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FROM THE TETHYS OCEAN TO THE MEDITERRANEAN SEAS : A PLATE TECTONIC MODEL OF THE EVOLUTION OF THE WESTERN ALPINE SYSTEM

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ABSTRACT

- We propose a series of paleogeographic maps of the western alpine system, from Triassic to Present, based on the geologic structure and evolution of the Mediterranean, its adjacent folded belts and the associated basins, and on the evolution of the North Atlantic ocean according to the magnetic anomaly informations. The kinematic framework is relatively precise for the Cenozoic but the accuracy is quite poorer for the Mesozoic. Between Triassic and Upper Cretaceous, the reconstructed continental margins can be compared to present passive or active margins. The geologic evolution can be described in terms of plate tectonics. After Upper Cretaceous, the oceanic areas are quite limited and the geologic evolution is dominated by the continental collision processes.- For each of eight different key geologic periods (including Present), Africa and Europe are positionned according to the kinematics deduced from the opening of the Atlantic ocean. Three major intermediate plates are identified : Iberia, Apulia and Anatolia. The dimensions of the initial cratons are obtained through a palinspastic restoration taking into account the basement nappes and the effect of superposed tectonics. It is shown that, prior to Lower Jurassic, an ocean (the Tethys) separated Eastern Europe from Africa-Arabia. It is being consumed during Mesozoic because of the left lateral motion of Africa with respect to Europe, which induces the separation of Apulia and Anatolia from Africa and their accretion to Europe. Distension prevails in the wake of the motion of Apulia-Anatolia, especially between Tunisia and Arabia, which is related to the formation of a new oceanic surface, called the Mesogea. The collision of Apulia occurs at different times depending on the morphology of the European southern margin. It is initiated in Uppermost Jurassic, with a resulting fracturation of Apulia in three blocks ; and ends during Uppermost Cretaceous to the east and west of Rhodope in the median portion. The consumption of the Tethys is accompanied by the creation of marginal basins : the Carpathian flyschs trough and the Black Sea. The motion of Moesia toward the southwest, related to the opening of the Black Sea, increases the Carpathian arcuation. After Upper Cretaceous, the change in the motion of Africa will lead to the following facts. New strike-slip faults appear in the Apulian plate. The Mesogea is being consumed as well as its different narrow troughs which extended toward the Tethys and the Atlantic. This consumption is accompanied by the formation of marginal basins. In the Western Mediterranean, where the consumption is complete, the marginal seas are well developed. In the Eastern Mediterranean, where the consumption is still only partial, they are barely initiated.

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FROM THE TETHYS OCEAN TO THE MEDITERRANEAN SEAS : A PLATE TECTONIC MODEL OF THE EVOLUTION OF THE WESTERN ALPINE SYSTEM.

I. INTRODUCTION

This paper is an intermediate stage in a systematic attempt at reconstructing the evolution from the early Mesozoic Tethys ocean to the present Mediterranean seas, within the framework of plate tectonics. In an earlier publication (Biju-Duval et al, 1976a), we outlined the way in which we approach this reconstruction, which incorporates, in a synthetic fashion, the very large amount of data now available on the continental margins as well as on the folded belts surrounding the Mediterranean area (Biju-Duval et al. 1977). The main result of this effort is a series of paleogeographic maps at key geologic periods which were prepared with the collaboration of V. Apostolescu, for the distribution of the main geologic facies, and of J.C. Sibuet, for the plate kinematic reconstructions (Biju-Duval et al., 1976 b). These maps are presented in such a way that they can be easily used, for addition or modification, by other scientists.

The purpose of this paper is to give to the reader the necessary elements to have a clear knowledge of the basic methodology followed by us and to outline the main conclusions, the major problems and the directions along which we intend to proceed in future stages.

We have limited, rather arbitrarily, the present reconstruction to the western part of the alpine system which surrounds the Mediterranean seas, Black sea included. It will be obvious to the reader that a full understanding of the eastern Mediterranean area would require a broader framework including the Caspian sea area and extending to the Oman sea to the south-east.

Starting from the present structure of the Mediterranean region, (Ryan et al, 1971, Biju-Duval, 1974, Biju-Duval et al, 1974), we tried to investigate how the geologic evidence for past distension, for the distribution of epicontinental and pelagic facies, and for the superposition of tectonic deformations in the folded belts fit within the pattern of relative motion between Africa and Eurasia since early Mesozoic time, as given by plate kinematics.

In the last few years the structure of the Mediterranean seas has been intensively studied (Auzende et al., 1972 ; Rehault et al., 1974 ; Finetti and Morelli, 1973, 1974 ; Biju-Duval et al., 1977 ; etc ...). Plate I[⁎] shows that it is characterized by narrow zones of thin crust inserted within the alpine folded belt, along the fairly broad Africa-Eurasia plate boundary which is outlined by a diffuse but intense seismicity (e.g. Mc Kenzie, 1972). The limited size of these oceanic basins has been the source of considerable controversy. Actually, only a small part of the surface of the Mediterranean basins are located more than 100 km away from the continental shelfs. The continental margins, which mark the transition from continental to oceanic crust have an average width of 100 km or more (e.g. Worzel, 1965) and their deep structure is characterized by a rapid evolution in space and time. It cannot be easily related to either oceanic or continental crust. As a result, the nature of the crust, in the Mediterranean basins, where opposite continental margins can be considered to be contiguous, is necessarily complex and difficult to characterize clearly as either oceanic or continental.

However, we consider that the oceanic nature of the crust underlying the abyssal plains of the western Mediterranean and the southern Tyrrhenian seas is well established. The very large accumulations of sediments over the deepest parts of the eastern Mediterranean and the Black seas indicate that the igneous crust is very thin (Biju-Duval et al, 1976 a). In addition, the existence of deep seismic zones under the Tyrrhenian and Hellenic arcs (e.g. McKenzie, 1972) indicates that active subduction of crust has proceeded there for the last few million years. We consequently also assume an oceanic nature for these portions of crust. The age of formation of the basins can be estimated on the basis of a study of the continental margins which surround them. Although they have often been affected by tectonics, it is possible to recognize that some of them are quite old (Mesozoic) whereas others are much more recent. We estimate on this basis that the eastern Mediterranean basins were formed in Jurassic time, the Black sea in Cretaceous-Eocene, the Western Mediterranean in Oligo-Miocene (Le Pichon et al., 1971 ; Hsü, Montadert et al., 1977), the Tyrrhenian since Upper Miocene (e.g. Morelli, 1975). The present Pannonian basin (see Channell and Horwath, 1976), although not of an oceanic nature, was also formed by distension in Neogene (Boccaletti et al., 1976, Biju-Duval et al, 1976 a).

[⁎] Plates I to VIII are inserted in a paper pocket placed at the end of the volume.

The notion of resorbable oceanic lithosphere is fundamental to any reconstruction of folded belts. It requires however to be able to clearly identify traces of former continental margins, whether active or passive. Unfortunately, our ability in this domain is still very limited as shown by the numerous differences between the interpretations made by different authors.

In addition, it becomes ever clearer that considerable shortening may also occur through folding and thrusting of continental crust. For example, in the Alps (Trumpy, 1975) and in the Hellenides (Dercourt et al. 1976), the basement nappes obviously originated from a much wider continental platform than the present folded belt. The numerous studies made within the perimediterranean basins have shown that, to restore the original basement platform, it is necessary to unfold the present tectonic structures, due to a superposition of tectonics, over distances which often exceed 500 km. Thus, the reconstruction of the original cratonic plates requires such a palinspastic restoration.

Finally, as vividly illustrated by Mc Kenzie (1972), the present pattern of the Africa-Eurasia collision is dominated by the fragmentation of the continental crust through a wide belt of deformation. This state of fragmentation through intracontinental collision processes was probably initiated in Upper Cretaceous. It is the present complex pattern of fragmentation which probably led to the identification of numerous (20) plates which evolved independently since early Mesozoic in the Dewey et al. (1973) reconstruction. This reconstruction of the western alpine system is probably the most widely used. But we prefer to consider that the present complexity is mostly the result of the late Mesozoic and Cenozoic intracontinental collision : the main independent plates should be identified only on the basis of an association of unambigous evidences for the existence of former plate margins.

As wasdone in the pioneering work of Dewey et al (1973), we have placed our reconstruction within the framework of plate kinematics. The solution adopted for the Africa-Eurasia relative motion was essentially derived from the work of Pitman and Talwani (1972) from anomaly 31 (68 M.y.) on, whereas the earlier kinematics is obtained from the work of Le Pichon et al (1977). It will not be discussed in detail here.

Similarly, the bases for our choice on the present structure of the Mediterranean basins have been discussed by Biju-Duval et al (1977) and will not be presented again here.

Finally, due to space limitations, we will not comment in detail the geological data which are used in the paleogeographic maps of (PL. II to VIII). We will only give brief general comments and will postpone a more elaborate discussion to a later paper.

Many of the earlier attempts at reconstructing the alpine evolution are partial attempts which only consider portions of the Mediterranean system (Laubscher, 1969, 1971 ; Dercourt, 1970 ; Alvarez 1972, 1974 ; Boccaletti et al. 1974, etc ...). Others ignore a considerable part of the available information in one or several of the three major domains : plate kinematics, present geophysical structure, geological structure (1) (Smith, 1971 ; Bosellini and Hsü, 1973; Channell and Horwath, 1976, etc ...). Our attempt, on the contrary, is built on a broad base in each of these three domains.

But there is one major set of data which we have not used for the reconstruction. These are the so-called "absolute" position data which relate the position of a plate to the axis of rotation of the earth. We feel that there is still too much uncertainty to use these data to position the intermediate plates. We did, however, position the paleolatitudes on our paleogeographic maps modified from the paleomagnetic work of Van Der Voo and French (1974).

A last word should be said about the nomenclature adopted. We call Tethys the ocean which existed between Europe and Africa during early Mesozoic. We call Mesogea the fairly broad ocean which was created during Mesozoic, and we reserve the name of Mediterranean to the present basins, parts of which are relics of the Mesogea.

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(1) Numerous reconstructions have been recently proposed : Herz and Savu, 1974 ; Dimetrijevic and Dimetrijevic, 1973 ; Géczy, 1973 ; Hawkesworth et al, 1972 ; Bernoulli and Laubscher, 1972 ; Boccaletti et al. 1974 a, 1974 b; Dimetrijevic, 1974 ; Hadzi et al.1974 ; Radulescu and Sandulescu, 1973 ; Dal Piaz, 1974 ; Dal Piaz et al, 1972 ; Hsü, 1971 ; Boccaletti et al., 1971, 1972 ; Elter andPertusati, 1973; Mattauer andProust, 1976 ; etc ...

II. METHODOLOGY

1. The framework of our attempt is the plate kinematic evolution of the Africa/Europe plate system obtained from an identification of the Vine and Matthews (1963) isochrons in the Atlantic ocean between Africa and North America and between Europe and North America. The first systematic attempt at identifying the magnetic anomalies on a large scale over these two areas is the one by Pitman and Talwani (1972) which was the basis of the Dewey et al (1973) kinematic solution. Unfortunately, mostly because of fairly slow spreading rates, the anomalies are difficult to identify and the Pitman and Talwani (1972) identifications cannot be considered as final. Several modifications or additions have been proposed since, which include, Williams (1975), Kristoffersen and Talwani (1977) and Kristoffersen (1977) for the Europe-America system, Hayes and Rabinowitz (1975), Barret and Keen (1976) for the Africa-America system and others will undoubtedly come in the near future.

In addition, the kinematic solution is obtained by fitting together corresponding anomalies from both sides of the ridge crest. However, in general, we do not have a good definition of the isochrons over a sufficient length to obtain a very precise fit. As a result, the Africa-Europe relative motions which are obtained by composition of the Africa/America and America/Europe motions cannot be expected to be known with a good precision. For example, Francheteau (1973), using the anomalies identified by Pitman and Talwani (1972) as well as informations on fracture zones trends, has shown that a somewhat different kinematic solution could be obtained for the Africa/America motion. Kristoffersen and Talwani (1977) and Kristoffersen (1977) have obtained a different kinematic solution for the America/Europe motion mostly because of additional anomaly identifications to the north of 50°N.

The complexity of the kinematic problem is increased by the existence of two relatively mobile zones on each side of the Açores-Gibraltar line. Iberia has had an independent motion from Europe in Late Mesozoic and part of Early Cenozoic and the anomalies between Iberia and America cannot be used to obtain the America/Europe motion without allowing for this independent displacement. Similarly there is some indication that Morocco has been affected by limited displacement with respect to Africa during the opening (e.g. Le Pichon et al., 1977) and the anomalies between Morocco and America should only be used with caution to obtain the Africa/America motion.

Finally, there is some significant uncertainty on the absolute ages of these Vine and Matthews anomalies. The most recent Cenozoic polarity time scale by Tarling and Mitchell (1976), which we have adopted, differs considerably from the Heirtzler et al (1968) time scale or even the one proposed by Larson and Pitman in 1972. For example, according to Larson and Pitman (1972), anomaly 24 is 60 M.y. old (Middle Paleocene) whereas it is 49 M.y. old (Lower Eocene) for Tarling and Mitchell (1976). For the Mesozoic, we have adopted the time scale proposed by Thierstein (1977). The maximum difference between the time scales may reach 11 M.y. for a given anomaly, as shown in the example above.

