

The Mesozoic and Cenozoic of the Malaguide Complex in the Málaga area: a Paleogene olistostrome-type chaotic complex (Betic Cordillera, Spain)

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Abstract

This paper analyses the stratigraphic disorganization of the Mesozoic and Cenozoic in the Malaguide Complex of the Málaga area and concludes that this disorganization was caused by gravitational tectonics, which arranged most of the Meso-Cenozoic in olistostrome-type chaotic masses. The deformations occurred between the Middle Eocene and the latest Oligocene. The paper also reports the presence of up to now partially unknown Eocene sediments, deposited in lagoonal environments. Finally, for the first time, the existence around Málaga of sediments belonging to the Upper Oligocene – Aquitanian Ciudad Granada Group and the Lower Burdigalian Viñuela Group is shown.

Introduction

The Malaguide Complex occupies the uppermost tectonic position in the sequence of nappes which constitutes the Internal Zones of the Betic Cordillera. It lies on the Alpujarride Complex, which in turn rests on the Nevado-Filabride Complex.

The Malaguide Complex mainly consists of tightly folded Paleozoic (Ordovician – Carboniferous) rocks, slightly metamorphic in the lower levels. Several authors have shown that this Paleozoic was affected by the Hercynian diastrophism (Foucault & Paquet 1971, Felder 1978, Bourgeois 1978, Kockel 1963, Martín Algarra 1987, see also Chalouan 1983 for the Gomarides, the Moroccan equivalent of the Malaguides). According to some authors this diastrophism was not very intense (Roep 1974, Mäkel 1985). A thin Mesozoic and Cenozoic sequence with important stratigraphic gaps covers the Paleozoic. Outcrops of this sequence occur sporadically in small areas. The largest outcrops, providing the best conditions for study, are found in the regions of Sierra Espuña (Murcia), Vélez Rubio (Almería) and in the vicinity of Málaga (Fig. 1A).

In outline, two large lithological groups predominate in the Meso-Cenozoic part of the Malaguide Complex. The lower one, designated as Saladilla Formation (Soediono 1971, Roep 1972, Geel 1973), is mainly detrital. It displays variegated colours, giving a characteristic red tone to the terrain. The sediments are arranged in a fining-upward sequence, with prevalence of quartz conglomerates and sandstones in the lower and middle layers, and claystones with evaporites (thin gypsum and dolostone intercalations) towards the top. In the Vélez-Rubio and Sierra Espuña areas, dolomite beds as well as conglomerates with quartz and dolomite pebbles are abundant in the upper part (Paquet 1969, Soediono 1971, Roep 1972, Geel 1973, Mäkel 1985). No organic remains older than the Triassic have been found in this formation neither in the Betic Cordillera, nor in the Rif (Baudelot et al. 1984, Kozur et al. 1985, Maate et al. 1993), although it has traditionally been attributed to the Permo-Triassic.

The upper lithological group is a mainly carbonate succession, which overlies normally the Saladilla Formation. It contains latest Triassic dolostones with marly intercalations, Jurassic limestones with facies differing according to age, very thin and sparse Cretaceous marly limestones, and Lower – Middle Eocene

