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THE GHOMARIDES NAPPES, RIF COAST RANGE, MOROCCO: AN AFRICAN TERRANE IN THE WEST MEDITERRANEAN ALPINE BELT

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A B S T R A C T

The Ghomarides nappes, together with the Betic Malaguides, are the uppermost basement nappes in the Gibraltar Arc. Their Paleozoic rocks were formerly located to the East of the Morocco Variscan belt. Their Mesozoic-Cenozoic sequences confirm this easterly origin and plead for an African homeland, south of the Tethyan break. Correlation with the Upper Austro-Alpine units and local stratigraphic and isotopic data support the hypothesis of a Late Cretaceous initiation of collision. Late Alpine metamorphism, coeval with that of the deeper units (25 Ma), affected the base of the Ghomaride pile.

INTRODUCTION AND GEOLOGICAL SETTING

Although they correspond to rather small hills along the southern coast of the Alboran sea (Fig. 1), the Ghomarides nappes (Durand-Delga and Kornprobst, 1963) are certainly worthy to consider since they belong to one of the main structural component of the West Mediterranean Alpine belt. Their plain equivalent north of the Gibraltar strait are the Malaguides nappes (Didon et al., 1973), and similar units are found in the Algerian Tell (Chenoua and Kabylias), northern Sicily (Peloritan mountains) and Calabria (Durand-Delga and Fontboté, 1980). In every place, these nappes are the uppermost basement nappes of the inner tectonic pile and they consist of (or at least involve: Kabylias) weakly metamorphic Paleozoic sediments overlain by a thin, virtually unmetamorphosed Mesozoic-Cenozoic cover.

In the Rifan inner zones (Figs. 1 & 2), four Ghomarides nappes can be distinguished (Chalouan, 1986, 1987) namely, from base to top, the Aakaili, Koudiat-Tizian, Beni-Hozmar and Talembote nappes, the total thickness of which does not exceed 5000 m. These nappes overlay the Sebtides units, which include the Beni-Bousera infra-continental peridotites (Kornprobst, 1974) and suffered Alpine metamorphism (Michard et al., 1983). The Dorsale Calcaire units are thought to represent either a part of the Ghomaride cover detached from its Pa-

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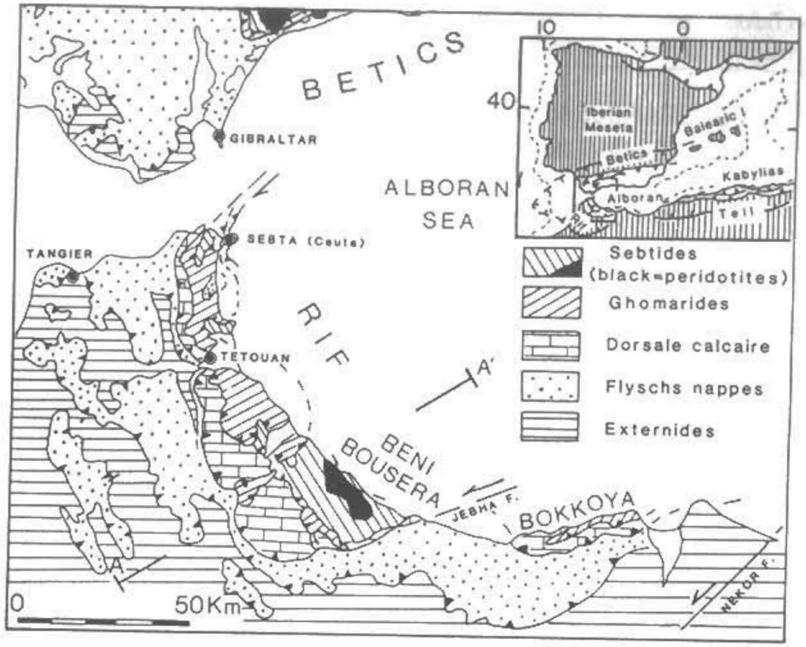

Fig. 1: Sketch map of the Rif Coastal Range. Insert: location in the Western Mediterranean domain (ruled: foreland domains; dashed lines: 2500 m-isobath).

leozoic basement (Durand-Delga and Fontboté, 1980; Durand-Delga and Olivier, 1988), or lateral equivalents of this cover, detached from the uppermost Sebtides units and stacked in front of the Ghomarides (Wildi, 1983). The whole pile is thrust southwestward over the External Rif foredeep deposits through extensive Flysch nappes, the origin of which remains controversial (Durand-Delga and Fontboté, 1980; Trümpy, 1983; Coutelle and Duée, 1984; Leblanc and Olivier, 1984; Coutelle and Delteil, 1989; Bouillin, 1989). A klippe of such Flysch nappes is preserved upon the northern Ghomarides area (Jebel Zemzem). Oligo-Miocene deposits are engaged below this klippe and within the quoted, southwest-verging thrusts.