However, the greatest difficulty in the reconstruction of the Africa/Europe kinematics is related to the early stages for which we do not have Vine and Matthews isochrons but rather have to rely on a reassembly of the continents prior to the break-up. Yet this reassembly is difficult to obtain on purely objective ground. It becomes abundantly clear that no given isobath can be considered to reflect accurately the edge of the original continental crust break-up (Le Pichon et al, 1977). As the break-up between Europe and America most probably did not occur before 95 - 90 My (Cenomanian), all reconstructions prior to that time are plagued by the fairly large uncertainty in the Europe-America reconstruction. This is illustrated in figure 1 which shows the large differences produced by the different Europe/America solutions prior to 90 M.y. At one extreme, there is the solution of Bullard et al. (1965) which fit at the 1000 m isobath. It is not acceptable as it is now known that large portions of the sea-floor, down to a water depth of 4000 m in places, are continental. For example, between Europe and North America, this is true for the Rockall plateau in its entirety, the Orphan Knoll area, the area just south of the Porcupine sea-bight, the Galicia bank etc .. (e.g. Le Pichon et al., 1977). At the other extreme there is the most recent solution by Kristoffersen (1977). Actually, the initial fits obtained from a study of the ocean floor features and continental margins have regularly tended to get looser from Bullard et al (1965) to Dewey et al (1973) to Le Pichon et al (1977) and Kristoffersen (1977). We feel that the actual position is probably within 200 km of the Le Pichon et al (1977) solution for Europe-North America and that the resulting position for Africa - Europe may be eventually in error by as much as 300 km to the west and 500 km to the east.

The precision, however, gets considerably better posterior to 90 M.y., as shown in figure 1. It is of the order of 200 km to the west and somewhat more to the east. It may be fairly poor for the Campanian-Maestrichtian as Kristoffersen (1977) has suggested that Pitman and Talwani (1972) generally identified anomaly 31 (which is Maestrichtian, 68 M.y.) where it should be 33 (which is Campanian, 76 M.y.).

In this paper, we do not propose any new magnetic anomaly identifications or kinematic solutions. Rather, we have chosen among the solutions proposed what seems to us to be the most probable, recognizing that it may be illusory at the present time to expect a precision in the position of Africa with respect to Europe better than 300 - 500 km prior to 90 M.y. ago and 200 - 300 km later than that. Although these possible errors are large, they only represent about 20 % of the motion of Africa with respect to Europe since the corresponding time.

Table I indicates the solution adopted and figure 2 illustrates the resulting kinematics. The solution chosen is essentially based on the work of Pitman and Talwani (1972) from anomaly 31-33 on. However, between Africa and North America, we have used the slightly different finite rotation angles proposed by Francheteau (1973). Between Europe and North America, we have also used the parameters proposed by Kristoffersen (1977) for anomaly 24 (49 M.y., Ypresian) and anomaly 31-33. Prior to anomaly 31-33, we adopt the solution proposed by Le Pichon et al (1977) for the initial reconstruction and the Oxfordian reconstruction. The Barremian position (anomaly M2) is not very precise and the Cenomanian position which is an interpolation, even less precise. The latter one has not been used in this paper.

2. Within this kinematic framework, we have chosen seven key geologic periods for which there was a fair control of the relative position of Africa and we have established a paleogeographic map for each of these periods (figure 3 and plates II to VIII). Starting from the present time, these are :

- Tortonian, 9 M.y., anomaly 5 (plate VIII) : just before the Messinian event
- Stampian, 35 M.y., anomaly 13 (plate VII) : just before the opening of the western basin.
- Lutetian, 44 M.y., anomaly 21 (plate VI), which corresponds to an important tectonic event in the whole Mediterranean area (Pyrenean phase)
- Campanian - Maestrichtian, 76-68 M.y., anomaly 33-31 (plate V), which represents the main period of evolution of the future eastern Mediterranean area
- Tithonian-Berriasian, 140 M.y., interpolated between anomaly M 25 and M 2 (plate IV) because of the very important sedimentary and tectogenetic processes (first obduction of ophiolites)
- Dogger, 165 M.y., interpolated between anomaly M 25 and the initial reconstruction (Plate III) during which the main isopic zones are defined as a result of the liassic distension
- Upper Triassic, about 200 M.y., initial fit (plate II) corresponding to the first distentional phases between the Tethys and the future Atlantic ocean.

In addition, plate I gives the present situation. We have not made the Cenomanian reconstruction (112 M.y.), although it is a key geologic period, as we felt that the relative position of Africa was poorly known.

However, it is obvious that, for a given geologic period, the major events that should be illustrated are not synchronous over the whole area. It should be stressed, further, that the dating of geologic facies or events may still be quite imprecise. For example, plate IV shows data concerning the Campanian as well as the Maestrichtian era. Actually, each map shows the general geological pattern in the vicinity of the chosen period and it may include events which occurred immediately before or after the date chosen.

Thus, we often find the same range of possible errors in the chronology of geologic data as in the kinematic data, which confirms that it is probably illusory at the present time to look for much better accuracy in such a reconstruction. It is quite clear that the precision of our paleogeographic reconstructions gets worse with increasing age. The following features have been shown on each map :

The repartition of continental and oceanic areas with a transitional zone which corresponds to the continental margins. This continental margin area distribution has been determined in a very schematic fashion. We must keep in mind, as previously said, that their deep structure is characterized by a rapid evolution in space and time, especially in the case of the active margins. So the size and the shape of such margins have been drawn with some modificacions from one map to the other. Moreover, we have not attempted to illustrate systematically the possible existence of marginal basins which have since disappeared. Although we do not exclude this possibility, we have only shown on the plates those for which the evidence seems to us to be unambiguous.

The repartition of major facies in each zone based on both our field experience and a detailed bibliographic study which cannot be exposed in full in this paper for lack of space. Taking in account the previous remarks about the precision of dating and the fact that many rapid changes of facies are known to occur in space and time, we have only drawn in a schematic fashion the main facies, many fine variations being impossible to show at the scale of the maps.

To show the lateral variations we had to adopt a certain number of hypotheses on the initial positions of the different paleogeographic and (or) structural units within the different belts. For example the Rif, Kabyle and Calabrian basement units have been considered to be parts of the southern margin of Iberia to the north of the "Mauretanian-Massylian" trough. Our choice is illustrated in figure 4 which should be used as a reference map for plates II to VIII. To establish these reconstructions one needs to reposition at each stage the paleogeographic zones ; this requires analysing each part of the Alpine belt in which superimposed tectonics are known. Because of lack of space it is not possible to mention here the data we have used on the different branches of the Alpine belt, data which are necessary to understand, and to explain the paleogeographic or tectonic hypotheses chosen. This will be done in a future paper. Nevertheless figure 4 localizes the key paleogeographic zones which existed after the liassic distension. It shows also the main bibliographic references in a condensed form (author, year) even if we have not adopted the conclusions of the mentioned authors. The figuration of zones within stable areas is not difficult but to represent the former margins now included in "internal zones" is not easy : they correspond to the most tectonized, polyphased, granitized and metamorphosed areas. The study of present margins show that they are formed by horsts and grabens which size and shape are difficult to define in these former margins. It is also known that the type of deposits varies enormously over short distances on present continental margins (closeness of clastics sources, relative bathymetry-carbonate compensation depth, currents, ..).

Moreover we have used a study of the major lineaments revealed by the Landsat I satellite to define major fractures related to continental collision (Biju-Duval et al, 1976).

A possible or probable kinematic pattern, although in many cases it would be possible to reconstruct fairly different kinematic patterns. The main rationale was one of minimum complexity. It is clear that onland geological data have been used in priority. For example the relation between facies, tectonic development, overthrusting of ophiolites, calcoalcaline volcanism in north Anatolia during Late Cretaceous leads us to suggest the existence of a subduction zone. In a few cases clear geological data do not exist but the kinematic evolution obliges us to infer the existence of a plate boundary. The minimum complexity criterion has led us to identify only three main plates between Africa and Europe, which are Iberia, Apulia and Anatolia. The size and shape of these intermediate plates is obtained from a rough palinspatic restoration for Apulia and Iberia. For Anatolia the geological data are often so imprecise that we simply chose a size roughly compatible with the inferred kinematic evolution ; it should in particular result in continental collision by Late Cretaceous.

The major volcanic manifestations and the main phases of tectonic emplacement of ophiolites. Because the knowledge of the geochronology, petrography and geochemistry is still quite variable from one area to another a synthetic view of the volcanic activity all around the Mediterranean area is not yet well established (see Bellon and Letouzey, this volume). Nevertheless we have mentioned the main occurrences of widespread volcanism (including resedimented volcanic deposits). We have assumed in this paper that the obduction of ophiolites was related to the last stage of disparition of an oceanic area. This is not the only possibility (see for example Dewey, 1976) and we actually chose a different one in our preliminary publication (Biju Duval et al, 1976 a).

Finally, we note that these maps are prepared in such a way that they can be easily adapted or modified by others in order to obtain a better fit to other sets of data. The solution chosen is only one among several possible at the present time and we are still seriously considering an alternative solution in which the continental collision between Apulia and Europe only occurs in Late Cretaceous. All the maps are at the same scale in an oblique Mercator projection (pole at 52° N, 150° E) with Europe in its present position. The scale of the map is given by the latitude marks on the side. The paleolatitudes are figured modified from Van Der Voo and French (1974).

III. PROPOSED MODEL OF EVOLUTION

Figures 2 and 3 illustrate schematically the displacements of Africa with respect to Europe (arbitrarily kept fixed in its present position) since the beginning of the opening of the Atlantic ocean. Three main phases can be recognized.

a)From Mesozoic to Late Cretaceous, Africa is moving left laterally at a fairly high rate (2 to 4 cm/yr).

b)In Upper Cretaceous, the motion is slowed, most probably because of the first major intracontinental collision between Arabia, Anatolia and Eurasia. A relatively modest right lateral motion of Africa follows between Upper Cretaceous and Ypresian (49 M.y.), being related to the initiation of spreading between Europe and North America.

c)Finally, from Ypresian on, there is a general state of intracontinental collision which is characterized by a trigonometric rotation of Africa around a eulerian pole situated in the vicinity of Morocco. Thus the motion is very limited to the west but increases rapidly to the east where it is essentially north-south. Note that the pole of rotation tends to migrate with time to the west in the Atlantic ocean, which results in increasing compression in the whole western Mediterranean area.

The corresponding paleogeographic evolution is shown in figure 3 and plates II to VIII. During the first phase (prior to Upper Cretaceous), the geologic structure is mostly the result of the plate tectonic evolution of the three main intermediate plates, Iberia, Apulia and Anatolia. From Early Cretaceous on, the geologic structure corresponds to the fragmentation of the intermediate plates, with progressive disparition of the remaining oceanic areas. It is a process of continental collision where the concept of individual plates is difficult to use any more.

In this paper, the motion of Iberia has been obtained from kinematic criteria in the Bay of Biscay, as proposed by Le Pichon et al (1970, 1971), Le Pichon and Sibuet (1971) and Choukroune et al (1973). We do not have such criteria to obtain the motion of Apulia. We chose a solution which is compatible with the Africa-Europe motion and results in collision with Europe in Late Jurassic at the time of emplacement of ophiolites in the Hellenides (Dercourt et al, 1976). We still consider as a viable alternative a solution where collision only occurs in Upper Cretaceous and ophiolites obduction is not related to this continental collision. Note that the formation of the Bay of Biscay and of the Mesogea is not of a "marginal sea" type but rather is due to the displacements of intermediate plates induced by the motion of the main plates. On the other hand, the Black Sea and the Western Mediterranean probably represent fossil marginal basins.

The paleogeographic map will be commented starting from Early Mesozoic. However, their reconstruction was done starting from the present situation (plate I*) and moving back and forth in time.

1. Upper Triassic (plate II)*

The opening fit, which is pre-middle-Jurassic, is most probably valid for the whole Triassic time. We have chosen to draw the paleogeography of the Upper Triassic (200 M.y.). We previously discussed the

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[*] Plates I to VIII are inserted in a paper pocket placed at the end of the volume.

fairly large inaccuracy of this reconstruction, especially in the Iberia-Morocco area.

a) Plate II shows that a broad Tethys ocean exists to the northeast although. Argyriadis (1975) has argued that there is no geologic evidence for oceanic facies in this area. Nevertheless, the distribution of fauna may suggest the existence of such an oceanic hiatus (Enay, 1972 ; Hirsch, 1976). It could be argued further that the distribution of the epicontinental facies is in fair agreement with the existence of an eastward Tethys. For example, north of Apulia, platform carbonate facies merged into deep water deposits (Bernoulli and Jenkyns, 1974). Sediments associated will pillow-lavas have been described but their present tectonic setting is complicated ; so it is still difficult to define exactly the relation between oceanic and marginal facies (Terry, 1971 ; Juteau, 1970). Evaporite germano - andalousian facies extend of Europe and over North Africa ; Nubia west facies are found to the south east ; and carbonate platform deposits are found all along the margins of the Tethys and along the areas of future rifting (Bernoulli and Jenkyns, 1974).

b) Upper Triassic is the period when the first distension occurred (Fallot, 1945, 1948 ; Jenkyns, 1970 ; Ginzburg et al, 1975 etc ...) along the future continental margins of the Mesogea and the future Atlantic ocean. However, the distension on the eastern margins of Apulia, which already existed at that time, is not properly explained by this model, unless one relates it to the formation of marginal seas (Blanchet, this volume). It would accordingly be interesting to be able to distinguish between the different types of volcano-sedimentary deposits in the now tectonized Dinarides - Hellenides folded belts (Ciric, 1966 ; see Cadet et al, this volume)

c) In plate II, the gap between Apulia (still connected to Africa) and the African margin is too large. It could be reduced in part with a different more compact fit of the now dissociated parts of Iberia (including Corsica-Sardinia, Calabria, East end West Kabylias, Rif etc ...) such as the one proposed by Bayer et al. (1973) and Le Pichon et al (1977) or with a different position of Northern Africa. In this paper, we have adopted the more conservative reconstruction of Corsica and Sardinia proposed by Biju-Duval et al (1977). The gap would be greatly increased, in any case, if the position for Iberia is the one proposed by Bullard et al (1965). We feel that this gap may not be significant in view of the large inaccuracies involved in such a reconstruction.

d) Another problem is the interpretation of the Isparta line of Turkey (Brunn et al., 1971) as corresponding to an ancient Transform Fault separating Apulia from Arabia - Anatolia, in spite of very little field evidence for it.

e) A better knowledge of the Cimmerian folding phase in Dobroudgea, Crimea, Caucasus would probably lead to a modification of the scheme proposed in the north-eastern area where an active margin already existed. Continuous deformations and thrusting occurring NW of the Pontides until Triassic time and including so-called "green rocks" (Fourquin, 1975) could indicate the existence of a subduction zone south of Europe.