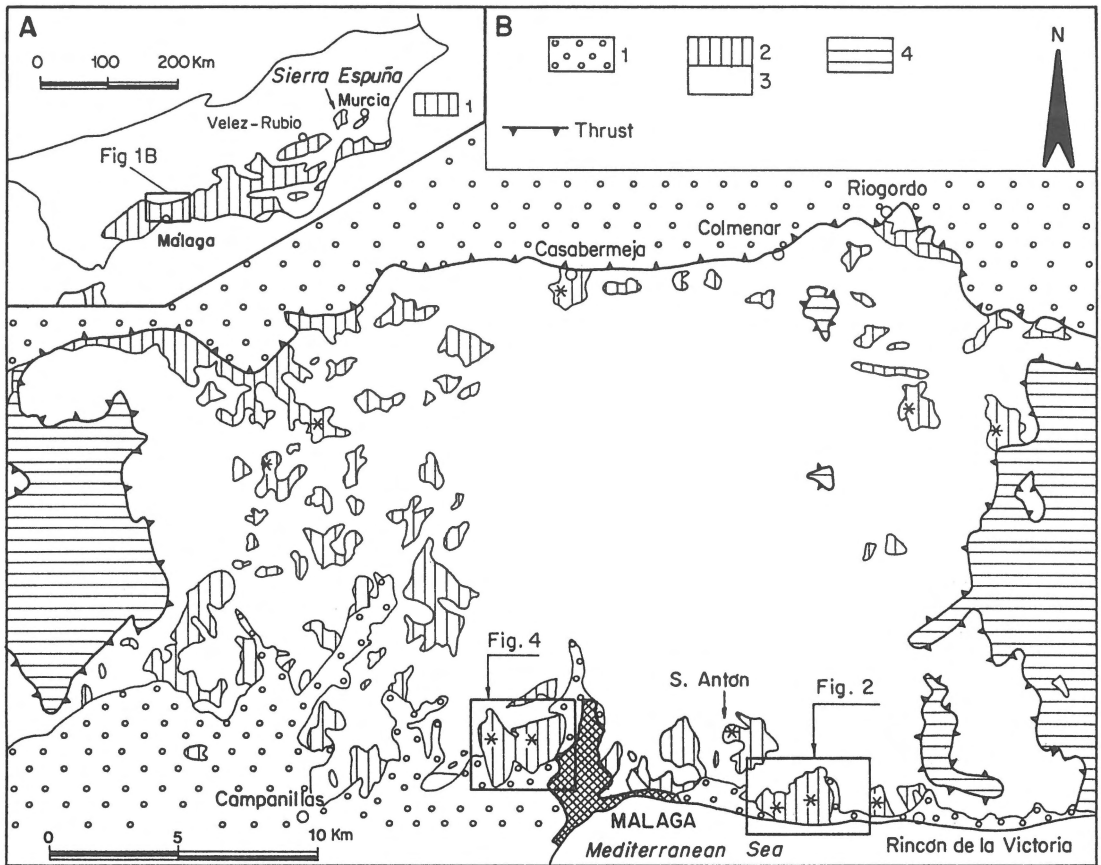


Fig. 1. Location of the study area. A: General situation in the Betic Cordillera. 1: Internal Zone. B: Simplified geological map of the Málaga region. 1: Tertiary and Quaternary. The Tertiary corresponds to autochthonous and allochthonous sediments not belonging to the Malaguide Complex. 2, 3: Malaguide Complex; 2: Mesozoic and Tertiary. Most of the outcrops are Triassic rocks. The most important outcrops with Jurassic and younger rocks are indicated by asterisks (*); 3: Paleozoic. 4: Alpujarride Complex.

limestones and calcarenites (Azéma 1961, Dürr 1967, Paquet 1969, Geel 1973, Roep 1980, Maate 1984, Mäkel 1985, Martín Algarra 1987, Lonergan 1991).

With the exception of the Sierra Espuña area, where the thickest and fairly continuous sedimentary sequence from the Triassic up to Lower Miocene occurs, sediments younger than the Middle Eocene are rarely present in the Malaguide Complex. The inclusion of these sediments in the Malaguide Complex is not clear, because the age of its folding and thrusting on the Alpujarrides are strongly debated. Most authors accept the existence of, at least, two deformational phases, but different ages are assigned to them. In Sierra Espuña, Paquet (1969) considered that the main tectonic event responsible for the thrusting of the Malaguides on the Alpujarrides was of Late Eocene age; the 'Auversian' – Oligocene – Aquitanian thick

clastic succession outcropping in this area would be postorogenic and transgressive on different Malaguide tectonic units. The whole ensemble would have been affected by a younger tectonic event at the end of the Early Miocene. A similar conclusion was reached by Navarro-Vilá (1976) in Sierra Arana, in the central sector of the Betic Cordillera, where he noticed the existence of a Late Eocene deformation related to the nappe emplacement of the Malaguides on the Alpujarrides, and a second event in the Early Miocene. More recently, Lonergan (1991, 1993) has found in Sierra Espuña major thrust movements in Late Eocene and Late Oligocene times, and smaller movements in the earliest Miocene. However, in the Vélez-Rubio area, the geologists of the University of Amsterdam do not accept the existence of major thrusting phases in the Malaguide before the Early Miocene (MacGillavry et

al. 1963, Roep 1972, Geel 1973, Mäkel 1985). Even the 'post-nappe' nature of the Late Eocene and younger succession of Paquet in Sierra Espuña was disputed by Hermes & Kuhry (1969). Moreover, they considered the unconformity at the base of the Ciudad Granada Group as a sedimentary contact, rather than as a tectonically generated contact, and affirmed that the main deformations of the Malaguide Complex happened after deposition of the Ciudad Granada Formation and before the sedimentation of the Espejos Formation (see below).

Similar discrepancies exist in the western Betic Cordillera and in the Moroccan Rif, where several authors affirmed that major thrusting occurred before the deposition of the Upper Oligocene – Aquitanian on the Malaguides and the equivalent Rifian Ghomarides (Olivier 1984, Feinberg et al. 1990, Durand-Delga et al. 1993). Bourgois (1978) and Felder (1978) noted a thrusting phase before the Late Oligocene and another one during the Aquitanian, between the deposition of the Alozaina Formation (Ciudad Granada Group) and the Viñuela Formation. Other authors (Martín-Algarra, 1987; Guerrero et al., 1993) reached conclusions similar to those of the Dutch geologists in the eastern part of the chain.

In any case, the Malaguide Complex, more or less deformed during the Late Paleogene, constituted the sedimentation area of the Upper Oligocene – Aquitanian Ciudad Granada-type formations (MacGillavry et al. 1963, Soediono 1971, Martín-Algarra 1987, González Donoso et al. 1988). The Lower Burdigalian Viñuela-type formations were deposited on both the Malaguide and the Alpujarride rocks (MacGillavry et al. 1963, Vera 1969; Boulin et al. 1973, González Donoso et al. 1982); consequently, they do not belong to the Malaguide Complex.

In this paper we show that the original stratigraphic contact between the Triassic and Jurassic – Cenozoic units is rarely preserved in the surroundings of Málaga, even though the superposition of the two units generally remains the same. Parts of one or both units are missing at the contact itself, and in some places rocks of other ages are intercalated. In addition, the rocks of the upper unit, mainly carbonates, are chaotically arranged and the stratigraphic sequence is only preserved in the larger blocks. The Paleogene sedimentation of the Malaguide Complex in this area reaches levels younger than the Early Lutetian, including sediments of the Ciudad Granada Group. On the other hand, sediments that can be correlated with the Viñuela Group are also present.

The Meso-Cenozoic of the Malaguide Complex around Málaga

East of Málaga, between El Palo and Cala del Moral (Fig. 2), Bertrand & Kilian (1889) described the Cortijo del Cantal section, which was later revised by Azéma et al. (1960). They demonstrated the existence of a relatively complete series spanning from the Permian-Triassic to the Ypresian or Early Lutetian. Azéma (1960a, b, 1961) made a detailed study of this section, describing a sedimentary sequence that seems to present considerable continuity. He also demonstrated the presence of at least two tectonic wedges, causing partial repetition of the series. Malaguide post-Lutetian sediments have not been found around Málaga. However, Upper Oligocene – Aquitanian deposits belonging to the Ciudad Granada Group are present some tens of kilometres west of Málaga, in Alozaina and Ardales (Alozaina and Pantano Andrade formations: Bourgois et al. 1972, Bourgois 1978, González Donoso et al. 1983, Martín Algarra 1987). Outcrops of the Viñuela Group nearest to Málaga have recently been found 20 km west of Málaga, close to Cártama (Sanz de Galdeano et al. 1993).

