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Sicily in its Mediterranean geological frame

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ABSTRACT

The Island of Sicily is generally considered to be the geological link between the North African Fold Belt and the Appennines, in Italy. This comes from a cylindristic meaning and is only partly exact. As a matter of fact, Sicily is essentially Greek; Ionian. Up to Middle Cretaceous time, the Sicilian area was a submerged shoal in the sea or the Panormide area, bordering the Ionian Ocean. This shoal lay between the future North African Fold Belt and the Appennines, forming an intermediate link between the Appenninic, Apulian, Panormian and Tunisian platforms. It was only during the Middle to Upper Cretaceous that the Atlantic and Ligure Oceans merged, making a continuous relationship between the Appenninic, Sicilian and North African sedimentary series. The key time periods are the Permian, Cretaceous and Oligo-Miocene periods leading to the formation of the actual Calabro-Sicilian arc. From the Permian to the present, the Sicilian geological history pertains to three oceanic domains: Ionian, Ligurian and Atlantic, of which the Ionian and Ligurian were under the influence of Tethys (Neo and Paleo-Tethys). The Tethysian identity of Sicily constitutes the major aspect of its geological history. However, the European and African plate tectonic movements complicated its structure. During the Middle Miocene subduction, southern Sicily became African, meanwhile its north-eastern part became, in Pliocene time, Maghrebian by accretion. Sicily is thus a truly geological patchwork, but its main section remains Ionian and now constitutes a link between North Africa and the Appennines. With older data, but also by means of recent results, we will replace Sicily in its Mediterranean frame, giving the mean stages of its paleogeographical and then its tectonic evolution. We will review the calabro-sicilian arc evolution from the Oligocene, developing the actual context and recalling the main fundamental play of the Numidian flysch.

Key words: Appennines, North African Fold Belt, Tethys, Sicily

Sicilia en el contexto geológico mediterráneo

RESUMEN

Frecuentemente, se acepta que Sicilia constituye un nexo geológico entre el Magreb y los Apeninos. Esta suposición se basa en un razonamiento "cilindrista", que solo es parcialmente correcto. De hecho, Sicilia es esencialmente jónica, es decir de origen griego. Hasta el Cretácico Medio constituyó una zona del alto fondo panórmide, que bordeaba el océano jónico. Este alto fondo era una transición entre el Magreb y los Apeninos, estableciéndose una continuidad entre las plataformas apenínicas, apulia, panórmide y tunecina. A partir del Cretácico Medio-Superior, los océanos ligur y Atlántico se unieron, estableciendo una continuidad entre las series sedimentarias apenínicas, sicilianas y magrebíes. Para alcanzar la estructura actual del arco Calabro-Siciliense los periodos claves son el Pérmico, el Cretácico y el Oligo-Mioceno. La historia geológica de Sicilia entre el Pérmico y el Cuaternario está ligada a la de tres dominios oceánicos: jónico, ligur y atlántico, de los cuales los dos primeros están relacionados con el Tethys (Neo y Paleotethys). La identidad de Sicilia con el Tethys constituye su rasgo dominante, aunque su estructura se hizo más compleja debido al juego del movimiento entre la placa europea y la africana. Sicilia fue africana hacia el sur, en el Mioceno medio, por subducción y magrebí hacia el noreste, durante del Mio-Plioceno, por acreción. Como un auténtico rompecabezas geológico, no dejó de ser esencialmente jónica, pero constituye, sin embargo, un nexo actual entre el Magreb y los Apeninos. A partir de datos antiguos pero reinterpretados por investigaciones recientes, se ha resituado a Sicilia en el contexto mediterráneo, redibujando las grandes etapas de su evolución paleogeográfica y tectónica. En este trabajo se reinterpreta la evolución del arco calabro-siciliense desde el Oligoceno, poniendo el foco en el contexto actual y recordando el papel fundamental jugado por el flysch numídico.

Palabras clave: Apeninos, Cinturón de plegamiento del Norte de África, Thetys, Sicilia

VERSIÓN ABREVIADA EN CASTELLANO

Introducción y metodología

El objetivo de este artículo es resituar Sicilia (Fig. 1) en el contexto mediterráneo entre África del norte e Italia. Frecuentemente, se acepta que Sicilia constituye un nexo geológico entre el Magreb y los Apeninos. Esta suposición se basa en un razonamiento "cilindrista", que solo es parcialmente correcto. De hecho, Sicilia es esencialmente jónica, es decir de origen griego. Hasta el Cretácico Medio constituyó una zona del alto fondo panórmide, que bordeaba el océano jónico. Este alto fondo era una transición entre el Magreb y los Apeninos, estableciéndose una continuidad entre las plataformas apenínicas, apulia, panórmide y tunecina. A partir del Cretácico Medio-Superior, los océanos ligur y Atlántico se unieron, estableciendo una continuidad entre las series sedimentarias apenínicas, sicilianas y magrebíes. Para alcanzar la estructura actual del arco Calabro-Siciliense los periodos claves son el Pérmico, el Cretácico y el Oligo-Mioceno. La historia geológica de Sicilia entre el Pérmico y el Cuaternario está ligada a la de tres dominios oceánicos: jónico, ligur y atlántico, de los cuales los dos primeros están relacionados con el Tethys (Neo y Paleotethys). La identidad de Sicilia con el Tethys constituye su rasgo dominante, aunque su estructura se hizo más compleja debido al juego del movimiento entre la placa europea y la africana. Sicilia fue africana hacia el sur, en el Mioceno medio, por subducción y magrebí hacia el noreste, durante del Mio-Plioceno, por acreción. Como un auténtico rompecabezas geológico, no dejó de ser esencialmente jónica, pero constituye, sin embargo, un nexo actual entre el Magreb y los Apeninos. A partir de datos antiguos pero reinterpretados por investigaciones recientes, se ha resituado a Sicilia en el contexto mediterráneo, redibujando las grandes etapas de su evolución paleogeográfica y tectónica. En este trabajo se reinterpreta la evolución del arco calabro-siciliense desde el Oligoceno, poniendo el foco en el contexto actual y recordando el papel fundamental jugado por el flysch numídico.

Resultados y conclusiones

El periodo Pérmico es fundamental para la comprensión de la geología de Sicilia. El océano Pérmico (Neo-Tethys) se instaló entre la placa africana y el continente cimérico (fig. 2). Imprimió su marca en la geología siciliana y calabresa post-Pérmica, en particular en las series secundarias radiolaríticas denominadas de Sclafani y Lagonegro. En efecto, el periodo post-Pérmico se corresponde con la individualizacion de las zonas paleogeográficas sicilianas. El océano Jónico (zona de Sclafani-Cammarata) está bordeado al suroeste por una plataforma africana (zona de Sciacca-bloque pelágico) y al noreste por una plataforma jónica (zona de Panórmida), similar a la plataforma de Gavrovo-Tripolitza (Helénides). Nuestra propuesta es relacionar la zona de Sclafani con el microcontinente AlKaPeCam y más concretamente con la serie metaradiolarítica de Ali (montes Peloritianos). El análisis de la situación de las zonas con afinidades de facies con la Panórmida (plataforma Interna del surco de Sclafani) permite constatar que estas series constituyen un trazo de unión entre las zonas de Sclafani, los montes Peloritanos (serie de Novara) la Calabria Meridional (serie de Stilo), Cerdeña (región de Cala Gonone-Golfo de Orosei e Isla de San Antioco) y el borde meridional del surco tunecino (afinidades entre las series con rudistas de los Djebels Mok-Zembra y del Monte Sparagio-Erice del panórmide externo de Sicilia). Igualmente hay que hacer notar una cierta relación entre el flysch externo (serie del Monte Pomiere) y el panórmide (serie del Monte Acci). Estos datos han permitido establecer un mapa palinspástico de hace 130 Ma (fig. 4) sobre el cual hemos posicionado entre 115 y 100 Ma la apertura del surco ligur externo, patria de la serie de las arcillas Scagliosa del Cretácico Medio-Superior. En este periodo se estableció una comunicación entre los océanos Ligur y Atlántico. Estos datos conducen a interrumpir en el Mesozoico y hasta el Cretácico Medio el océano del Tethys, interpretado generalmente como la hipótesis de una fisura cortical continua de tipo californiano desde Gibraltar hasta los Alpes (fig. 3) y llevan a reconocer en la época mesozoica tres grandes conjuntos perimediterráneos: apenínico, jónico y magrebí.

Un cambio paleogeográfico radical se originó en el Oligoceno con la apertura del surco Numídico y la generación de un arco clásico en las cadenas de colisión. Un mapa palinspástico del Aquitaniense (hacia 20 Ma, fig. 5) indica la posición del flysch Numídico Interno, Intermedio y Externo (N1-N2-N3) y la de las formaciones arenisco-micáceas más externas. Es destacable la alimentación por el norte del flysch Numídico (fig. 5). La evolución tectónica de Sicilia se lleva a cabo en tres fases principales: la fase argelo-provenzal o sardo-balear (Oligoceno Superior-Mioceno basal?); la fase del Mioceno Medio y la Fase Tirreniense del Mioceno Superior-Plioceno.

El corte esquemático y sintético (fig. 6) presenta las principales unidades conocidas en el noreste de Sicilia. Los fenómenos tecto-sedimentarios del Oligoceno y del Mioceno Medio muestran en las figuras 7 y 8 la colocación de los klippes sedimentarios de apertura (Oligoceno) y de cierre (Mioceno Medio).

