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Triassic seaways and the Jurassic Tethys Ocean in the central Mediterranean area

IN the central Mediterranean area phases of middle Triassic and middle Liassic rifting are recognisable. The former produced only relatively deep pelagic basins founded on thinned continental crust; the latter, however, marked the opening of the central Tethys. The Porphyrit-Hornstein and the Diabas-Hornstein formations[1] are the results of such phenomena. During Dogger and Malm times the spreading continued and a large amount of oceanic crust was formed. The Tethys Ocean opened parallel to the long axes of some Triassic deep sea basins and across the long axes of others. Consequently, the positions of Triassic seaways along the southern continental margin of the Tethys 'geosyncline' are defined by the effects of at least two main palaeotectonic events.

In the Triassic System the Germano–Andalusian facies is characterised by prevalent continental deposits, whereas the Alpine facies is characterised by marine deposits. In the circum-Mediterranean area the basements of both Germano–Andalusian and Alpine facies sediments everywhere comprise continental crust which may underlie Palaeozoic sediments and volcanics. Only in the Antalya Nappe (Turkey) are there indications that a crust of oceanic composition underlies Alpine facies sediments.

The Alpine facies, occurring mainly in the Upper Triassic, is generally represented by shallow water carbonates (dolomites and limestones), and in certain areas by evaporites. Locally, *Halobia* limestones are known, showing relatively deep sea environments. The outcrops of *Halobia* limestones form narrow belts, more or less disconnected, which stretch along the circum-Adriatic chains from Greece to Sicily.

The complete Triassic sequence containing the *Halobia* limestones is not much varied in the whole Mediterranean region. The Lower Triassic is represented by shallow water terrigenous sediments and acid volcanics, which are a prolongation in time of the Upper Permian facies. The Middle Triassic is represented by terrigenous sediments simulating flysch deposits (Monte Facito Formation in the Apennines and Sicily; Montenegro 'flysch' in Yugoslavia), by mafic volcanics (Porphyrit-Hornstein Formation in Yugoslavia and in Greece), and less frequently by nodular limestones like Ammonitico Rosso (Han Bulog Beds in Yugoslavia and in Greece). The Upper Triassic is represented by *Halobia* limestones with interbedded rare mafic lavas and hyaloclastites, and locally by nodular limestones like Ammonitico Rosso (Hallstatt Beds in the eastern Alps).

The *Halobia* limestones have been considered as markers of an oceanic Palaeo-Tethys in the central Mediterranean area[2,3]. I suggest, however, the basins to which pelagic pelecypods and ammonites migrated originated from an eastern oceanic Palaeo-Tethys and penetrated deeply into a continental Palaeo-Mediterranean gulf as 'seaways' founded on thinned continental crust. Among these Triassic seaways the most considerable is the Pindos Basin, which stretches for more than 1,200 km through Greece, Albania and Yugoslavia. On the opposite side of the Adriatic Sea, after a gap of some 100 km, the basin is recognisable in the southern Apennines–Sicily arc as unconnected outcrops stretching for about 800 km.

In Jurassic times a real ocean separated the European and the African continents. Contemporaneously, large shearing movements began between Europe and Africa as a result of the opening of the southern Atlantic[4].

Jurassic Tethyan deposits consist of mafic and ultramafic rocks, radiolarites, pelagic limestones, claystones and sandstones, frequently affected by high pressure–low temperature metamorphism.

