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Paleogeographical reconstruction of the Malaguide-Ghomaride Complex (Internal Betic-Rifian Zone) based on Carboniferous granitoid pebble provenance

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Abstract: An outcrop of Carboniferous conglomerates is described in the Malaguide-Ghomaride Complex in Ceuta, comparable to the Conglomerate Formation of Marbella. Granite cobbles and pebbles belonging to deformed peraluminous granites from epizonal massifs are significantly present within the conglomerates studied. Granites with these characteristics abound in the Central Iberian and Western Asturian-Leonese Zones and differ from those predominating in the Ossa-Morena and South Portuguese Zones of the Iberian Massif, geographically nearest the current Malaguide outcrop. This suggests that the Malaguide-Ghomaride Domain was originally situated towards the east, thus forming the prolongation of the Central Iberian or Western Asturian-Leonese Zones. This paleogeographical hypothesis is also confirmed by stratigraphic comparisons indicating close similarities between the Devonian and Carboniferous series of the Malaguide and of the more distant Minorca or Catalonian Coastal Range, as well as clear differences with the successions of the South Portuguese and Ossa-Morena Zones. Furthermore, the correspondence of the Malaguide-Ghomaride Domain towards the south with the Moroccan Meseta is also discussed. The nature of the granite cobbles of the Malaguide is a new argument that supports the contention of its westward shift of hundreds of kilometers during the Early Miocene, then forming the Gibraltar Arc and occupying its present-day position.

Key words: Carboniferous, Betic-Rifian Internal Zone, Malaguide-Ghomaride Complex, paleogeographical reconstruction, granitoid pebbles, Marbella conglomerates.

Introduction, geological setting and objectives

Within the western Mediterranean, the Malaguide Complex (Ghomaride in the Rif) containing the conglomerates here discussed, occupy the highest tectonic position of the Internal Betic-Rifian Zone, together with the so-called *Dorsale Calcaire* (Figs. 1 and 2). Beneath lies the Alpujarride Complex (or Sebtide in the Rif) and, in the lower position, the Nevado-Filabride (which has no equivalent observable in the Rif). These two latter complexes have been completely affected by Alpine metamorphism, while the Malaguide shows at the base traces of this event, so that a great part of its Paleozoic series (and the very discontinuous Mesozoic and Tertiary series) have practically preserved their sedimentary characters. South of the Malaguide Complex and the Dorsale Calcaire were originally situated the basins of the Predorsale (here including the Tariquide Domain) and the Flysch Units, all presenting a sedimentary character.

Many reconstructions of the original position of the Internal Betic-Rifian Zone (Andrieux et al. 1971; Durand-Delga 1980; Durand-Delga & Fontboté 1980; Wildi 1983; Sanz de Galdeano 1990, among many other authors) show that they were located in the easternmost parts of the western Mediterranean, being later expelled to the west during the opening of the Algerian-Provençal Basin at the beginning of the Early Miocene. The original domain of the Internal Betic-Rifian Zone (Fig. 2) called with different names, such as AlKaPeCa (Bouillin et al. 1986), referring to the resulting sectors (Alborán, Kabylias, Peloritani Mountains and Calabria), Alborán Block or Domain and South Sardinian Domain (Sanz de Galdeano 1990).

Conglomerate deposits intercalated in Carboniferous sediments or attributed to the Carboniferous, according to the cases, have been described in different outcrops of the Malaguide Complex. These polymictic conglomerates ("Marbella Conglomerates") of Blumenthal (1949) contain abundant limestone cobbles, at times boulders, mixed with lydite, metasandstone and granite pebbles. Mollat (1968) considered the conglomerates post-Visean on the basis of the presence of cobbles of this age. Herbig & Mamet (1983) and Herbig (1984, 1986) recognized a late Visean age in many of the limestone cobbles and indicated that the deposits were post-Bashkirian — that is, of Westphalian or Stephanian age. Thus, these rocks were probably deposited at the end of the Variscan deforma-

