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RECONSTRUCTIONS OF THE WESTERN MEDITERRANEAN AREA FOR THE MESOZOIC AND TERTIARY TIMESPAN

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ABSTRACT

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Based on seafloor data and palaeomagnetic results, reconstructions are given for the Western Mediterranean area, for the period of 165 Myr. to 10 Myr. ago. Reconstructions for 13 episodes provide a framework that can be used to unravel the history of Alpine orogeny. Of crucial importance in these reconstructions is the Adriatic continental block, the movements of which determined to a large extent the location of Alpine foldbelts in the Western Mediterranean.

INTRODUCTION

CHANNELL & HORVATH (1976) advocated the 'African/Adriatic Promontory', which is essentially the same as the Adriatic block, and assumed this promontory to have moved with Africa ever since the early Mesozoic. They did not recognize the independent Tertiary movement of this block. Nevertheless, they showed that the concept of the Adriatic promontory provides a palaeogeographic framework which fits the evolution of the Alpine system. The reconstructions of BIJU-DUVAL ET AL. (1976), based on more recent sea-floor data, differ from Channell & Horvath's approach by the assumption that the Adriatic block was an independent entity during all the Mesozoic and Tertiary, which also conflicts with the palaeomagnetic data. Elsewhere in this volume it has been argued that palaeomagnetic data from various parts of the Italian peninsula and adjacent areas are consistent. These palaeomagnetic data defined a crustal block that was called the Adriatic continental block. It was shown that this block was part of the African continent until Early Tertiary times, and a rotation pole, that describes the Tertiary decoupling, was derived mathematically. The Mesozoic apparent polar wander curves of Africa and the Adriatic block are in such agreement that large differential movements during Mesozoic times are very unlikely.

From these palaeomagnetic results and from sea-floor data, a series of palinspastic maps can be reconstructed, with implications that shall be discussed. In a general way a causal relationship between tectonic phenomena of widely separated areas is suggested. References cited are only indicative and by no way cover all the literature on the subject.

OUTLINES OF THE ADRIATIC CONTINENTAL BLOCK

In the following reconstructions an outline has been used for the Adriatic block (heavy line in Fig. 1), which needs some explanation. It is fundamentally very difficult to delineate in an orogene the boundaries between blocks that varied in time and that are obscured by the latest tectonic phases. The margins of involved blocks probably changed during every movement phase and crustal fragments may have joined one or the other tectonic block for some time. Therefore the