2. <u>Dogger</u> (<u>pl. III</u>)

The distension gets generalized in Liassic time during which the left-lateral rotation of Africa, related to the opening of the Central Atlantic, has begun

a) We have chosen a position close to the position corresponding to M 25 (150 M.y., Oxfordian) in the absence of other magnetic anomaly data.

b) The left-lateral motion of Africa results in distension in Southern Iberia ("dorsale") (Fonbote et Quintero, 1960 ; Busnardo et Chenevoy, 1962 ; Paquet, 1974), in the Alps (Briançonnais) (Bourbon et al, this volume), in East Sicily and along the Levantine margin (Gvirstman , this volume) which can be considered as passive continental margins. These correspond to the formation of zones of Transform Faulting where the oceanic space is small (Alps) or even absent (Pyrénées, South Iberia) or to the formation of the future Mesogea (Monod, 1975), in the wake of the motion of Apulia away from Africa.

c) The left - lateral motion of Africa also results in the beginning of consumption of the Tethys with corresponding formation of marginal seas (Eastern Black Sea - Caspian, Dobroudgea sphenochasm). Important volcanism and granitisations known in the Pontides and Caucasus (Bergougnan, 1975 ;

Khain, 1963) could be related to a such phenomenon.

d) As a result of this evolution, the sedimentary facies get greatly differentiated around Apulia and in areas of subsidence near the margins of Iberia, Africa and Europe ("Citrabetic and Betic troughs" in Iberia, Azema et al. 1974, Atlas trough, Busson 1972, etc ..). Broad epicontinental seas extend on the cratons.

e) As discussed previously, the positions of Apulia and Anatolia are fairly arbitrary. The size of the Mesogea depends of course on the positions adopted. The connection between Apulia and Anatolia is also quite speculative. The absence of known oceanic facies between the two plates leads us to consider that they were separated by a Transform continental Fault with left- lateral motion at that time.

3. Tithonian - Berriasian (pl. IV)

The position of Africa was obtained by interpolation between the position corresponding to anomaly M 25 (Oxfordian) and anomaly M2 (Barremian).

a) We consider that this is the time of a first limited closure of the Tethys between Apulia and the Moesian area because this is the main time of tectonic emplacement of ophiolites in the Hellenides (Dercourt, 1970 ; Aubouin et al, 1970 ; Juteau et al, 1973 ; Terry, 1974) which we interpret here as due to incipient continental collision (Maxwell, 1970 ; Hynes et al, 1972). We previously noted that we consider as possible another solution where collision only occurs in Upper Cretaceous time in this area (Biju-Duval et al, 1976 a). In our present scheme, this collision will initiate the fragmentation of Apulia.

b) The oceanic realms, to the east (North Anatolian trough) and west (Alpine Margins) (Bezzi et Picardo, 1971 ; Decandia and Elter, 1972 ; Dietrich and Scandone, 1972 ; Contesogno et al., 1975) of the continental collision (Rhodopian), are fairly restricted. Two marginal basins have been created, the eastern Black Sea and the Carpathian flysch trough ("Siret Ocean" of Herz and Savu, 1974 ; Boccaletti et al. 1974 b) which are affected by important volcanic activity.

c) This very important event is followed by the wide-spread deposition of flyschs during Lower Cretaceous. We note the occurrence of such clastic turbiditic deposits not only along the Hellenides - Dinarides tectonized margins (Blanchet et al. 1969 ; Charvet, 1973 ; Terry et Mercier, 1971 ; Celet et al. 1976) but also in other areas (Durand-Delga et Lambert, 1955) extending to the Atlantic ocean. The flysch deposition may be, at least partly, related to a major change in the paleogeography of the continental areas (Purbeckian facies in England, France, Spain, etc ...) accompanied by a general regression (see Histoire structurale du golfe de Gascogne, Technip edit.). This is also the time during which the Bay of Biscay and the North African trough (Bouillin et al., 1970 ; Bouillin et Kornprobst, 1974 ; Obert, 1974) were initiated.

d) The size of the Mesogea depends on the position chosen for Apulia. It is possible that an active margin started at this time along the southern border of Anatolia, inducing the formation of a marginal sea (the future Troodos - Kizil Dag).

4. Campanian - Maestrichtian (pl. V)

The Barremian (anomaly M 2) and Campanian - Maestrichtian (anomaly 31 - 33) positions being fairly inaccurate, we have not used the interpolated Cenomanian position, in spite of the important paleogeographic changes occurring at that time. The Cenomanian saw an early tectonic event in the Alps, the initiation of new flyschs and a broad epicontinental transgression.

However, the Uppermost Cretaceous is a major period in the evolution leading from the Tethys to the Mediterranean, as it is the time of the final consumption of the Tethys. The left-lateral motion of Africa is stopped due to continental collision between Europe-Anatolia and Africa - Arabia. This continental collision, which is the first true collision between the Africa - Arabia and Europe plates, will continue from then on.

a) The consumption of the Tethys is marked by a broad phase of obduction of ophiolites and mélanges (accretionary prisms) south of the Tethys (Pontides, Bergougnan, 1975 ; Apuseni , Lupu, 1974) and north of Africa - Arabia (from Cyprus to Oman; Gass, 1968 ; Lapierre, 1976, Ricou, 1971). An important calco-alcaline volcanism from the Balkans to the Lesser Caucasus (Adamia, 1975 ; Boccaletti et al., 1974) accompanies the final oceanic subduction in this area ; the completion of the opening of the Black Sea is probably related to this event (see Letouzey et al., this volume). The Carpathian Sea continues to evolve as a marginal basin.

b) The narrow oceanic trough which ran from the Tethys to the Atlantic north of Apulia has completely disappeared along the Alps (See Tollman, 1969 ; Haccard et al., 1972). To the south, on the contrary, the Mesogea, which is broadly opened toward the Atlantic, has reached its maximum size. Flysch continues to be deposited on both margins of the North African trough (from Lower Cretaceous to Eocene) (see Paquet, 1974). The tectogenesis of the Pyrénées, related to the final stage of opening of the Bay of Biscay, is now engaged (Choukroune et al, 1973 ; Mattauer et Henry, 1974).

c) This general collision to the east results in the fragmentation of Apulia and Anatolia.

The motion of Africa will now change and, until Ypresian (49 M.y.), will correspond to right lateral strike slip, because of the faster opening between Europe and North America than between Africa and North America. After this limited right-lateral motion, Africa will start rotating trigonometrically around a pole near Morocco, resulting in pure compression to the east (fig. 3).

5. Lutetian (plate IV)

a) To the west, this is the time of consumption of the narrow western extension of the Mesogea between Africa and Iberia, attested by overthrusts which include fragments of ophiolites (Durand-Delga, 1971 ; Andrieux et Mattauer, 1963 ; Bouillin et Kornprobst, 1974). Paquet (1974) has suggested that transverse wrench faults cut the southern margin of Iberia at this time. The small maximum size of this oceanic area and the slow rate of consumption might explain the absence of calco-alcaline volcanism.

b) This is also the time of the main phase of tectogenesis in the Pyrénées (Mattauer et Henry, 1974) and the Alps (see Debelmas et Lemoine, 1970 ; Caby 1973). The fragmentation of Apulia may help to explain the arcuate development of the Alps, as proposed by Laubscher (1969, 1971).

c) To the east, the oceanic area gets smaller, mostly by Transform faulting along the northern border of the Mesogea. Anatolia is now fully accreted to Arabia but a new active margin is initiated south of the Caucasus (see Khain, this volume).

d) The collision in the Rhodopian - Moesian area generates underthrusting associated with volcanism (Boccaletti et al., 1974) and new continental fragmentation with movement toward the west, to the west, and toward the east, to the east.

6. Stampian (plate VII)

a) The process of continental collision with progressive consumption of the oceanic areas continues to the east. In particular, the old marginal Carpathian basin (initiated in Jurassic) begins to get reduced in size (Contescu, 1974).

b) The present Western Mediterranean still does not exist (Wezel, 1974). However, to the north, the rifting will take place during Upper Oligocene - Aquitanian (Le Pichon et al., 1971 ; Hsu, Montadert et al. 1977). To the south, we assume the formation from Gibraltar to Calabria of a marginal basin located north of the continental fragments of Iberia (Kabylies, Peloritan and Calabria) along the North African consuming plate boundary.The Numidian flysches are deposited both in internal and external positions as proposed by Caire (1971), Wezel (1970), Hoyez (1974).

It is interesting to note that the fragmentation of Iberia corresponds to the migration of the Africa-Europe pole of rotation toward the west.

c) To the east, the Mesogea is being consumed from the west to the east. This will lead to the future development of the Tyrrhenian arc and the opening of the Western Mediterranean followed by the opening of the Tyrrhenian sea. It is the beginning of the Apennines orogenesis (Roman, 1970 ; Boccaletti et al., 1976 ; Haccard et al. 1972).

7. Tortonian (plate VIII)

The paleogeography gets very similar to the present one (Biju-Duval et al., 1977).

a) The Mesogea is being consumed along two arcs, the Calabrian and Aegean arcs and is progressively being reduced to the size of the present Eastern Mediterranean.

b) The opening of the Red Sea corresponds to a faster northward movement of Arabia. As a result, the fragmentation of Anatolia is accentuated. The North Anatolian fault is initiated and allows a migration of Anatolia to the west (e.g. McKenzie, 1972).

c) The Carpathian arc continues to evolve with the formation of the Pannonian basin, as a continental marginal basin (Stegena et al, 1975 ; Contescu, 1974).

d) The subduction ends to the west in North Africa (Magne et Raymond, 1974) and along Italy. It is the age of the main nappes emplacement. The western basin has essentially its present configuration although the Tyrrhenian is smaller than today. Its basins are deep, subsidence is continuous, and Messinian salt deposition will occur in the deepest area, the margins being then affected by erosion (Montadert et al. 1977).

IV. CONCLUSIONS

The evolution from the Tethys to the present Mediterranean occurred in two main stages

1. From Triassic to Uppermost Cretaceous

Africa is moving left laterally with respect to Europe. The paleogeography is essentially controlled by the plate tectonic evolution of three intermediate plates, Iberia, Apulia and Anatolia, with respect to the two major plates, Africa and Eurasia. We adopted the hypothesis of a marginal basin for the Carpathian flyschs basin and for the Black Sea. We did not however try to reconstruct the evolution of the Hellenides in terms of marginal basins, although we do not exclude this possibility which is compatible with our scheme.

In Early Mesozoic, the paleogeography is characterized by a wide Tethys ocean between Europe and Africa. Its exact surface is difficult to define precisely. Previous studies had minimized the extent of the basement overthrusts in the Alps, the Dinarides and the Hellenides etc... Recent studies tend to increase them considerably (see Aegean Congres, Paris ; Tollmann, 1969 ; Derycke et al., 1974 ; Ferrière, 1974). The analysis of the different superposed metamorphic units of alpine age leads to an increasing surface estimate for the now tectonized initial cratons. Is it possible to get further than we have done and to completely eliminate the oceanic surface extending from the Carpathians to the Alps ? In any case, the existence of the Eastern Tethys between the Apulian margin, now incorporated into the Dinarides and Hellenides, the Anatolian margin, now incorporated into the Pontides, and the Rhodope and European margins, is difficult to doubt. The presence of the Eastern Tethys may be inferred from the volcanic activity in Pontides caucasus which suggests its subduction under Europe since Triassic. The geometry of the Tethys is partly controlled by the position of North Africa with respect to the old African shield. We did not take into account a possible deformation due to intra-African fractures, in particular the so-called "South Atlas" fault system (Dubourdieu, 1962).