Un esquema ya antiguo presenta las principales etapas de la evolución paleogeográfica y tectónica de los Madonies (Sicilia), entre el Pérmico y el Cuaternario (fig. 9) con un corte sísmico simplificado del manto de Gela que precisa la edad de la colocación de este manto hacia 1 Ma (fig. 10).

El arco sículo-calabriense (esquema palinspástico en la fig. 11) está presente en el Cretácico Superior como un arco paleogeográfico heredado bajo la influencia de las direcciones apenínicas (noroeste-sureste) y magrebíes (este-oeste). A partir del Oligoceno Superior, el arco se convierte en tectónico y afecta al margen activo móvil panórmide, en el frente del cual se encuentra la antefosa de Sclafani. Se pueden distinguir tres partes: una cuenca oceanizada de trasarco (fig. 7-N1), un arco activo (fig. 7-N2) con un arco volcánico, y una cuenca de antearco (fig. 7-N3). En el Serravalliense el margen activo móvil incorpora el flysch interno, el panórmide, la zona de Sclafani y las unidades sicanas con sus coberturas frecuentemente desolidarizadas. La cuenca sicana corresponde a la antefosa que se apoya en el antepaís hiblense (placa africana). Después del bloqueo de la zona de subducción, al sur, Sicilia realizó una rotación horaria de unos 50° entre el Tortoniense y la actualidad. En esta época funcionó una amplia zona de cizalla dextra en el Pliocuaternario, con apertura y oceanizacion del mar Tirrénico que correspondió a una cuenca de trasarco (fig. 11-1), separada del océano Jónico de antearco por un arco volcánico (las Islas Eólicas) y por el arco sículo-calabrense destinado, después de la apertura del sillón tirrenojónico a suministrar los klippes sedimentarios de apertura. Es remarcable la analogía existente entre los periodos Oligoceno y actual, con la orientación este-oeste y noroeste-sureste de las cuencas de ante y postarco.

El reparto de los grandes dominios estructurales en el Mediterráneo central (fig. 12) condujo a la situación actual, destacando la importancia de los desgarres-cabalgamientos post-tortonienses (fase tirrénica), cuyo origen estuvo en la acreción lateral dextra que hizo transformarse a la Sicilia jónica en magrébide hacia el noreste a partir del Mioceno Superior-Plioceno, después de haber sido africana hacia el sur mediante la subducción del Mioceno Medio.

Introduction

Sicily is subdivided into several natural areas (Fig. 1) which correspond to the main paleogeographical zones and tectonic units essentially defined in the 1960's (Ogniben, 1960;

Truillet, 1968; Broquet, 1968; Duée, 1969; Mascle, 1979). From NE to SW, this means from inside to outside of the Mountain Belt, between the Peloritans Mountains (the area between Toaormina-L.T. and Messina) and the Sicani Mountains (area between Cammarata and Sciacca), the paleogeographical domains are as follows:

- The internal Peloritan domain, which continues beyond the Messina Straight by the southern part of the Calabrian Massif (Aspromonte and Serre areas). Its basement is composed of a paleozoïc series, metamorphized during the Variscan period (Truillet, 1968), in an inverted zoneographical Himalayan-type context and intruded by Variscan granites (Duée, 1969).
- This basement is covered by Mesozoic-eocene series (calcareous chain), listed from the exterior to the interior (Truillet, 1968; Duée, 1969) Longi – Taormina – Ali – Novara and Stilo Calabria Units (Bonardi *et al.,* 2004).
  - This complex forming basement-thrust nappes is superimposed, from the NE to the Cretaceous flysch zone (Monte-Soro), which crops out in the Nebrodi Mountains.
  - There is the Longi and Taormina zone, which form the margin and passes into the Cretaceous flyschs.
- The Peloritan and Cretaceous flyschs constitute the Maghrebian-origin series, as they have similarities with the Kabylian basement and the Mauretanian and Massylian flyschs from North Africa. Since 1963 (Broquet *et al.*) we have considered the AlKaPeCam (Alboran – Kabylies – Péloritains – South Calabria) domain as a intermediate microcontinent between Africa to the south and Europe to the north.

Figure 1. Geographical situation.
Figura 1*. Situación geográfica.*

- The Ionian domain in the Madonies, consists, from inside to outside (Broquet, 1968) of the Panormide (from Panormos, the Greek name of Palermo) platform which largely crops out in the west of Sicily, between the Acci and Sparagio Mountains, forming the Palermian, Termini Imerese and the Madonies Mountains.
  - This platform passes to the S at the radiolaritic serie of Sclafani, which largely crops out between the Egades Islands (Marettimo), and passing by Sclafani, forms the Judica Mountain.
- Since the Permian, this oceanic domain extends from the S in the Sicani Mountains and to the Sicanes series: Vicari – Cammarata zone and to the external zone of Sciacca (Mascle, 1979). This domain also continues to the African platform which crops out in the Hyblean Mountains.
  - The Miocene basins of Trapani and Caltanisetta (or Centro-Sicilian bassin) which represent Middle-Upper Miocene depocenters of the nappes.

All the recognized tectonic units are overthrusted from NE (Peloritans Mountains) to SW (Sicani Mountains), except for the Cretaceous to Tertiary "Argille Scagliose" nappe which covers all the subordinant nappes, including the most internal ones in the Peloritan Mountains, and for this reason, we have called it an internal flysch (Broquet *et al.*, 1963).

In addition, it is necessary to note that the greatest basaltic European strato-volcano, Mount Etna (about 3,340 m high), with its Middle Pleïstocene and Quaternary volcanism, lies on the east coast of Sicily.

A more comprehensive paper about the Sicilian Geology and a geological map is available in a booklet dedicated to the Memory of Professeur André Caire (Broquet *et al.*, 1984). We can now see how Sicily fit into its West-Tethysian context.

General feature of the western Tethysian domain

Permian

An understanding of Permian paleogeography is fundamental for the understanding of Sicilian Geology. A Permian flysch called the «Lercara Friddi (Broquet, 1968) » crops out in the Sicani Mountains. This flysch has also been identified in drill holes, as well as the well known reefal facies series of Palazzo Adriano, which were discovered in 1887 (Gemmellaro, 1887-1899) and very well described in 1979 (Mascle, 1979). Beyond the Sicilian region, the Permian is also known in Tunisia, in the Djebel Tebaga near Medenine and also in some additional outcrops and drill holes. Among these outcrops, the age of the Djebel Hairech (North-Tunisia) has always been the subject of controversy (Rouvier, 1977). In any case, these data can allow the reconstruction of a part of the Neo-Tethys Ocean, between the African plate and the Cimmerian Continent, as it proceeds from the eastern part of Africa (Stampfli *et al.*, 2001 – Fig. 2).

The Neo-Tethys will correlate the Sicilian and Calabrian Geology with the Mesozoic radiolaritic series of Sclafani and Lagonegro.

During the Permian, what was the northern end of the Neo-Tethys ? This remains uncertain. It seems that it could have been at the end of the Alboran Block. Thermoluminescent studies of detritic quartz and feldspars in Permian sandstones (Broquet et al., 1965) suggest that this material came from a domain with a Peloritan character. They are identical to the

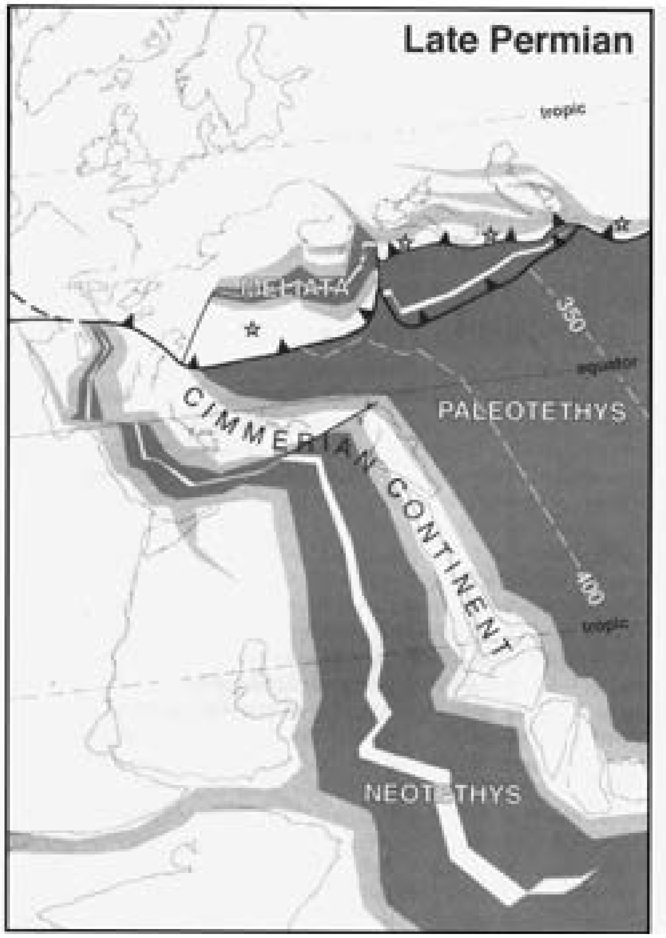

Figure 2. Paleogeographic reconstruction of the Tethysian Area during the Upper Permian (from Stämpfli *et al.*, 2001).
Figura 2. *Reconstrucción paleogeográfica del área del Thetys durante el Pérmico Superior (según Stämpfli* et al.*, 2001).*

Lower Cretaceous flysch sandstones (Monte-Soro), which have been clearly supplied by the AlKaPeCam (Alboran) domain. This allows us to consider that, since the Permian, the detritic supply has come predominantly from the north.