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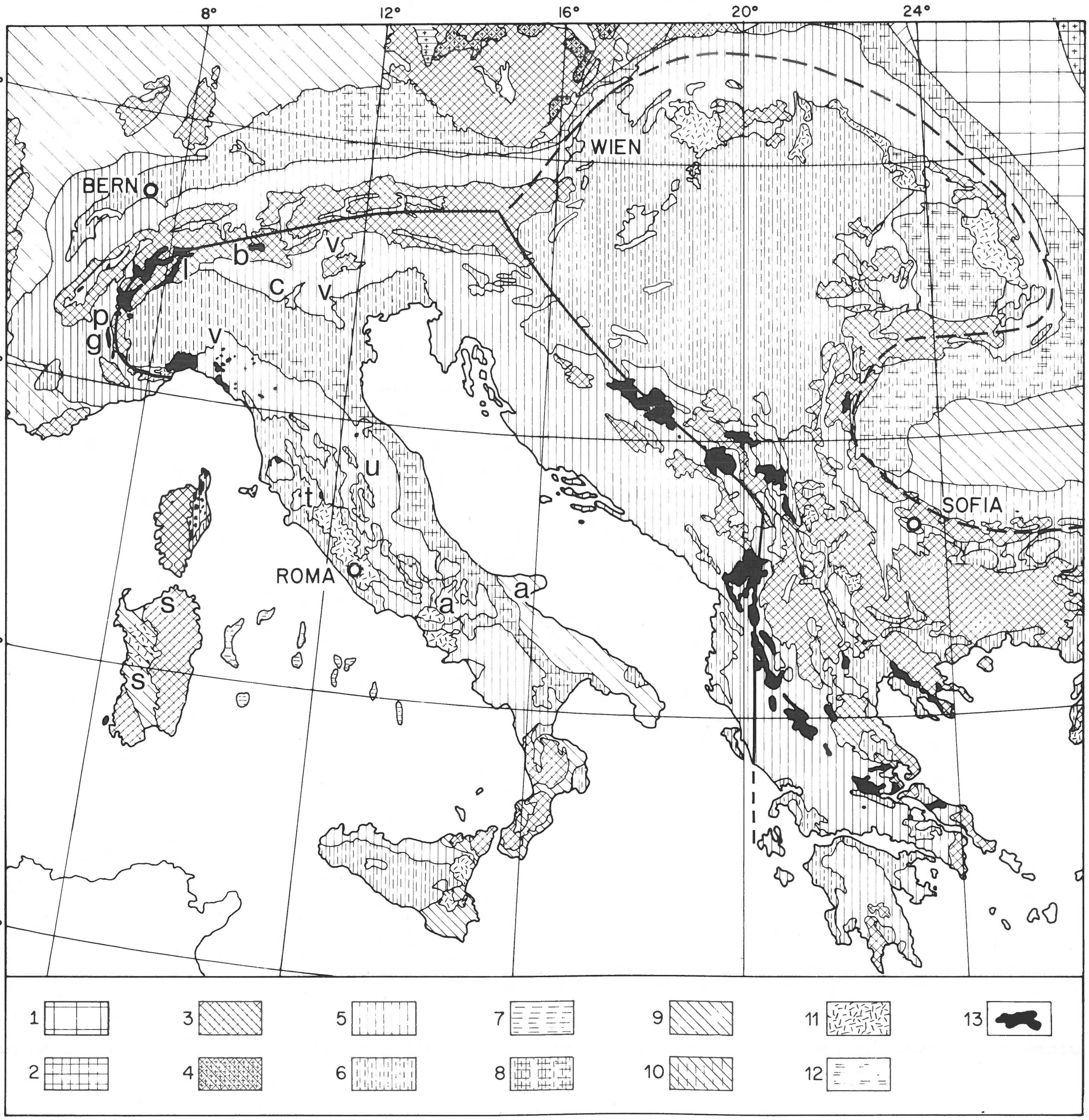


Fig. 1
Geological map of the Alpine system around the Adriatic Sea. Legend: 1= Russian shield, undifferentiated; 2= Archaean shield; 3= Hercynian, undifferentiated; 4= Hercynian with Cadomian nuclei; 5= Alpine fold belts; 6= inner basins; 7= Hercynian metamorphic basement (Selli, 1974); 8= Alpine molasse; 9= Mesozoic platforms; 10= Palaeozoic platform, Alpine reactivated; 11= volcanic complex; 12= area of salt tectonics; 13= ophiolites. Heavy line is referred to in the text.

boundary of the Adriatic block in the Western and Eastern Alps has been taken arbitrarily.

The eastern margin of the Adriatic block is not sharply defined either. The Mesozoic sequences of the outer Dinarides show a close affinity to the Southern Alpine sequences, but have been thrusted towards the Adriatic sea (AUBOUIN, 1965). The ophiolitic suture is assumed to represent a fundamental boundary during Mesozoic times (CHANNELL & HORVATH, 1976), but during the Tertiary the boundary had most probably a more external position (closer to the Adriatic Sea) represented by the Insubric fault system. The eastern boundary has been drawn southward across Albania, initially following the ophiolitic suture and then along the structural trends of the external Hellenides, west of the Gavrovo-Tripolitza zone. Support for the last part of the boundary is found in BIJU-DUVAL ET AL.'s (1976) reconstructions, in the analysis of structural trends by LETOUZEY ET AL. (1976) and in the offshore continuation (MORELLI ET AL., 1975-a) of these trends.