The Malaguide Meso-Cenozoic was formerly described as a strongly tectonized, but more or less continuous stratigraphic sequence. However, its fragmented nature, chaotic appearance and structural disorganization can be observed in most of the outcrops in the Málaga area (Fig. 1B). Particularly in the vicinity of the Harania cement factory east of Málaga (Fig. 2), where the aforementioned Cortijo del Cantal series was established, excellent exposures were made through quarrying and major roadworks. According to their arrangement (Fig. 3), the rocks overlying the Triassic can be subdivided into three groups: a) Paleogene sediments containing blocks and breccias of up to Eocene age, b) the blocks and breccias themselves, which constitute a chaotic complex of olistostrome type, and c) sediments deposited on the chaotic complex.

Paleogene sediments containing blocks and breccias

In the Harania sector, Paleogene sediments overlying red Triassic rocks display three lithofacies: Lagoonal facies, *Microcodium* facies, and *Alveolina* limestones. Their stratigraphic relations are not clearly observed, but they seem to correspond to distinct stratigraphic levels.

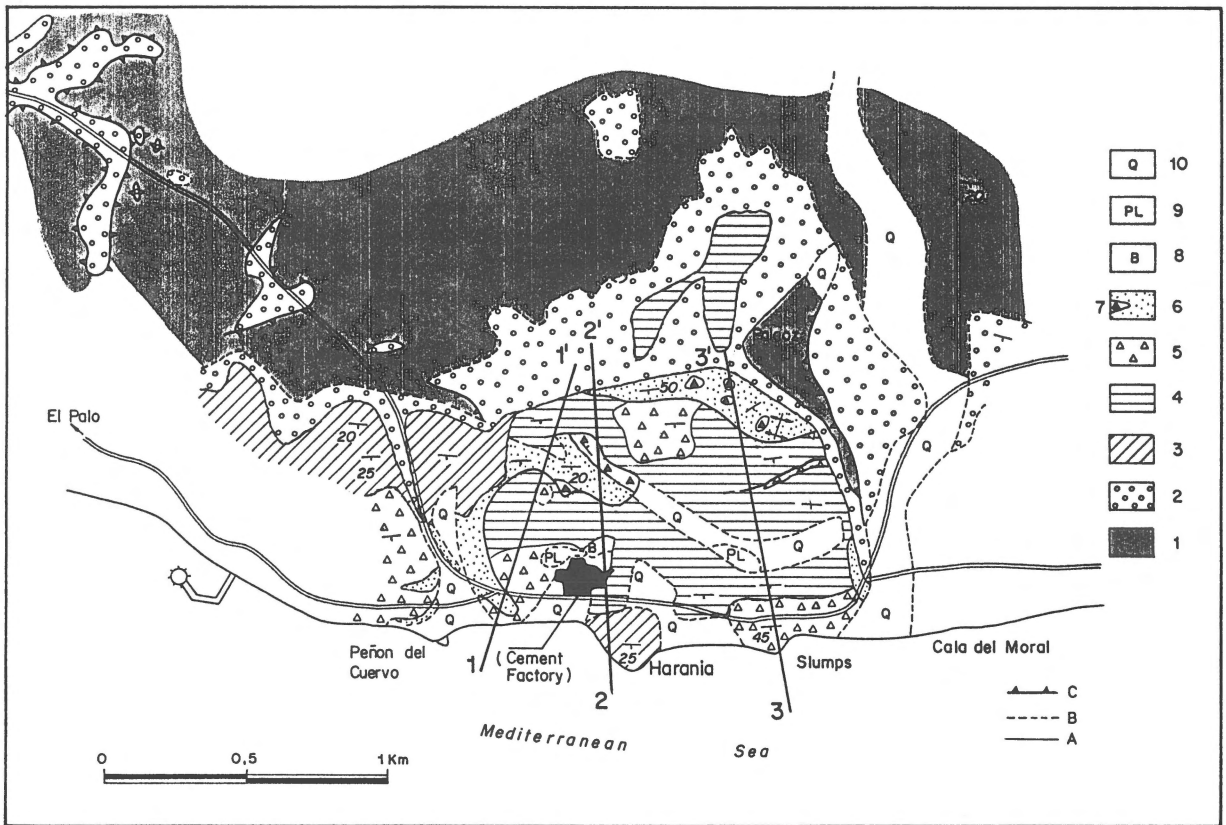


Fig. 2. Geological map of the Harania cement factory sector. A: Tectonized contact. B: Unconformity. C: Thrust. 1: Paleozoic shales. 2: Red Triassic conglomerates, sandstones and claystones. 3: Latest Triassic marls and dolostones (in many cases olistolith-like blocks). 4: Main olistolith-like blocks of Jurassic limestones. 5: Main olistostrome-like breccias. 6, 7: Paleogene sediments; 6: Non-differentiated clays, marls, gastropod limestones and microcodites; 7: Blocks of Early Eocene alveolinid limestones. 8: Lower Burdigalian Viñuela Group. 9: Pliocene. 10: Quaternary. Geological sections 1–1' to 3–3' are shown in Fig. 6.