The Post-Permian Period

We identify "Ionian" as the Neo-Tethysian Ocean (Sclafani, Vicari, Campofiorito- Cammarata zones), with its western platform series as the Pelagian (Sciacca zone) and the eastern platform series as (Panormide). This latter is linked to the Gavrovo-Tripolitza series (Hellenides) and is just contigüous with the Apulian and Apenninic platforms. It is interesting to remark that the Panormid platform develops on sandstones and granitic Cambrian to Precambrian African basement, of which the outcrops, so far remain unknown.

However, this basement is revealed in drill hole Puglia 1 (AGIP, 1968) on the Apulian platform, drilled by the AGIP Mineraria, in 1968, in the drilled interval between 6,100 m and 7,070 m deep, i.e. at 970 m of drill hole samples. The underbasement of this supposed Permo-Triassic series is made up of cristalline rocks, thought to be Precambrian and geophysically discovered by the same drilling compagny.

Until today, it has been considered that the Mesogean Fold Belts are the product of two continental margins collision. These African and Eurasiatic margins were separated by an oceanic crust. Thus, the Tethysian Ocean has generally been interpreted as a Californian type crustal "fissure "which was continuous from the Straights of Gibraltar to the Alps (Stampfli *et al.*, 2001-Fig. 3). This assumption does not seem certain.

As a matter of fact, what was the northern end of the Ionian Ocean during the Mesozoic?

The last outcrops of the Sclafani zone are only known on the north and north-western coast of Sicily. It has always been considered that the Lagonegro zone is the prolongation of the Sclafani zone of which the San Fele series could be the most northern part, situated about 200 km to the north on the present-day coast of Sicily.

A problem appears with the closure of the Sclafani zone, bordering the Panormide platform. It seems possible to see a link between the internal Sclafani zone and the metaradiolaritic Ali serie in inferior Jurassique time. In this case the Sclafani serie rests on the Kabylo-Peloritan microcontinent where the Ali series (see p. 3) is lying in an internal position to the north (Truillet, 1968). We know that the Sclafani zone is linked to the north at the Panormide platform which seems to join the Sardinia (Cala Gonone –Orosei Gulf and San Antochio area), allowing the Lower Cretaceous Orbitolinidae and Rudist facies to splay out between Apulia, Balearic Islands and South Tunisia trough: Hammam-Zriba and Djebels Moktar, Zembra (cf. Monte Sparagio - Erice series in Sicily), and Bou Kornine series (cf. Monte Acci series in Sicily). We also know of a tie between the Monte Pomiere (external flysch) and the Monte Acci serie (Panormide).

As a matter of fact, the Orbitolinidae and Rudist facies have been identified in Apulia, in the Sicilian Panormide, in Eastern Sardinia, in the Balearic Islands (Barremian to Lower Cenomanian), as well as in Tunisia. Cutting the Ligurian Ocean to the north, they produce a platform separating the Ligurian and Atlantic Oceans.

Therefore, three Oceans are distinguishable: to the west, the Atlantic (i.e. Maghrebian), the Ionian

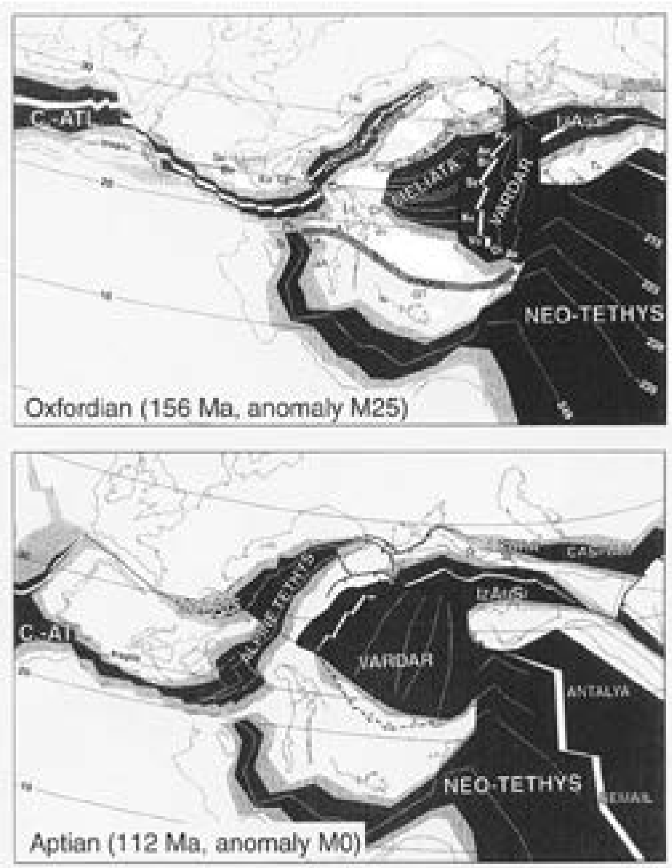

Figure 3. Paleogeographic reconstruction of the Tethysian area during the Oxfordian and Aptian (from Stämpfli *et al.*, 2001).
Figura 3*. Reconstrucción paleogeográfica del área del Thetys durante el Oxfordinese y Aptiense (según Stämpfli* et al.*, 2001).*

(Sicilian) to the center, and the Ligurian (Apenninic) to the north-east (Broquet, 2007).

The Ligurian and Atlantic Oceans probably merge in the Vracono-Cenomanian (- 96 My), with the same Upper Cretaceous facies between the Apenninic and Sicilian series, ("Argille Scagliose" series or so-called internal flysch Broquet *et al.*,1963) and maghrebians (Adissa serie in Tunisia, Rouvier, 1977) and of the Massylian and Mauretanian Upper Cretaceous flysch in Algeria).

The relationship between the Panormide, the Peloritans and southern Calabria

In the Upper Jurassic, the Clypeina facies of limestones was present in the Peloritans, (Rocca Novara serie (Truillet, 1968), and in the southern Calabria (Aspromonte and Serre series, Bonardi *et al.*, 2004). But, during the Lower Cretaceous, the Rudists limestones are reworked into Rudists breccias, which unconformably rest upon the Clypeina limestones, (Stilo series at the Mammicomito Mountain Bonardi *et al.,* 2004), which represent a paleogeographical change.

To the end of Lower Cretaceous, the Panormide is the source of allodapic limestones, i.e. the Rudists breccias of southern Calabria and the Sclafani zone.

To sum up, the Neo-Tethys Ocean (Sclafani zone) could have disappeared possibly during the (Pliensbachian) to Middle Jurassic in the Ali zone (Peloritans).

The Panormide facies overlapped the Sclafani radiolarites (Peloritans), during the Upper Jurassic and Lower Cretaceous, between the borderous calcareous chain of Peloritans and the Sclafani zone, when the expansion was complete.

An intermediate series formed, between the Panormide and the Sclafani zones, as demonstrated by the Imerese Castel mixed series with its Sclafani Triassic to Tithonian fauna and facies and above it, the Tithonian-Lower Cretaceous Panormide Palermian facies

Briefly, the Panormide affinity series constitute a link between the Sclafani zone, the northern Peloritans, southern and northern Calabria (Sila), Sardinia and Tunisia.

The large paleogeographical domains of Sicily

The Peloritano-south Calabrian cristallophyllians massifs and their associated flyschs have caused a wide divergence of opinions on this topic.