Sardinia is assumed to have been part of the Adriatic block at least during post-Hercynian times, for the following reasons: (1) palaeomagnetic data clearly indicate so; (2) a continental Moho is indicated all over the traject Sardinia-Triëst at 35 km (NOLET ET AL., 1978); (3) the Tyrrhenian Sea only became in the Pliocene a deep sea (SELLI, 1971; MORELLI, 1970) and had essentially a continental crust, now melting up after its foundering. This is proved by the results of dredging (Fig. 1), which revealed Hercynian rocks over a vast area in the northern Tyrrhenian sea (SELLI, 1974; HEEZEN ET AL., 1971). An almost continuous basement of Hercynian folded and metamorphic rocks is present in a region that comprises Western and Southern Tuscany, Sardinia and most of the Tyrrhenian Sea; (4) finally, Alpine elements in Northeastern Corsica do not continue southward and therefore do not separate Sardinia from the Italian mainland.

Deep seismic reflection profiles reveal that in the Sardinia channel (AUZENDE, 1971) the continental Palaeozoic basement is continuous between Sardinia and Africa, while the overlying unconsolidated sediments do not show any folding.

A stationary position relative to the European continental block is assumed for Corsica at least during the Tertiary. During the Mesozoic, Corsica is assumed to have moved with the Iberian peninsula, separated from Europe by an eastward branch of the Pyrenean fault zone, as proposed by BIJU-DUVAL & MONTADERT (1976).

RECONSTRUCTION PARAMETERS

Reconstructions of the Western Mediterranean area were made for 13 episodes between 165 Ma and 10 Ma (Figs. 2 and 3). The reconstruction parameters used are essentially those proposed by SCLATER ET AL. (1977), who incorporated the new sea-floor data from the Bay of Biscay, which are of course crucial in any reconstruction of the Western Mediterranean.

The reconstruction parameters used for the Adriatic block are given in table I. These were calculated, assuming the Tertiary rotation relative to Africa of the Adriatic block to have started later than 30 Ma. A constant rotational movement for the Adriatic block around the pole 15.15°E 36.04°N and over an angle of 27° was assumed during Late Oligocene and Miocene times, from 30 Ma to 5 Ma. The Adriatic block is kept fixed to Africa in all pre-21 Ma reconstructions. The initial fit of the major continents (Fig. 3) is essentially that of LE PICHON ET AL. (1977), with a slight modification after SCLATER ET AL. (1977).

DRIVING FORCES OF THE COUNTERCLOCKWISE TERTIARY ROTATION

Inspection of the 65 Ma to 10 Ma reconstructions (Fig. 2B) shows that during the Tertiary, differential movements between Africa and Europe were very small. Spreading rates in the North and Central Atlantic appear to have been about

Table I
Reconstruction parameters for Adriatic block

	rel. to Africa			rel. to N. America 1)		
5 MA	36.04	15.15	0.0	70.50	341.30	- 1.35
10 MA	36.04	15.15	- 7.0	45.80	9.81	- 9.26
15 MA	36.04	15.15	-12.0	44.95	9.69	-15.49
21 MA	36.04	15.15	-18.0	44.09	9.55	-22.72
30 MA	36.04	15.15	-27.0	43.37	9.04	-33.66
38 MA	-	-	-	44.98	7.45	-35.75
53 MA	-	-	-	48.36	4.96	-41.23
65 MA	-	-	-	50.42	3.22	-45.71
80 MA	-	-	-	57.90	358.60	-53.05
95 MA	-	-	-	57.54	356.17	-60.22
110 MA	-	-	-	57.20	354.24	-67.39
125 MA	-	-	-	56.87	352.71	-74.52
140 MA	-	-	-	56.68	350.63	-81.60
165 MA	-	-	-	56.08	349.24	-98.25

1) Calculated from parameters according to Sclater et al., 1977.