The Ghomarides-Malaguides homeland is controversial. It could have been located in one of the following areas: i) the northern margin of Africa, on the western side of the Adriatic promontory (Argand, 1924; Staub, 1926; Brouwer, 1926), or possibly of a broken piece of this margin, north of some prolongation of the Azores-Gibraltar fault (Caire, 1970, 1978; Tapponnier, 1977; Aubouin and Debelmas, 1980; Coutelle and Duée, 1984; Coutelle and Delteil, 1989); ii) the south-western European (south-eastern Iberian) margin (Bourrouilh

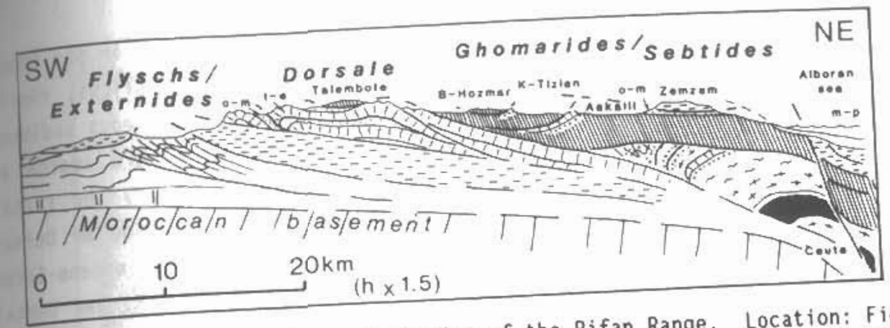

Fig. 2: Schematic cross-section of the Rifan Range. Location: Fig. 1 (AA'). Large dots: Triassic redbeds (Ghomarides, Sebtides); briks: Triassic-Jurassic carbonates, with scarce Cretaceous-Eocene deposits (t-e, Dorsale); fine dots: Oligocene- Early Miocene clastics (e-m, Dorsale, Ghomarides); white: Late Miocene-Pliocene (m-p, foredeep and Alboran).

and Gorsline, 1979; Bouillin, 1984; Leblanc and Olivier, 1984; Dercourt et al., 1985, 1986; Ricou et al., 1986; Bouillin et al, 1988; Gealey, 1988; Durand-Delga and Olivier, 1988); iii) an Alboran "sous-plaque" (Andrieux et al., 1971) or (micro)plate (Wildi, 1983) or block (Bourgois, 1980), also named "socle méso-méditerranéen" (Durand-Delga and Fontboté, 1980). However, the separation between Alboran and Africa is thought to be incomplete and would correspond mostly to thinned continental crust - a situation that is fairly similar to that of the first model.

A complete discussion of the problem is beyond the aim of this paper. We described recently the Paleozoic section of the Ghomarides nappes, with emphasis on its stratigraphy (Chalouan, 1987), then on its deformation and associated low-grade metamorphism (Chalouan and Michard, 1990). We concluded that the Ghomarides Paleozoic rocks originated on the northern Paleozoic margin of the African continent, likely on the northeastern continuation of the Hercynian belt of Eastern Morocco, in an Hercynian zone that can be traced up to the Upper Austro-Alpine units. However, one can wonder if the Ghomarides and equivalent units were left on the African side during the Mesozoic Neo-Tethyan opening. In the present paper, we adress this problem and focuse on the Mesozoic-Cenozoic evolution and Alpine correlations of the Ghomarides nappes.

