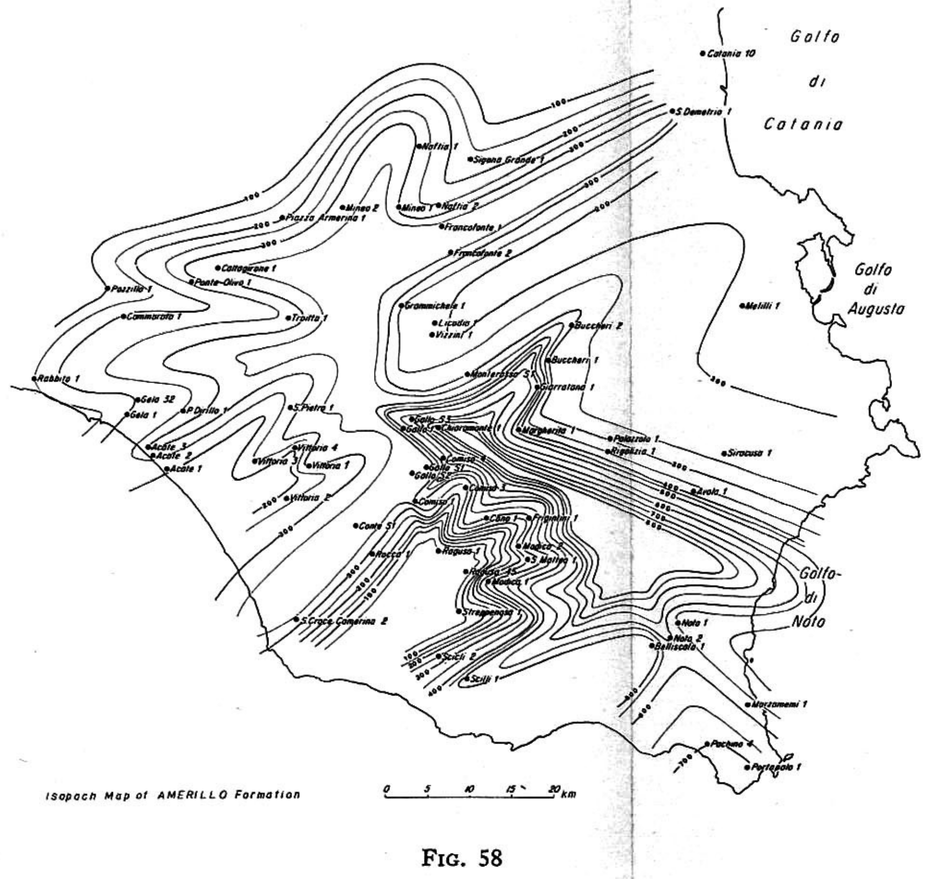


FIG. 58

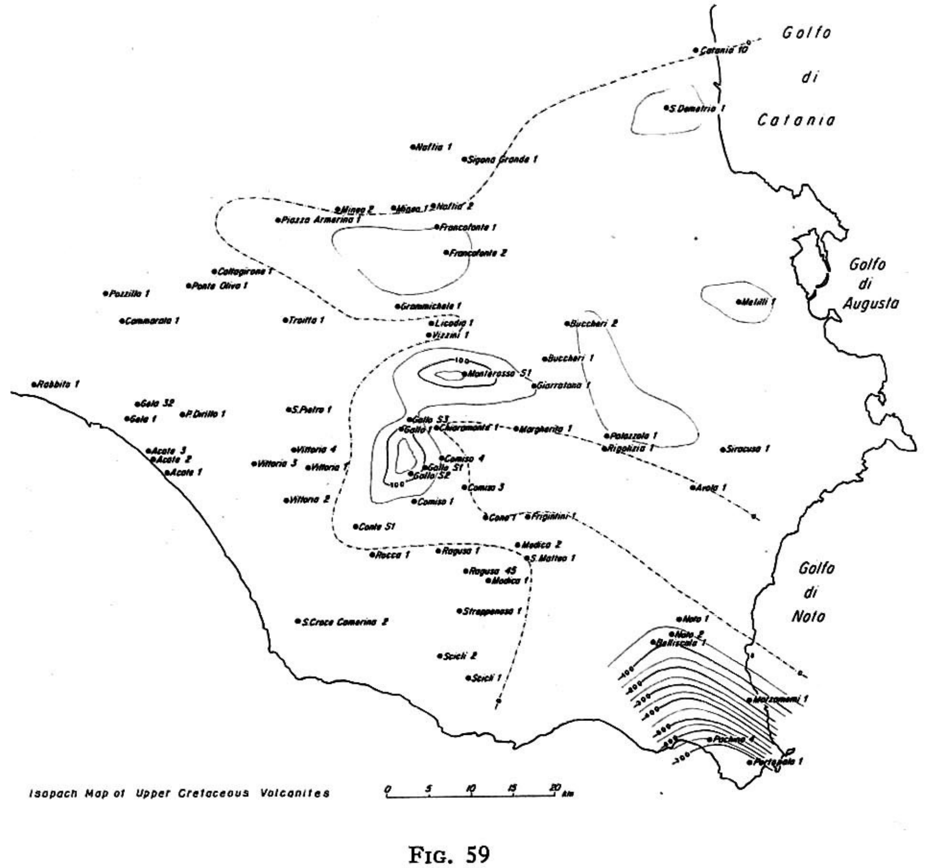


FIG. 59

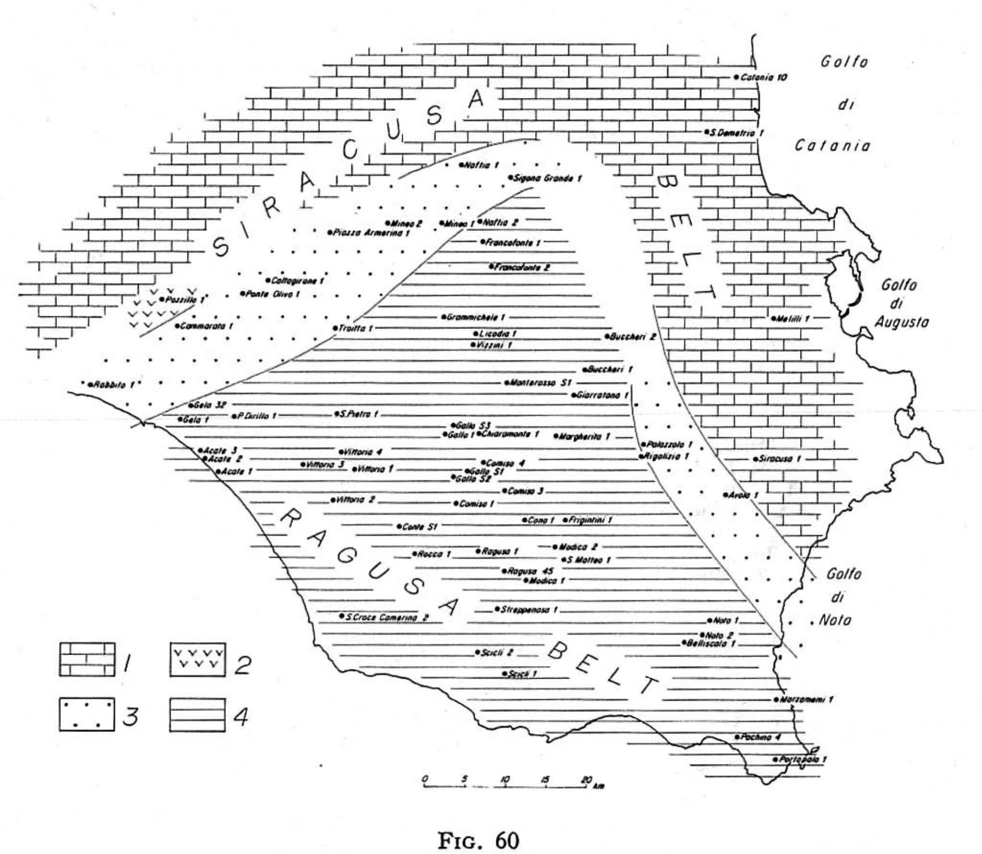


FIG. 60