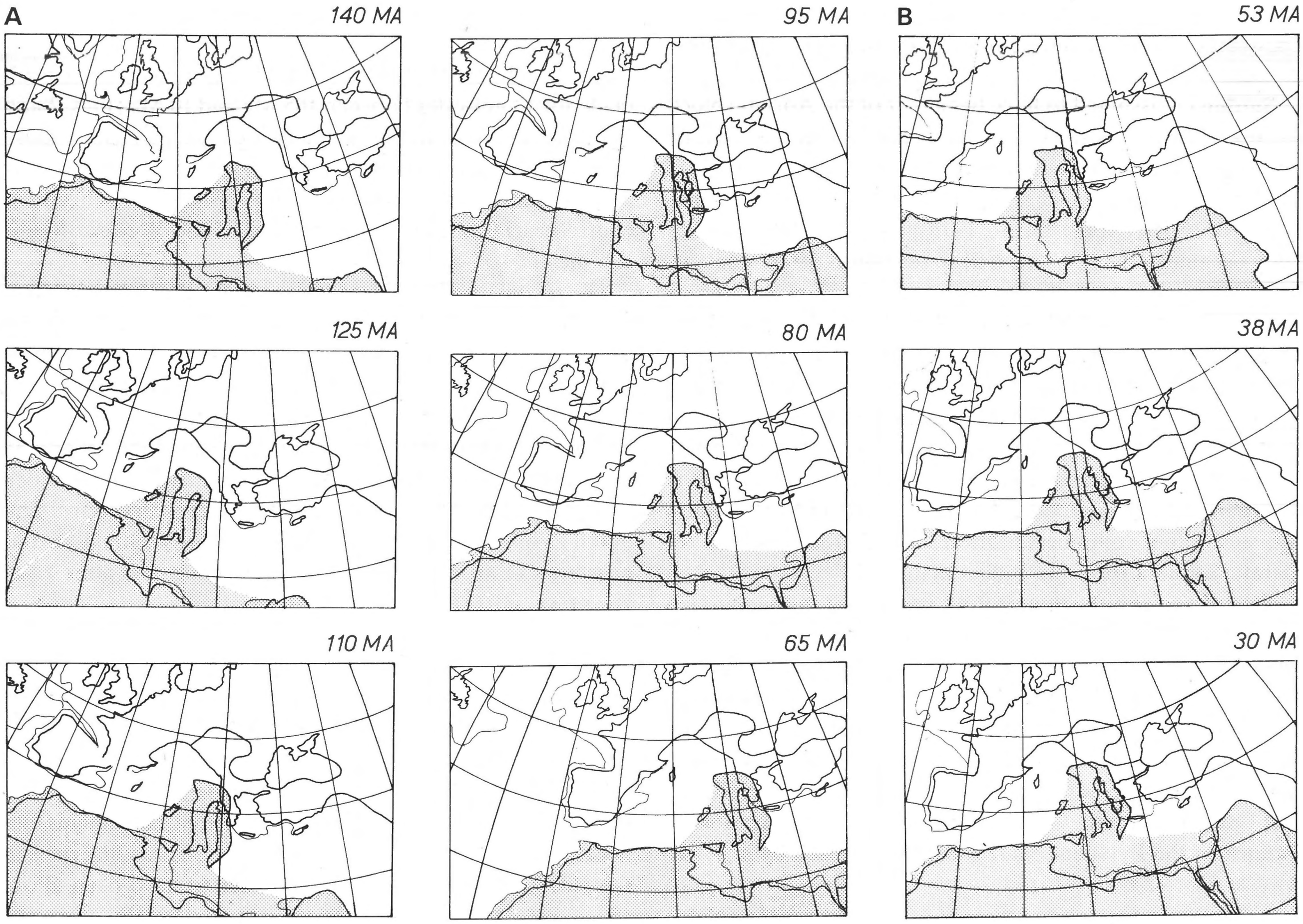
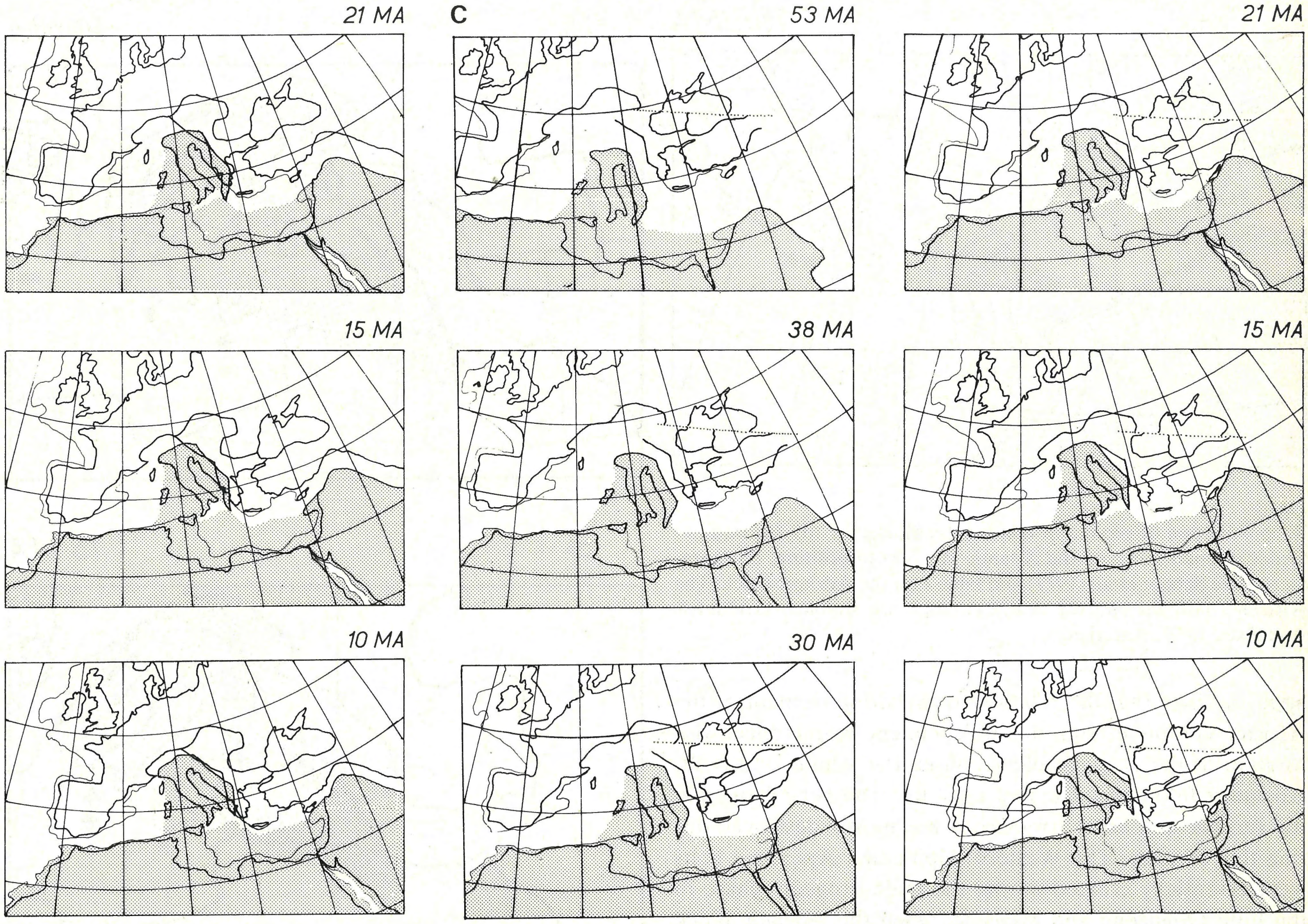