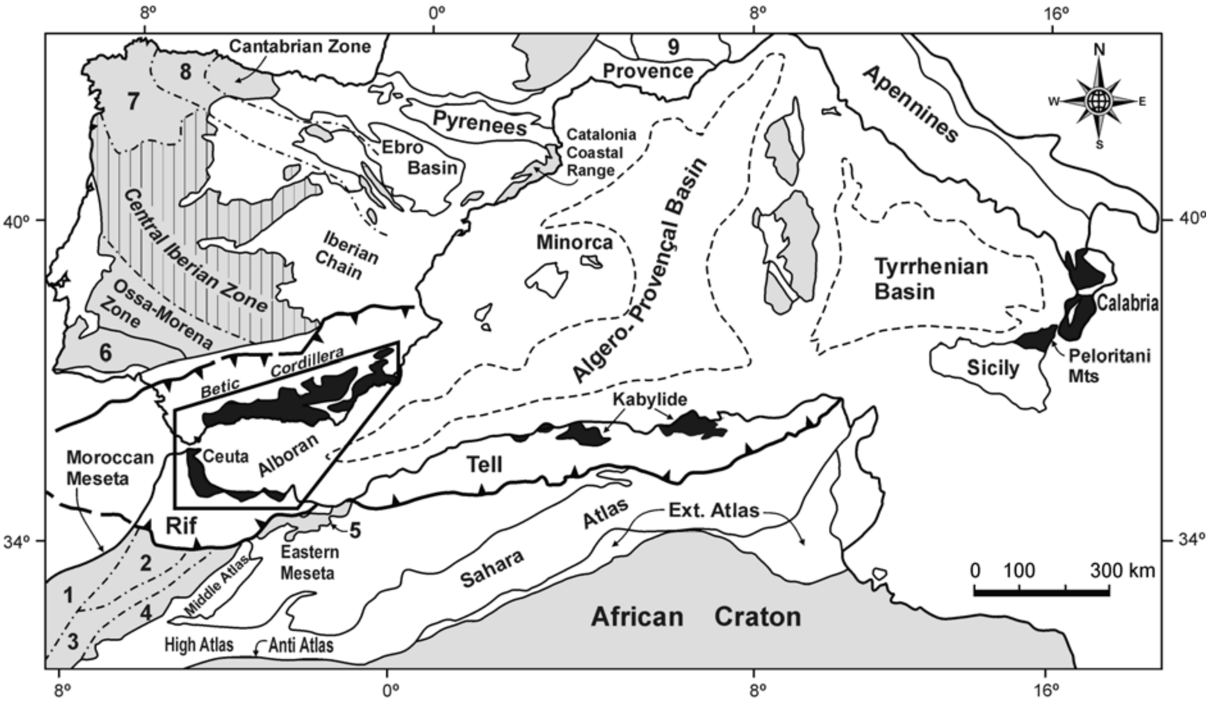

Fig. 1. Geological scheme of the western Mediterranean. The position of Fig. 2 is boxed in thick lines. In black are indicated the Internal Zones of Alborán (Betic-Rifian Internal Zone), Kabylias, Peloritani Mountains and Calabria originally forming part of the same (AlKaPeCa, South Sardinian or Mesomediterranean) domain. Non-labeled areas: 1 — Coastal Block; 2 — Sidi-Bettache Basin; 3 — Western Meseta; 4 — Kenifra Nappe Zone; 5 — Oujda Zone; 6 — South Portuguese Zone; 7 — Galicia-Trás-os-Montes Zone; 8 — Western Asturian-Leonese Zone; 9 — Alps.

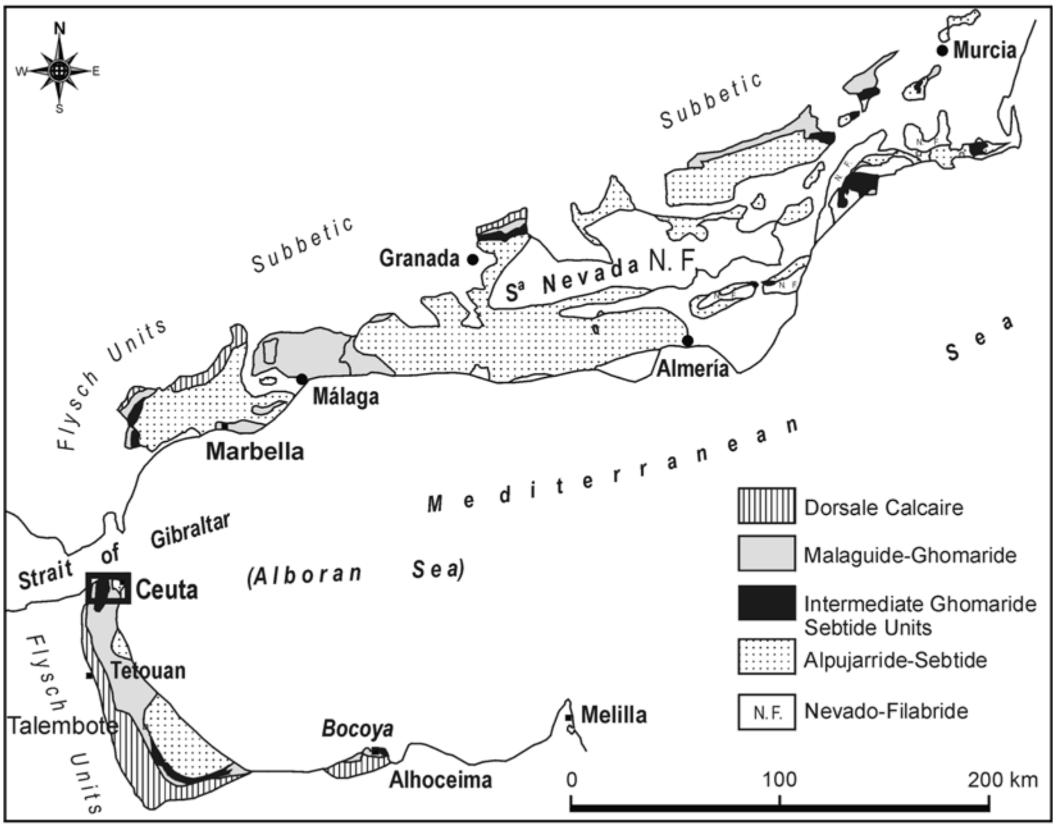

Fig. 2. Geological scheme of the Betic-Rifian Internal Zone. Simplified from Sanz de Galdeano et al. (2001). Its position is marked in Fig. 1. The position of Fig. 3 is indicated.

tions. The conglomerates are separated from the lower sediments by a regional unconformity, as proposed by Bourgois (1978) and Felder (1978) and as reflected by the existence of previously foliated cobbles, although some authors, as noted by Mäkel (1985), contended that this was a local unconformity. Above, Triassic sediments often appear, and thus this upper contact corresponds to a major regional unconformity. The conglomerates have a highly variable thickness, generally of several meters, to a maximum of 100 m.

In the Rif (Morocco) these polymictic conglomerates in the Malaguide-Ghomaride have also been described and contain cobbles of lower Carboniferous limestones as well as of the underlying Paleozoic sequence rocks, including quartzites and different metamorphic cobbles. These conglomerates have been considered indicative of an orogenic event (Michard & Chalouan 1978; Mourier 1982; Mäkel 1985). In the Iberian Massif, upper Carboniferous conglomerates are known in different localities of Asturias, the Iberian Ranges and the Ossa-Morena Zone. Lower Westphalian deposits are still syn-tectonic in Asturias, but the Westphalian D to Stephanian deposits are invariably late or post-tectonic.