The kinematics of Apulia cannot be directly deduced from the kinematics of the Africa-Europe plates system. Does Apulia collide with Europe as early as Uppermost Jurassic or does the corresponding Jurassic ophiolites obduction occur on the margin of an oceanic basin ? We have chosen, in this paper, the first solution whereas we developed the second one in an earlier paper (Biju-Duval et al., 1976 a). The large amount of clastic turbiditic deposits in the alpine belts during Upper Jurassic - Berriasian seems to us to be easier to interpret if high reliefs have been produced by continental collision. The alternative is still open.

From Triassic to Jurassic, a period of distension, which manifests itself in particular in the formation of continental margins affects the whole area. This is the time during which the Mesogea was formed in the wake of Apulia. After the Upper Jurassic-Lower Cretaceous collision of Apulia with Europe, intracontinental fractures cut Apulia in three sections.

During Cretaceous, the portions of Apulia situated to the east and to the west of the Upper Jurassic collision zone also collide with Europe. Consequently, the initial Tethys has been completely consumed in Maestrichtian time whereas the Mesogea has reached its maximum size.

2. From Uppermost Cretaceous to Present

Africa ceases to move left laterally and starts a right-lateral motion of limited extent until Ypresian. Then it rotates trigonometrically about a pole of rotation close to Morocco, thus resulting in north-south compression to the east. This is a time of intracontinental collision during which the concept of plates is difficult to use any more. The collision of Apulia and Anatolia with Europe results in an intracontinental fragmentation accompanied by large strike-slip faulting which allows the formation of important overthrusts in the Alps.

The Mesogea starts being consumed ; this consumption is accompanied by the creation of heterochronous marginal basins (the Balearic and Tyrrhenian basins). The remnents of the Eastern Mesogea correspond to the present Eastern Mediterranean where the Aegean marginal basin is barely initiated. The consumption of the Carpathian flyschs marginal basin is closely related to the Pannonian basin distension which is marked by very active volcanicity.

We have not taken into account the paleomagnetic data for the reconstruction of the positions of the intermediate plates, as we feel that they still are inadequate for this purpose. Due to a lesser quality of geological data, the reconstructions of Anatolia are less precise than those of the other parts of the Mediterranean area.

We are aware that we did not have enough constraints to reconstruct unambignously the position of Apulia and Anatolia. As we pointed out earlier, we previously chose another solution in which Apulia collides later with Eurasia with a much smaller rotation during Jurassic. If this is so, we would have only to change the Dogger and Upper Jurassic paleogeographic maps. It is clear that the answer to this problem lies primarily in a better knowledge of the evolution of the paleomagnetic poles for the intermediate plates.

However, although this model is far from being final, it suggests some interesting new geologic problems.

a) Great differences exist between the Mesozoic and Cenozoic sedimentary history and tectonic development. During the Mesozoic, in spite of great uncertainties in the plates positions, the size of the oceans and the exact locations of subduction zones, a comparison can be attempted with present oceans and the tectonic evolution of their associated marginal basins. But, in Cenozoic, after the continental collision occurring in Late Cretaceous between Africa and Europe, the tectonic development changes completely because of reduced oceanic areas and intracontinental fragmentation with large strike-slip faulting which makes comparison with present oceanic margins quite dubious.

b) The former Tethys ocean has completely disappeared. The present Mediterranean basins are either remnants of the Mesozoic Mesogea created by rifting in the wake of the motion of Apulia - or marginal type basins (whether oceanic or intracontinental) associated to a subduction zone.

c) The recent history of the Mediterranean basins (which includes subsidence, the Messinian evaporitic episode, the continuous Africa-Europe collision) masks differences.

d) The importance given to intracontinental strike-slip faulting suggests a new examination of different portions of the Alpine belt.

e) The presence of a Mesogea which is being consumed to the north and west suggests a revision of the schemes of evolution which have been proposed for the Hellenides, and of the relationship between Calabria and the Apennines.

f) The major roles given to the Dobroudgea and Isparta geologic features should be confirmed by more detailed studies.

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BIBLIOGRAPHY

ABBATE E., BORTOLOTTI V., PASSERINI P., SAGRI M. (1970).- Introduction to the Geology of the Northern Apennines. Sediment. Geol. 4, n° 3-4, 207-250

ADAMIA S.A. (1975).- Plate tectonic and the evolution of the Alpine System : discussion. Geol. Soc. Amer. Bull., 86, n° 5, 719-720

ALVAREZ W., GOHRBANDT K.H.A. (1970).- Geology and History of Sicily Tripoli. Petr. Explor. Soc. Libya, 291 p. (12th annual field conference)

ALVAREZ W. (1972).- Rotation of the Corsica Sardinia microplate Nature (Phys. Sci.), 235, 103-105

ALVAREZ W., COCOZZA T., and WEZEL F.C. (1974).- Fragmentation of the Alpine orogenic belt by microplate dispersal Nature (Phys. Sci.), 248, 309-314

ANDRIEUX J., MATTAUER M. (1963).- Sur la présence de roches vertes à la base des nappes ultra du Rif. Soc. Géol. France, Compt. Rend., 213-215

ANDRIEUX J. (1971).- La structure du Rif central. Etude des relations entre la tectonique de compression et les nappes de glissement dans un tronçon de la chaîne alpine. *Notes Mem.* Serv. Geol. Maroc, 235, 1-155

APOSTOLESCU V., BIJU-DUVAL B., GONNARD R., LETOUZEY J., DEVAUX E. (1975).- Synthèse des données géologiques et géophysiques de la Méditerranée occidentale. Internal Report Inst. Franc. Pétrol. Ref. 23458

ARGYRIADIS I. (1975).- Mésogée permienne, chaîne hercynienne et cassure téthysienne. Soc. Géol. France, Bull. (7), XVII, 56-70

AUBOUIN J. (1960).- Essai sur l'ensemble italo-dinarique et ses rapports avec l'arc alpin. Soc. Géol. France, Bull. (7), II, 487-526

AUBOUIN J. (1963).- Essai sur la paléogéographie post-triasique et l'évolution secondaire et tertiaire du versant Sud des Alpes orientales (Alpes méridionales ; Lombardie et Venétie, Italie ; Slovenie occidentale, Yougoslavie). Soc. Géol. France, Bull. (7), V, 730-766

AUBOUIN J., NDOJAJ I. (1964).- Regards sur la Géologie de l'Albanie et sa place dans la géologie des Dinarides. Soc. Géol. France, Bull. (7), VI, 593-625

AUBOUIN J., BLANCHET R., CADET J.P., CELET P., CHARVET J.
CHOROWICZ J., COUSIN M., RAMPNOUX J.P. (1970).- Essai sur la géologie des Dinarides. Soc. Géol. France, Bull. (7), XII, 1060-1095

AUZENDE J.M., OLIVET J.L., BONNIN J. (1972).- Une structure compressive au Nord de l'Algérie : Deep-Sea Res., 19, n° 2, 149-155

AZEMA J., BOURROUILH R., CHAMPETIER Y., FOURCADE E., RANGHEARD X. (1974).- Rapports stratigraphiques, paléogéographiques et structuraux entre la Chaîne ibérique, les Cordillères bétiques et les Baléares. Soc. Géol. France, Bull. (7), XVI, 140-160

BARRETT D.L., KEEN C.E. (1976).- Mesozoic Magnetic lineations, the Magnetic Quiet zone, and Sea Floor Spreading in the North west Atlantic. J. Geophys. Res., 81, n° 26, 4875-4884

BAYER R. LE MOUEL J.L., LE PICHON X. (1973).- Magnetic anomaly pattern in the western Mediterranean : Earth Planetary Sci. Lett., 19, 168-176

BEIN A. (1976).- Rudistic Fringing Reefs of Cretaceous shallow Carbonate Platform of Israël. Amer. Ass. Petrol. Geologists, Bull., 60, n° 2, 258-272

BERGOUGNAN H. (1975).- Relations entre les édifices pontique et taurique dans le Nord-Est de l'Anatolie. Soc. Géol. France, Bull. (7), XVII, 1045-1057

BERNOULLI D., LAUBSCHER H. (1972).- The palinspatic problem of the Hellenides. Eclogae Geol. Helv., 65, 107-118

BERNOULLI D., JENKYNS H.C. (1974).- Alpine, Mediterranean and central Atlantic Mesozoic facies in relation to the early evolution of the Tethys. In : Modern and Ancient Geosynclinal sedimentation, R.H. Dott and R.H. Shaver, edit. Tulsa, Soc. Econ. Pal. Mineral., 129-160 (Spec. Bull. n° 19)

BEZZI A., PICCARDO G.B. (1971).- Structural features of the ligurian ophiolites : Petrologic evidence for the "oceanic" floor of the Northern-Apennines geosyncline : A contribution to the problem of the Alpine type gabbro-peridotite association. Mem. Soc. Geol. Ital., 10, 53-64

BIJU-DUVAL B. (1974).- Commentaires de la carte géologique et structurale des bassins tertiaires du domaine Méditerranéen. Rev. Inst. Franc. Pétrol., 29, n° 5, 607-639

BIJU-DUVAL B., LETOUZEY J., MONTADERT L., COURRIER P., MUGNIOT J.F.
SANCHO J. (1974).- Geology of the Mediterranean Sea Basins. In : The Geology of continental Margins Drake and Burk Edit. New-York, Heidelberg, Berlin, Springer Verlag, 695-721

BIJU-DUVAL B., DERCOURT J., LE PICHON X. (1976a).- La genèse de la Méditerranée. La Recherche, 7, n° 71, 811-822

BIJU-DUVAL B., DERCOURT J., LE PICHON X., APOSTOLESCU V. (1976b).- Evolution from Tethys to Mediterranean Basins. Abstract In XXV° Congrès CIESM Split in press

BIJU-DUVAL B., LAMPEREIN C., RIVEREAU J.C., LOPEZ N. (1976c).- Commentaires de l'Esquisse Photogéologique du Domaine Méditerranéen grands traits structuraux à partir des images du satellite Landsat 1. Rev. Inst. Franc. Pétrol. 31, 365-400

BIJU-DUVAL B., LETOUZEY J., MONTADERT L. (1977).- Structure and Evolution *of the Mediterranean Sea Basins.* In : Initial Report of DSDP, vol. XXXXII, Washington (U.S. Government Printing Office) in press

BLANCHET R., CADET J.P., CHARVET J., RAMPNOUX J.P. (1969).- Sur l' existence d'un important domaine de flysch tithonique-crétacé inférieur en Yougoslavie : l'unité du flysch bosniaque. Soc. Géol. France, Bull. (7), XI, 871-880

BOCCALETTI M., ELTER P., GUAZZONE G. (1971).- Plate tectonic models for the development of the western Alps and Northern Apennines, Nature (Phys. Sci.), 234, n° 49, 108-111

BOCCALETTI M., GUAZZONE G. (1972).- Remnant arcs and marginal basins in the Cainozoic development of the Mediterranean, Nature, (Phys. Sci.) 242, 18-21

BOCCALETTI M., GUAZZONE G. (1974a).- Remnant arcs and marginal basins in the Cainozoic development of the Mediterranean, Nature, 252, 18-21

BOCCALETTI M., MANETTI P., PECCERILLO A. (1974b).- Hypotheses on the plate tectonic evolution of the Carpatho-Balkan arcs. *Earth Planetary Sci. Lett.*, 23, 193-198

BOCCALETTI M., HORVATH F., LODDO M. MONGELLI F., STEGENA L. (1976).- The Ty-rhenian and Pannonian Basins : A comparison of two Mediterranean interarcs bassins. Tectonophysics, 35, 45-69

BOGDANOFF A.A., MOURATOV M.V., SCHATSKY N.S. (1964).- Tectonique de l'Europe ; notice explicative pour la carte tectonique internationale de l'Europe au 1:2 500 000 Nanka, Moscou, Nedra ... Congrès géol. Intern.) 360 p.

BOSELLINI A., HSU K.J. (1973).- Mediterranean Plate tectonics and Triassic Paleogeography, Nature, 244, n° 5412, 144-146

BOUILLIN J.P., DURAND DELGA M., GELARD J.P., LEIKINE M., RAOULT J.F.,
RAYMOND D., TEFIANI M., VILA J.M. (1970).- Définition d'un flysch massylien et d'un flysch mauretanien au sein des flyschs allochtones d'Algérie. Compt. Rend. Acad. Sci. Fr., 270, 2249-2252

BOUILLIN J.P., KORNPROBST J. (1974).- Associations ultrabasiques de petite Kabylie : péridotites de type alpin et complexe stratifié comparaison avec les zones internes bético-rifaines. Soc. Géol. France, Bull. (7), XVI, 183-194

BOUSQUET J.C. (1973).- La tectonique récente de l'Apennin calabro-lucanien dans son cadre géologique et géophysique. Geol. Romana, 22, 104 p.

BRINKMANN R. (1972).- Mesozoic troughs and crustal structure in Anatolia. Geol. Soc. Amer. Bull., 83, n° 3, 819-826

BRUNN J.H., DUMONT J.F., GRACIANSKY P. ch. de., GUTNIC M., JUTEAU
Th., MARCOUX J., MONOD O., POISSON A. (1971).- Outline of the geology of the western Taurids. In Geology and History of Turkey A.S. Cambell Edit. Tripoli, Petr. Explor. Soc. Libya, 225-255 (13th annual field conference)

BULLARD E.C., EVERETT J.E., SMITH A.G. (1965).- The fit of the continents around the Atlantic. In Symposium continental drift, P. M.S. Blackett. E. Bullard and S.K. Runcorn, edit., Phil. Trans. R. Soc. London, A. 1088, 1-51

BUREAU DE RECHERCHES GEOLOGIQUES ET MINIERES, SOCIETE ELF RECHERCHE, SOCIETE ESSO DE RECHERCHE ET D'EXPLOITATION DU PETROLE, SOCIETE NATIONALE DES PETROLES D'AQUITAINE (1974).- Géologie du Bassin d'Aquitaine, Paris, B.R.G.M., 27 pls.