Lagoonal facies

These sediments, unknown so far in the Málaga area, are constituted by greenish-grey clays and marls with lignite beds alternating with gastropod-rich limestones. In the cement factory quarry, they display a thickness of more than 30 m unconformably on the red Triassic rocks. The clays and marls usually contain abundant pyrite, together with phanerogam remains, smooth ostracods (Cypridacea), microgastropods, fish remains and, less commonly, Characea oogonia and *Microcodium* pieces. Some beds also present Corallinacea algae, echinoderm radioles and benthic foraminifera (Miliolidae, Rotalidae, Discorbidae, Lituolidae). Bioturbated limestone beds with 'cailloux noirs' become prevalent towards the upper part; they are rich in gastropods, small bivalves, oncolites and benthic foraminifera similar to those mentioned above.

The lithological characteristics and fossil assemblages indicate deposition in a lagoon-type environment. This was sporadically connected with the open sea, more frequently during the deposition of the upper part.

The age of these sediments is not clear. J.P. Berger from the Fribourg University (written comm. to F. Serrano) attributes the Characea flora to the Late Eocene, close to the Eocene-Oligocene boundary. In the Malaguide Complex of Sierra Espuña, some 300 km northeast of Málaga, very similar sediments were described by Paquet (1969) as Lutetian or undifferentiated Lower – Middle Eocene. Current studies have allowed M. Martín from Granada University (pers. comm. to A. Martín-Algarra) to date this mainly lagoonal sequence of Sierra Espuña as Early – Middle Lutetian by means of thin *Alveolina*-rich limestone intercalations.

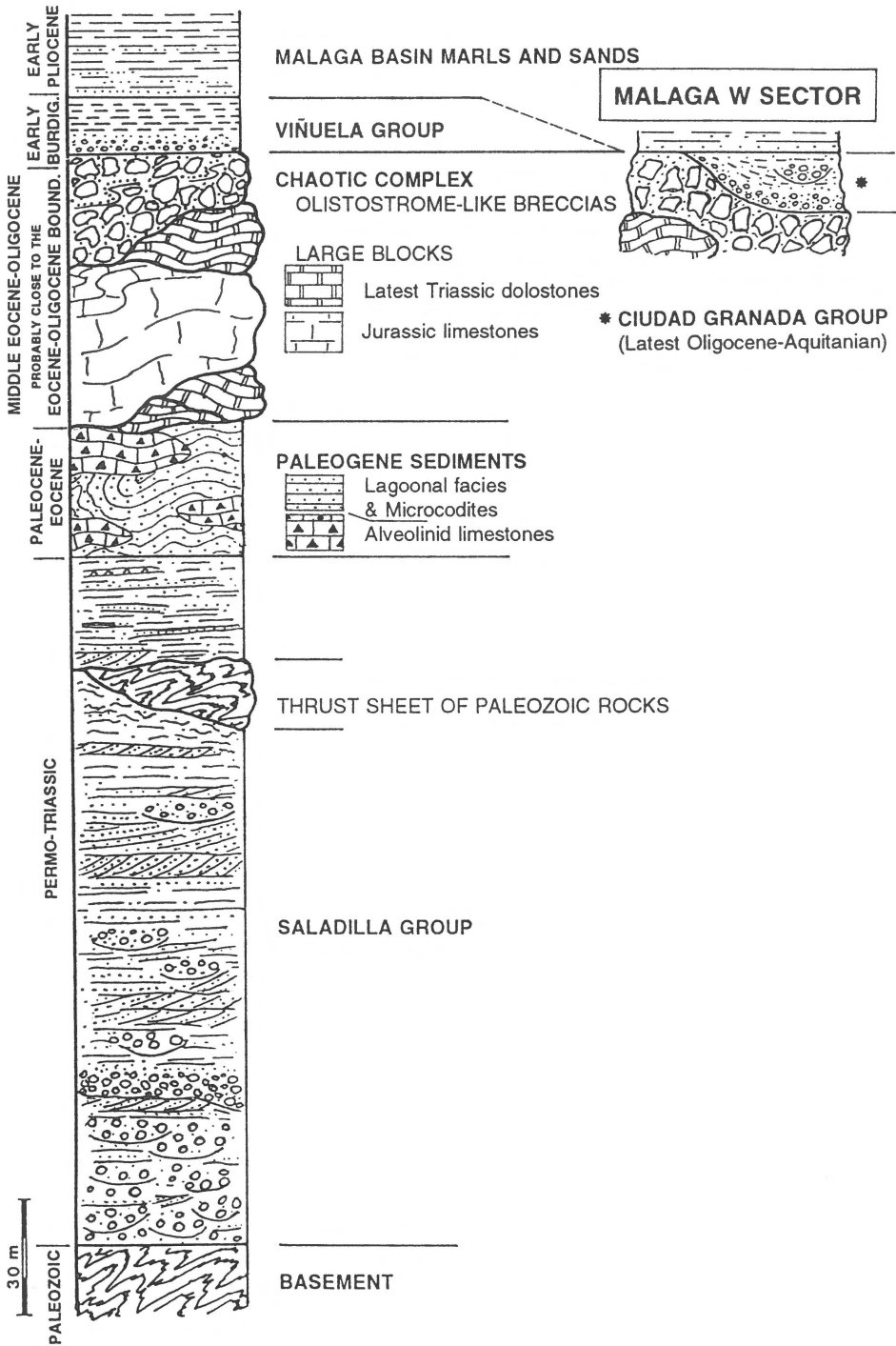


Fig. 3. Arrangement of the Permo-Triassic to Paleogene rocks of the Malaguide Complex in the Harania cement factory sector (for explanation of lithological characteristics, see text).