In addition to these Carboniferous conglomerates, there are others much more modern, from the upper Oligocene-Aquitanian (formations of the Ciudad-Granada/Fnideq type) (Martín-Algarra et al. 1993; Serrano et al. 1995), deposited unconformably overlaying the Malaguide-Ghomaride Complex and containing numerous cobbles inherited from the underlying Malaguide succession, as well as granite cobbles (Olivier et al. 1979), metamorphic rocks and basic igneous rocks. Conglomerates with cobbles and pebbles of these types are intercalated within some Flysch Units (Puglisi et al. 2001; Gigliuto et al. 2004a), such as the Oligocene-Aquitanian Beni Ider Flysch (Zaghoul & Puglisi 2003; Gigliuto et al. 2004a,b and Careri et al. 2004). These latter are not sediments formed over the Internal Zone, but rather more to the south, in nearby realms. These Tertiary deposits will not be specifically treated here, although possibly their cobbles have an origin similar to those that will be discussed, or they are inherited from the same Marbella-like conglomerates.

In Ceuta, a small, poorly exposed outcrop of conglomerates of the Marbella type appears near the western edge of the port, in the Benítez beach, at the beginning of what was Bazurko beach. Furthermore, another new outcrop, large and well exposed, is found in the Tarajal sector, the name of the border between Ceuta territory (belonging to Spain) and Morocco on the Mediterranean coast (Figs. 3 and 4). There, the talus of a new highway shows the outcrop, situated roughly between 800 and 1200 m from the border.

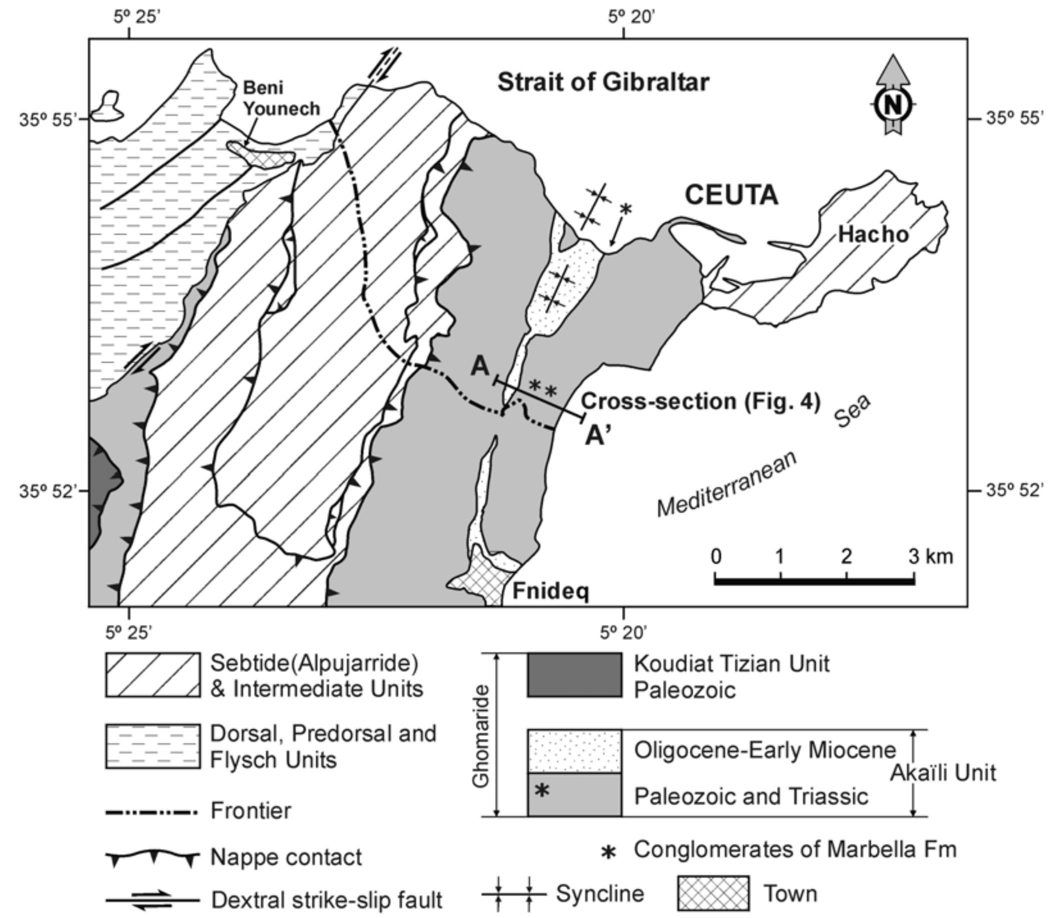

Fig. 3. Simplified geological map of Ceuta and nearby sectors. The position of the geological section of Fig. 4 is indicated.