BUSNARDO R., CHENEVOY M. (1962).- Dolérites intrusives dans le lias et de dogger d'Andalousie. Leurs différenciations pegmatitiques alcalines et auréoles de Métamorphisme. Soc. Géol. France, Bull. (7), IV, 461-470

BUSSON G. (1972).- Principes, méthodes et résultats d'une étude stratigraphique du Mésozoïque saharien. Mém. Mus. Nat. Hist. Nat., Nouv. sér., C, XXVI, 441 p.

CABY R. (1973).- Les plis transversaux dans les Alpes occidentales, implications pour la genèse de la chaîne alpine. Soc. Géol. France, Bull. (7), XV, 624-634

CAIRE A. (1971).- Chaînes alpines de la Méditerranée centrale. In : Tectonique de l'Afrique, Paris, UNESCO, "Sciences de la Terre n° 6, 61-90

CAMPBELL A.S. ed. (1971).- Geology and History of Turkey, Tripoli. Petr. Expl. Soc. Libya, 511 p. (13th annual field conf.)

CELET P., CLEMENT B., FERRIERE J. (1976).- La zone béotienne en Grèce : implications paléogéographiques et structurales. Eclogae. Geol. Helv., 69, n° 3, 577-599

CHANNEL J.E.T., HORVATH F. (1976).- The African - Adriatic Promontory as a palaeogeographical premise for alpine orogeny and plate movements in the Carpatho-Balkan region. Tectonophysics, 35, 71-101

CHARVET J. (1973).- Sur les mouvements orogéniques du Jurassique - Crétacé dans les Dinarides de Bosnie orientale. Compt. Rend. Acad. Sci. Fr., 276, sér. D, 257-259

CHOUKROUNE P., LE PICHON X., SEGURET M. SIBUET J.C. (1973).- Bay of Biscay and Pyrénées, Earth Planetary Sci. Lett., 18, 110-118

CIRIC B. (1966).- The magmatism of Montenegro, a geological Survey Bull. Inst. Geol. Geophys. Res., Beograd, 22-23, 17-33

CONANT L.C., GOUDARZI G.H. (1967).- Stratigraphic and tectonic framework of Libya : Amer. Assoc. Petrol. Geologists Bull., 51, n° 5, 719-730

CONTESCU L.R. (1974).- Geologic history and paleogeography of Eastern Carpathians : example of Alpine Evolution. Amer. Assoc. Petrol. Geologists Bull., 58, n° 12, 2436-2476

CORTESOGNO P., GIANELLI G., PICCARDO G.B. (1975).- Preorogenic metamorphic and tectonic evolution of the ophiolite mafic rocks (northern Apennine and Tuscany), Boll. Soc. Geol. Ital., 94, 291-327

DAL PIAZ V., HUNZIKER J.C., MARTINOTTI G. (1972).- La zona Sesia-Lanzo e l'evoluzione tettonico metamorfica delle alpi nord occidentali interne. Mem. Soc. Geol. Ital., XI, 433-460

DAL PIAZ V. (1974).- Le métamorphisme de haute pression et basse température dans l'évolution structurale du bassin ophiolitique alpino-apenninique (1° partie) : considérations paléogéographiques. Boll. Soc. Geol. Ital., 93, 437-468

DEBELMAS J., LEMOINE M. (1970).- The Western Alpś : palaegeography and structure. Earth. Sci. Rev., 6, n° 4, 221-256

DEBELMAS J. (1972).- A propos de quelques synthèses récentes sur la genèse de l'arc alpino-apenninique. Rev. Géogr. Phys. Géol. dyn. XIV, 3, 229-241

DECANDIA F.A., ELTER P. (1972).- La zona ofiolitifera del Bracco nel Settore compresso fra Levanto e lo Val Graveglia (Apennino ligure). Mem. Soc. Geol. Ital., XI, 503-530

DERCOURT J. (1970).- L'expansion océanique actuelle et fossile ; ses implication géotectoniques. Soc. Géol. France, Bull. (7), XII, 261-317

DERCOURT J., CELET P., COTTIN J.Y., DE WEVER P., FERRIERE J., GRANDJACQUET C., HACCARD D., TERRY J., WIGNIOLLE E. (1976).- Importance d'une tectonique jurassique supérieur sur les marges de la plaque d'Apulie (Hellenides et Apennin ligure). Coll. ATP Montpellier, Soc. Géol. France in press.

DERYCKE F., GODFRIAUX I., ROBASZYNSKY F. (1974).- Sur quelques paragenèses du métamorphisme de haute pression-basse température dans l'axe et le pourtour de la fenêtre de l'Olympe (Grèce). Compt. Rend. Acad. Sci. Fr., 279, sér. D, 227-230

DEWEY J.F., PITMAN W.C. III, RYAN W.B.F., BONNIN J. (1973).- Plate Tectonics and the evolution of the Alpine system. Geol. Soc. Amer. Bull., 84, n° 10, 3137-3180

DEWEY J.F. (1976).- Ophiolite obduction. Tectonophysics, 31, 93-120

DIETRICH D., SCANDONE P. (1972).- The position of the basic and ultrabasic rocks in the tectonic units of the Southern Apennines. Att. della Accad. Pont., XXI, 1-15

DIMETRIJEVIC M.D., DIMETRIJEVIC M.N. (1973).- Olistostrome melange in the Yugoslavian Dinarides and Late Mesozoic Plate tectonics. J. Geol., 81, 328-340

DIMETRIJEVIC M.D. (1974).- The Dinarids : a model based on the new global tectonics. In : Jankovic S., Metallogeny and concepts of the geotectonic development of Yugoslavia. Belgrade. 141-178

DUBOURDIEU M. (1962).- Déplacement et déformation du pourtour de la Méditerranée occidentale depuis la fin du Miocène. Compt. Rend. Acad. Sci. Fr., 254, 2029-2031

DURAND DELGA M., LAMBERT A. (1955).- Existence d'un flysch schisto-gréseux tithonique aux abords des massifs anciens kabyles. Soc. Géol. France, Compt. Rend., 200-203

DURAND DELGA M. (1969).- Mise au point sur la structure du Nord-Est de la Berbérie. Publ. Serv. Geol. Algérie (N.S) 39, 89-131

DURAND DELGA M. (1971).- Les unités à mésozoïque métamorphique d'El Milia à Texenna (Algérie) et leur cadre structural. Soc. Géol. France, Bull. (7), XIII, 328-337

DZOTSENIDZE A.D. (1968).- Essai of comparison of the Meso-cenozoic magmatism of the caucasus, Crimea, Balkans and the Carpathians. Int. Geol. Congr., 23d, Prague, Proc. Sect. 2, 81-98

ELTER P., PERTUSATI P. (1973).- Considerazioni sul limite alpi-appennino sur relazioni con l'arco delle alpi occidentali. Mem. Soc. Geol. Ital., 12, 359-375

ENAY R. (1972).- Paléobiogéographie des Ammonites du Jurassique terminal (Tithonique-Volgien-Portlandien l.s.) et mobilité continentale. Soc. Géol. France, Compt. Rend., 163-168

ENTE NAZIONALE IDROCARBURI (1962-1971).- Colombo, Carlo, ed., Enciclopedia del Petrolio e del gaz naturale, v. 1-8

FALLOT P. (1945).- Estudios geologicos en la zona subbetica entre Alicante y el Rio Guadiana Menor ; Madrid ; Publ. Inst. "Lucas Malladas", C.S.I.C., 719 p.

FALLOT P. (1948).- Les cordillères bétiques. Est. Geol., 8, 83-172 Madrid (Cons. Sup. Invest. Cient. - Inst. Invest geol "Lucas Mallada")

FERRIERE J. (1974).- Etude géologique d'un secteur des zones helleniques internes subpélagonienne et pélagonienne (massif de l'Othrys - Grèce continentale). Importance et signification de la période orogénique anté Crétacé supérieur. Soc. Géol. France, Bull. (7), XVI, 543-562

FINETTI I., MORELLI C. (1973).- Geophysical exploration of the Mediterranean Sea. Boll. Geofis. Teorica. Appl., 15, n° 60, 263-341

FONBOTE J.M., PUINTERO L. (1960).- Lavas almohadillas (pillow-lavas) en los afloramientos volcanicos de la transversal Iznallos-Jaen (Cordilleras beticas). Notas comun. Inst. Geol. Miner. Espan., n° 60, 85-90

FOURQUIN C. (1975).- L'anatolie du Nord-Ouest, marge méridionale du continent européen, histoire paléogéographique, tectonique et magmatique durant le secondaire et le tertiaire. Soc. Geol. France, Bull. (7), XVII, 1058-1070

FRANCHETEAU J. (1973).- Plate tectonic model of the opening of the Atlantic ocean south of the Azores. In : Implication of Continental Drift to the Earth Sciences, ed. D.H. Tarling and S.K. Runcorn, 1, London, Academic Press, 197-202

GASS I.G. (1968).- Is the Troodos massif of Cyprus a fragment of Mesozoïc ocean floor ? Nature, 220, n° 5162, 39-42

GECZY B. (1973).- Plate tectonics and paleogeography in the east mediterranean mesozoic. Acta. Geol. Acad. Sci. Hung., 17, 421-428

GEYSSANT J., TOLLMANN A. (1966).- Réunion extraordinaire de la S.G.F. Alpes autrichiennes. Soc. Géol. France, Compt. Ren., 413-472

GINZBURG A., COHEN S.S., HAY-ROE H., ROSENZWEIG A. (1975).- Geology of Mediterranean shelf of Israël. Amer. Ass. Petrol. Geologists, 59, n° 11, 2142-2160

GRAY C. ed. (1971).- Symposium on the geology of Libya. Tripoli, Faculty of Science, Univ. Libya, 522 p.

HACCARD D., LORENZ C., GRANDJACQUET C. (1972).- Essai sur l'évolution tectogénétique de la liaison Alpes-Apennins (de la Ligurie à la Calabre). Mem. Soc. Geol. Ital., XI, 309-341

HADZI E., PANTIC N., ALEKSIC V., KALENIC M. (1974).- The Alpides of Southeastern Europe in the light of plate tectonics. In : Jankovic op. cité, 275-310

HAWKESWORTH C.J., WATERS D.J., BICKLE M.J. (1975).- Plate tectonics in the Eastern Alps, Earth Planetary Sci. Lett., 24, n° 3, 405-413

HAYES D.E., RABINOWITZ P.D. (1975).- Mesozoic magmatic lineations and the magmatic quiet zone of the eastern North Atlantic, Earth Planetary Sci. Lett., 28, 105-115

HEIRTZLER J.R., DICKSON G.O., HERROW E.M., PITMAN W.C., LE PICHON X. (1968).- Marine magmatic anomalies, geomagmatic field reversals, and notions of the ocean floor and continents. J. Geophys. Res., 73, 2119-2136

HERZ N., SAVU H. (1974).- Plate tectonic history of Romanie. Geol. Soc. Amer. Bull., 85, n° 9, 1429-1440

HIRSCH F. (1976).- Sur l'origine des particularismes de la faune du Trias et du Jurassique de la plateforme africano-arabe. Soc. Geol. France, Bull. (7), XVIII, n° 2, 543-552

HORSTINK J. (1971).- The late Cretaceous and Tertiary Geological Evolution of Eastern Turkey. In : First Petrol. Cong. Turkey, Keskin C. and Demirmen F. Edit. Ankara, Ass. Turkish Petr. geologists, 25-41

HOYEZ B. (1974).- Cadre et évolution du bassin numidien sicilien. Compt. Rend. Acad. Sci. Fr., 278, sér. D, 1007-1010

HSU K.J. (1971).- Origin of the Alps and Western Mediterranean. Nature, 233, n° 5314, 44-48

HSU K.J., MONTADERT L. et al. (1977).- Initials Reports of the Deep Sea Drilling Project, vol. XXXXII, Washington (US Government Printing office) in press

HYNES A.J., NISBET E.G., SMITH A.G., WELLAND M.J.P., REX D.C. (1972).- Spreading and emplacement ages of some ophiolites in the Othrys region (Eastern Central Greece). Z. Deut. Geol. Ges. 123, n° 2, 455-468

INSTITUT FRANCAIS DU PETROLE ET INSTITUT DE GEOLOGIE DE GRECE (1966).- Etude géologique de l'Epire, Grèce nord-occidentale. Paris, Technip ed., 306 p.

JENKYNS H.C. (1970).- Submarine volcanism and the Toarcian pisolites et Western Sicily. Eclogae Geol. Helv., 63, 2, 549-572

JUTEAU T. (1970).- Pétrogenèse des ophiolites des nappes d'Antalya (Taurus Lycien oriental, Turquie). Leur liaison avec une phase d'expansion océanique active au Trias supérieur. Sci. Terre, 15, 3, 265-288

JUTEAU T., LAPIERRE H., NICOLAS A., PARROT J.F., RICOU L.E., ROCCI G., ROLLET M. (1973).- Les idées actuelles sur la constitution, l'origine et l'évolution des assemblages ophiolitiques mésogéens. Soc. Geol. France, Bull. (7), XV, 478-493

KESKIN C., DEMIRMEN F. Edit. (1971).- First Petroleum Congress of Turkey - Proceedings Ankara. Ass. Turkish Petrol. Geologists, 175 p.