A basic assumption in any attempt at a palinspastic restoration of Triassic and Jurassic palaeogeography[3,5] is that the volume of continental crust remained roughly the same before and after the Alpine deformation. Consequently, the kinematic system is considered a closed system. But a lot of continental crust must have disappeared into the asthenosphere[6,7] and, therefore, huge volumes (or surfaces in a two-dimensional

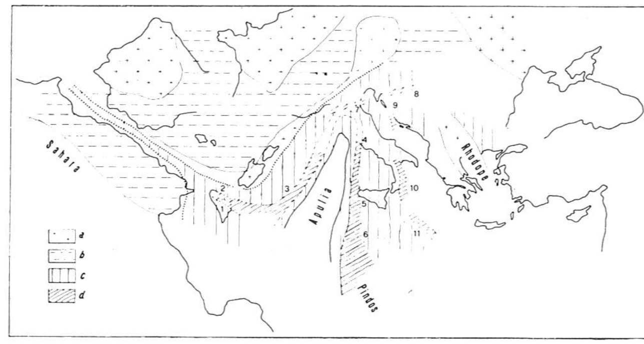

Fig. 1 Palinspastic restoration of Upper Triassic palaeogeography in the central Mediterranean area. *a*, Stable areas with slight subsidence; *b*, subsided basins of Germano–Andalusian facies; *c*, shallow-water carbonates of Alpine facies; *d*, 'seaways'; 1, Sicani zone; 2, Imerese zone; 3, Lagonegro zone; 4, Triassic pelagic sediments of Slovenia; 5, Budva-Kotor zone; 6, Pindos zone; 7, Australpine of Hallstatt; 8, Australpine of the Gemerides; 9, Australpine of the Balaton Lake; 10, Subpelagonian Triassic pelagic limestones of Serbia; 11, Subpelagonian Triassic pelagic limestones of Northern Pindos and Othrys.

calculation) have been taken out of the system. These lost volumes are not counterbalanced by additional small volumes of new oceanic crust. In any palinspastic restoration it is therefore necessary to smooth out all the nappes of the peri-Mediterranean Alpine systems to calculate the real shortening of the plate margins during the Alpine compression. Figures 1 and 2 attempt such a palinspastic restoration for the Upper Triassic

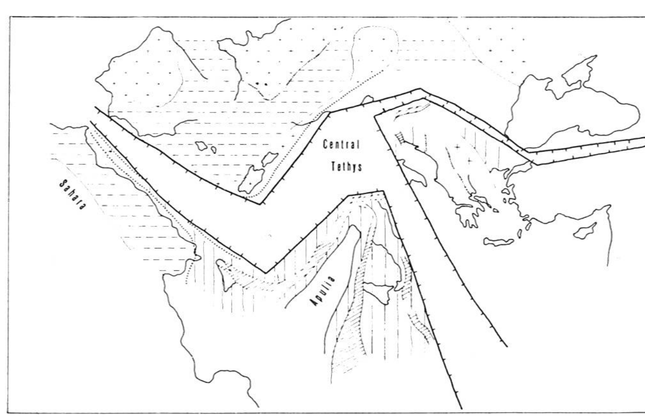

Fig. 2 The Tethys Ocean in the central Mediterranean area.

and Upper Jurassic. The original position of the palaeogeographical units has been obtained by fixing the 'stable' European and the Saharan plates, smoothing out folds and nappes, removing the main lateral displacements and connecting those belts which are common to the African and European margins. This construction of the Western part of Fig. 2 relied upon the palinspastic restoration of Laubscher[7].

This reconstruction produces an area corresponding to the Alpine facies, forming a gulf open in the direction of the Palaeo-Tethys and surrounded by regions characterised by

Germano–Andalusian facies. In these regions it is possible to distinguish stable zones, slightly subsident and unaffected by synsedimentary tectonics, and less stable or clearly unstable zones, characterised by high rates of subsidence and sedimentation, synsedimentary faulting and mafic volcanism.

In the area comprising Alpine facies the palaeogeography changes radically from the Lower to the Upper Triassic because of a Middle Triassic tectonic phase, which was responsible for the tectonic regime immediately before the opening of the Tethys. This tectonic phase included an attempt at rifting, which produced a complex system of tensional faults that crossed the Palaeo-Mediterranean Gulf in several directions. The faulted blocks underwent different vertical movements. The uplifted blocks often underwent severe erosion, whereas flysch-like sediments were deposited on the downshifted blocks. Contemporaneously, widespread mafic magmatic activity (comprising an alkali-basaltic series) occurred along the main faults. Deep sea basins developed along preferential directions (probably corresponding to strips of crustal thinning) within the Palaeo-Mediterranean Gulf, allowing the diffusion of the pelagic fauna from the Triassic Palaeo-Tethys through Turkey, Greece, Albania, Yugoslavia, Hungary, Czechoslovakia, Austria, Italy, and as far as western Sicily. The absolute homogeneity of the fauna proves that close intercommunications were established between all of the seaways. Figure 1 shows the region during the late Triassic.