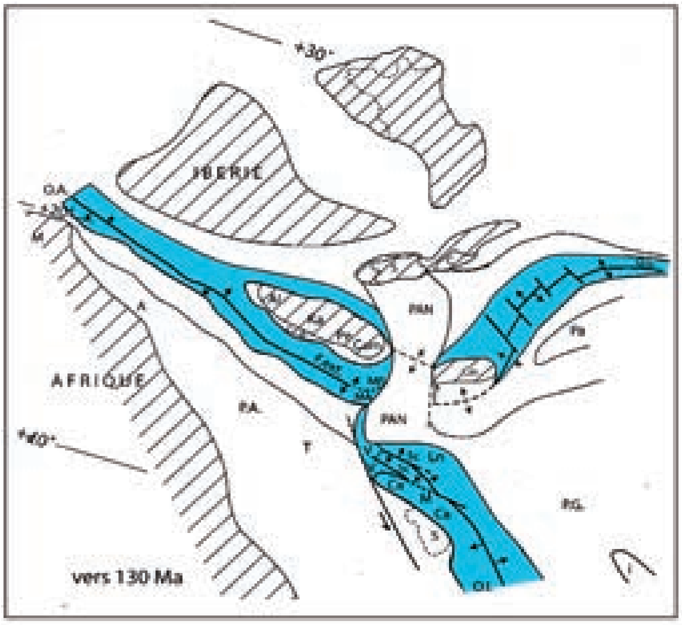

Figure 4. Palinspastic reconstitution during the Upper Jurassic-Basal Lower Cretaceous (from Broquet, 2007 , modified).
O.A. = Atlantic Ocean ; AlKaPeCam = Alboran-Kabylies-Peloritans-Southern Calabria ; c.c.b.= borderous calcareous chain; F.ext = external flysch trough, (Guerrouch and Monte Soro) ; M.A. = Monte Acci ; M.P. = Monte Pomiere ; O.L. = Ligurian Ocean with a dashed line which corresponds to the SW at the opening line of the external Ligurian Ocean, and also with a dashed line in the Panormide, the opening line to W in middle-upper Cretaceous (Vracono-Cenomanian) of the "Argille Scagliose" basin. Since this time both the Atlantic and Ligurian Oceans are melting and the "Argille Scagliose" series or lateral equivalent can be in an internal and external position regarding the AlKaPeCam microcontinent. They are intra-Panormide and part of the base of the more northern units (Pizzo Dipilo type) during the tangential oligo-miocene phases.
The Ligurian Ocean performs evolution with an internal part Triassico-Jurassic in north of northern Calabria and an external part built up in Jurassic (?)-lower Cretaceous in the south of northern Calabria. Ligurian external Ocean contains during oceanization stage Jurassic (?)-Cretaceous Lucanian flyschs with in upper Cretaceous the "Argille Scagliose" series common to Apennines, Calabria and Sicilia. The Ligurian external rift is in relation with the eo-alpine phase (about 115 My) which cause the northern Calabria structuration, towards Europe, with the structural units of Sila, Diamante, Malvito, Bagni etc... (Bonardi *et al.*, 2004). The opening of external Ligurian Ocean goes to SW between 115 and 100 My; then after a north migration, it extends to the opening intra-Panormide line about 100 – 95 My (Vracono-Cenomanian) melting with the Atlantic Ocean (Broquet, 2007).
Cas = northern Calabria ; Pa = Austro-alpine Platform; O.I. = Ionian Ocean (Neo-Tethys) and its margins : PAN = Panormide Platform ; P.G. = Gavrovo Platform; i = Hellenic Ionian sillon ; Ln = Lagonegro ; Sc = Sclafani ; V = Vicari ; M = Montagnola (near Cammarata) ; Ca = Campofiorito-Cammarata ; S = Sciacca. Straight lines are emerged lands. Europe: S = Sardinia; C = Corsica. Africa: P.A. = African Platform and its margins. M = Morocco with the prerifean trough; A = Algeria with the Tellian trough; T = Tunisia with the Tunisian trough.
Figura 4*. Reconstrucción palinspástica durante del Jurásico Superior-Cretácico Inferior basal (modificado de Broquet, 2007).*

They have been analysed and summarized during the 32nd International Geologial Congress in Florence (Bonardi *et al.*, 2004). In summary, a discontinuity exists between the Peloritans Mountains and northern Calabria, as we thought in 1963 (Broquet *et al.*,) with internal and external flyschs. The mobiliy of the blocks by accretion allows us to see the oriental termination of the microcontinent AlKaPeCam towards the west in Maghrebian area (Fig. 4).

It is impossible to see any relationship between Iberia and Sicily. We can only note a similarity between the Subetic, Penibetic and the Cammarata zone in Sicily, during the Mesozoïc.

The Ionian Ocean

This ocean (Fig. 4) had its origin during the Permian (Neo-Tethys), between the African and Apulian plates. After the Lias, from Africa to Apulia, we can distinguish the Sciacca, Campofiorito – Cammarata, Vicari (Sicanian series), Sclafani and Panormide series. This latter can be related to the Greek Gavrovo series on one side and to Sardinia on the other. To the west, it is linked to the external flysch and to the Tunisian trough. Clearly, Sicily is Ionian but the positions of the southern Italian platforms of Apulia, Abruzzes - Campania, Calabria - Campania and Panormide remain unresolved. They seem to communicate during the Mesozoïc but the relationship of the Marches, Ombrian, of the Molise trough to the north remain imprecise, as well as the Sclafani – Lagonegro trough, which, for us, is internal to south of these platforms.

To explain their actual superposition in Calabria, a three-phase tectonic process was necessary, which took place in Upper Oligocene-Aquitanian, Middle Miocene and Pliocene, as in Sicily, with an external Numidian flysch which is involved in the thrust structures.

There is still one problem to resolve: where is the end of the Budva zone?

(Stampfli *et al.*, 2001– Fig.3) Could it extend to Calabria?

The three main premediterranean domains and their evolution

They are:

1. Apenninic to the east of a line near Balagne (Corsica) to southern Calabria which crosses along the external side of the Apulian plate. This is the Ligurian Ocean domain which is open from the NW to the SE. From the Upper Cretaceous the Apulian-Adriatica block is moving towards the NW, due to movement of the African Plate of about 1000 km to the east (Stampfli *et al.*,2001).
2. To the centre, it is Ionian, limited to the east by the Corso-Calabrian line and to the west by a major and ancient regmatic north-south axis of which a replica is well known in Tunisia (north – south to north 30° east).
3. Maghrebian to the west. This is the Maghrebian series, pertaining to the Tello-Rifean domain (Algeria – Morocco – Tunisia) with an external "Monte-Soro or Guerrouch" flysch. If we agree that the Tellian trough, which prolongates the Prerifean one, is paleogeographically completely absent in Sicily, we have to admit that it must be the same for the external flysch trough, open to the west to the Atlantic Ocean. It seems that (Olivet, 1996) since the Middle Jurassic, the central Atlantic was open to the east, to the south of the AlKaPeCam block, towards the Ligurian domain, following a W-E (transform?) fracture line.

The merging of the Ligurian and Atlantic Oceans was made in the Middle-Upper Cretaceous. It can be marked by the "Argille Scagliose" (Upper Cretaceous external Ligurian series) deposition.

This series is well known and documented from north of the Appennines to Sicily and North Africa, although some lateral facies evolution occurs along this transect. According to Durand-Delga's team, the Cretaceous flyschs are external, but according to Professeur André Caire's Algerian and Sicilian teams, there are both external and internal types.

As far as the geological field section of the Betic (Paleogene) and (Burdigalian) Maghrebian subductions are concerned, (Durand-Delga, 2006– fig. 7), there are ophiolites to the south and to the north of the AlKaPeCam block, which means that the flysch are both ultra and citra-kabyles.

We should recall that the tectonic history of the Maghrebides begins just at the Eocene (Caire et al., 1963; Paquet, 1966; Raoult, 1967) and that the Gibraltar Arc could have been created after the Burdigalian (Durand-Delga, 2006).

In Sicily, the age of the Frazzano formation, (Aquitanian), and Stilo Capo d'Orlando (Aquitanian-Burdigalian) has been rejuvenated (Bonardi *et al.*, 2004), the internal structuration of the internal zones takes place about the Aquitanian-Burdigalian limit (AlgeroProvençal phase), but not during Eocene, as considered previously.

A radical paleogeographical change occured during the Oligocene, leading to the opening of the Numidian trough and to the birth of the Siculo-Calabrian Arc, classical in the collision chains. During this time a new kind of sedimentation appears with a silico-clastic series following a Mesozoic biochemical one and then to an Eocene calci-lutitic one (Broquet, 1968).

Two palinspastic maps depict the Upper Jurassic - Lower Cretaceous reconstruction for one side and with the Aquitanian for the other side (Figs. 4 and 5, Broquet, 2007). Note that the Numidian occurs in an internal position; while the micaceous-sandstones cover the Peloritan-Calabrian domain in an external position.

The Numidian Ocean was penetrating towards the south between the kabylo-peloritan microcontinents and was connected with the micaceous sandstone basins to contribute to the mixed facies (Fig. 5).

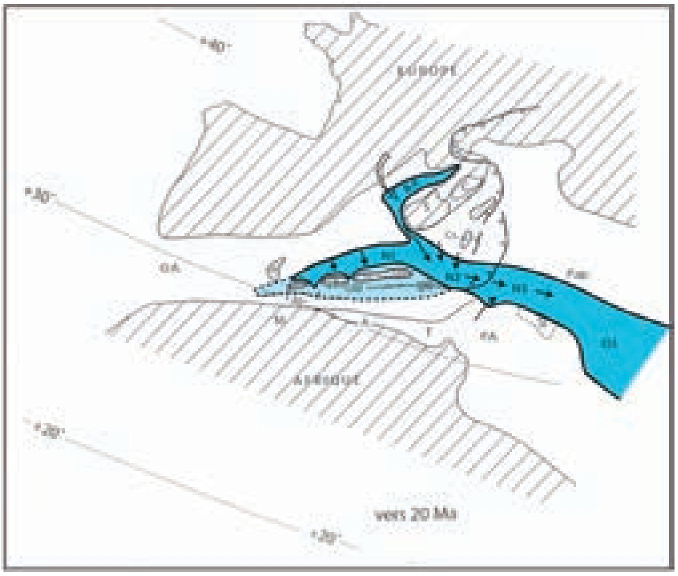

Figure 5. Palinspastic reconstitution during Aquitanian (from Broquet, 2007). O.A. = Atlantic Ocean ; O.I. = Ionian Ocean ; P.A. = African Platform and its margin; M = Morocco ; A = Algeria ; T = Tunisia ; Si = Siciliy ; Al = Alboran ; K = Kabylia ; P = Péloritans ; Cam = Southern Calabria; Cs = Northern Calabria; P.ap. = apulian Platform; B.P. = Provençal Basin ; S = Sardinia ; C = Corsica. Oligo-miocenic Formations: G M = Micaceous Sandstones = Oligo-miocenic Kabylo-Peloritan formations and Reitano formation; N = Numidian: N1 = Internal Numidian with a external Ligurian substrat of "Argille Scagliose"; N 2 = Middle Numidian ; N3 = External Numidian with a Ionian (Panormide + Sclafani) substrat. Double arrow = opening of the Provençal basin. Single Arrow = feeding of the Numidian flysch in detrital material from the north (Cimmerian panormide basement) and with NNW – SSE transport. Straight lines are ermerged areas. Numidian penetrates to the south between the Kabylo-Peloritan microcontinents.