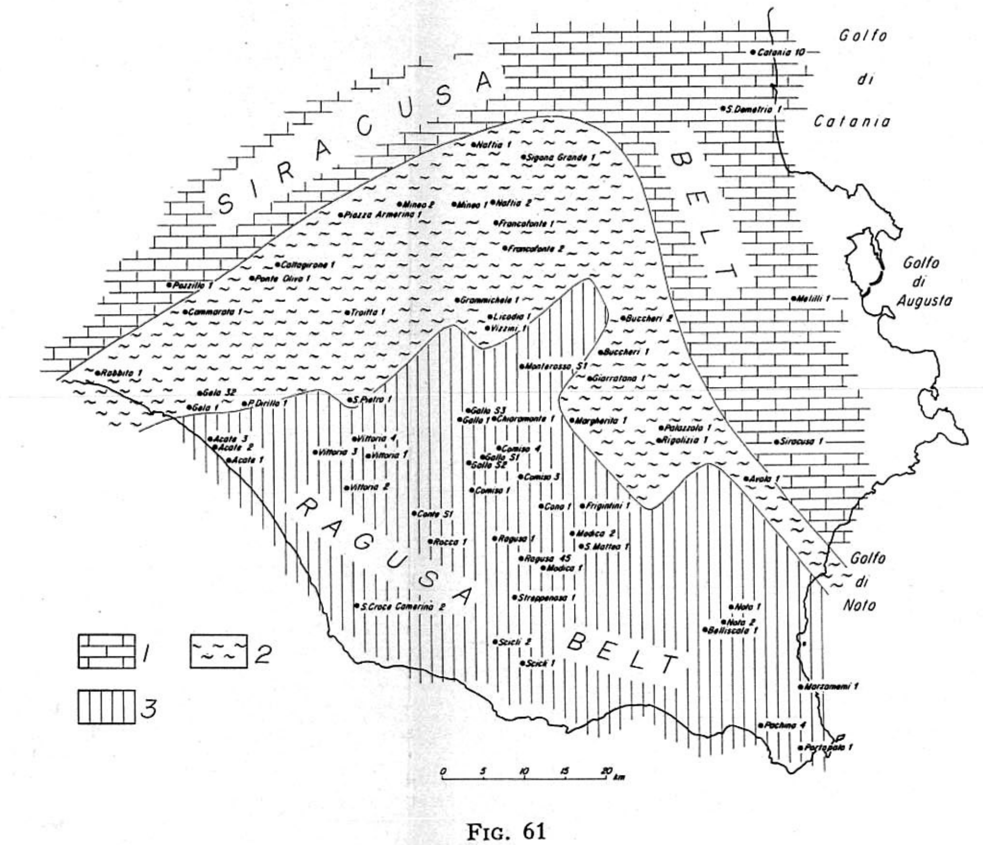


FIG. 61

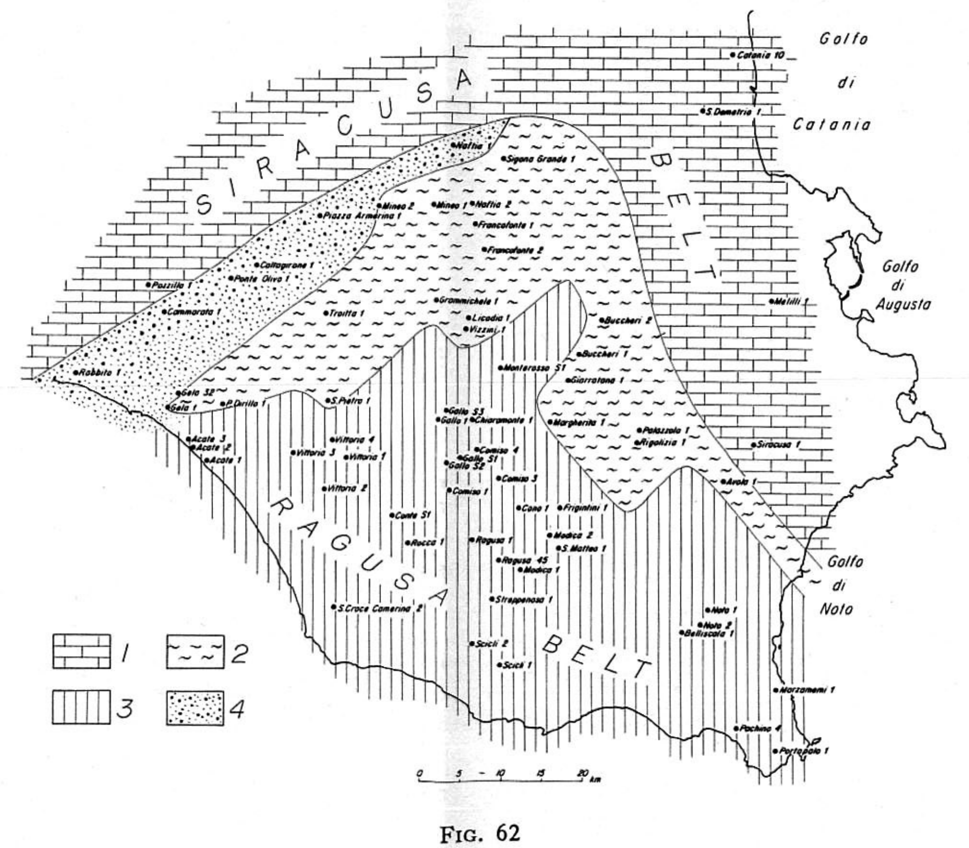


FIG. 62

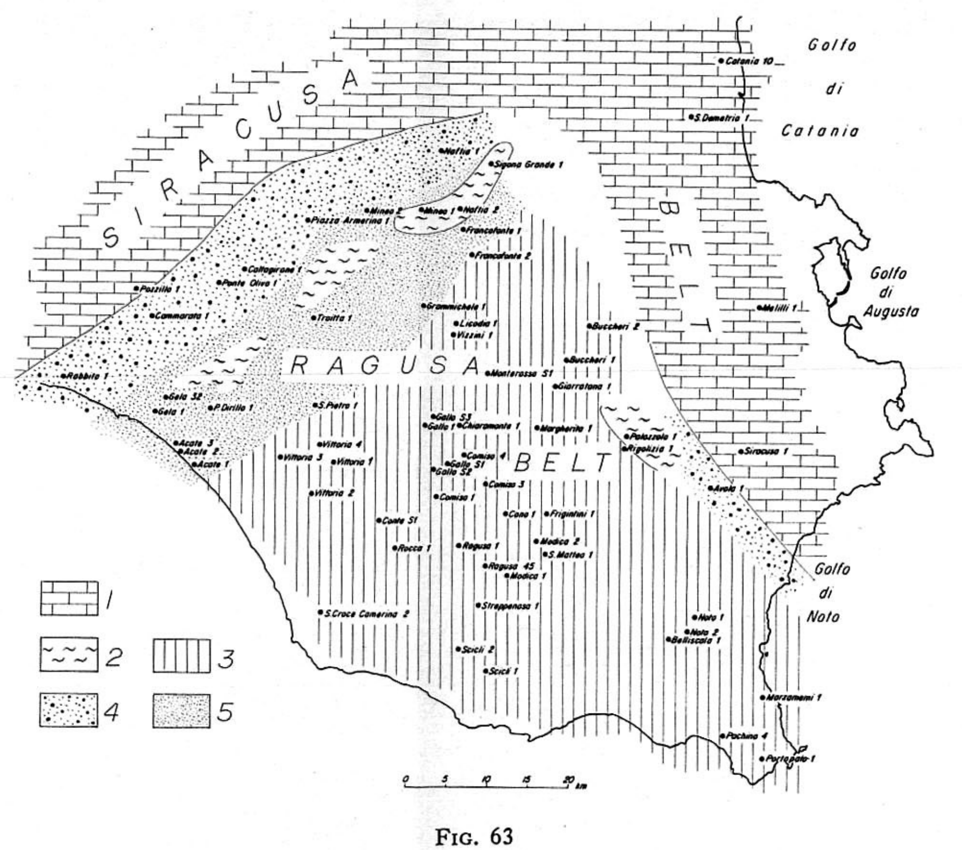


FIG. 63