MESOZOIC-CENOZOIC STRATIGRAPHY

The Triassic to Oligocene sequences (Fig. 3) record the Tethyan opening and the earliest Alpine compressive (or transpressive: Belhaï et al., 1990) events. The oldest post-Hercynian sediments consists of Middle Triassic conglomeratic redbeds (Baudelot et al., 1984; Mäkel, 1985; Simon, 1987) which include subordinate alkaline volcanic rocks. They are followed by Upper Triassic dolostones and Liassic algal limestones. Maate (1984) described sedimentary dykes of Toarcian reddish silts on top of such limestones pinched in the Ghomaride pile, north of Tetouan. In the adjoining Internal Dorsale slices, similar sequences are followed by pelagic, Middle Jurassic to Early Cretaceous sediments (Wildi et al., 1977; Wildi, 1979). Late Cretaceous sediments are scarce and consist mainly of Late Senonian marls that can directly overlay the Liassic rocks (Griffon, 1966; Maate, 1984). Most frequently, the Ghomaride or Dorsale Triassic-Jurassic carbonates are overlain by a shallow-water, Paleocene-Eocene onlap sequence that frequently begins with Microcodium limestones. The Dorsale sedimentation ends with Upper Eocene-Oligocene (and Aquitanian?) conglomeratic marls that are lacking on the Ghomarides .

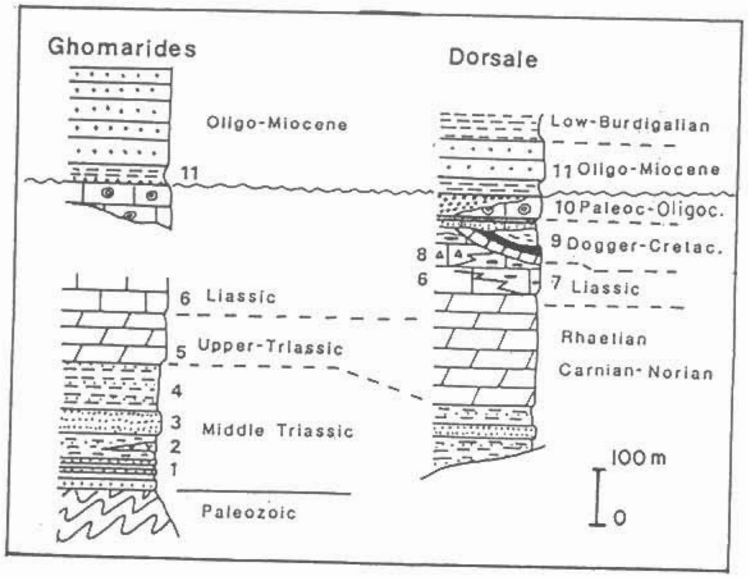

Fig. 3: Mesozoic-Cenozoic stratigraphy of the Ghomarides and associated Dorsale units, mainly after Wildi et al. (1977) and Durand-Delga and Olivier (1988). 1: red conglomerates and sandstones; 2: alcaline volcanics; 3: quartzites; 4: argillaceous redbeds; 5: dolomites; 6: algal limestones; 7: cherty limestones; 8: pelagic breccias, limestones; 9: nodular limestones, radiolarites (black), Aptychus limestones; 10: sandstones, calcarenites with benthic Foraminiferous; 11: marls, sandstones and conglomerates.

The unconformable, Late Oligocene-Neogene clastic deposits post-date the main Alpine collisional and metamorphic events and accumulate in response to the Western Mediterranean basins opening and evolution (Durand-Delga, 1981; Le Pichon et al., 1988). It is convenient to separate a deformed, Oligo-Miocene "post-nappe" sequence (Fig. 4) from a virtually undeformed, Mio-Pliocene sequence (Faure-Muret and Choubert, 1971). The earliest sequence consists of argillaceous sandstones, limestones and conglomerates (locally olistostromal),

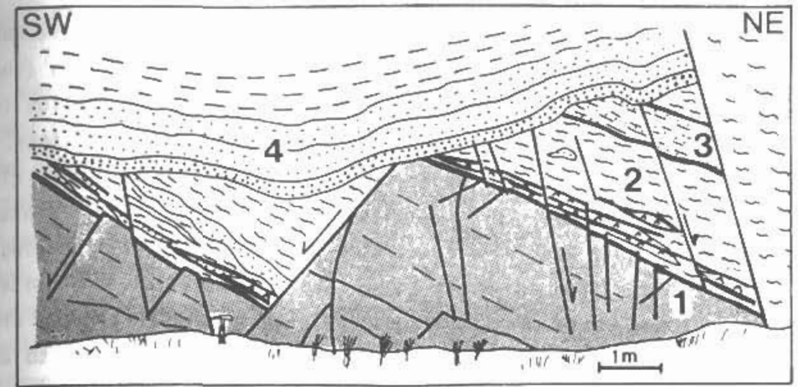

Fig. 4: The Oligocene-Early Miocene unconformity at Fnideq, 5 km south of Ceuta (road-cut). 1: Carboniferous flysch (Aakaili nappe); 2: Cataclastic shear zone (Triassic dolomitic lenses within Paleozoic pelites); 3: Triassic redbeds; 4: Oligocene-Early Miocene sandy marls and conglomerates.