***Figura 5**. Reconstrucción palinspástica durante el Aquitaniense (modificado de Broquet, 2007).*

The tectonic evolution of Sicily

We will not comment here about the Cretaceous-Eocene tectonic phase, which affected the Apennines and North Calabria, probably due to the movement of the Apulian plate. So far, this movement remains unclear and in northern Calabria it is probably in relation with the openning of the external Ligurian Ocean (Fig. 4) and with an eastward subduction. We will also leave for another occasion the crushing to the west, of the AlKaPeCam block, between the African and European plates (Betic subduction), followed during the Burdigalian by the Maghrebian subduction in an opposite direction (Durand-Delga, 2006).

We will only deal with Sicily:

A schematic and synthetic field section gives us the main tectonic units known in the NE of Sicily (Fig. 6).

Three main tectonic phases can be distinguished as:

1. The Upper Oligocene – Lower Miocene (?) Algero-Provençal or Sardo-balearic phase (28 to 22 My),
2. The Middle Miocene phase,
3. The Upper Miocene-Pliocene Tyrrhenian phase.

The Upper Oligocene – Lower Miocene Algero – Provençal or Sardo-Balearic phase initiates the Gulf of Genova sphenocasm opening between the 29 My (?), Oligocene, and up to 15 My, with an anticlockwise rotation of 30° for Corsica and of 60° for Sardinia.

This sphenochasm has apparently never been related to the Upper Oligocene Panormide tectonics and the opening of the Numidian trough. As a matter of fact, such an Upper Oligocene-Lower Aquitanian (?) phase, superposing several Panormide tectonic units in Sicily (Ogniben, 1960; Broquet, 1968), as demonstrated for example by the spreading sedimentary klippe of Cozzo Giampetra in the Gratteri formation (Broquet,1968), which was emplaced in Upper Oligocene-Lower Aquitanian (?). In the most external Panormide units, there appears a wildflysch at the same time (Monte San Salvatore – Pizzo Carbonara) (Ogniben, 1960; Broquet, 1968).

In the Madonies the superposition of the Pizzo Dipilo unit on the Pizzo Carbonara is marked by the occurrence of Upper Cretaceous - Eocene flysch inside the tectonic contacts. However, this tectonic phase is difficult to observe, due to the more recent tectonic phases.

The tectonic phases are related with the opening and closure of the sedimentary basins, as demonstrated by the sedimentary klippes and by the tecto-sedimentary phenomena (Broquet, 1968; 1989), (also known as spreading and filling sedimentary klippes).

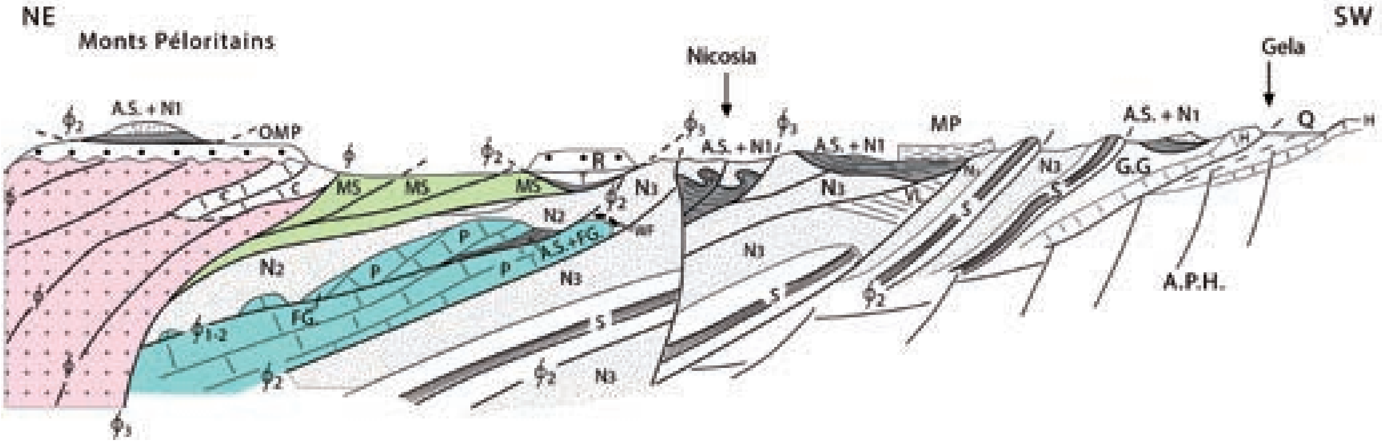

Figure 6. Schematic, simplified and synthetic NE-SW field section of NE Sicily. This section shows the relationship between the large structural units outcropping in the Peloritans, Nebrodi, Madonie, up to the area of Gela. It shows two main parts: the lowermost is Ionian, where all the units are separated by overthrusts (in French: *surfaces de décollement*). It has been structured by the 3 main orogenic phases, the first is Algero-Provençal, the second is Middle Miocene, the last is Thyrrhenian. This Ionian material is overlaying the Hyblean foreland (A.P.H. = African plate) and this is the internal Numidian (A.S.+N1) flysch which structuraly overlies the whole. The uppermost part, Maghrebian, which has been structurated during the Maghrebian phases, is emplaced (dextral lateral accretion) during the Tyrrhenian phase. It lies on a Tortonian to Pliocene erosional surface (between about 8My and 3My) related to the opening of the Tyrrhenian Sea, during the Sicilian clockwise rotation. It is formed during the Pliocene and Pleistocene. As noted by G. Duée [4] the internal flysch series and its Numidian cover (A.S.+N1) structurally overlies the whole and is never implicated in the frontal contact of the Peloritans Mounts, between the calcareous chain and the external flysch. This series corresponds to the "Sicilide" and not to the "anti-Sicilide" of (Ogniben, 1960). *Abreviations* The whole Ionian: P = Panormide; FG. = Oligocene Gratteri Formation ; A.S. = Upper Cretaceous- Eocene "Argille Scagliose"; S = Sclafani ; H = External Sicanian ; A.P.H. = Hyblean Foreland (African Plate) ; N1 = Internal Numidian; N2 = Middle Numidian; N3 = External Numidian ; G.G. = Glauconitic Sicanian Sandstones ; VL = Burdigalian series of the Lisca Valley, passage of the Numidian flysch to the Centro-Sicilian molasse basin ; MP = Upper Miocene - Pliocene transported and discordant basin ("piggy-back") ; Q = Quaternary ; phi 1 = Upper Oligocene – Aquitanian (?) phase ; phi 2 = Middle Miocene phase; phi 3 = Tyrrhenian phase. Maghrebian: A.S.+N1 = internal Numidian series; OMP = Discordant Peloritanian Oligo-Miocene on the basement and on the Peloritanian calcareous chain (cc); The Pelorītan mount structure – phi – is Eocene, before OMP, after A. Caire and R. Truillet (1963) and G. Duée (1969). This datation has been rejuvenated after more recents facts [6]. The internal structuration of these internal zones takes place around the Aquitanian and Burdigalian limit. It is coherent with the metamorphic age of the Aspromonte (25 to 22 My Bonardi *et al.,* 2004). MS = Monte Soro external flysch; T+R = Upper Cretaceous-Miocene Troina, Tusa and Reitano "Argille Scagliose" series; phi = Peloritanian phase; phi2 = Middle Miocene phase; phi3 = Tyrrhenian phase.
***Figura 6**. Sección NE-SO esquemática, simplificada y sintética del NE de Sicilia.*

During the Oligocene a very important paleogeographical change occurred; the Numidian trough which developed, from W to E, both on the Upper Cretaceous-Eocene internal flysch "Argille Scagliose ", and the Panormide and Sclafani series. It is evidently an Ionian trough the filling of which comes from the north to the south.

Just after the Upper Oligocene-Lower Aquitanian (?) emplacement of the Panormide sedimentary klippes, a large detrital break up may correspond to the W-Cimmerian Panormide basement (Great Apulia-Eastern Africa, see Figure 2).

The Panormide was an active margin, during the Upper Oligocene (Broquet *et al.*, 1984;

Broquet, 1973; Hervouet *et al.*,1987). It runs along the Sclafani zone, which played a foredeep trough role near the Sicani series of the foreland. It is also possible to interpret them as a Panormide arc, with a back-arc (internal Numidian) and a fore-arc or foredeep basin (Sclafani zone).

During the Upper Oligocene-Lower Aquitanian (?), the sedimentary klippes of the opening were emplaced on the Panormide arc and sealed by the intermediate Numidian sandstones, meanwhile the foredeep Sclafani trough is filled with the external Numidian, which is in continuity during the Upper Burdigalian (Di Lisca Valley series) with the foredeep Middle to Upper Miocene deposits.

The associated volcanic phenomena are present at the Lower Miocene (N5 – N6 Blow zones i.e. Upper Aquitanian-Lower Burdigalian) as demonstrated by indirect products, such as the internal Numidian silexites and the external Karsa Numidian tuffites (Faugères *et al.*,1992) as well as the Oligo-Miocene Sardic lavas.

The eroded volcanic arc leaves only two prints, after erosion; silexites (internal Numidian basin) and tuffites (external Numidian basin) or the two (medium Numidian basin).Tuffites are also present at the same time to the south of the Troïna-Reitano Unit (Tusa formation).