Fig. 2
A: Mesozoic reconstructions of the Western Mediterranean area. Stippled area represents the African continent and the Adriatic block. For parameters see Sclater et al. (1977), for the major continents and for the Adriatic block see table I. Gridnet is kept fixed to N. America.

equally fast. No important shear movement, that could have caused the counterclockwise Tertiary rotation of the Adriatic block, was therefore present. The 110 Ma to 10 Ma reconstructions (Fig. 2A, 2B) suggest a very unlikely major overlap of continental crust in the Dinarides and Western Hellenides. To eliminate this overlap the Tertiary reconstructions have been redrawn in figure 2C. This can only be accomplished by eastward shifting of the Balkan-Rhodope-Turkey continental block. The new 21 Ma to 10 Ma reconstructions (Fig. 2C) demand a gradually westward shift of this Balkan-Rhodope-Turkey block to avoid an overlap of the Balkan-Rhodope-Turkey block and the Arabian block. This Late Tertiary to recently active movement of the Balkan-Rhodope-Turkey block is a well-known phenomenon (MCKENZIE, 1972, 1976) and is inferred to be caused by the northward movement of the Arabian (African) block relative to the European continent. The continent-to-continent contact in the Western Hellenides and Dinarides does not allow the movement of the Balkan-Rhodope-Turkey block to be absorbed by large-scale crustal shortening. And therefore this movement was passed on to the Adriatic continental block. Together with the relative northward movement of the African continent a stress field was created in which the Adriatic block was constrained to rotate counterclockwise and to separate from the African continent.