KHAIN V.E., MILANOVSKY E.E. (1963).- Structure tectonique du Caucase d'après les données modernes. In : Livre à la Mémoire de P. Fallot, Soc. Géol. France, Mém. H. ser. 663-703

KLEMME H.D. (1958).- Regional geology of circum-Mediterranean region : Amer. Assoc. Petrol. Geologists Bull., 42, n° 3, 477-512

KRISTOFFERSEN Y. (1977).- Sea-floor spreading and the early opening of the North Atlantic, Earth Planetary Sci. Lett., in press.

KRISTOFFERSEN Y., TALWANI M. (1977).- The extinct triple junction south of Greenland and Tertiary motion of Greenland relation to North America. Geol. Soc. Amer. Bull., in press.

LAPIERRE H. (1975).- Les formations sédimentaires éruptives des nappes de Mamonia et leurs relations avec le massif du Troodos (Chypre occidental). Mém. Soc. Géol. France, N.S., t. LIV, 123, 1-132

LARSON R.L., PITMAN W.C. III (1972).- Worldwide correlation of Mesozoic magnetic anomalies and its implications. Geol. Soc. Amer. Bull., 83, 3645-3666

LAUBSCHER H.P. (1969).- Mountain Building. Tectonophysics, 7, n° 5-6, 551-563

LAUBSCHER H.P. (1971a).- Das Alpen Dinariden problem und die Palinspatik der Süduchen Tethys. Geol. Rundsch., 60, 819-833

LAUBSCHER H.P. (1971b).- The large scale kinematics of the Western Alps and the northern Apennines and its palinspatic implications. Amer. J. Sci., 271, 193-226

LE PICHON X., BONNIN J., SIBUET J.C. (1970).- La faille nord-pyrénéenne : faille transformante liée à l'ouverture du golfe de Gascogne. Compt. Rend. Acad. Sci. Fr., 271, ser. D, 1041-1044

LE PICHON X., SIBUET J.C. (1971).- Comments on the evolution of the Northeast Atlantic, Nature, 233, 257-258

LE PICHON X., BONNIN J., FRANCHETEAU J., SIBUET J.C. (1971).- Une hypothèse d'évolution tectonique du golfe de Gascogne. In Histoire structurale du golfe de Gascogne, Paris. Edit. Technip, "Coll. et séminaires" n° 22, 11-44

LE PICHON X., PAUTOT G., AUZENDE J.M., OLIVET J.L. (1971).- La méditerranée Occidentale depuis l'Oligocène. Schéma d'évolution : Earth and Planetary Sci. Lett., 13, n° 1, 145-152

LE PICHON X., SIBUET J.C., FRANCHETEAU J. (1977).- The fit of the continents around the North Atlantic ocean, Tectonophysics, in press

LIVRE JUBILAIRE M. SOLIGNAC (1973).- Ann. Mines et Geol. Tunis, n° 26, 643 p.

LUPU M. (1974).- The Southern Apuseni Zone of metaliferous Mountains. In : Tectonics of the Carpathian - Balkan Regions. Bratislava. Inst. Geol. Dionyz Stur. éd., 234-239

McKENZIE D. (1972).- Active tectonics of the Mediterranean region. Geophys. J., 30, n° 2, 109-185

MAGNE J., RAYMOND D. (1974).- Le Néogène "post-nappes" de la région de Dellys-Tizi Ouzou (Algérie), un enregistrement de l'évolution dynamique du NW de la Grande Kabylie après le Burdigalien. Soc. Géol. France, Bull. (7), XVI, 537-542

MAHEL M. édit. (1973).- Tectonic problems of the Alpine system Bratislava. Veda - Slovak Acad. Sci.

MAHEL M. édit. (1975).- Carte tectonique du système Carpathes - Balkans. Notice explicative. Paris UNESCO - Bratislava inst. Geol. Dionyz Stur., 9-44 (Sciences de la Terre n° 14)

MARTIN L. édit. (1967).- Guide-book to the Geology and history of Tunisia. Petr. Exploi. Soc. Libya. 9th annual field Conference, 293 p.

MATTAUER M., HENRY H. (1974).- Pyrénées in : Spencer A.M. ed. op. cit.

MATTAUER M., PROUST F. (1975).- La Corse alpine : un modèle de genèse du métamorphisme haute pression par subduction de croûte continentale sous du matériel océanique. Compt. Rend. Acad. Sci. Fr., 282, sér. D, 1249-1252

MAXWELL J.C. (1970).- The Mediterranean ophiolites and continental drift. In : Johnson H. edit. The megatectonics of continents and oceans, New Brunswick N.J. Rudgers Univ., 167-193

MONOD O. (1976).- La "courbure d'Isparta" : une mosaïque de blocs autochtones surmontés de nappes composites à la jonction de l'arc hellenique et de l'arc taurique. Soc. Geol. France, Bull. (7), XVIII, 521-532

MONTADERT L., MAUFFRET A., LETOUZEY J. (1977).- Messinian Event : seismic contribution. In : Initial Reports of the Deep Sea Drilling Project, vol. XXXXII, Washington op.cit.

MORELLI C. (1975).- Geophysics of the Mediterranean. Rapp. Comm. Int. Mer. Medit. Sp. Issue 7, 29-111

NAIRN A.E.M. edit. (1977).- The Mediterranean, vol. IV, New-York. Plenum, in press.

NEGRONI P. (1971).- Bassin Pannonien. Intern. Report IFP. Réf. 20492

OBERT D. (1974).- Phases tectoniques mésozoïques d'âge anté cénomanien dans les Bâbors (Tell nord-setifien, Algérie). Soc. Geol. France, Bull. (7), XVI, 171-176

OKAY H., DILEKÖZ E. edit. (1974).- Second Petroleum Congress of Turkey. Proceedings. Ass. Turk. Petrol. Geol., Ankara, 310 p.

OZGUL N. (1976).- Some Geological aspect of the Taurus orogenic belt (Turkey). Bull. Soc. Geol. Turkey, 19, 65-78

PAQUET J. (1974).- Tectonique éocène dans les Cordillères Bétiques : vers une nouvelle conception de la paléogéographie en Méditerranée occidentale. Soc. Géol. France, Bull. (7), XVI, 58-73

PITMAN W.C., TALWANI M. (1972).- Sea Floor spreading in the North Atlantic. Geol. Soc. Amer. Bull., 83, 619-649

RADULESCU D.P., SANDULESCU M. (1973).- The plate tectonic concept and the geological structure of the Carpathians. Tectonophysics, 16, 155-161

RAOULT J.F. (1974).- Géologie du centre de la chaîne numidique (N. Constantinois, Algérie). Soc. Géol. France, Mém. Nelle série, n° 121, 163 p.

REHAULT J.P., OLIVET J.L., AUZENDE J.M. (1974).- Le Bassin nord-occidental méditerranéen : structure et évolution. Soc. Géol. France, Bull. (7), XVI, 281-294

RICOU L.E. (1971).- Le croissant ophiolitique péri-arabe. UNe ceinture de nappes mises en place au Crétacé supérieur. Rev. Géogr. Phys. Géol. Dyn., (2), 13, 4, 327-350

ROMAN C. (1970).- Seismicity in Romania - Evidence for the sinking lithosphere. Nature, 228, 1176-1178

RYAN W.B.F., DANIEL J., STANLEY J., HERSEY J.B., FAHLQUIST D.A., ALLAN J.D. (1971).- The Tectonics and Geology of the Mediterranean Sea. In : The Sea, vol. IV, (II), 387-492, New York, Wiley

SAID R. (1962).- The Geology of Egypt, Amsterdam. Elsevier, 377 p.

SALEM R. (1976).- Evolution of Eocene - Miocene sedimentation Patterns in Parts of Northern Egypt. Amer. Ass. Petrol. Geologists Bull., 60, n° 1, 34-64

SANDER N.J. (1970).- In : Geology and History of Sicily, 43-132 op. cit.

SANDULESCU M. (1975).- In : Les Carpathes roumaines. Soc. Géol.

France, Bull. (7), XVII, 299-358

SOCIETE GEOLOGIQUE DE FRANCE (1962-1963).- Livre Mémoire Prof. P. Fallot

SOCIETE GEOLOGIQUE DE FRANCE (1970).- Géologie des Dinarides. Soc. Géol. France, Bull. (7), XII, 941-1124

SOCIETE GEOLOGIQUE DE FRANCE (1973).- L'arc de Gibraltar. Soc. Géol. France, Bull. (7), XV, 77-189

SOCIETE GEOLOGIQUE DE FRANCE (1974).- Débat sur la structure des Taurides occidentales. Soc. Géol. France, Bull. (7), XVI, 101-127

SOCIETE GEOLOGIQUE DE FRANCE (1975a).- Alpes maritimes franco-italiennes et Apennin septentrional. Soc. Géol. France, Bull. (7), XVII, 901-1014

SOCIETE GEOLOGIQUE DE FRANCE (1975b).- Anatolie. Soc. Géol. France, Bull. (7), XVII, 1015-1083

SOCIETE GEOLOGIQUE DE FRANCE (1976a).- Colloque sur la géologie des régions égéennes. Soc. Géol. France, Bull. (7), XVIII, 199-567. and Coll. intern. CNRS n° 244

SOCIETE GEOLOGIQUE DE FRANCE (1976b).- Réunion Extraordinaire en Corse. Soc. Géol. France, Bull. (7), XVIII, in press.

SOCIETE GEOLOGIQUE DU NORD (1970).- Mémoires du Centenaire.

SMITH A.G. (1971).- Alpine deformation and the oceanic areas of the Tethys, Mediterranean, and Atlantic : Geol. Soc. Amer. Bull., 82, n° 8, 2039-2070

SPENCER édit. (1974).- Mesozoic-Cenozoic orogenic belts data for orogenic studies - Edinburgh, Scottish Acad. Press, 809 p.(The Geol. Soc. Spec. Publ., n° 4)

STEGENA L., GECZY B., HORVATH F. (1975).- Late Cenozoic Evolution of the Pannonian Basin. Tectonophysics, 26, 71-90

SUBBOTIN S.I., SOLLOGUB V.B., PROSEN D., DRAGASEVIC T., MITUCH E. POSGAY R. (1969).- Junction of deep structure of the Carpatho-Balkan region with those of the Black and Adriatic Seas. Can. J. Earth Sci., 5, 1027-1035

TAPPONNIER P. (1976).- Essai d'interprétation globale de l'évolution tectonique du système alpin en Europe. Coll. Geodyn. Méditer. occid. Montpellier. CNRS, INAG, p. 176

TARLING D.H., MITCHELL J.G. (1976).- Revised Cenozoic polarity time scale - Geology, 4, n° 3, 133-136

TECHNIP Edit. (1971).- Histoire structurale du Golfe de Gascogne. t. 1 et t. 2. Inst. Fr. Pétrole. Collection "Colloques et séminaires" n° 22, 944 p., 315 fig.

TERRY J., MERCIER M. (1971).- Sur l'existence d'une série détritique beriasienne intercalée entre la nappe des ophiolites et le flysch éocène de la nappe du Pinde (Pinde septentrional, Grèce) Soc. Géol. France, Compt. Rend, 71-73

TERRY J. (1974).- Ensembles lithologiques et structures internes du Cortège ophiolitique du Pinde septentrional (Grèce). Construction d'un modèle pétrogénétique. Soc. Géol. France, Bull. (7), XVI, 204-213

THIERSTEIN H.R. (1977).- Biostratigraphy of marine Mesozoic sediments by calcareous nannoplankton, Third planktonic Conference Proceedings, in press.

TOLLMANN A. (1969).- Die tektonische Guederung des Alpen-Karpaten Bogens. Geol. Jahrfuch, 18, n° 10, 1131-1158

TRUILLET R. (1970).- In : Geology and History of Sicily. Petr. Expl. Soc. Libya op. cit.

TRUMPY R., HACCARD D. (1969).- Réunion extraordinaire de la Société géologique de France - Les Grisons. Soc. Géol. France, Compt. Rend., 329-396

TRUMPY R. (1971).- Stratigraphy in mountain belts. Quart. Geol. Soc London, 126, 293-318

TRUMPY R. (1975).- Penninic-Austroalpine boundary in the Swiss Alps. A presumed former continental margin and its problems. Amer. J. Sci., 275A, 209-238

TRUMPY R. (1976).- Du pelerin aux Pyrénées. Eclogae Geol. Helv., 29, n° 2, 249-264

VAN DER VOO R., FRENCH R.B. (1974).- Apparent polar Wandering for the Atlantic-Bordering Continents : late Carboniferous to Eocene. Earth. Sci. Rev., 10, 99-119

VINE F.J., MATTHEWS D.H. (1963).- Magnetic anomalies over oceanic ridges. Nature, 199, 947-949

VOGT P.R., ANDERSON C.L., BRACEY D.R. (1971).- Mesozoic magnetic anomalies, sea floor spreading and geomagnetic reversals in the southwest north Atlantic. Journal Geophys. Res., 66, 4796-4823

WEZEL F.C. (1970).- Numidian Flysch : an Oligocene early Miocene continental rise deposit off the African platform. Nature, 228, 275-276

WEZEL F.C. (1974).- Flyschs successions and the tectonic evolution of Sicily during the oligocene and early miocene. In : Guide book of the Geology of Italy. Petr. Expl. Soc. Libya

WILLIAMS C.A. (1975).- Sea floor spreading in the Bay of Biscay and its relationship to the North Atlantic. Earth Planetary Sci. Lett. 24, 440-456

WORZEL J.L. (1965).- Deep structure of coostal margins and mid-oceanic ridges. In : Submarine Geology and Geophysics, W.H. Whittard and R. Bradshaw éd., London. Butterworths, 335-361

YOUSSEF M.I. (1968).- Structural pattern of Egypt and its interpretation. Amer. Ass. Petrol. Geologists Bull., 52, 601-614

ZIEGLER W.H. (1975).- Outline of the Geological History of the West Europe. vol. 1. Wooland A.W. edit., 165-187. Barking, Essex. Applied. Science Publ.