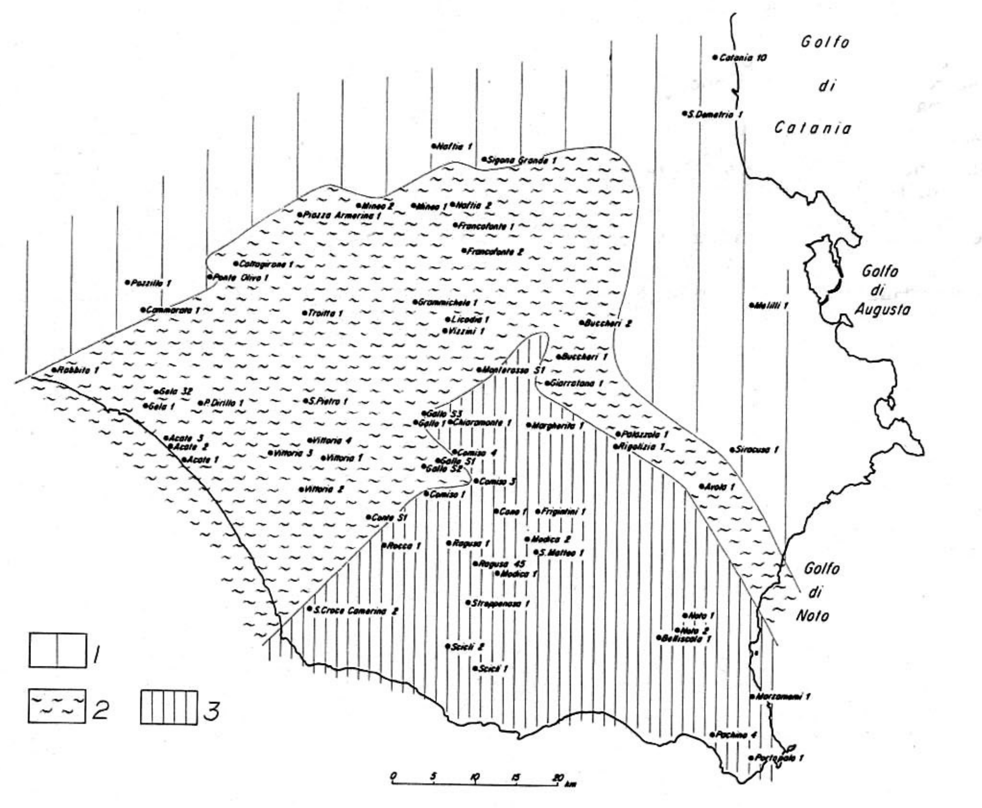


FIG. 64

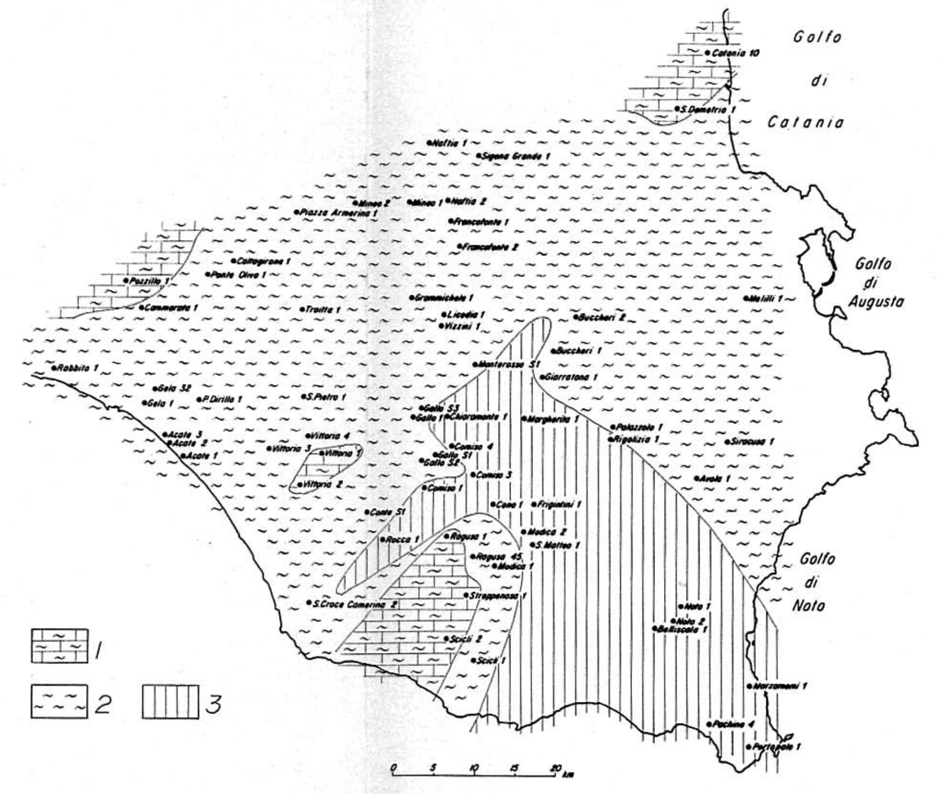


FIG. 65

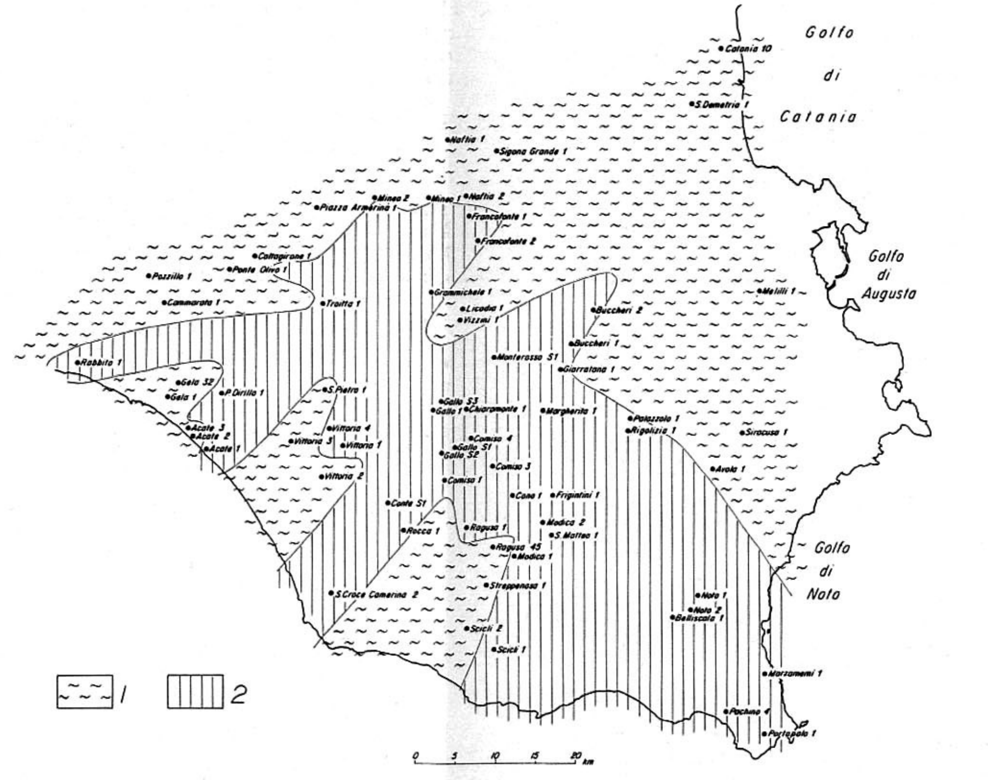


FIG. 66