deposited at increasing depth. This was essentially dated from Aquitanian to Lower Burdigalian but begins as early as Chattian (about 25 Ma, nannoplankton zone NP25: Durand-Delga, 1981; Belhadad, 1983; Feinberg and Olivier, 1983; Ben Yaich et al., 1986). The conglomeratic beds include pebbles of every older rock type of the Ghomarides and Dorsale nappes. In the Betic Cordilleras, Malaguides thrust contacts are locally sealed by Oligocene conglomerates (Durand-Delga, 1980) that can also include metamorphic Triassic rocks and peridotites from the underlying Alpujarrides (= Sebtides) nappes (Didon et al., 1973; Martin-Algarra and Estévez, 1984).

During and after the Lower Miocene sedimentation, a severe shortening event stacked the Ghomarides-Dorsale units onto the Flyschs and External zones (Figure 2) and achieved the present thrusts and back-thrusts pattern prior to the sedimentation of the post-tectonic, shallow-water Upper Miocene-Pliocene sands and clays (Ben Yaich et al., 1986). The emplacement of the Jebel Zemzem flyschs klippe over the Ghomarides (either by thrusting or back-thrusting) is bracketed between both sequences. Neogene calc-alkaline magmatism is widespread in the Betic-Rif Arc and its Algerian prolongation, but hardly affected the Ghomarides area. However, aplitic dikes from the underlying Beni Bousera massif were dated at 22±4 Ma (Priem et al., 1979) and 18±1 Ma (Polvé, 1983) by the Rb/Sr method, while in Western Betic Cordilleras, a dike swarm of andesitic basalts cutting through the Alpujarrides-Malaguides pile was dated at 22-23 Ma by the K/Ar method (Torres-Roldan et al., 1986).

ALPINE DEFORMATION AND METAMORPHISM

In the Ghomarides nappes, tight folds, schistosity and metamorphism are only found in Paleozoic rocks and result from the Variscan orogeny (Chalouan and Michard, 1990). In the Triassic sandstones, penetrative deformation is virtually lacking and illite cristallinity indicates anchizonal conditions. However, at some places, even from the upper nappes (Beni Hozmar), a spaced cleavage formed in the argillaceous silts by parallel-bedding shear. It was tentatively ascribed to flexural-slip mechanism associated with E-W and NW-SE-trending post-nappe folds (Chalouan, 1986). However, these Late Miocene folds show quite large wavelength and formed while the Ghomarides Triassic beds were already close to the surface. Hence, we now propose to ascribe the observed cleavage to an earlier event, likely the piling-up of the Ghomarides nappes. In that case, the SW-dipping cleavage indicates NE-directed thrusts.

Within the Paleozoic rocks, Alpine structures are locally superposed to Eo-Variscan and Variscan. At the base of the upper and middle Ghomaride nappes, a foliated, semi-brittle deformation zone runs parallel to the thrust