Figure 7 gives us the paleogeographical context of the Numidian with the deposition of the silexites (N5 – N6 zones) and then the erosion of the volcanic arc which disappear to give birth to the tuffites (N6 Blow zone). In this context, the internal Numidian sandstones may be older than the external Numidian, as we have always proposed, without any micropaleontologic proof.

It seems that the erosion of the present day Eolian Islands could have, in the future, a similar evolution to become tuffites in the Ionian domain.

The Middle Miocene phase

In Sicily, the main Miocene phase corresponds to the subduction of the Apulian and African plates. From west to east, the subduction is a generalized phenomenon of a foredeep zone, from Morocco to the Apennines with a small offset in time. Figure 8 (Broquet, 1968; 1973) shows the Caltanisetta basin structure between the Madonies and the Sicani mountains.

In Sicily, the African subduction was initiated during the Middle Miocene (i.e. about 14 My) and caused the filling of the Caltanisetta basin or Centro-Sicilian basin by sedimentary klippes. These filling sedimentary klippes closed the basin (in French: *klippes de fermeture ou de comblement*).

Inside this foredeep basin, which lies on the Sicani units, not only the allochtonous material but also the normal sedimentary material came from the internal margin, forming a north to south prograding system with a tecto-sedimentary prograding talus (Broquet *et al.*, 1984). A foreland domain (hyblean –African plate domain), a foredeep trough (Caltanissetta basin) and an active and mobile margin constituted by the Sclafani, Panormide and "Argille Scagliose" (or internal flysch) units.This evolution led to the opening of the Tyrrhenian Pliocene back-arc basin (Rehault, 1981).

In Sicily, the most recent displacements in the fore-arc basins are Quaternary, (Gela thrust (Beneo, 1957), as well as in Calabria, (Metaponto thrust, bradanic trough Ogniben, 1969). The paleogeographical evolution of Sicily has already been summarized, by means of a former figure (Fig. 9 Broquet, 1968; 1973) on which the most recent events have not been shown, from Pliocene to Pleistocene. Between the Cretaceous and Pliocene, this figure shows the migration of the maximum subsidence axis towards the south, and the correlative starting of the tectonic phases.

I have been using the term "underthrusting" rather than "subduction", to explain that the allochtonous units (filling sedimentary klippes) were not deformed, either by striking nor by thrusting, but appear to be passive material only moving by sedimentary sliding. This figure represents the birth of the Ionian trough during the Upper Trias-Lias (Carixian). That is to say that the Permian rift aborted and gave birth to a Liassic rift slightly more to the east (in French: *saut de dorsale*).

We must note that the Upper Triassic rests unconformably upon the former formations and that it is neritic. In the same sense, a new rift was created during the Oligocene paleogeographic change. Despite the Tyrrhenian phase, it probably continued. As the age of the Ionian trough oceanic crust remains unknown, various hypotheses can be advanced for an age between Permian and Tertiary (see p. 16).

The post-Pliocene period is evidenced by analysis of seismic lines (Catalano *et al.*,1993; Agate *et al.*, 1993;

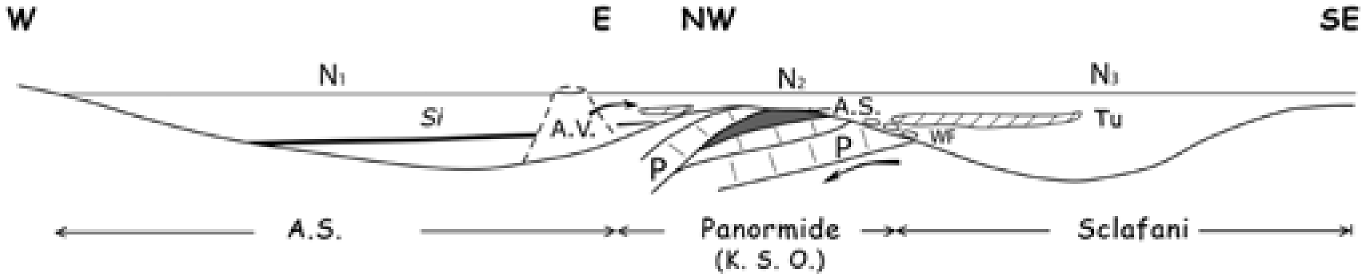

Figure 7. The Numidian basin during Burdigalian (N6 zone of Blow). A.V. = Volcanic arc before erosion; Si = Silexite (N5-N6 zones of Blow) ; Tu = Tuffites (N6 zone of Blow) ; K.S.O. = Sedimentary opening klippes ; WF = External Panormide wildflysch; A.S. = Upper cretaceous – Oligocene "Argille Scagliose" series; P = Panormide (Trias to Oligocene) ; N 1 = Internal Numidian ; N 2 = Middle Numidian covering the Internal Panormide ; N3 = External Numidian covering the External Panormide and Sclafani zones.
Figura 7. *La cuenca numídica durante el Burdigaliense (zona N6 de Blow).*

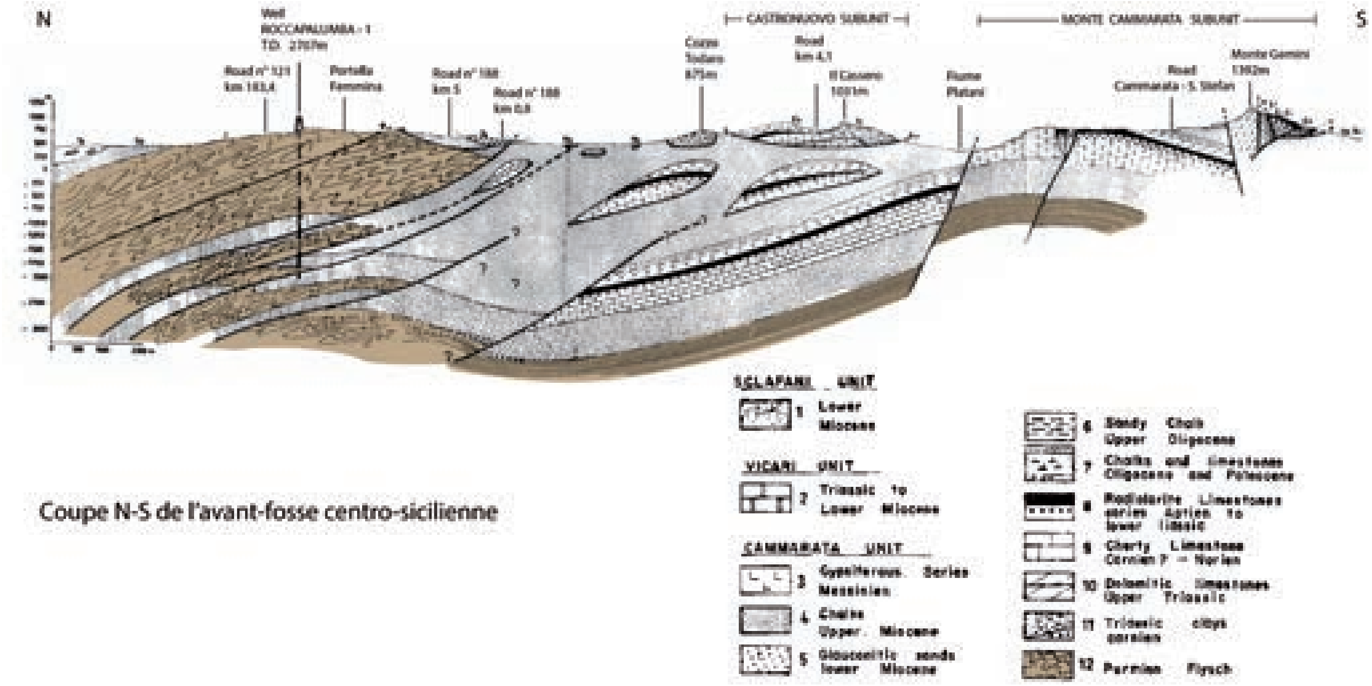

Figure 8. North-south field section of the Centro-Sicilian foredeep (from Broquet, 1968). This foredeep lies on the Sicani units with a Permian flysch substratum. The active margin units took place by tectono-sedimentary phenomena (filling klippes) and contributed to filling the foredeep.