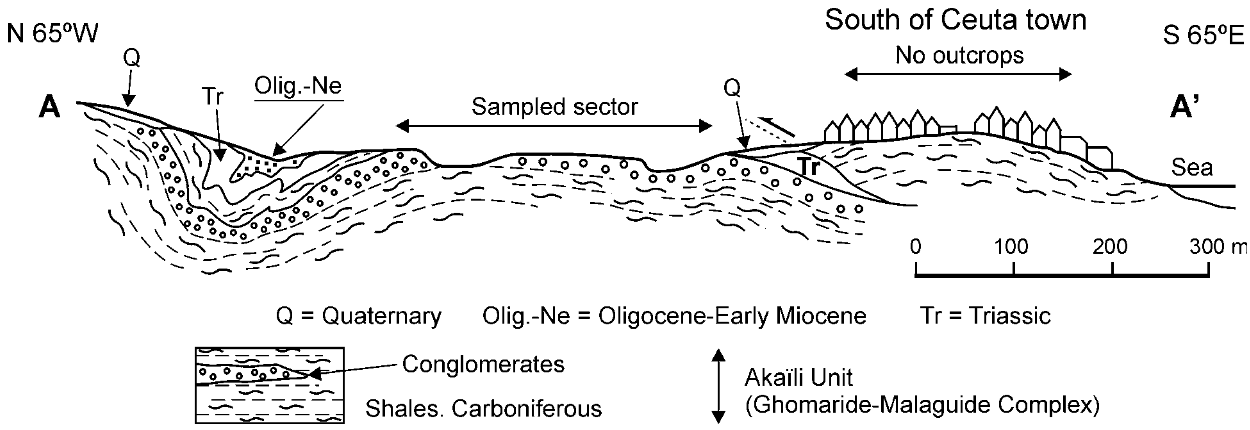

Fig. 4. Geological section of the study outcrop of the Carboniferous conglomerates in the Tarajal sector.

These conglomerates enable the comparison and possible correlation of the lithology of the cobbles with that found at other points of the Malaguide-Ghomaride and with the domains of the Iberian Massif and of the Moroccan Paleozoic. Moreover, the comparison of the Devonian-Carboniferous sedimentation of the Malaguide with that of these last domains strengthens the conclusions drawn from the analysis of the nature of the cobbles. These topics are the focus of this study, with the aim of contributing to the paleogeographical reconstruction of the region.

Description of the conglomerates of Tarajal (Ceuta)

In this area, dark brown slates and meta-arenites, bluish in fresh sections, attributed to the Carboniferous of the Malaguide-Ghomaride, crop out. In the Tarajal sector, conglomerate levels occur at the top of the succession, well exposed in the talus of the highway, with a thickness of about 5 m. These conglomerates, locally medium-bedded, show abundant centimeter-sized pebbles, rare cobbles more than 20 cm in diameter and boulders up to 1 m in size arranged in levels at times exceeding 2 m in thickness. Pebbles of 5 cm abound, but also cobbles surpassing 20 cm in diameter and some boulders that can reach nearly 1 m in diameter. There is also fine gravel of 1–2 cm and even smaller. The matrix, generally arenaceous, is scarce. The stratification is not always evident, although there are some thinner levels, even formed by sandstones, showing a lenticular geometry, enabling the polarity of the succession to be established. This is a fining-upward sequence, ending with levels of sandstones and lutites. There is no evidence of channelized facies suggesting mass transport, possibly linked to a delta. These conglomerates reach at least 40 m in thickness.

Unconformably above, there are some levels, several meters thick, of Triassic red conglomerates, clays and lutites and, at the top, Burdigalian sediments containing numerous spillages of Triassic and Paleozoic rocks. The conglomerates crop out in a practically N-S anticlinal, located to the E of the great synclinal of Fnideq (Kornprobst & Durand-Delga 1985), with the same N-S axial direction, showing Oligocene-Lower Miocene successions (Figs. 3 and 4).

Petrographic description

The conglomerates studied are formed mainly by cobbles of quartzites and of fossiliferous limestones and, subordinately, by granite, rhyolite, pegmatite, phyllite and lydite cobbles. These cobbles present foliations, evidently linked to deformational events prior to the sedimentation of the conglomerates. The cobbles of limestone or lydite have not been studied microscopically because it is well known that they derived from older levels of the Malaguide Complex; thus the attention has been focused on the igneous or metamorphic cobbles (Fig. 5A,B).

Twelve samples of granite cobbles studied under the microscope present a moderate mylonite deformation, responsible for their gneissic appearance. The quartz shows undulatory extinction and, at times, a polycrystalline aspect, without the development of ribbons. There is textural evidence of grain-boundary migration, but the development of dynamically recrystallized new grains is scarce. Feldspars often appear somewhat fractured and the micas are oriented according to the foliation or have kinked folds (Fig. 5C–F). These observations imply that the foliation of these granites developed under low-grade metamorphic conditions and, given the scant development of the dynamic recrystallization, they can be qualified as proto-mylonite granites. In terms of mineralogical composition, there are some biotitic granites, but the great majority are two-mica granites, frequently leucocratic, with almost pure albite and variable microcline perthite and, locally, with garnet or cordierite. Thus, their provenance is closely linked to plutonic sources formed by peraluminous, two-mica, cordierite-bearing granite/leucogranite, which have been affected by a penetrative deformation under low-grade metamorphic conditions.

Furthermore, four metasandstone cobbles have also been studied. These are represented by arkoses and arkosic wackes, with grains of quartz (predominant), plagioclase, potassium feldspar, micas, metapelite fragments, and zircon, apatite and tourmaline as heavy mineral accessories. This