MESOZOIC RECONSTRUCTIONS

The 165 Ma reconstruction (Fig. 3) has been produced before by various authors, following very different lines of reasoning (SMITH, 1971; BOSELLINI & HSÜ, 1973; DEWEY ET AL., 1973). Corsica, Sardinia and the Balearic islands constituted an arc in a very similar way as has been proposed by ALVAREZ ET AL. (1974). If we suppose that the Great and Little Kabylian Massifs were originally located close to the Balearic islands, then the Western Mediterranean was completely closed by pre-Hercynian continental crust.



B: Tertiary reconstructions of the Western Mediterranean area. For parameters see Sclater et al. (1977) and table I for the Adriatic block. Simple application of these parameters result in an overlap in the Dinarides/Hellenides region. Gridnet is kept fixed to N. America.

C: Tertiary reconstructions of the Western Mediterranean. To avoid continental overlaps the Balkan-Rhodope-Turkey block has been shifted eastward relative to Eurasia, and is gradually shifted back in the 21 Ma to 10 Ma reconstructions. Gridnet is kept fixed to N. America.

During the period of 165 Ma to 110 Ma the opening of the Central Atlantic caused the creation of new oceanic crust and extension of the former continental crust in the Western Mediterranean and Alpine region. Sardinia and the Kabylian Massifs formed the western continental margin of the Adriatic block (Fig. 2A). The extensional regime lost most of its effect in the Western Mediterranean after the Iberian peninsula started to separate from North America at about 110 Ma and the formation of new crust ceased. In the Alpine region the formation of new crust ceased later after the European continent separated from Greenland and North America at about 95 Ma (Fig. 2A). Early deformation phases in the Alps resulted from differences in spreading rate between the Central and North Atlantic. From 65 Ma on the spreading rates in the Central and North Atlantic became almost equal.

While in the Western Mediterranean and Alpine region an extensional regime dominated during the Late Jurassic and Early Cretaceous, in the Hellenides and Dinarides crustal shortening occurred during that time (AUBOUIN, 1965; BLANCHET, 1976). This can only be connected in a qualitative way with these reconstructions (Fig. 2A), since it is not known to what extent the Balkan-Rhodope-Turkey block was actively involved. The continental overlap in the Hellenides and Dinarides, as shown in the 110 Ma to 65 Ma reconstructions (Fig. 2A) only shows *that* the Balkan-Rhodope-Turkey block had to be situated in a more easterly position relative to Europe but it does not show how long this had been so. An eastward movement of this block during the early Mesozoic as a result of spreading in the Eastern Mediterranean has been suggested (DEWEY ET AL., 1973; LAUBSCHER & BERNOUILLI, 1976; and others) to explain the ophiolite occurrences in Greece, Cyprus and Turkey.

TERTIARY RECONSTRUCTIONS

From the 53 Ma to 10 Ma reconstructions of figure 2C it

165 MA

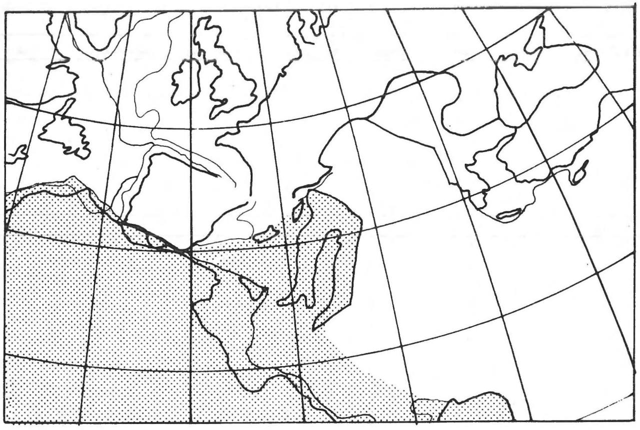


Fig. 3
Reconstruction of the major continental blocks for 165 Ma and before. Continents around the Atlantic in a best fit position. For parameters see Sclater et al. (1977) and table I for the Adriatic block. The African continent and the Adriatic block are stippled. Gridnet is kept fixed to N. America.