Figura 8. *Sección norte-sur del foredeep de la zona central de Sicilia (según Broquet).*

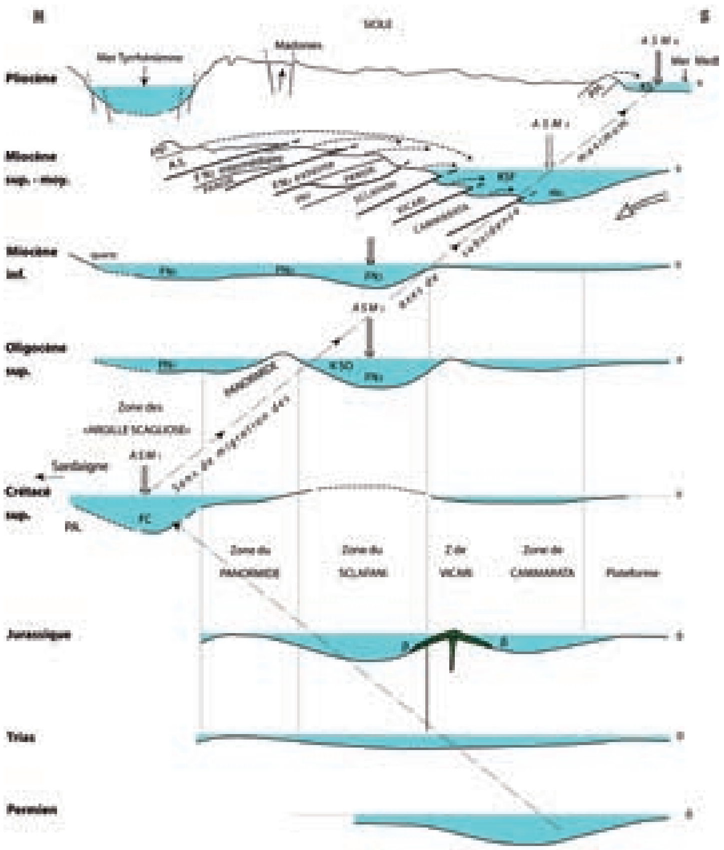

Figure 9. Schematic paleogeographical and tectonical evolution of the Madonies (Sicily) completed with the Permien (from Broquet , 1968 and 1973). This scheme shows between Permian and middle-upper Cretaceous the expandsion of the Ionian trough and the middle-upper Cretaceous formation of the external Ligurian trough. We observe the non-localisation of the Permian rift (unknown position). During upper Trias-Lias it becomes established in the Sclafani zone. From the Oligocene there is a paleogeographical modification which shows a jerky subduction north to south up to the Quaternary with migration of the basins maximum subsidence axis to the south in three phases. Each migration of the subsidence maximum axis corresponds to a major tectonic phase. Each tectonic phase is particular. During upper Oligocene-Aquitanian (?) we see the formation of opening (spreading) klippes (KSO) then in middle Miocene, the formation of filling klippes (KSF) in the Centro-Sicilian basin. The locking of the suduction zone in Tortonian during the Tyrrhenian phase, an important shear-fault which shows in the interior with a lateral dextral accretion when in the exterior the Gela nappe took place and corresponds at the complete closing of the Centro-Sicilian foredeep, 1 My ago.

Figura 9*. Evolución esquemática paleogeográfica y tectónica de los Madonies (Sicilia), completada con el Pérmico (según Broquet).*

Nigro *et al.*, 2001) which allows the correlation of the field outcrops with the seismic results (Nigro *et al.*, 2001). After the emplacement of the Gela thrust 1 My ago (Fig. 10 Catalano *et al.* 1993), the maximum subsidence axis moved towards the south about 0.8 My ago.

Between Sardinia and Calabria the collisional stage has never been effective. However, the occurrence of ophiolites off the Orosei Gulf as well as the occurrence of calco-alkaline volcanism between the Chattian and the Burdigalian (Beccaluva *et al.*, 1985) in Sardinia suggests the presence of a jerky subduction of an oceanic lithosphere under the Sardinian continental crust (Pasci, 1997), during the Oligo-Miocene time.

The Tyrrhenian phase

A new paleogeographic change occurs, presenting some analogues with the Oligocene period.

The Tyrrhenian phase is linked with the opening of the Calabro-Sicilian Arc to the E-SE as a result of the effects of a drift (Moussat *et al.*, 1985) of the oceanic crust basins of the Tyrrhenian Sea. (Vavilov, drift from 4,5 to 2,6 My and Marsili, drift at 1,8 My, basins Serri *et al.*, 2001). The opening begins to the west and progressively migrates to the E-SE.

After the Middle Miocene, when the subduction surface is blocked in the Tortonian, the continuous thrust causes the birth of intra-Tortonian late thrust

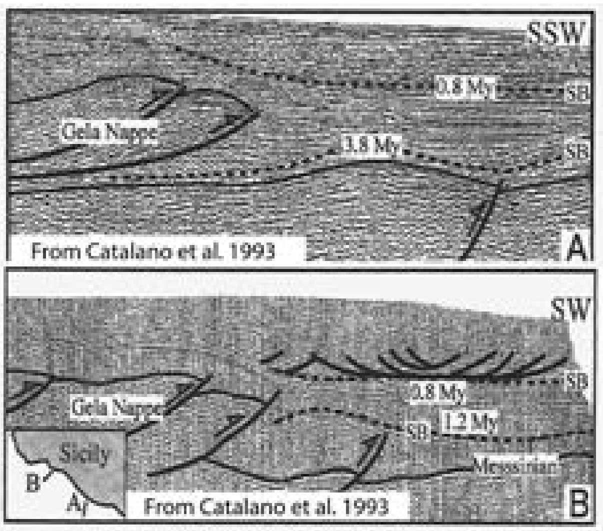

Figure 10. Simplified field section of the Gela Nappe, derived from seismic lines of the southern Coast of Sicily, from Catalano *et al.* 1993).

Figura 10*. Sección geológica simplificada del manto Gela, interpretada según las líneas sísmicas de la costa sur de Sicilia, según Catalano* et al. *(1993).*

faults. They affect the resedimentation basins, such as for example the small Trapani basin, to the west of Sicily, as well as the diapiric extrusions (in French: *diapiroïdes*) with kilometric offset faults to the south of the Madonies mountains (Sclafani and Caltavuturo areas) (Broquet, 1968).

Major accidents are utilized as evidence of dextral E-W shear faults accompanied by flower-structures (for example: the Nicosia area). They have been cited for a long time (Ruggieri, 1966; Caire, 1978 - Vicari line), but have only been well documented in recent years (Nigro *et al.*, 1999; Renda *et al.*, 2000). These accidents control the recent evolution of the Tyrrhenian basin (Renda *et al.*, 2000, Fig.1). An erosion surface appears to the north of Sicily, towards the Tyrrhenian Sea, between the Upper Tortonian and the Pliocene followed by a lateral dextral accretion of the Maghrebian series (fig. 6).

The Siculo- Calabrian Arc

The Tyrrhenian is about 3,600 m deep. Between Sardinia and the Siculo-Calabrian Arc, the sea contained the Vavilov and Marsili basins (two abyssal basins) and the typical volcanic arc of the Eolian Islands which consists of a semi-circular arc of seven islands which prolongates up to Mount Vesuvious. At the front of the volcanic arc, separated basins were formed from the Tortonian forward (Cefalu – Gioia – Paola basins) in which 2,500 m of plio-pleistocene sediments were accumulated. These probable pull-apart basins were created by motion on a dextral mio-pliocene strike slip fault. The Crotone-Spartivento basin is suspended and directly lies on the arc itself.

These large strike-slip faults seem to be related to the Maghrebian flyschs and with the peloritano-calabrian massif translations to the east.

Sicily became Maghrebian on its north coast. These large strike slip displacements from west to east are related with Riedel faults affected by N120 thrusts (Renda et al., 2000). This is the case of the Peloritan Mountains thrusts and of their oligo-miocene Cretaceous flyschs (accretionnary prism of the oligocene-miocene maghrebian subduction – see Fig. 6).

During Middle Miocene, the thrusts formed perpendicularly to the envelope of the arc, to South, in Sicily; after a clockwise motion, rotated about 50° (Broquet *et al.*, 1984). However, between the Tortonian and Quaternary, the strike-slip faults and thrusts are to the east-south east. All this leads to the formation of the current Siculo-Calabrian arc, which seems to be an inherited arc under permanent deformation. Various authors have recently agreed and present a similar evolution for the Siculo-Calabrian arc, since the Oligocene (Nigro *et al*., 2001; Bonardi *et al*., 2001; Sartori, 2003; Lentini *et al*., 2006), of which it is possible to give a view in the following figure (Fig. 11).

Morphology of the Siculo-Calabrian Arc (Sartori, 2003).

In Figure 12, to the SW lies the African plate and to the NE the Apulian plate, both with an African basement. They are separated by the Ionian trough with an oceanic crust. This oceanic crust has an unknown age and it is bordered by two 3km-high cliffs: the Apulian cliff (Apulian platform) and the Hyblean cliff (Hyblean-African platform). The Ionian trough received the olistostrome front zone and the sedimentary spreading klippes (in French: *klippes d'ouverture*) from the Calabrian arc.

The Ionian Sea reached a depth of 4100 m in the abyssal plain of Messina.

The subducting oceanic lithosphere is marked by a Benioff surface (Sartori, 2003, fig. 2) which is deformed on a 700 km length and a 250 km width and to a maximum depth of 450 km. Its age is not very well known, i.e. Permian to Tertiary, as well as its situation in the centre of the Ionian basin (oceanic or a thin continental crust), where this crust is covered by several kilometres of sedimentry rocks. However, if we consider that the oceanic spreading-ridges have moved in the Ionian zone, between the Permian and the upper Trias-Lias, and between the Cretaceous and the Oligocene during paleogeographic drastic changes, this oceanic crust (?) may have a hypothetical Oligocene age.

We observe that, from the NW to the SE, in an internal position, the back-arc Tyrrhenian basin, of which the thin continental crust results from the tectonic stretching to the E-SE of 350 km (Moussat et al., 1985), with a 50 to 70 km large oceanic crustal gap (Marsili and Vavilov basins). Then, the Eolian island volcanic arc (formed 1,5 to 2 My, Sartori, 2003), and in an intermediate position, the Siculo-Calabrian continental crust arc essentially was formed by a crystalline series, which represented the active moving margin bordering the external domain with olistostromes and spreading sedimentary klippes with an external fore-arc basin (Ionian basin). It is, mutatis mutandis, the same picture as the Numidian trough (fig.5 and 7) which was divided, during the Oligocene in three similar parts i.e. an internal oceanic (Tubotomaculum muds), a medium part with the opening sedimentary klippes of the Panormide (active margin), and an external Ionian through (Sclafani zone).