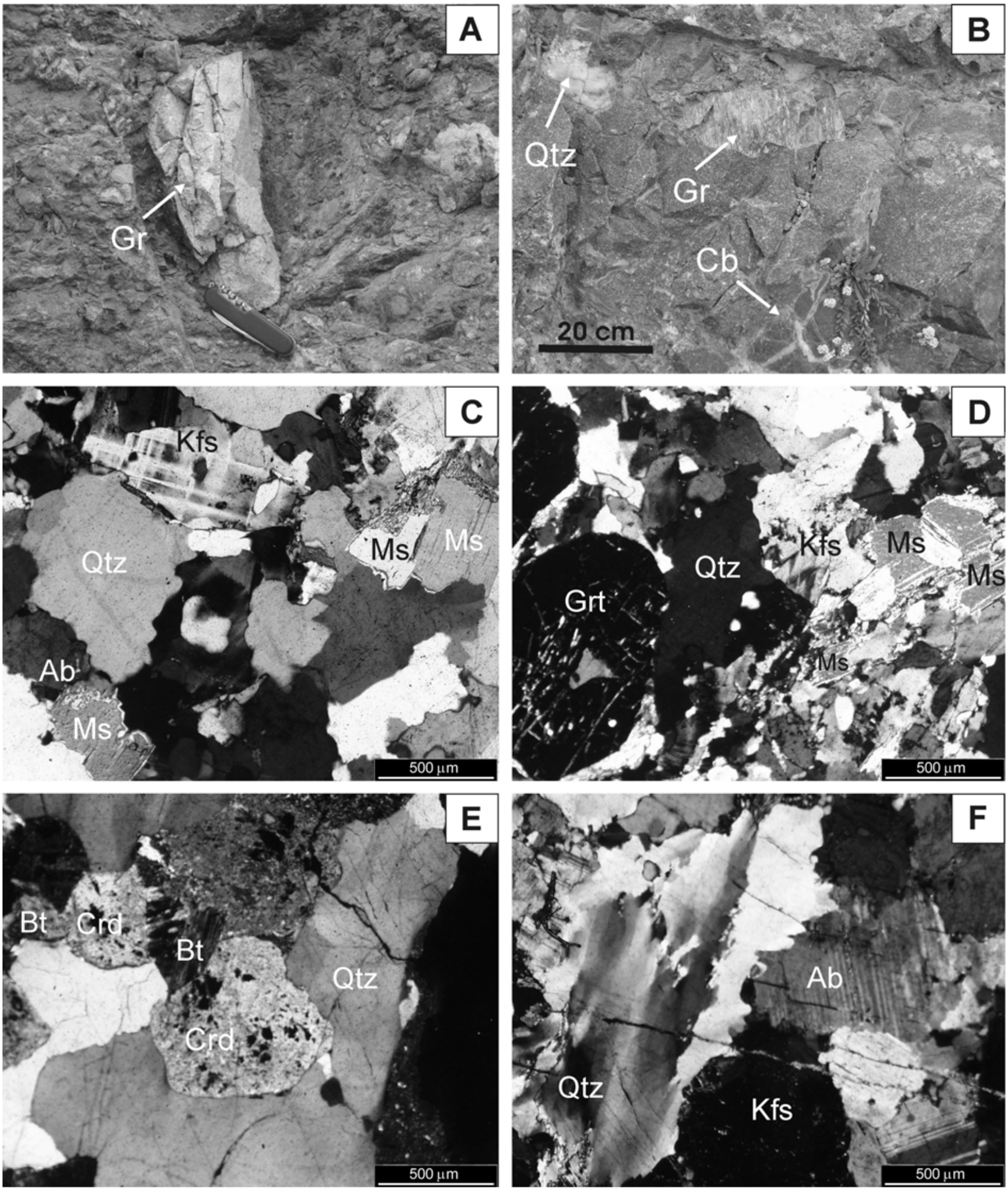

Fig. 5. A, B — Outcrop photos, showing decimeter-scale granite cobbles (Gr). The usual gneissic appearance of the deformed granite can be appreciated in B together with other types of decimeter-sized cobbles (Cb = limestone; Qtz = quartz). **C, D, E** — Mineralogy of the granite cobbles (Qtz = quartz; Kfs = K-feldspar; Ab = albite; Ms = muscovite; Bt = biotite; Gr = garnet; Crd = cordierite). **F** — Protomilonitic texture of the granites. Undulatory extinction and elongated polycrystalline quartz grains with irregular grain boundaries (boundary migration recrystallization). Note also fine cracks perpendicular to the elongation of quartz grains.

composition reflects a provenance from detritus linked mainly to the dismantling of granitoid massifs and, in minor proportions, to fine-grained epimetamorphic rocks.

Given that the conglomerates show no clasts of medium/high-grade metamorphic rocks, it can be hypothesized that the granite-massif sources of the cobbles did not belong to anatectic complexes, but rather were epiplutonic granite bodies, intruding into the high levels of the crust. Peraluminous, two-mica, cordierite-bearing granite/leucogranite, such as in the cobbles of the Tarajal conglomerate, crop out characteristically in the Central Iberian and Western Asturian-Leonese Zones of the Iberian Massif (Fig. 1). Thus, the presence of these types of granite cobbles in a conglomerate of the Malaguide-Ghomaride Complex is indicative of a north-western origin of the detritus, related mainly to the erosion of those terrains, as discussed below.

Discussion

Main features of the Variscan organization in Iberia and in Morocco, some being useful for comparisons with the Malaguide-Ghomaride Complex

Three structural domains form the northern part of the Iberian Massif. Apart of the allochthonous Galicia-Trás-Os-Montes Zone, these are, from the south-west to the north-east (Figs. 1 and 6): a — an internal domain characterized by lower Paleozoic shelf deposits (the Central Iberian Zone), b — an early Paleozoic graben that trapped thick sedimentary deposits (the Western Asturian-Leonese Zone) and c — an external shelf, evolving into a foreland basin during late Carboniferous times (the Cantabrian Zone). To the ESE, Mesozoic and Tertiary successions belonging to the Iberian Chain and to part of the External Zone of the Betic Cordillera transgressively covered these zones. However, patchy outcrops of Paleozoic rocks emerged in some parts of the Iberian Chain and the Coastal Catalonian Range. Variscan granitoids are particularly diverse and abundant in the Central Iberian Zone and in the westernmost border of the Asturian-Leonese Zone. The first tectonometamorphic event occurred as early as the Early Devonian in the western allochthonous units. Its deformational contraction migrated eastwards and reached the easternmost regions in Westphalian times. The orogenic vergence in northern Iberia is towards the E/NE, whereas the southern Iberia transect, formed by the Ossa-Morena and the South Portuguese Zones (Figs. 1 and 6), shows a southward vergence (Simancas et al. 2002).