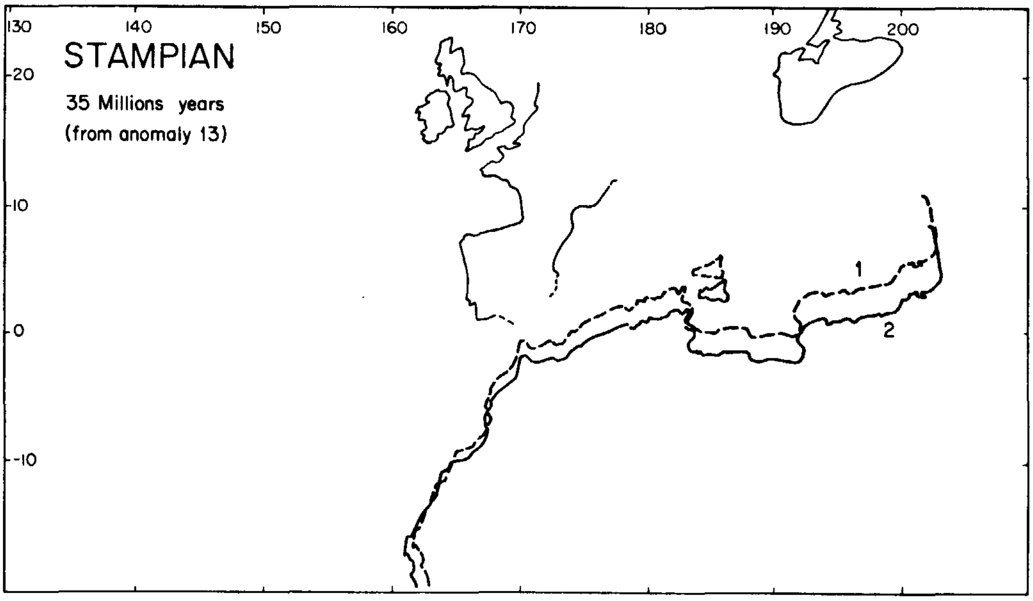
TABLE I

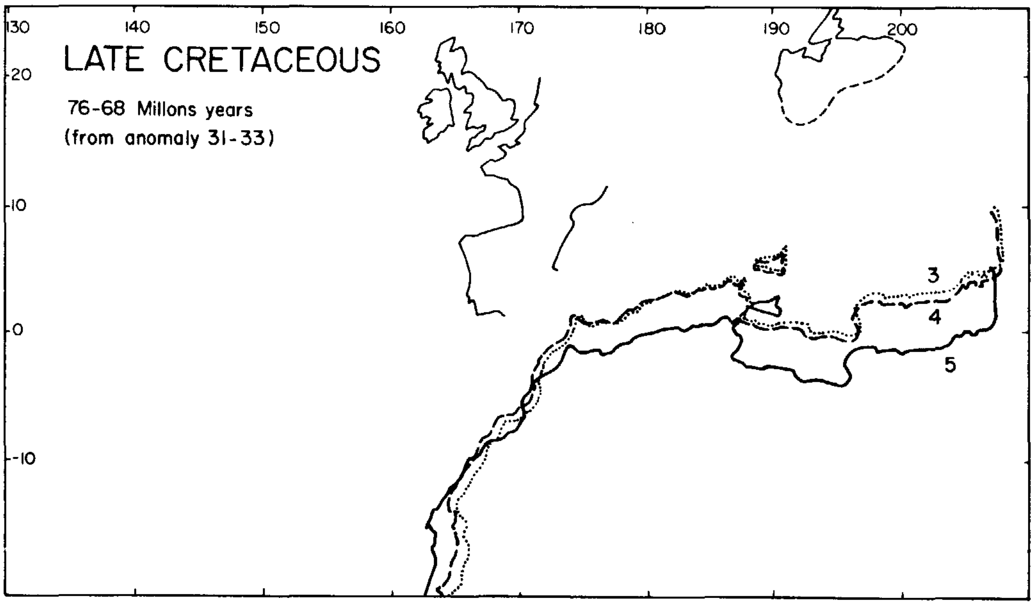
PARAMETERS USED FOR RECONSTRUCTION

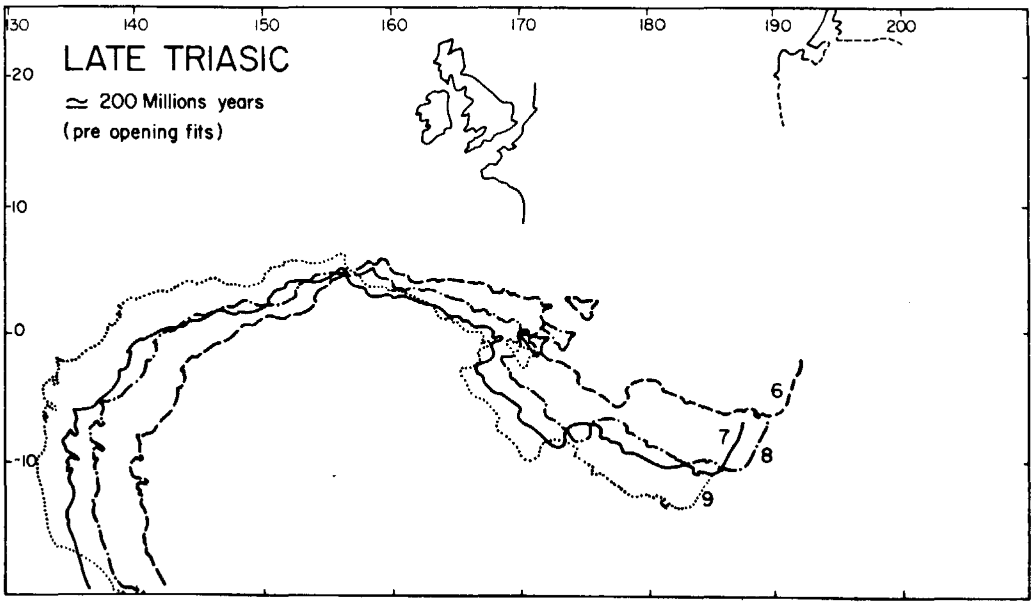
Anomaly	Age in M.y.	Geologic Age	Rotation applied to Africa Latitude	 Longitude	 Angle	Movement AF/NA	Movement NA/EU
	Initial	-	52.	- 0.4	- 49.6	Initial fit (1)	Initial fit (1)
M 25	148	Oxfordian	50.	- 2.1	- 41.4	Quiet zone fit(1)	Initial fit (1)
M 2	112	Barremien	45.7	2.6	- 31.5	(2)	Initial fit (1)
-	90	Cenomanian-Turonian	30.3	- 3.6	- 18.4	Interpolation	Initial fit (1)
31-33	76-68	Campanian Maestrichtian	20.1	- 11.3	- 16.0	(3)	(4)
24	49	Ypresian	31.9	- 16.6	- 14.8	(3)	(4)
21	44	Lutetian	33.7	- 18.8	- 12.9	(3)	(5)
13	35	Stampian	29.3	- 26.6	- 7.8	(3)	(5)
5	9	Tortonian	27.1	- 27.9	- 2.4	(3)	(5)

(1) Le Pichon et al (1977)
(2) Hayes and Rabinowitz (1975), Vogt et al (1971), Larson and Pitman (1972)
(3) Francheteau (1973)
(4) Kristoffersen (1977)
(5) Pitman and Talwani (1972)

Ages according to Tarling and Mitchell (1976) for anomaly 31 on, according to Thierstein (1977) prior to that. Positive latitude for north, positive longitude for east, convention for sign is negative when seen clockwise from pole of rotation.


STAMPIAN
35 Millions years
(from anomaly 13)
130
140
150
160
170
180
190
200
20
10
0
-10
1
2


LATE CRETACEOUS
76-68 Millons years
(from anomaly 31-33)
130
140
150
160
170
180
190
200
20
10
0
-10
3
4
5


LATE TRIASIC
≃ 200 Millions years
(pre opening fits)
130
140
150
160
170
180
190
200
20
10
0
-10
6
7
8
9

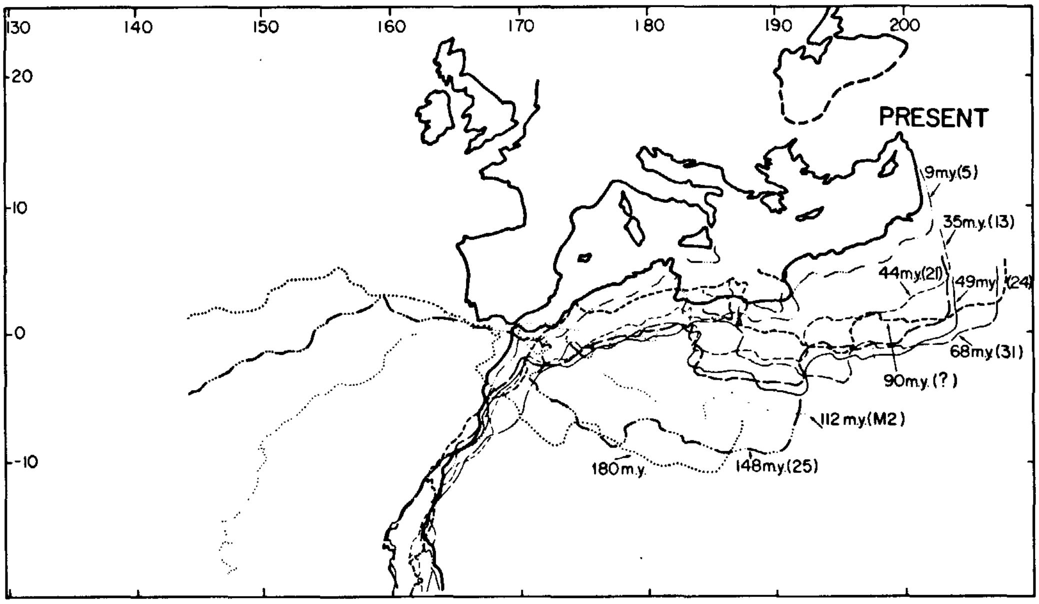
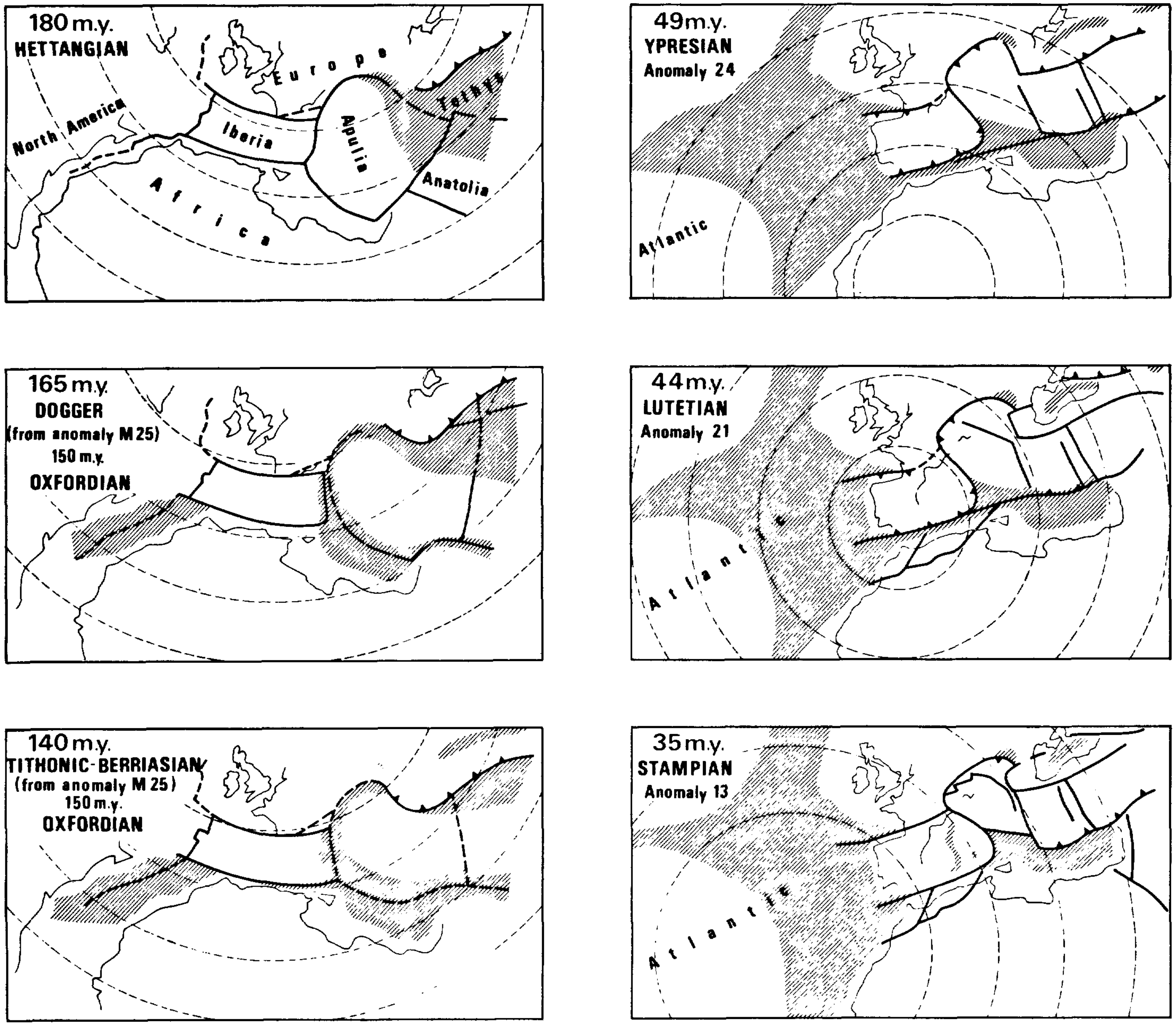


Figure 2 : Plate Kinematics of the Africa-Europe plate system. Parameters are given in table I.