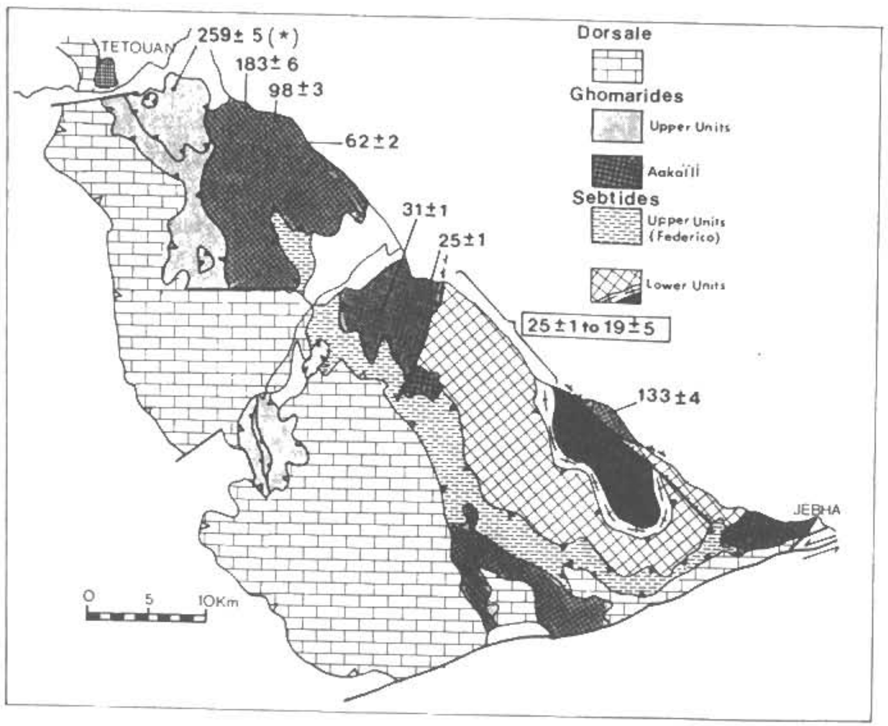

Fig. 5: Distribution of the isotopic ages (Ma) in the Ghomarides and underlying Sebtides units south of Tetouan, mainly from K/Ar results on white micas (Laboratoire de Géochimie, R. Montigny, Strasbourg; references in Chalouan and Michard, 1990, except (*): S. Huon, Genève, unpubl. data).

contact and, therefore, can be regarded as Alpine. Similar foliated zones, sometimes a few decimetres-thick, run between hectometric lenses that occur above these thrusts. At the base of the lowest Ghomaride (Aakaili) nappe, we must consider the possibility of a more ductile regime, since the Triassic sediments of the underlying Sebtides units are metamorphic. The northward-verging shear structures that characterize the Lower Paleozoic rocks are more intense toward the base of the nappe, where recrystallization also increases (Chalouan and Michard, 1990). Part of this basal metamorphism is Alpine since K/Ar dating gave the same Oligo-Miocene ages in the lowest part of the Ghomarides rocks than in the underlying Sebtides units (Fig. 5). Therefore, we retain that the Eo-Variscan structures of these rocks were reactivated during the Alpine thrust emplacement, with a similar northward transport direction.

Other Alpine structures post-date the nappes emplacement onto the Sebtides. The oldest are pre-Oligo- Miocene normal faults (Figure 4) that likely correlates with the initiation of Western Mediterranean basins opening. At that time, the thrust contacts were partially reactivated as extensional faults under conditions of brittle deformation (Balanya and Garcia-Duenas, 1987). During the Lower Miocene clastic sedimentation, further shortening and thrusting affected the whole Betic-Rifan belt, bringing the innermost zones onto the Dorsale, Flyschs and External units (Fig. 2). The structures refered to this period are some large, open folds, a number of brittle thrusts and back-thrusts, some of them extensional and a system of wrench-faults such as the sinistral Jebha fault and the dextral Jebel Mousa (Sebta) fault (Olivier, 1982; Frizon de Lamotte, 1987).

DISCUSSION

In a recent paper (Chalouan and Michard, 1990), we concluded from the study of the Ghomaride Paleozoic rocks that their homeland was somewhere in the northeastern prolongation of the Eo-Variscan foldbelt of Eastern Morocco. They had to slid for 500 km at least during a sinistral displacement along North-Africa, before being thrust upon Western Morocco. Using the same Paleozoic data, we precised the correlations of the Ghomaride "terrane" with its direct equivalents in Western Mediterranean, i.e. the Malaguides, Chenoua-Kabylias and Calabria Paleozoic allochthons, and extended the correlations eastward to the Tuscan, South-Alpine and Austro-Alpine basements (Fig. 6).