In Morocco (Figs. 1 and 6), the Anti-Atlas chain, which formed the northern margin of the Western African Craton, shows a Precambrian basement (in the so-called "boutonnières") that was partly involved in the Proterozoic Pan-African orogeny. Its Paleozoic cover underwent a relatively weak Variscan deformation, with respect to its deepest northern prolongation: the Meseta domain. The latter corresponds to the true Variscan chain, usually divided into a Western and an Eastern Meseta (Piqué 1994). The Western Meseta shows a thick siliciclastic Paleozoic sequence and a variety of late-orogenic granites that make it closely correlate to the Central Iberian Zone (Martínez-Poyatos et al. 2004; Simancas et al. 2005). The transition to the Eastern Meseta occurs at the Kenifra-Bouagri Nappe zone (the so-called Central Meseta), which presents a distinctive Devonian succession of calcareous flysch and olistoliths (Zahraoui 1994). The Eastern Meseta bears the records of different sedimentary environments: the Silurian being represented by pelagic deposits and the Lower–

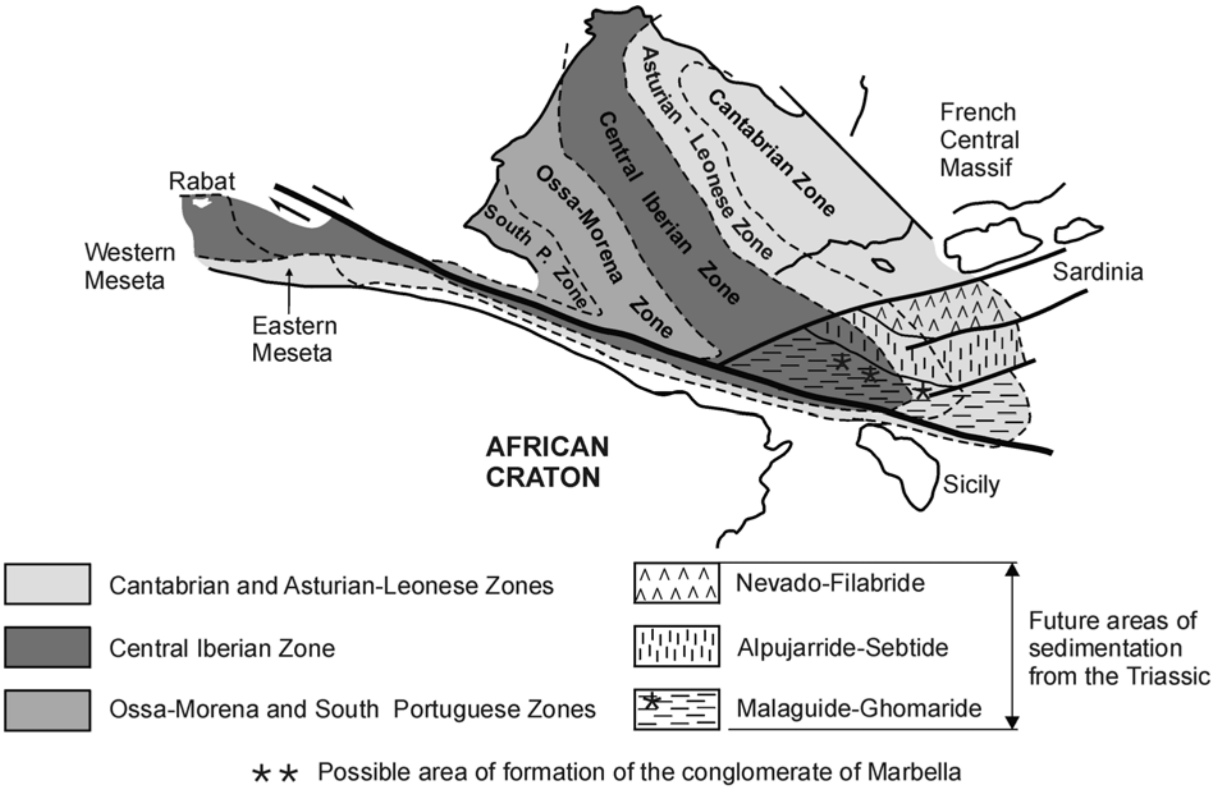

Fig. 6. Paleogeographical reconstruction showing the location of Iberia and of Morocco at the end of the Paleozoic and the approximate location of the future sedimentary basin during the Mesozoic evolution of the AlKaPeCa Domain.

Middle Devonian by turbidites (Hoepffner 1987; Zahraoui 1994). Later, during the Early–Middle Devonian, the Eastern Meseta evolved into a deep trough receiving turbiditic sediments, which announced a Late Devonian deformation. It is noteworthy that, although no Devonian rocks outcrop to the east of the Eastern Meseta, the existence of Devonian blocks in Carboniferous deposits suggest that a carbonate platform would have existed east of the turbiditic trough (Hoepffner 1987). A similar observation has been reported by Herbig (1985) in Spanish outcrops of the Malaguide-Ghomaride Complex.