The internal to external basins merge, at least from the Lower Burdigalian (N6 Blow zone), when the

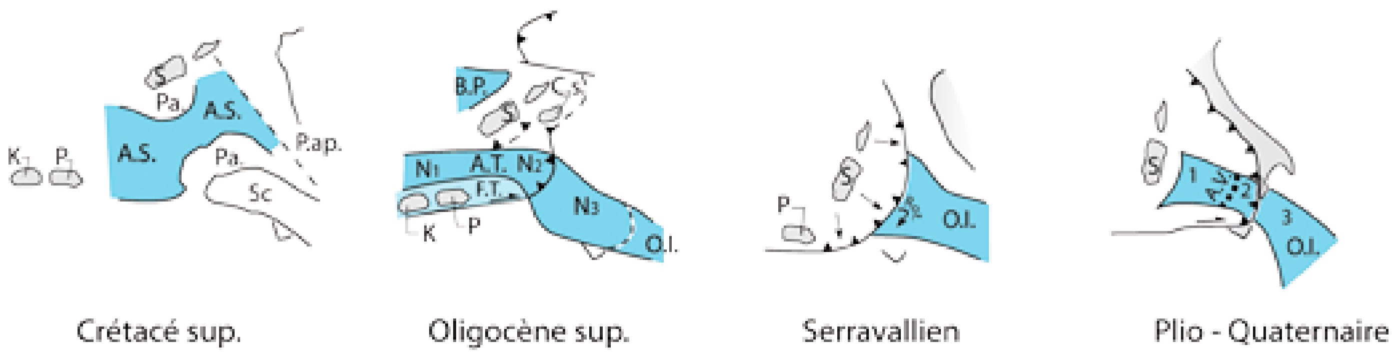

Figure 11. Palinspastic schemes showing the evolution of the Siculo-Calabrian Arc between the Upper Cretacaceous and the Quaternary. During the Upper Cretaceous, a paleogeographic arc is formed under the Apenninic NW-SE directions and the E-W maghrebian ones. From the Oligocene, the arc becomes tectonic and affects the Panormide mobil active margin, just in front of the Sclafani (fig. 7-N3) zone foredeep. Three parts are distinguishable: A back-arc (Fig. 7-N1) oceanized basin, an active arc (Fig. 7-N2) and a fore-arc basin (Fig. 7-N3). In the Serravallian, the mobil active margin incorporates the Panormide, the Sclafani zone and the Sicanian units, with there are often disorganized covers. The Sicanian basin corresponds to the foredeep which is before the Hyblean foreland (African Plate). After the subduction zone has been blocked, to the south, Sicily begins a clockwise rotation of about 50° between the Tortonian and the present day. During this time a large dextral slip zone is acting, during the Plio-Quaternary, with an opening and oceanization of the Tyrrhenian Sea. This sea corresponds to a back-arc basin, (1) separated from the fore-arc Ionian Ocean (3) by an volcanic arc (A.V. – Eolian Islands) and by the Siculo-Calabrian Arc (2) which will form the sedimentary spreading klippes during the Tyrrheno-Ionian opening. The analogy between the Oligocene and actual period is remarkable, the same fore-arc and back-arc basin, which are similarly orientated. *Abreviations:* Ks = Kabylies ; P = Peloritans ; S = Sardinia ; Pa. = Panormide ; Sc = Sclafani ; A.S. = « Argille Scagliose » ; P.ap. = Apulian Plateform; c.c. = Corsica-Calabria line ; B.P. = Provençal Basin; A.T. ="Tubutomaculum Argiles" in upper part of the "Argille Scagliose" serie ; F.T. = Troina-Tusa Formation; C.s. = Northern Calabria ; O.I. = Ionian Ocean ; Rot. = rotation ; A.V. = volcanic arc.

***Figura 11.** Esquema palinspástico mostrando la evolución del arco sículo-calabriense entre el Cretácico Superior y el Cuaternario.*

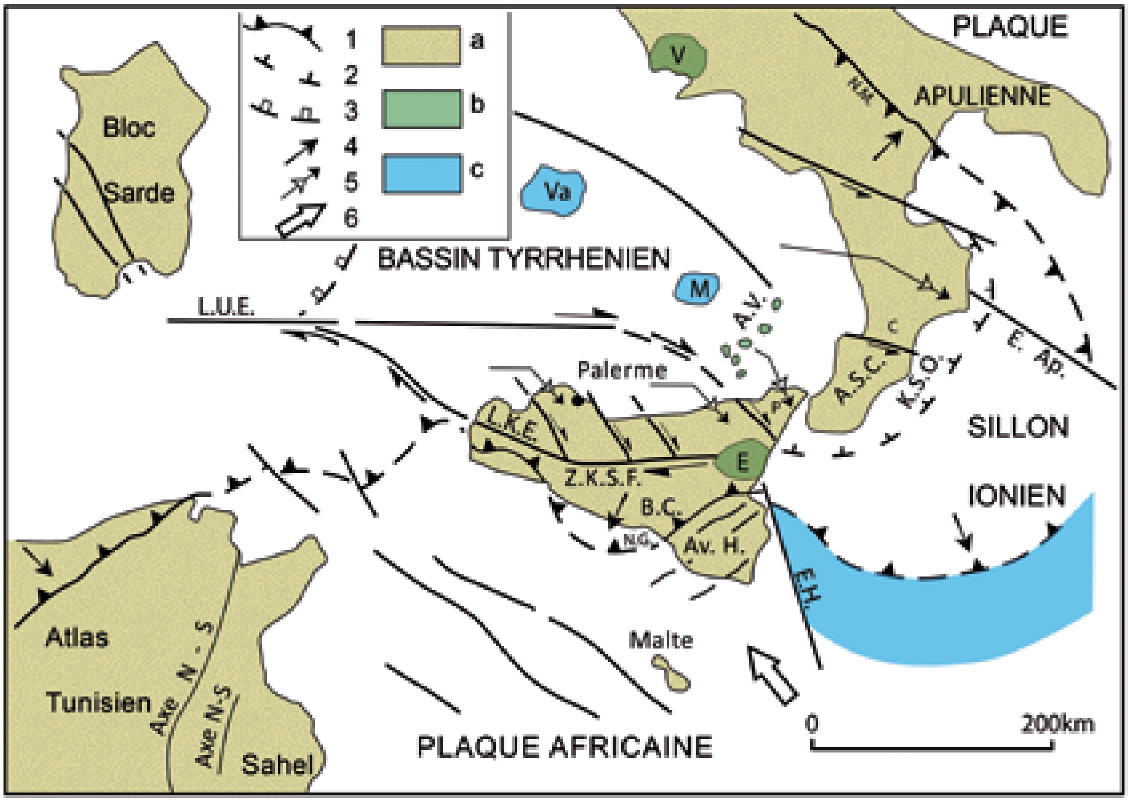

Figure 12. The large structural domains in the Central Mediterranean, from Renda *et al.*, 2000, modified. Apparent limit, on the external domains, of the front of the Miocene to Quaternary nappes B.C. = Caltanissetta Basin (Centro-Sicilian foredeep); Z.K.S.F.= Filling sedimentary klippes; N.G. = Quaternary Nappe of Gela ; N.M. = Quaternary Nappe of Metaponto inside the Bradanic foredeep; Av.H.= Hyblean Foreland. Plio-Quaternary basin in front of the accretionary prism with spreading sedimentary klippes (K.S.O.) bordered by shear faults; A.S.C.= Siculo-Calabrian Arc; P = Peloritans ; C = Catanzaro. Sardinia thrust front on the Tyrrhenian basin. Actual apparent direction of thrusts during the Middle Miocene phase. Strike-slip faults–thrusts post-Tortonian (Tyrrhenian phase); L.U.E. = Ustica-Eolian line; L.K.E.= Kumeta-Etna line. African Plate - Movement direction. a = continental domain ; b = actual volcanoes : E = Etna ; V = Vesuvious ; A.V. = Islands Eolian volcanic Arc (1.5 My) ; c = oceanic domain : Actual basins of Vavilov (= Va, 4.5 à 2.6 My) and Marsili (= M, 1.8 My) and Ionian trough with probable oceanic crust, between the African and Apulian plates, which is limited by Hyblean scarpments (E.H.) and Apulian (E.Ap.).
Figura 12. *Los grandes dominios estructurales en el Mediterráneo Central, de Renda* et al.*, 2000, modificado.*

Numidian sandstones are deposited over the whole trough. These sandstones covered the Panormide spreading klippes in the Middle Numidian. The supply of Numidian material had to come from the NW to the SE (Broquet, 1968). The occurrence of African zircons (1700 – 1800 My, Gaudette, 1975) in the Ionian flyschs, since the Permian and their identification in the Djebel Tebaga, near Medenine (Tunisia) but also in the whole Numidian, from the Aljibe (Spain) to Sicily has been noted by numerous authors.

Conclusion

To conclude, Sicily is genetically Ionian. Its Panormide platform was active from the Upper Trias to the Middle Cretaceous, linking the Ionian, Apenninic, Apulian domains to the east with the Tunisian and Maghrebian domains to the west. Nevertheless, Sicily appears to be complex, because it was born from three primitive Oceans: the Ionian Ocean from the Permian to the south, the external (Apenninic) Ligurian Ocean to the north, which since the Vracono-Cenomanian, merged with the (Maghrebian) Atlantic Ocean to the west. Sicily became African to the south, due to the Middle Miocene subduction and Maghrebian to the north-east, due to the lateral and dextral accretion only from the Upper Miocene – Pliocene.

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