The associated Mesozoic sequences remarkably confirm the preceding correlations. The easterly, Alpine affinities of the Betic-Rifan-Kabylian Dorsale Triassic sequences were frequently stressed since Staub (1926), Brouwer (1926), and Fallot (1937) (e.g. Bosellini and Hsu, 1973; Wildi et al., 1977; Trümpy, 1983; Wildi, 1983; Coutelle and Delteil, 1989). The Ghomarides-Rifan

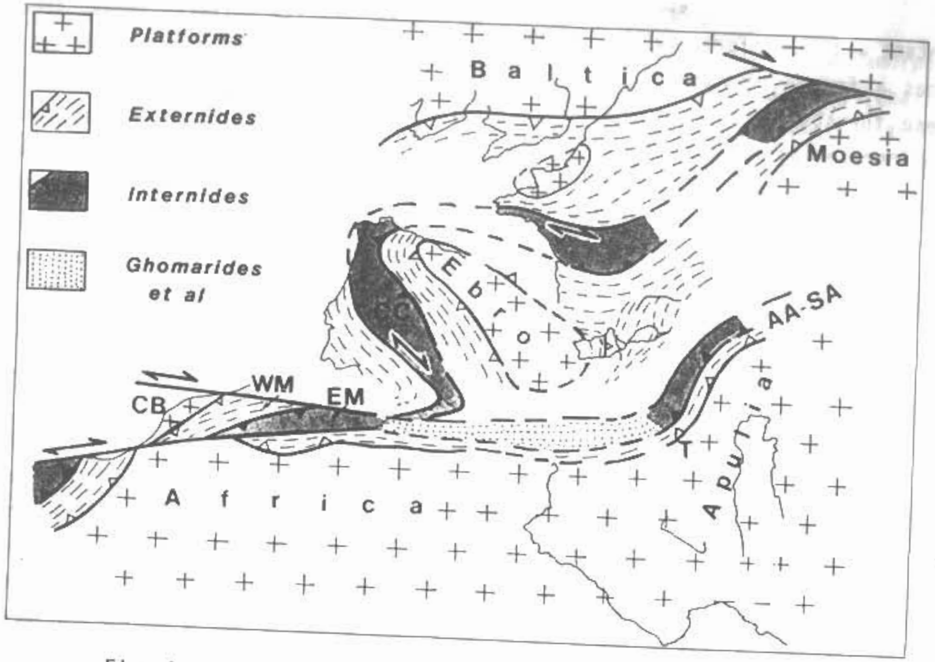

Fig. 6: A restaured position of the Ghomarides and equivalent Paleozoic rocks (Malaguides, Kabylias, Calabria) in the Late Variscan framework (Chalouan and Michard, 1990).

Dorsale pair virtually prolongates in the Kabylias, and the Peloritan-Calabrian allochthonous massifs are strikingly similar to the Kabylian, even with regard to their post-Hercynian cover (Dubois, 1976; Caire, 1978; Durand-Delga and Fontboté,1980; Bouillin, 1984). In the Longobucco nappes ("écailles"), Bouillin et al. (1988) describe a Mesozoic passive margin setting, from Triassic to Late Jurassic. But was this margin on the northwestern (Bouillin et al., 1988; Dietrich, 1988) or south-eastern side (Haccard et al., 1972; Coutelle and Delteil, 1989) of the Tethyan gap, marked by the Ligurian ophiolites? No more data is available there for an unambiguous answer than on the Ghomaride transect itself.

By contrast, both the African (Apulian) and European margins are shown on the Alps transect, respectively in the Tuscan - Upper Austro-Alpine and Central Corsica-Briançonnais units (Coward and Dietrich, 1989). The latter, European units show several differences in their Mesozoic sequences with respect to the Ghomarides (Alboran) units. In the Briançonnais paleomargin (Lemoine et al. 1986), the post-Hercynian sedimentation begins with a Permo-Triassic Verrucano facies, older than the Alboran-Tuscan type (Cassinis et al., 1979) and the carbonates of the pre-rift stage occupy the whole Middle to Late Triassic timespan. The Liassic block-faulting ends with an extended, Toarcian-Early Bathonian emersion, and Malm limestones may overlie directly Triassic to Permian rocks.