During Liassic times, starting mainly in the Middle Liassic, important new events occurred in the central Mediterranean area: along giant tensional fractures, partly parallel to, and partly discordant with, the former seaways, the Tethys Ocean began to open. In the internal nappes of the Dinarides and of the Hellenides at least two main ophiolite assemblages deriving from the oceanic Tethys may be distinguished: the Diabas-Hornstein Formation, and the ultrabasic massifs at Zlatibor and Vourinos, with their basalts and sediments. The Diabas-Hornstein Formation comprises alternated diabases, radiolarian cherts, sandstones, claystones, graded calcareous microbreccias, allodapic and pelagic limestones, and intraformational conglomerates. This sequence may overlie Jurassic limestones founded on continental crust[8].

The generally tectonic basal contact and the occurrence of slices of serpentinites between the Jurassic limestones and the Diabas-Hornstein Formation suggest that the latter (at least in part) was possibly founded on oceanic crust. On the other hand, the occurrence of terrigenous material and of neritic calcareous turbidites suggests provenance from a very near continental platform. I suggest that the Diabas-Hornstein Formation is the product of the Liassic rifting which marked the beginning of the opening of the Tethys Ocean, so it may be considered as a marker of the continental margin or the continental rise. As the opening of the Tethys Ocean continued, the areas in which the Diabas-Hornstein Formation had been deposited were shifted laterally and, according to plate accretion models, new areas of oceanic crust were generated in their place. These new areas of oceanic ridges which are, of course, younger than the Diabas-Hornstein Formation, are today recognisable as the ultramafic massifs.

In the Alps and in the Apennines this distinction between initial rifting (Diabas-Hornstein Formation) and real ocean spreading (ultramafic massifs) of the central Tethys is not so clear as it is in the Dinarides, but it is probable that the Ligurian and Piemontese ultramafic rocks represent an ancient, oceanic ridge area, whereas parts of the Southpennine *Bündnerschiefer* represent an equivalent of the Diabas-Hornstein Formation.

During the Middle and Upper Liassic the combination between the Atlantic and the Tethyan movements produced a renewal of synsedimentary tectonic activity, and consequently the palaeogeography became modified not only around the central Tethys, but also around the former Triassic seaways. For example, in western Sicily the former Imerese seaway, which during the Upper Triassic ended at the longitude of Palermo, suddenly lengthened westwards during the Liassic, in the direction of the Maghreb along a newly generated deep furrow in which radiolarian oozes and calcareous turbidites stratigraphically overlie collapsed shallow water dolomites[9]. Contemporaneously, in areas of maximal tension (Imerese, Sicani, Pindos), flows of alkali-basalts were erupted.

During post-Jurassic times the Triassic seaways near to the margin of the Tethys Ocean, and those which were cut across by the opening of the ocean, were affected by Cretaceous compression. These orogenic phases, the earliest in the central Mediterranean area, were responsible for the reduction, and the local disappearance, of large oceanic zones. In Greece (Northern Pindos[10] and Othrys), sediments deposited very near to the Tethys Ocean were affected by Cretaceous compression, and were involved in the building of the ophiolite nappes.

On the other hand, the continuing sedimentary history of those seaways which lie more within continental areas, will cease only after the collision between Europe and Africa. In Sicily (Sicani Mountains[11]), such sedimentary deposits were affected by compression during the Upper Miocene, when Europe and Africa had already collided and a lot of continental crust from both plates had disappeared because of subduction.

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