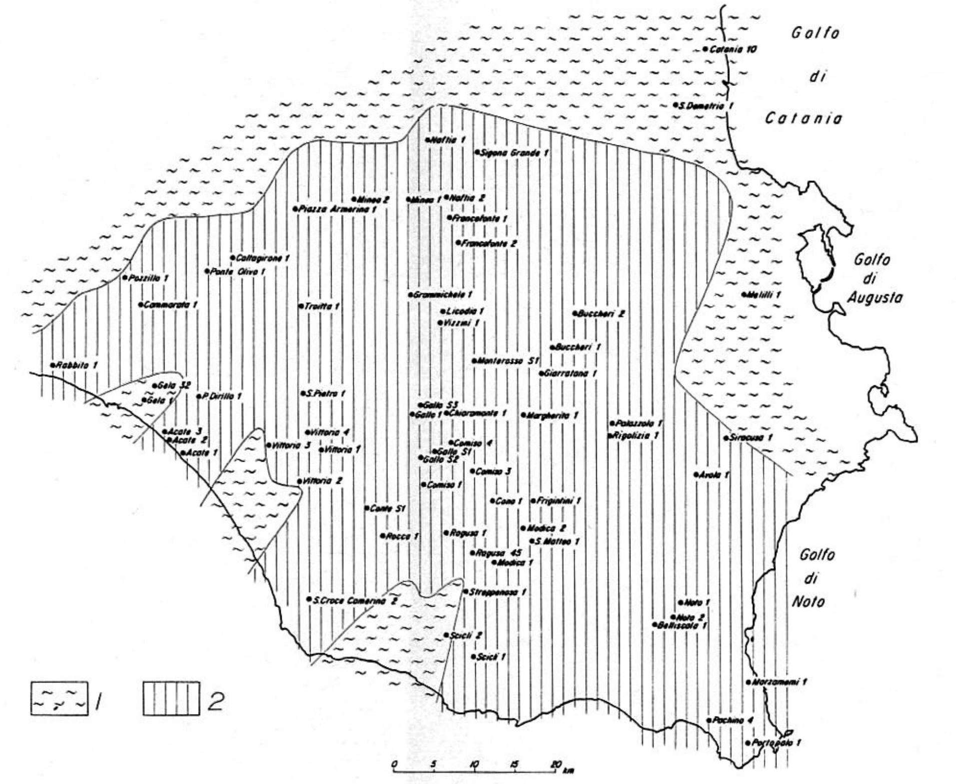


FIG. 67

FIG. 60 — Facies map of the uppermost Rhetian deposits in Southern Sicily. 1) white calcarenites (open carbonate platform, subtidal flat). Gela Formation; 2) brownish dolomites and evaporites (supratidal flat). Naftia Formation; 3) ooidal and bioclastic calcarenites (tidal flat, beach ridge). Noto Formation; 4) thinly laminated dark dolomitic limestones and clays; associated dolomitic deposits (tidal flat, channels and ponds). Noto Formation.