A 21 MA

B 15 MA

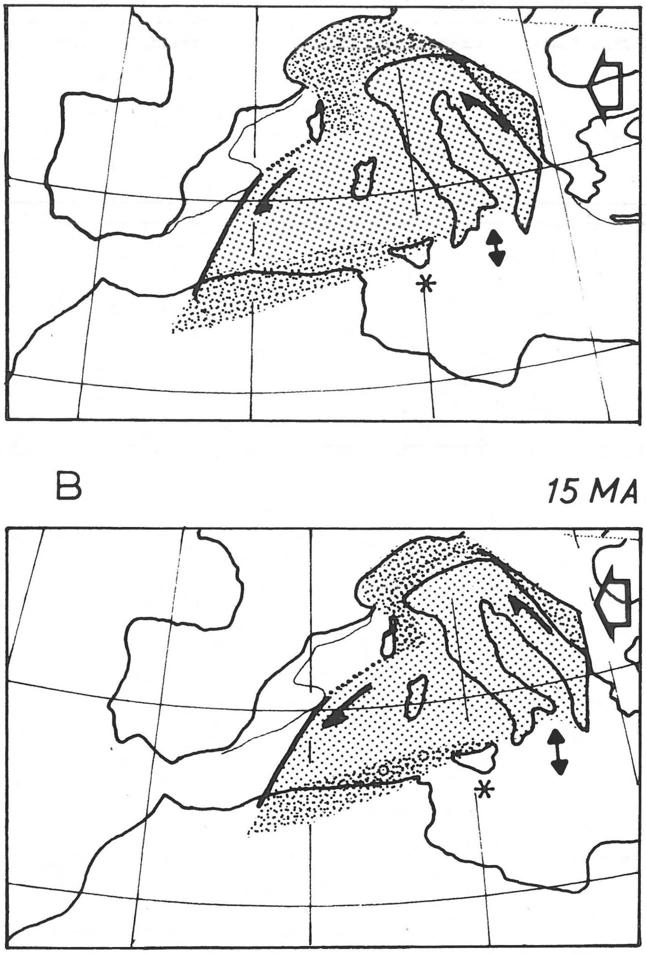


Fig. 4
Enlargements of the Tertiary reconstructions of 21 Ma and 15 Ma (Fig. 2C). The Adriatic continental block is stippled, and the areas of crustal shortening are shaded. Arrows indicate relative movements. Asterisk indicates location of Malta rotation pole (see text).

appears likely that the relative northward movement of the African continent and the independent counterclockwise rotation of the Adriatic block caused the Alpine and N.W. Apennine fold belts. The new crust that had been formed in the Jurassic and Early Cretaceous was mostly destroyed during the Tertiary. The Western Alpine and Apennine belts were essentially created during the main orogenic phase in the Late Oligocene and Miocene, when the Adriatic block performed its counterclockwise rotation (Fig. 2C). This rotation could have generated the extensive Insubric and peri-Adriatic strike-slip fault system (compare the 30 Ma to 10 Ma reconstructions of Fig. 2C). The different structural evolution of the N.W. Apennines and the Southern Apennines was the logical consequence of the protruding position of Corsica. Crustal shortening occurred in the Alpine region and the N.W. Apennines, while the position of Corsica, east of the external Massifs in the Western Alps, caused the present offset between the N.W. Apennines and Western Alps. LAUBSCHER (1971) has pointed this out before. The present reconstructions (Fig. 2C) clearly show that a Tertiary rotation of Corsica (ALVAREZ ET AL., 1974; BOCCALETTI & GUAZZONE, 1972) is not necessary to explain the evolution of the Western Alps and the N.W. Apennines, although it is not unlikely that as a reaction to the stress field the position of Corsica was adjusted.