On the basis of regional tectonic data (correlation of the sutures of the Variscan orogeny), together with stratigraphic affinities and similarities in the granite plutonism, it can be suggested that (Simancas et al. 2005): a — the Western Moroccan Meseta with the Central Iberian Zone and the Eastern Moroccan Meseta with the Western Asturian-Leonese/Cantabrian Zones, respectively, were approximately equivalent paleogeographical domains during early Paleozoic times belonging to the same margin of the Gondwana continent. b — On the contrary, there are no counterparts in Morocco for the Ossa-Morena and South Portuguese Zones. Thus, only the paleogeographical zones of central and northern Iberia would extend into the Moroccan Meseta (Fig. 6). In this broad context, the original location of the Malaguide-Ghomaride Complex is discussed below.

Comparison of the petrological characteristics of the Tarajal conglomerates with those of the domains of the Iberian Massif and of Morocco: original location of the Malaguide-Ghomaride Complex

Carboniferous granitoids crop out in all zones of the Iberian Massif and in the Western and Eastern Mesetas of Morocco and their abundance and petrographic/geochemical features markedly differ along these areas. The Central Iberian and the Asturian-Leonese Zones have far greater diversity and volume of granitic magmatism (Bea 2004). The granitoid cobbles of the Malaguide conglomerate of Tarajal correspond to peraluminous, two-micas, cordierite-bearing granite/leucogranite. Furthermore, their source areas should be represented by epiplutonic massifs because the exclusive presence of cobbles of low-grade metamorphism indicates that only the highest crustal levels were eroded at that time. Granites with these characteristics crop out abundantly in the northern half of the Central Iberian Zone and in the Western Asturian-Leonese Zone, being extremely rare in other zones of the Iberian Massif (Bea 2004). The Central Iberian and Western Asturian-Leonese Zones form a wide belt extending from Galicia through the central area of the Iberian Peninsula and must continue towards the ESE (Figs. 1 and 6), where its outcrops are hidden by the Tertiary sediments of the Duero Basin, of the Iberian Chain and of the Betic Cordillera in its easternmost sector.

An original location of the Internal Betic-Rifian Zone to the very ENE of its present-day position, to the south of Sardinia, still in crustal continuity with the European Plate, has been argued from different geological evidence (see López Casado et al. 2001). Thus, at the end of the Paleozoic, the Malaguide-Ghomaride terrains could have been located in the easterly prolongation of the Central Iberian/Western Asturian-Leonese belt and they could have been fed from the erosion of these areas. The finding of granitic cobbles in the Malaguide Complex is a further argument in favour of situating this complex several hundred kilometers to the east, specifically in the ESE continuation of the aforementioned zones of the Iberian Massif. This agrees well with the opinion of Bourrouilh & Gorsline (1979), Bourrouilh et al. (1980) and Henningsen & Herbig (1990), who indicate that the Carboniferous sediments of Minorca (Balearic Islands) formed the continuation of the Malaguide Carboniferous Basin, and even the Minorcan conglomerate of Binifaillet is thought to be equivalent to the Malaguide Marbella Conglomerates. At the same time, the Carboniferous of Minorca is linked with that of the Catalonian Coastal Range.

In the same line, it should be noted that Herbig (1985) and Herbig & Stattegger (1989) described in Malaguide outcrops large blocks of Devonian limestones inside Visean deposits, correlating them with those existing in Minorca in identical positions, and concluding that they derive from different sectors of a common primary sedimentary shelf located just east of the Malaguide Basin. Herbig (1990) correlated the Carboniferous and Devonian of the Malaguide with Minorca and with the Chenoua Massif, situated 70 km to the west of the Algiers. In turn, Chalouan (1986) and Chalouan & Michard (1990) described the Paleozoic series of the Ghomaride Units and indicated the presence of Devonian limestones in all of the series, highlighting the presence of reef limestones in the Talembote Unit, the highest tectonic slice of the Ghomaride Complex. This same unit also presents large Devonian limestone boulders included in the Carboniferous. Devonian limestone boulders in Visean deposits have also been pointed out in the Eastern Moroccan Meseta (Hoepffner 1987). Furthermore, there are noticeable similarities in the Silurian/Devonian stratigraphy of the Malaguide-Ghomaride and the Nappe Zone/Eastern Meseta. Thus, these now dispersed regions may have been in a similar paleogeographical domain, bounded to the east by a Devonian carbonate platform. In the Iberian Massif (Fig. 1), the Cantabrian Zone has a Devonian shelf of carbonates, including some reef limestones (Aramburu et al. 2004). Finally, on a broad tectonic, stratigraphic and petrologic basis, Simancas et al. (2005) have indicated that it is not possible to correlate these domains with the Ossa-Morena or South Portuguese Zones, as indicated also by Henningsen & Herbig (1990) on sedimentological grounds.

Summarizing all the above data, we conclude that the Malaguide-Ghomaride Complex belonging to the Betic-Rifian Internal Zone may have been located in connection with the Central Iberian Zone/Western Asturian-Leonese Zone (by the type of granites in conglomerates), with the Western Asturian-Leonese Zone (by the existence to the east of a common Devonian carbonate shelf, cropping out in the Cantabrian Zone), or with the Catalonian Coastal Range/Minorca (by the similarities observed within the

Carboniferous successions). To the south, the Malaguide-Ghomaride Complex shows some stratigraphic and petrologic affinities with the Nappe Zone/Eastern Meseta. Accordingly, all these regions were probably in approximate paleogeographic continuity during Paleozoic times. This correlation can probably be extended to the Chenoua Massif and even to another sector farther east, as some internal units of the Calabrian area in southern Italy. Certainly, the above-mentioned correlations and attributions are only approximate because the characteristics of a paleogeographical pre-orogenic or orogenic zone usually change laterally. Fig. 6 shows a reconstruction of this former continuity, indicating the mutual relationships between the domains involved. The results of Gigliuto et al. (2004a,b) relating the granitoid pebbles of the Oligocene-Miocene Beni Ider Flysch and of the coeval successions unconformably overlying the Internal Rifian sectors with the granites of Central Iberia agree with our conclusion. Careri et al. (2004), in the discussion of the Gigliuto et al. (2004a), relate the granitic pebbles with the Calabria region, without considering the geochemical differences indicated by Gigliuto et al. (2004a) between the Calabrian plutonites and the granitoid pebbles of the Oligocene-Miocene Rifian successions. In any case, if Calabria was the source area of the plutonic pebbles, it is very probable that this sector was, broadly, in the prolongation of the Central Iberian and Western Asturian Leonese Zone, as we propose.