— Distribuzione delle litofacies del Retico superiore nella Sicilia meridionale. 1) calcareniti bianche (depositi subtidali di piattaforma carbonatica con circolazione aperta). Formazione Gela; 2) dolomie brune ed evaporiti (depositi sopratidali di pianura tidale). Formazione Naftia; 3) calcareniti ooidiche e bioclastiche (barre costiere di pianura tidale). Formazione Noto; 4) calcari dolomitici grigio scuri e argille nere fittamente laminati; depositi dolomitici associati (canali e lagune di piana tidale). Formazione Noto.

FIG. 61 — Facies map of Hettangian deposits in Southern Sicily. 1) white limestones (open carbonate platform, intertidal-subtidal zone). Siracusa Formation; 2) grey nodular marly limestones, marls and glauconitic calcarenites (scarcely subsiding flat area, seat of condensed deposition below the photic zone). Streppenosa Formation, Facies 2; 3) turbiditic deposits consisting of grey-greenish dolomitic limestones with black shale interlayers (strongly subsiding basin with dysaerobic conditions at the sea floor). Streppenosa Formation, Facies 1.

— Distribuzione delle litofacies dell'Hettangiano nella Sicilia meridionale. 1) calcari bianchi (depositi intertidali-subtidali di piattaforma carbonatica). Formazione Siracusa; 2) calcari marnosi grigi nodulari, marne e calcareniti glauconitiche (depositi condensati in aree scarsamente subsidenti al di sotto della zona fotica). Formazione Streppenosa, Facies 2; 3) calcari dolomitici grigio-verdi con intercalazioni di argille nere (depositi torbiditici accumulati in un bacino fortemente subsidente con scarsa ossigenazione al fondo). Formazione Streppenosa, Facies 1.

FIG. 62 — Facies map of Sinemurian *s.s.* deposits in Southern Sicily. 1) white limestones (open carbonate platform, intertidal-subtidal zone). Siracusa Formation; 2) grey nodular marly limestones, marls and glauconitic calcarenites (scarcely subsiding flat area, seat of condensed deposition below the photic zone). Streppenosa Formation, Facies 2; 3) turbiditic deposits consisting of grey-greenish dolomitic limestones with black shale interlayers (strongly subsiding basin with dysaerobic conditions at the sea-floor). Streppenosa Formation, Facies 1; 4) coarse-grained resediments with shelf-derived calcareous materials (toe of fault slopes). Streppenosa Formation, Facies 3.

— Distribuzione delle litofacies del Sinemuriano *s.s.* nella Sicilia meridionale. 1) calcari bianchi (depositi intertidali-subtidali di piattaforma carbonatica). Formazione Siracusa; 2) calcari marnosi grigi nodulari, marne e calcareniti glauconitiche (depositi condensati in aree scarsamente subsidenti al di sotto della zona fotica). Formazione Streppenosa, Facies 2; 3) calcari dolomitici grigio-verdi con intercalazioni di argille nere (depositi torbiditici accumulati in un bacino fortemente subsidente con scarsa ossigenazione al fondo). Formazione Streppenosa, Facies 1; 4) risedimenti carbonatici grossolani con elementi provenienti da aree di piattaforma carbonatica (depositi al piede di scarpate di faglia). Formazione Streppenosa, Facies 3.

FIG. 63 — Facies map of Lotharingian deposits in Southern Sicily. 1) white limestones (open carbonate platform, intertidal-subtidal zone). Siracusa Formation; 2) red nodular limestones (« shortlived » submarine hills in scarcely subsiding areas). Modica Formation, Facies 2; 3) fine-grained resediments of pelagic material, represented by grey limestones and marls (moderately subsiding basin). Modica Formation, Facies 1; 4) coarse-grained resediments with shelf-derived calcareous materials (toe of fault slopes). Modica Formation, Facies 3; 5) lime turbidites with fine-grained shallow water and pelagic components (scarsely subsiding-gently dipping ramp). Modica Formation, Facies 3.

— Distribuzione delle litofacies del Lotaringiano nella Sicilia meridionale. 1) calcari bianchi (depositi intertidali e subtidali di piattaforma carbonatica). Formazione Siracusa; 2) calcari rossi nodulari (depositi sviluppati su altofondi pelagici temporanei in aree scarsamente subsidenti). Formazione Modica, Facies 2; 3) calcari marnosi e marne (risedimenti di materiale pelagico a grana fine accumulati in un bacino moderatamente subsidente). Formazione Modica, Facies 1; 4) risedimenti carbonatici grossolani con elementi provenienti da aree di piattaforma carbonatica (depositi al piede di scarpate di faglia). Formazione Modica, Facies 3; 5) calcareniti a componente neritica e pelagica (depositi torbiditici accumulati su aree scarsamente subsidenti debolmente inclinate verso il bacino meridionale). Formazione Modica, Facies 3.