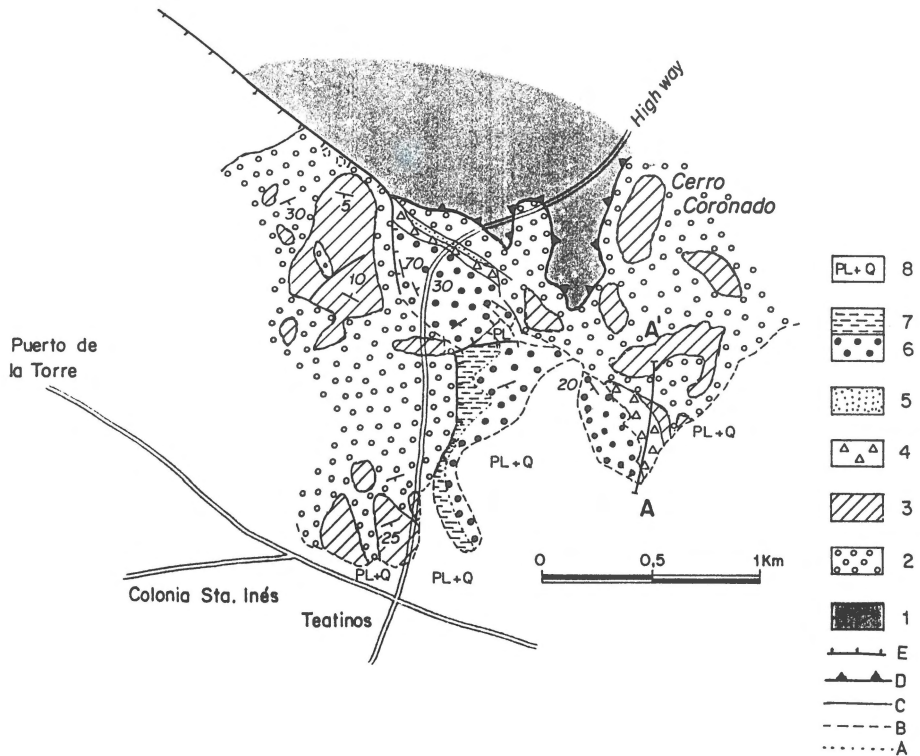


Fig. 4. Geological map of the southern Cerro Coronado-Teatinos sector (west Málaga city). A: Conformity. B: Unconformity. C: Tectonized contact. D: Thrust. E: Normal fault. 1: Paleozoic shales. 2: Red Triassic conglomerates, sandstones and claystones. 3: Latest Triassic marls and dolostones. 4: Olistostrome-like breccias. 5: Paleogene greenish-grey clays with gypsum. 6, 7: Latest Oligocene – Aquitanian Ciudad Granada Group; 6: Conglomerates with sandstones and marls; 7: Reddish sandstones and silts with conglomerate lenses. 8: Pliocene and Quaternary. A-A': Geological section in Fig. 5.

In the Teatinos area (west of Málaga, Fig. 4) 5–7 m of greenish-grey clays with abundant pyrite can be observed as overlying red Triassic rocks. These clays are similar to those outcropping at Harania, although in Teatinos gypsum beds occur in addition. In many other locations around Málaga (Cerro Coronado, Arroyo de las Palmas, Ventorrillo de la Mosca, Cerrado de Calderón) and more distant areas (Cerro del Higuero in Rincón de la Victoria, 15 km east of Málaga; Los Pacos northeast of Fuengirola, 28 km southwest of Málaga) greenish-grey clays appear among more or less brecciated Triassic and Jurassic rocks. These clays ought to be equivalent to those of the Harania quarry, but they are generally highly altered and have a white powdery appearance. Absence of fossils makes their correlation uncertain.

Microcodium facies

Near the cement factory, in the vicinity of the Peñón del Cuervo beach (Fig. 2), the talus of the main road

displays a good section of red Triassic rocks overlain by means of a detached contact by yellowish dolomitic marls and dolostones. This sequence is followed by a reddish-brown sandstone formation, almost exclusively made of *Microcodium* fragments, with intercalations of breccia and conglomerate with mainly Jurassic pebbles. Similar sediments are present inside the cement factory; across the quarry track a thickness of 30–35 m of *Microcodium*-rich sandstones with polygenic conglomerate intercalations occurs. The conglomerates occur in 1 m-thick banks with a lenticular geometry and erosive basis; their sandy-silt matrix is rich in *Microcodium*. The uppermost part of the formation contains calcarenite beds with abundant *Nummulites* bioclasts.

Since Azéma et al. (1960), it has been accepted that the microcodites of the Malaguide Complex belong to the Upper Cretaceous – Lower Eocene, particularly the Paleocene. Nevertheless, in the quarry and near the storage building intercalations of *Microcodium* beds

occur in the greenish-grey clays and marls and the gastropod limestones; these sediments also contain fragments of *Microcodium*. So, these microcodites could be of an Eocene age, close to that of the lagoonal formation.

Alveolina limestones

White-cream, massive, *Alveolina*-rich limestones are a very typical Lower Eocene facies in the Malaguide Complex. Around Málaga, these limestones frequently appear as isolated blocks without lateral continuity within breccias mainly consisting of Triassic and Jurassic blocks. Inside the cement factory, large masses of alveolinid limestones (> 20 m long) overlie microcodites and lagoonal sediments, and also appear to occur within them. However, unambiguous stratigraphic contacts have not been observed; so stratigraphic relations cannot be established clearly.