The presented Mesozoic and Tertiary reconstructions (Fig. 2A, 2C) provide the space necessary for a palinspastic reassembly of the sedimentary basins of the Alps and N.W. Apennines (LAUBSCHER, 1971). Notice that without a Tertiary rotation of the Adriatic block (CHANNELL & HORVATH, 1976) this reassembly should be problematic, since the differential movement between the European and African continent had been very small in the Tertiary, and a relative small northward movement of the African continent can hardly have resulted in east-west directed movements and compression in the Western Alps during the Miocene.

In figures 4A and 4B two enlargements are given of the 21 Ma and 15 Ma reconstructions (Fig. 2C). It was assumed that the Tyrrhenian sea floor consisted of continental crust and formed, together with Sardinia, part of the Adriatic block, which mainly during the Mesozoic had been enlarged westward with newly formed oceanic crust. A Tertiary rotation of the Adriatic block would then imply crustal shortening in the area of the Tell Atlas and strike slip movements along the Baudot escarpment (East of Majorca) and its supposed northeastward continuation as illustrated in figures 4A and B. These movements have been recognized by several authors (AUZENDE ET AL., 1973, 1974; CAIRE, 1973). Additional support is found in the directions of major onshore and offshore structural lineaments, which are lying more or less on small circles of the Malta rotation pole (Fig. 5), and are related with the structural evolution of the Tunisian and Algerian fold belts.

It is very likely that the Balearic block joined temporarily the Tertiary movement of the Adriatic block, and that at least a part of the movement was passed on to continental areas west of the Baudot fault zone. The synchronous opening of the Gulf of Valencia and the foundering of the Provencal basin (MORELLI ET AL., 1975-b) can very well be associated with the Tertiary movement of the Adriatic block (Fig. 4.).

The Tertiary movement of the Adriatic block implied an extensional regime during the Late Oligocene and Miocene (Figs. 2C and 4) for the area of the Ionian Sea. This is fully supported by the observations. The crust of the Ionian basin is continental, although presently involved in a process of oceanization (MORELLI ET AL., 1975-c). The Moho below the abyssal plain of the Ionian Sea is only at a depth of 17 to 19 km (WEIGEL, 1974). This Moho deepens towards Calabria, the Peloponnesus, the Eastern Mediterranean and towards the Malta shelf (MAKRIS, 1977; WEIGEL, 1974). Foundering of the continental crust was already active in Early Miocene times (FINETTI & MORELLI, 1972; HINZ, 1974), and continued until Quaternary times.

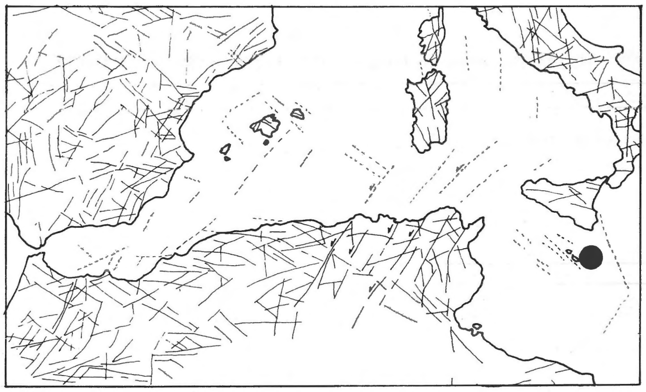


Fig. 5
Major structural lineaments in the Western Mediterranean area, onshore after Letouzey et al. (1976) and offshore according to Auzende et al. (1973, 1974). Dot indicates the location of the Malta rotation pole (see text).

CONCLUSIONS

Reconstructions of the Western Mediterranean area that are based on sea-floor data *and* palaeomagnetic results reveal a coherent picture and can be used as a framework for the Alpine orogeny.

The Tertiary independent counterclockwise rotation of the Adriatic block is an essential part of this framework and it brings very different fold belts and the foundering of the Ionian Sea into a causal relationship. The driving forces of this Tertiary rotation were generated by the westward movement of the Balkan-Rhodope-Turkey block and the Northward movement of the African continent.

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