FIG. 64 — Facies map of Toarcian deposits in Southern Sicily. 1) scarcely subsiding area with smooth bottom topography, characterized by non-deposition or submarine erosion; 2) red and greenish marls with pelagic-bivalve lumachelles, often displaying nodular structure (scarcely subsiding basinal margin). Buccheri Formation, lower interval, Facies 2; 3) hemi-pelagic grey-greenish marls and fine-grained lime resediments with pelagic components (moderately subsiding basin). Buccheri Formation, lower interval, Facies 1.

— Distribuzione delle litofacies del Toarciano nella Sicilia meridionale. 1) altofondo pelagico scarsamente subsidente caratterizzato da lacune di sedimentazione e/o da erosione sottomarina; 2) marne rosse e verdi, spesso a struttura nodulare, con sottili livelli lumachellici (depositi sviluppati su aree scarsamente subsidenti al margine del bacino meridionale). Formazione Buccheri, intervallo inferiore, Facies 2; 3) calcari marnosi e marne grigio-verdi (risedimenti di materiale pelagico accumulati in aree di bacino moderatamente subsidente). Formazione Buccheri, intervallo inferiore, Facies 1.

FIG. 65 — Facies map of uppermost Kimmeridgian — lowermost Tithonian deposits in Southern Sicily. 1) nodular pinkish limestones (condensed pelagic deposition on top of submarine hills and volcanic sea-mounts). Buccheri Formation, Facies 3; 2) Red and greenish marls and marly limestones often displaying nodular structure (scarcely subsiding basinal margin). Buccheri Formation, upper interval, Facies 2; 3) fine-grained resediments with pelagic components, represented by light cream cherty limestones with red-greenish marly interlayers (moderately subsiding basin). Buccheri Formation, upper interval, Facies 1.

— Distribuzione delle litofacies del Kimmeridgiano superiore-Titonico inferiore nella Sicilia meridionale. 1) calcari nodulari rosati (depositi pelagici condensati sviluppati su circoscritte aree di altofondo pelagico e sulla sommità di rilievi vulcanici sottomarini). Formazione Buccheri, Facies 3; 2) marne rosse e verdi e calcari marnosi, frequentemente a struttura nodulare (depositi sviluppati su aree scarsamente subsidenti al margine del bacino meridionale). Formazione Buccheri, intervallo superiore, Facies 2; 3) calcari biancastri con selce e marne rosso-verdastre (risedimenti di materiale pelagico accumulati in aree di bacino moderatamente subsidente). Formazione Buccheri, intervallo superiore, Facies 1.

FIG. 66 — Facies map of upper Tithonian-Berriasian *p.p.* deposits in Southern Sicily. 1) red-pinkish nodular limestones (condensed pelagic deposition over scarcely subsiding morphological highs). Chiaramonte Formation, Facies 2; 2) redeposited light cherty limestones with marly interlayers (basinal sedimentation in a morphological depression). Chiaramonte Formation, Facies 1.

— Distribuzione delle litofacies del Titonico superiore-Berriasiano *p.p.* nella Sicilia meridionale. 1) calcari nodulari rossastri (depositi condensati, sviluppati su aree di altofondo pelagico scarsamente subsidenti). Formazione Chiaramonte, Facies 2; 2) calcari selciferi biancastri con interstrati marnosi (risedimenti a componente pelagica accumulati in una depressione morfologica nella parte centrale della zona ragusana). Formazione Chiaramonte, Facies 1.

FIG. 67 — Facies map of Berriasian *p.p.*-lower Hauterivian deposits in Southern Sicily. 1) red-pinkish nodular limestones (condensed pelagic deposition over scarcely subsiding morphological highs). Chiaramonte Formation, Facies 2; 2) redeposited light cherty limestones with marly interlayers (basinal sedimentation in a morphological depression). Chiaramonte Formation, Facies 1.

— Distribuzione delle litofacies del Berriasiano *p.p.*-Hauteriviano inferiore nella Sicilia meridionale. 1) calcari nodulari rossastri (depositi condensati, sviluppati su aree di altofondo pelagico scarsamente subsidenti). Formazione Chiaramonte, Facies 2; 2) calcari selciferi biancastri con interstrati marnosi (risedimenti a componente pelagica accumulati in una ampia depressione morfologica nella parte centrale della zona ragusana). Formazione Chiaramonte, Facies 1.