Chaotic complex of blocks and breccias

Blocks and breccoid masses of older rocks, belonging to the different Meso-Cenozoic units of the Malaguide Complex, overlie the sediments described above. The individual blocks range in size from a few tens to several hundreds of cubic metres. The largest and most abundant are white micritic limestones with intraclasts and ooliths, derived from the dismantling of the Lias – Dogger(?) platform facies. In the larger blocks the rock is highly fractured and has a generally massive appearance, with diffuse stratification up to 1 m thick in the part corresponding to the oldest beds of the original stratigraphic sequence. Stratification is better defined at higher levels. There are also large blocks of grey and black micritic dolostone with intercalated well-stratified beds of dolomitic marls. These blocks come from Triassic or lowermost Lias sequences; they are affected by intense fracturing dividing the rock into packages with a thickness of a few to some tens of centimetres. In some sites where large dolostone blocks directly overlie red Triassic rocks (e.g. Cerro del Candado and Arroyo de los Judfos close to El Palo) the false impression of a normal sedimentary succession is given. Smaller blocks of Upper Jurassic red nodular limestones ('Ammonitico rosso' facies), Kimmeridgian – Tithonian grey micritic limestones with *Saccocoma*, and Lower Eocene limestones were also found.

The upper part of this ensemble is made up of an almost monogenetic breccia with scarce matrix, con-

sisting mainly of white Lias limestone clasts and, to a lesser extent, pebbles of dolostones and other lithologies similar to those of the blocks. Stratification is scarcely observable, but at times beds can be recognized and locally slump folds up to tens of metres in size are observed. The geometric relation with the large blocks seems to indicate a close genetic relation.

In this breccia some irregular lenses of Paleogene sediments occur. In some cases they appear to fill hollows and to cover paleoreliefs in the breccia, whereas in others they could be interpreted as detached masses incorporated into the sliding material.

Peñón del Cuervo is an islet about 25 m long, which is occasionally joined to the coast by a sandy-gravelly isthmus (Fig. 2). It consists of breccia with clasts of different lithologies, the most abundant of which are Lower – Middle Eocene limestones. The abundant matrix is made up of quartz sands, which in some beds predominate over the clasts. Because of its position with regard to the general dip of the formation of blocks and breccias, the islet must be the highest part of the breccia visible.

Sediments deposited on the chaotic complex

Until now, Neogene sediments older than the Early Pliocene had not been recognized in the Málaga area. However, in the Teatinos area (W Málaga), we found a thick, clastic succession mainly made of brown-reddish or orange-coloured conglomerates, slightly calcareous sandstones and pelites, unconformably overlying blocks and breccias of the chaotic complex (Fig. 4). The conglomerates contain a sandy matrix and are widely developed in the lower part of the succession, but they are also present at higher stratigraphic levels intercalated in slightly calcareous, quartzose and micaceous sandstones. The conglomerates are made of well-rounded clasts, mainly quartzitic in the lowest part, but clasts derived from all different stratigraphic levels of the Malaguide Complex, both the Paleozoic and the Triassic to Eocene have been found. Some clasts of metamorphic rocks (gneisses, micaschists), green basic subvolcanic rocks, and granites also occur, which could be derived from the basement of the Malaguide Paleozoic sediments. In Chirivel near Vélez-Rubio, both the Ciudad Granada Formation and the Paleozoic Piar Formation (units B and D) contain similar pebbles of metamorphic and igneous rocks (Soediono 1971); one of the gneiss boulders from the unit D of the Piar Formation (Marbella conglomerate), dated by H.N.A. Priem (ZWO Laboratory for Isotope Geology,

Amsterdam), yielded a radiometric age of 535 ± 75 Ma (Soediono 1971, Roep 1974). The pelites (mostly silts) are rich in benthic foraminifera with abundant *Almaena*, but planktic foraminifera are also present; among them are *Catapsydrax dissimilis* (Cushman & Bermúdez), *Globigerinoides primordius* (Blow & Banner) and *Globoquadrina dehiscens* (Chapman, Parr & Collins), which indicate an Aquitanian age. However, the sandy and gravelly lower part of the formation contains very few planktic organisms and we cannot discount a latest Oligocene age. This succession can be correlated both lithologically and chronologically with the sediments included in the Ciudad Granada Group by Soediono (1971), which sediments are widely present both in the western and eastern Betic Cordillera (Ciudad Granada, Estepona (in part), Alosaina, Pantano de Andrade formations: Soediono 1971, Roep 1972, Bourgois et al. 1972, Geel 1973, González Donoso et al. 1983, Mäkel 1985, Martín-Algarra 1987).

On the other hand, in a small outcrop within the Harania cement factory we have recorded a 20 m-thick sequence of grey and yellowish marls and marly limestones with thin (cm-dm) intercalations of silicites and siliceous marls overlying blocks and breccias of the chaotic complex. It is folded as a syncline beneath Pliocene clastic sediments. These sediments contain a microfauna rich in planktic foraminifera, including *Globigerinoides trilobus* (Reuss), *G. altiapertura* (Bolli) and *Catapsydrax dissimilis*, which is a characteristic assemblage of the Early Burdigalian. Taking into account their age and lithological characteristics, in particular the presence of siliceous layers, these deposits can be correlated with the formations included by Martín-Algarra (1987) in the Viñuela Group, particularly with the mudstone member (Sanz de Galdeano et al. 1993). However, the typical facies of coarse-grained and thick-bedded conglomerates and breccias of mainly Malaguide Paleozoic and Alpujarride metamorphic rocks, which characterize most of the Viñuela-like formations, are not present.

Structure in the Cerro Coronado and Harania sectors

Before this study it was thought (Azéma 1960 a, b, 1961, Azéma et al. 1960, Barba Martín et al. 1979) that the Jurassic was stratigraphically continuous with the Triassic in all the outcrops, even though fault contacts were common (Estévez & Chamón 1978). Fur-

ther west of the area studied here, Chamón et al. (1978) demonstrated that the contact of the dolostones with the red Triassic rocks is generally detached. Cano-Medina (1991) considered the contacts between the same rocks in the Ardales region (NW of Málaga) as tectonic.