Nevertheless, the former paleogeographical continuity among all these sectors does not exist at present, their distribution is the result of the Alpine deformations and in particular is due to the opening of the Algero-Provençal Basin, during the Early Miocene, which radially expelled the domain bearing the Betic-Rifian Internal Zone (Boillot et al. 1984; Sanz de Galdeano 1990): the Kabylide in Algeria migrated to the south, and the Betic-Rifian Internal Zone to the west, as indicated in Fig.7. The reconstruction of the former position of the Malaguide Complex is a new argument to support the strong westward tectonic transport undergone by the Betic-Rifian Internal Zone during the very late Oligocene, Early Miocene, and even Middle Miocene.

Conclusions

The new outcrop of Carboniferous conglomerates of the Malaguide-Ghomaride Complex of the Tarajal sector of Ceuta in the Gibraltar Arc is comparable to other equivalent ones related to the Marbella-like conglomerates (Blumental 1949; Herbig 1984).

The petrographic characters of the plutonic cobbles occurring within these conglomerates suggest that they can be ascribed to the peraluminous two-mica granite group, relatively young (syntectonic) and similar to other granitoid rocks of the Central Iberian Zone. In constrast, their characteristics do not admit a correlation with the granites of the Ossa-Morena and South Portuguese Zones, although, at the present, they are geographically nearer to the outcrop analysed here.

An original situation of the Internal Betic-Rifian Zone more to the east, and consequently of the Malaguide, to the south of Sardinia, places this domain roughly in the extension of the Central Iberian/Western Asturian-Leonese Zones. In this paleogeographical scenario the products of the erosion of these domains, assumed to be the source areas of the granitoid pebbles described here could easily reach the Malaguide-Ghomaride sedimentary basin. This situation is also supported by the correlations already performed by various authors, showing similarities between the Carboniferous successions of the Malaguide and that of Minorca and in the correlations based on tectonic and petrological criteria, between the Iberian Massif

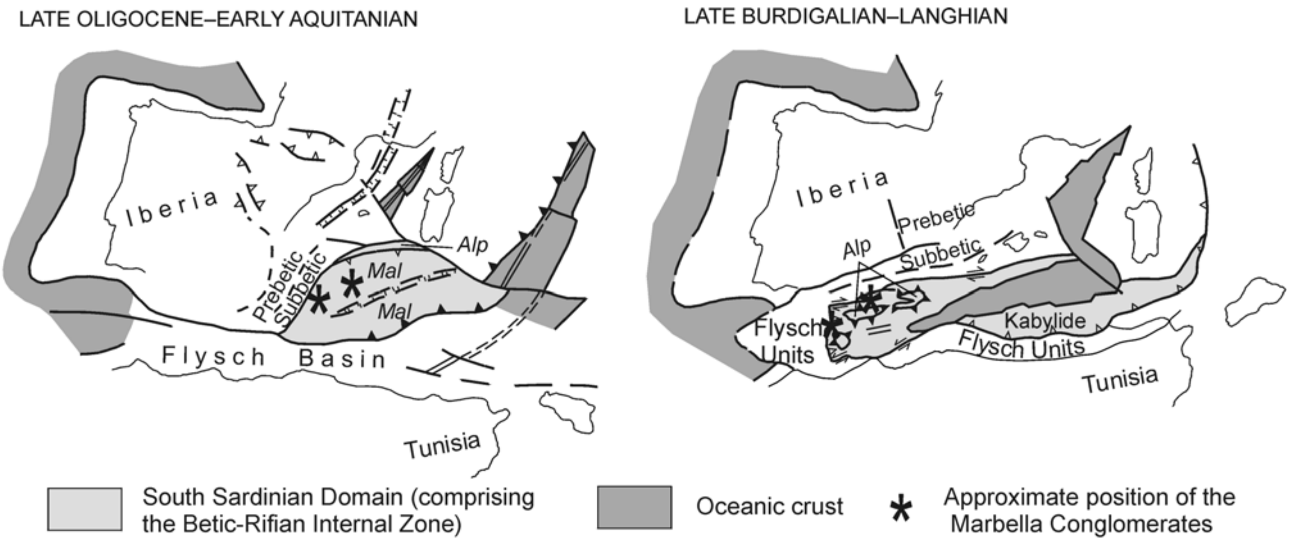

Fig. 7. Paleogeographical reconstruction of the western Mediterranean during the late Oligocene-early Aquitanian and the Burdigalian–Langhian times, indicating the strong westward displacement of the Betic-Rifian Internal Zone, which explains the present very westerly position of the Malaguide-Ghomaride Complex (modified from Sanz de Galdeano et al. 2001).

and the Moroccan Meseta. These correlations should be considered in a broad sense, as the zones must have changed laterally.

The original location inferred for the Internal Betic-Rifian Zone to the south of Sardinia fully supports the paleogeographical evolution of the Lower Miocene of the Betic-Rifian Chain, showing that during the opening of the Algerian-Provençal Basin, the Internal Betic-Rifian Zone was expelled hundreds of kilometers towards the west, to its present geographical position forming the Gibraltar Arc.

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