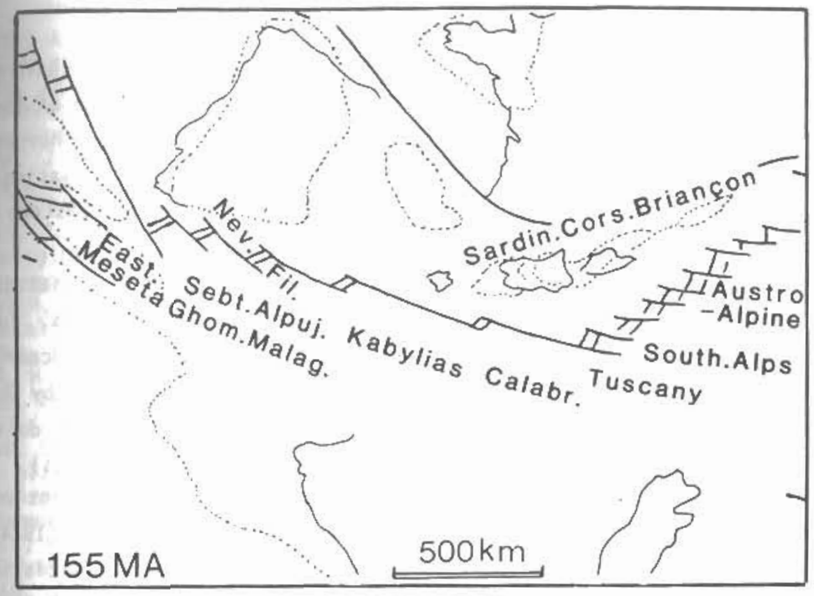

Fig. 7: The proposed location of the Ghomaride terrane and related units during the Neo-Tethyan opening. Position of African and European blocks from Dercourt et al. (1985).- Nev.- Fil.: schematic position of the ophiolite-bearing, eclogitic nappes of Sierra Nevada-Sierra de los Filabres windows, central and eastern Betic Cordilleras (Puga et al., 1989).

Such a Malm transgression is also found in the Razzo Bianco slices, on the western border of Alpine Corsica (Amaudric du Chaffaud and Lemoine, 1974).

Unlike the European paleomargin, the Apulian offers a Mesozoic record closely similar to that of the Ghomarides and associated units. As quoted above, the analogies between the Alboran and Tuscany - Upper Austro-Alpine Mesozoic sequences were repetedly stressed since the discovery of the Betic overthrusts (Brouwer's "Austrobetikum") and support an African origin for the Ghomarides. This correlation (Fig. 7) supports the hypothesis of a Cretaceous initiation of collision on the Alboran transect as on the East- Alpine (Geyssant, 1980; Winkler and Bernoulli, 1986, Fritz, 1988) and West Alpine (Dal Piaz and Lombardo, 1985; Goffé and Chopin, 1986). Two lines of arguments support the proposal: i) a stratigraphic gap characterizes usually the Ghomaride-Dorsale record for the Late Cretaceous period; in the Eastern Kabylian Dorsale, folding and low-grade recrystallization of the Jurassic-Neocomian pelagic rocks occurred prior to a Campanian-Paleocene clastic sedimentation (Raoult, 1974, p. 60-72); ii) a 80 Ma-aged metamorphism is suggested in the Greater Kabylia basement by some 39 Ar/40 Ar isotopic results (Monié et al., 1988). In the Rifan-Betic area, would such Eo-Alpine metamorphism have occurred, its isotopic trace would have been entirely (in the present state of knowledge) overprinted by the 27-22 Ma event, very common all around Western Mediterranean (Kligfield et al., 1986).

CONCLUSION

According to their Paleozoic section, the Ghomarides nappes have to be rooted more than 500 km to the east, on the northeastern prolongation of the Eo-Variscan belt of Eastern Morocco. They were close to the Malaguides nappes and to the upper Kabylian and Calabrian units, and would represent the missing link between the Eastern Morocco Hercynides and that of the Tuscany-Eastern Alps area, on the northern limit of the Paleozoic African platform.

The discussion of the Ghomaride Mesozoic cover and of the associated Dorsale units enable us to favor an African homeland for these units, in the Tethyan paleogeographic setting. Therefore a broad parallelism would occur between the Tethyan faults and the Variscan structures, as suggested by Argand (1916) and Debelmas (1986), even if local crosscutting relationships do exist (that often depend, in fact, of later, collisional or extensional events).

We particularly emphasize the Upper Austro-Alpine affinities of the Ghomarides nappes and equivalent units. This is an hommage to Argand (1924) and Brouwer (1926)! This point also to the likelyhood of a Cretaceous initiation of thrust tectonics on the Alboran transect. Any scenario of the Rifan-Betic orogeny should be constructed with such Alpine correlations in mind.

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