In the study area we have only detected very local sedimentary continuity between the red Triassic rocks and the overlying carbonate succession. South of Cerro Coronado, in Málaga city, and on the main road west of the cement factory, yellowish-white marls overlie red Triassic sandstones and clays. These marls contain intercalated dolostone beds and change over a thickness of 7 to 10 m gradually to dolostones. At both sites the Triassic rocks have been thinned by tectonic stretching caused by decollements at a lower level, so that the transition has only been observed within tectonically isolated blocks.

At many other places where the contact was thought to be stratigraphic, it can now be seen, largely due to the road works, that it consists of well-defined tectonic decollements, creating a band several tens of metres thick in which the rocks are disorganized. This is the case, for example, north of Teatinos, west of Cerro Coronado, at Cerro de San Antón and at Rincón de la Victoria. This phenomenon seems to extend outside the Málaga area, as tectonic decollements are also observed on the northern border of the Malaguide Complex between Casabermeja and Riogordo (Fig. 1) and at other distant locations (Comares, Fuengirola).

In the southern part of Cerro Coronado (Figs 4, 5) the structure is rather simple. The somewhat thinned red Triassic rocks are overlain by latest Triassic light-coloured marls with intercalated thin limestone and dolostone beds, which grade upwards into dolostones over a thickness of a few metres. Unconformably above the dolostones, an olistostromal breccia can be observed mainly made of Jurassic limestone blocks up to several tens of metres long. About 1 km to the northwest, on the highway, 5 to 7 m of Paleogene grey-greenish marls and clays similar to those of the Harania quarry are intercalated between red Triassic rocks and olistostrome-like breccias. In both localities uppermost Oligocene – Aquitanian sediments of the Ciudad Granada Group clearly cover the olistostromal breccia.

In the Harania sector the general structure observed is similar but more developed (Fig. 6). Dolostones are locally preserved, overlying red Triassic deposits, but usually Paleogene sediments directly overlie the Triassic. The contact is generally tectonic, but at Rincón

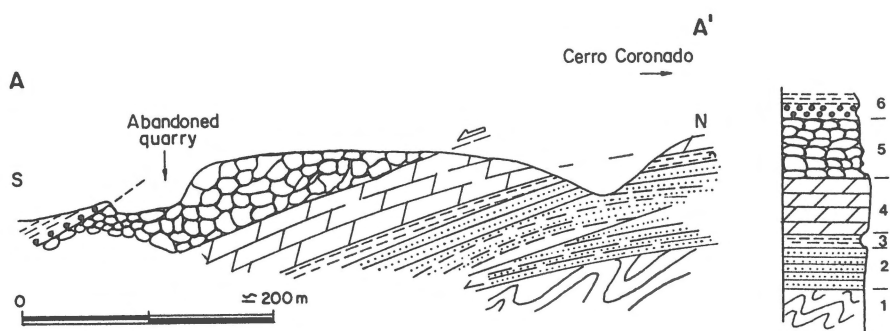


Fig. 5. Geological section of southern Cerro Coronado (Fig. 4). 1: Paleozoic shales. 2: Red Triassic conglomerates, sandstones and claystones. 3, 4: Latest Triassic; 3: Dolomitic marls; 4: Dolostones. 5: Olistostrome-like breccias. 6: Latest Oligocene – Aquitanian Ciudad Granada Group. Scale is approximate.