← Figure 1 - Comparison of different kinematic models for the Africa displacements with respect to Europe in its present position. Oblique Mercator projection with pole at 52° N and 150° E as in all the maps of this paper. Numbers refer to references of table I : 1) - ref. 5 ; 2) - ref. 3 for Africa-America and ref. 5 for Europe-America ; 3) - ref. 3 for Africa-America and ref. 5 for Europe-America ; 4) - réf. 5 for both ; 5) - ref. 5 for Africa-America and ref. 4 for Europe-America ; 6) - Bullard et al. 1965 ; 7) - Dewey et al., 1973 ; 8) - ref. 1 for both ; 9) - ref. 1 for Africa-America and ref. 4 for Europe-America.


180 m.y.
HETTANGIAN
Europe
Tethys
North America
Iberia
Apulia
Anatolia
Africa
49 m.y.
YPRESIAN
Anomaly 24
Atlantic
165 m.y.
DOGGER
(from anomaly M 25)
150 m.y.
OXFORDIAN
44 m.y.
LUTETIAN
Anomaly 21
Atlantic
140 m.y.
TITHONIC-BERRIASIAN
(from anomaly M 25)
150 m.y.
OXFORDIAN
35 m.y.
STAMPIAN
Anomaly 13
Atlantic

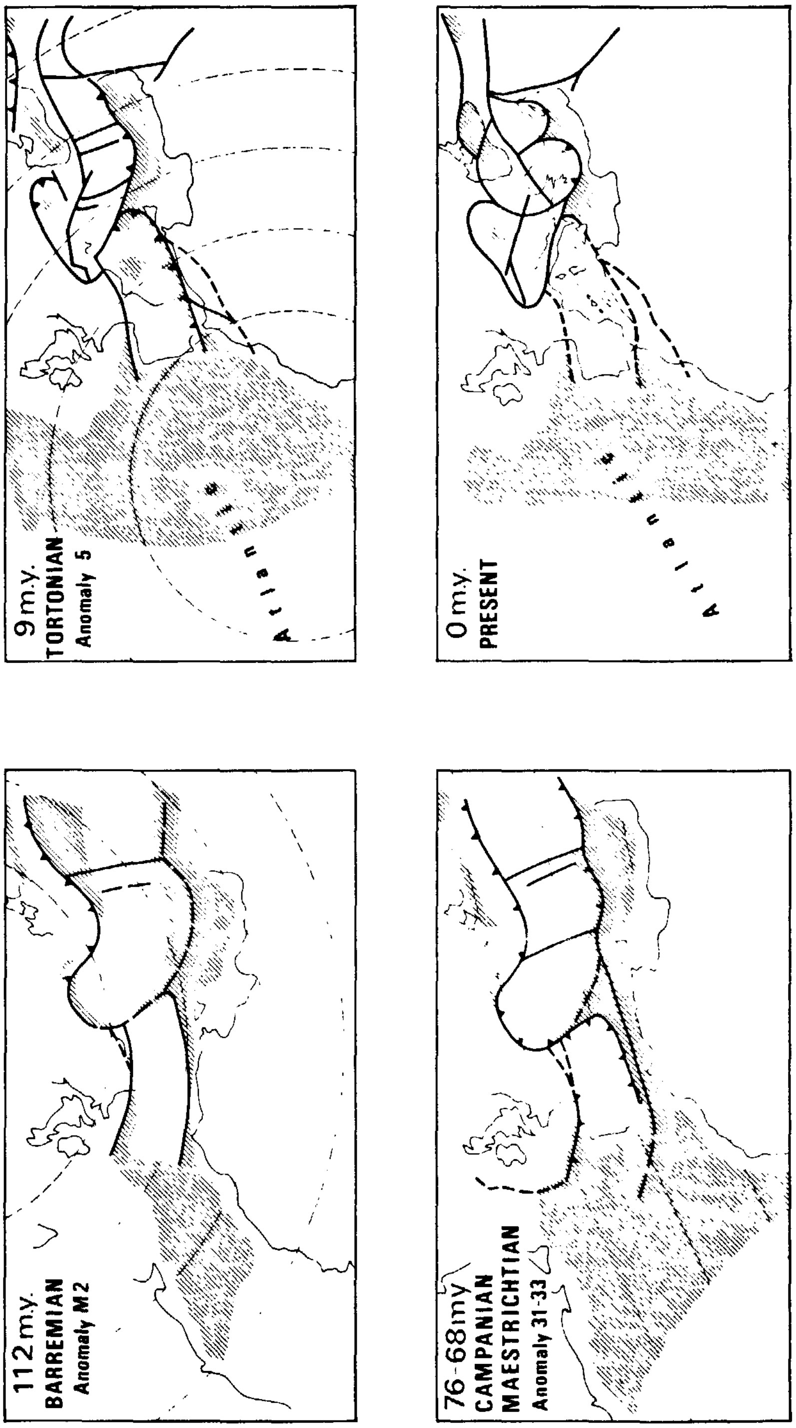
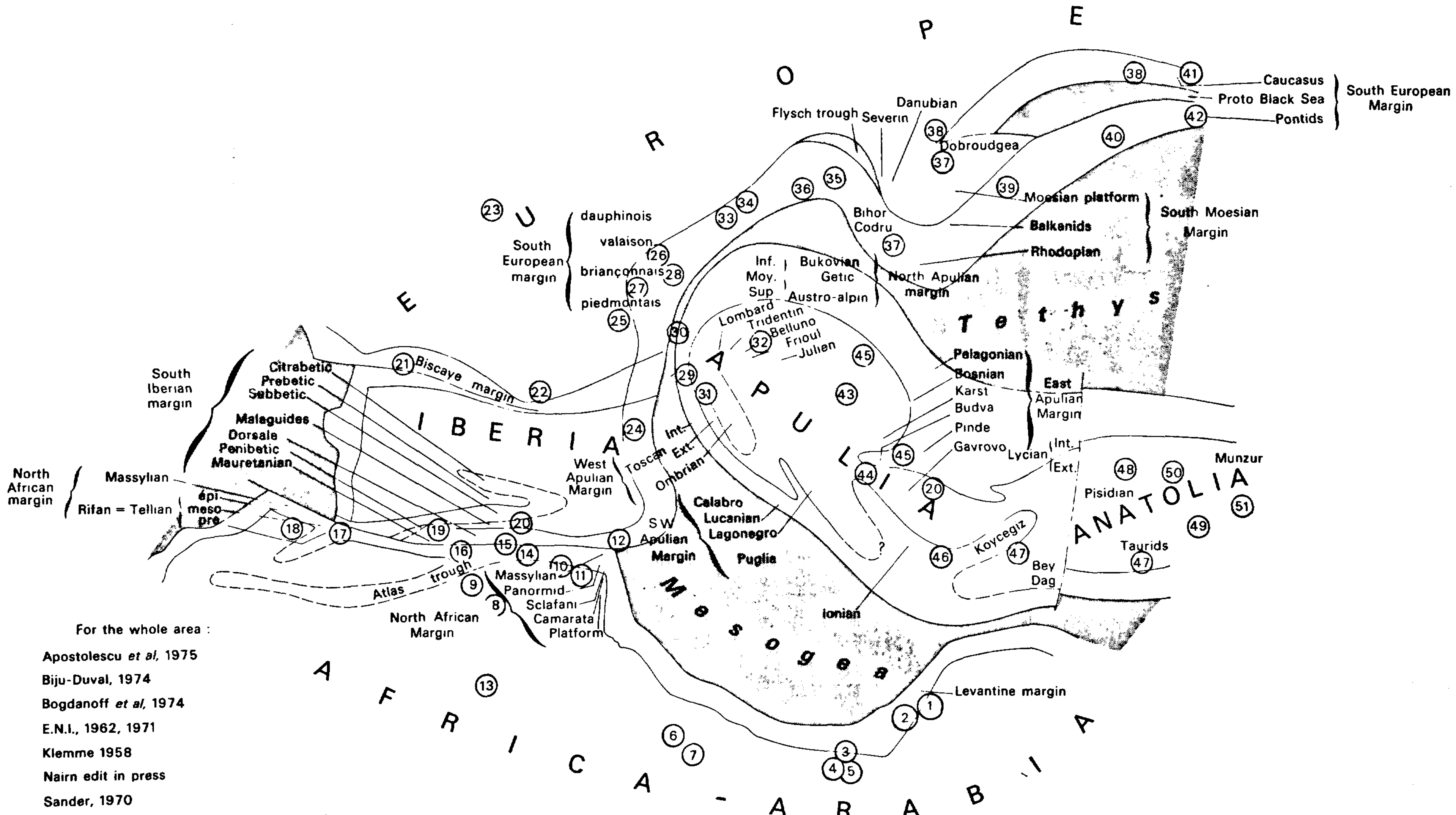


Figure 3 : Proposed evolution from the Tethys to the Mediterranean basins. Parameters are given in table I for positions of Africa. For positions of intermediate plates, see text. Small dotted circles are about pole of rotation of Africa with respect to Europe during the immediatly following period.



For the whole area :

Apostolescu *et al*, 1975
Biju-Duval, 1974
Bogdanoff *et al*, 1974
E.N.I., 1962, 1971
Klemme 1958
Nairn edit in press
Sander, 1970
S.G.F. mem, P. Fallot, 1962-63
S.G.F., 1974
Spencer edit, 1974

Figure 4

Main paleogeographic zones and general geological bibliography used in this paper illustreted on the Dogger reconstruction (see plate III). Numbers refer to following references (see detailed bibliography) : 1 - Ginzburg et al., 1975 ; 2 - Bein, 1976 ; 3 - Salem, 1976 ; 4 - Saïd, 1962 ; 5 - Youssef, 1968 ; 6 - Carlyle Gray edit, 1971 ; 7 - Conant and Goudarzi, 1967 ; 8 - Livre Jub. M. Solignac, 1973 ; 9 - PESL, Martin edit., 1967 ; 10 - Caire, 1971 ; 11 - PESL, Alvarez and Gahrbandt edit., 1970 ; 12 - Bousquet, 1973 ; 13 - Busson, 1972 ; 14 - Raoult, 1975 ; 15 - Bouillin et al., 1970 ; 16 - Durand Delga, 1969 ; 17 - S.G.F., 1973 ; 18 - Andrieux, 1971 ; 19 - Paquet, 1974 ; 20 - S.G.N., Mem. centenaire, 1970 ; 21 - Hist. Golfe Gascogne, Technip edit., 1971 ; 22 - BRGM, 1974 ; 23 - Ziegler, 1975 ; 24 - S.G.F., 1976 b ; 25 - Debelmas et Lemoine, 1970; 26 - Trumpy, 1975 ; 27 - Caby, 1973 ; 28 - Trumpy et Haccard, 1969 ; 29 - Haccard et al., 1972 ; 30 - S.G.F., 1975 ; 31 - Abbate et al., 1970 ; 32 - Aubouin, 1963 ; 33 - Tollmann, 1969 ; 34 - Geyssant et Tollmann, 1966 ; 35 - Sandulescu, 1975 ; 36 - Boccaletti et al., 1976 ; 37 - Mahel edit., 1975 ; 38 - Dzotsenide, 1968 ; 39 - Fourquin, 1975 ; 40 - Bergougnan, 1975 ; 41 - Khain, 1963 ; 42 - Adamia, 1975 ; 43 - Aubouin, 1960 ; 44 - Aubouin et Ndojaj, 1964 ; 45 - S.G.F., 1970 ; 46 - S.G.F., 1976 a ; 47 - PESL, Campbell edit., 1971 ; 48 - Brinkmann, 1972 ; 49 - Ozgül, 1976 ; 50 - Okay and Dileköz edit., 1974 ; 51 - Kestin and Demisman, 1971.