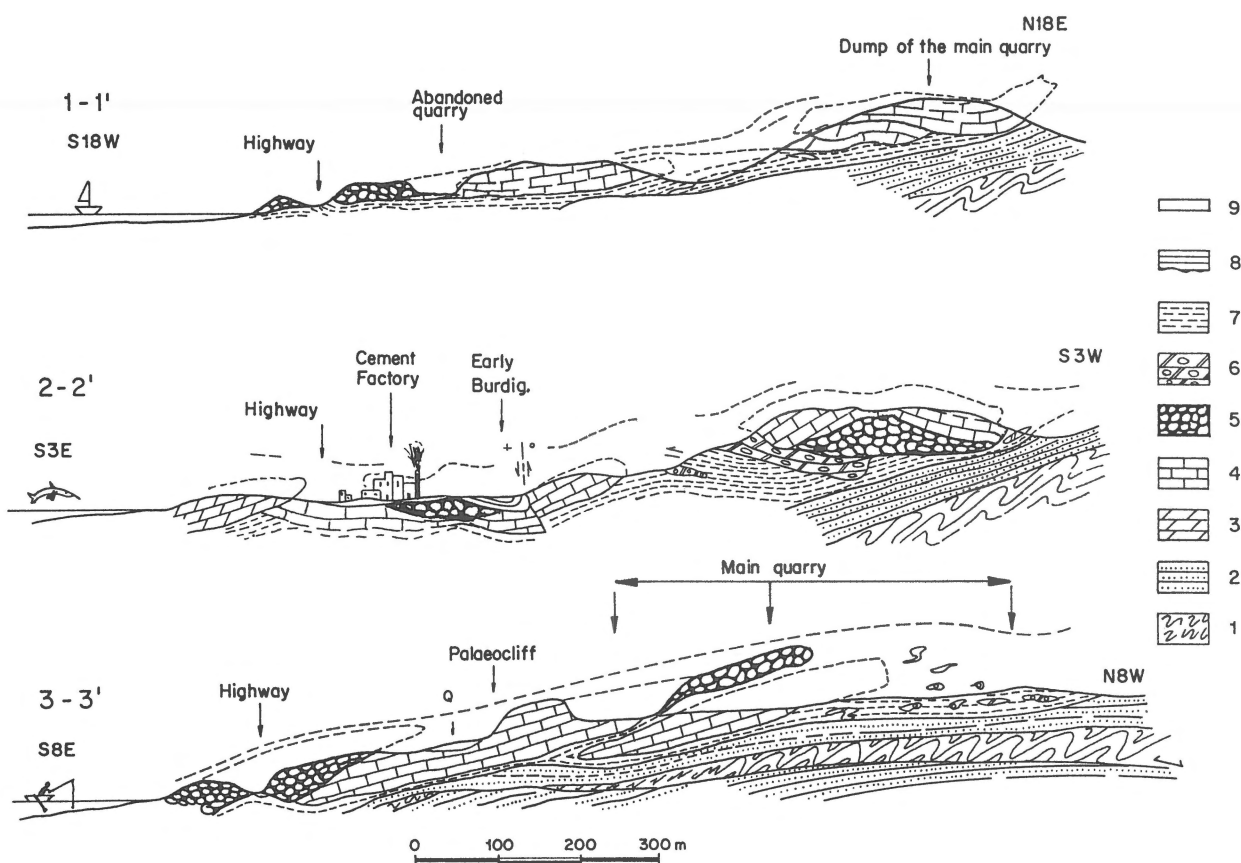


Fig. 6. Geological sections of the Harania cement factory sector (Fig. 2). 1: Paleozoic shales. 2: Red Triassic conglomerates, sandstones and claystones. 3: Latest Triassic dolostones and marls (blocks). 4: Jurassic limestones (blocks). 5: Olistostrome-like breccias. 6, 7: Paleogene sediments; 6: Lower Eocene alveolinid limestones (detached masses); 7: Clays, marls, gastropod limestones and microcodites. 8: Lower Burdigalian Viñuela Group. 9: Pliocene – Quaternary.

de la Victoria Paleogene sediments seem to have been deposited directly on an erosive surface of Triassic rocks. The Paleogene sediments are generally highly disorganized and include detached blocks (up to several tens of metres long) made of alveolinid limestones, as can be observed in the quarry of the cement factory where mechanical digging reveals outcrops only to be destroyed very shortly later. Large Lias – Dogger(?) limestone blocks up to 500 m long overlie Paleogene sediments. In some cases (Section 3, Fig. 6) large blocks are superposed, separated only by a thin, irregular layer of marls and polygenic breccias. The upper part of the chaotic complex can be observed near the sea (Sections 1 and 3, Fig. 6); it consists of important accumulations of breccias with poorly evolved slump folds.

Observations in the Harania sector of slump folds in the olistostrome-like breccias and of drag folds in Paleogene sediments indicate gravitational displacement towards the south or south-southeast (according to the present orientation; rotations of the Malaguide Complex may have occurred).

The tectonic phase between the deposition of the Ciudad Granada and Viñuela groups is not clearly discernible around Málaga, because sediments of both groups are not observed in contact. However, as is discussed in the Introduction, the importance of this phase is evident in other areas of the Betic Cordillera.

Regional considerations and conclusions

The Lower – Middle Eocene alveolinid limestones are equivalent to those found in the Morrón de Totana unit of the Malaguide Complex in Sierra Espuña (Paquet 1969) and in the Vélez-Rubio area (Geel 1973, Roep 1980). On the other hand, the lagoonal greenish-grey clays and marls with lignite beds are similar to those attributed by Paquet (1969) to the Lutetian in the Prat Mayor unit, also in Sierra Espuña, although the Characea flora seems to indicate a younger age, close to the Eocene – Oligocene boundary. However, the microcodites dated as Upper Cretaceous – Paleocene in previous papers (although they are probably younger) have so far not been detected in the Malaguide Complex in the eastern area of the Cordillera.

The oldest possible age for the olistostrome-like chaotic complex is determined by the most recent blocks, the Ypresian or Lower – Middle Lutetian alveolinid limestones, and by the youngest underlying sediments, the Middle – Upper Eocene lagoonal deposits

mentioned above. Moreover, the most ancient sediments overlying blocks and breccias of the chaotic complex belong to the uppermost Oligocene – Aquitanian Ciudad Granada Group. The complex must thus have formed between the Middle Eocene (Lutetian) and the latest Oligocene, probably in the latest Eocene or Early Oligocene. Its development took place in a context of tectono-gravitational deformations affecting the Malaguide Complex (Lonergan 1993) and the Betic-Rifian Frontal units ('Dorsal' units of authors; Naak et al. 1992), at the same time as metamorphism developed in the Alpujarride and Nevado-Filabride complexes.

To summarize, we may conclude that:

- In the Málaga sector, the Meso-Cenozoic of the Malaguide Complex is highly disorganized. It is arranged as a chaotic complex of differently sized blocks and olistostrome-like breccias. Only in a few places the sequence is preserved without tectonic detachment up to the lowermost Lias dolostones. At higher levels the stratigraphy is maintained only inside large blocks.
- The disorganization reveals clear tectonic instability in the region at least from the Late Eocene onwards. Probably, the transformation of a stratigraphically well arranged Malaguide Meso-Cenozoic into an olistostrome-like chaotic complex occurred during the latest Eocene or Early Oligocene. The tectonic effects of both the Late Aquitanian (post-Ciudad Granada Group) and Early Burdigalian (post-Viñuela Group) tectonic phases are not separable in the Málaga area, even though they appear clearly differentiated in the whole of the Betic Cordillera.
- Debris flow, mass flow and slumping processes can be recognized in the Paleogene olistostrome-like breccias, all of which were gravitational in origin. In view of the depositional characteristics, the source area seems to have been located in a nearby region to the north.

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