# A Field Guide to the Neogene Sedimentary Basins of the Almería Province, SE Spain

Edited by

A.E. MATHER, J.M. MARTÍN,

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# Chapter 1
# Introduction to the Field Guide

ANNE E. MATHER, JOSÉ M. MARTÍN,
ADRIAN M. HARVEY & JUAN C. BRAGA

## 1.1 Aim of this field guide

This field guide focuses on the Neogene and Quaternary evolution of the sedimentary basins of the Almería Province, south-east Spain, providing an integrated approach to the geology and geomorphology. The guide assumes a basic knowledge of geology and geomorphology and should be of interest to earth scientists at all levels, from the keen amateur through to undergraduate or postgraduate students and academics visiting the region. It touches on some areas of geology and geomorphology which are associated with specialist terminology (e.g. sequence stratigraphy and igneous and metamorphic geology). It is beyond the scope of this volume to expand on these areas in detail, but a list of texts which do so is given in the Appendix.

The emphasis of this guide is initially to provide a general background to the area based on the Sorbas Basin, where the Neogene depositional sequence is most continuous (Chapter 2). More specialist trips then examine the structure and development of the basins (Chapter 3), the shallow marine sedimentation (Chapter 4) the continental sedimentation (Chapter 5) and, finally, the uplift, dissection and geomorphological evolution of the basins (Chapter 6).

The modern geometry of the Neogene sedimentary basins is shown in Fig. 1.1.1, and the main excursion routes in Fig. 1.1.2.

## 1.2 Background to the study area

Almería is the easternmost province of Andalucía in southern Spain. It is at a latitude of 37°N, bordered by the Mediterranean Sea, some 200 km from the north coast of Africa.

The province lies within the Betic Cordillera, an Alpine mountain chain resulting from the collision of the European/Iberian and African plates from Late Mesozoic to Middle Cenozoic times. During the Miocene, compression was replaced by extensional and strike-slip tectonics, and the area

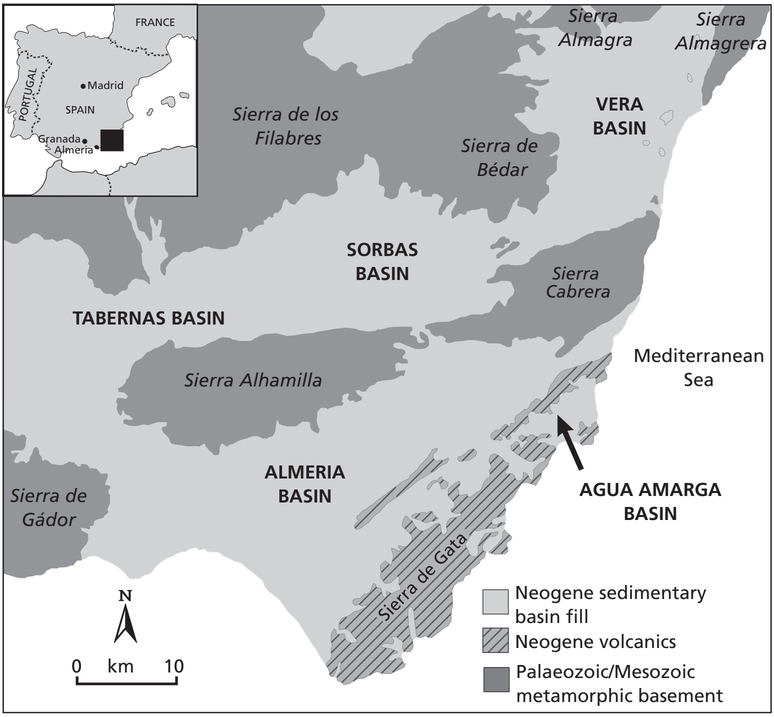


**Fig. 1.1.1.** The sedimentary basins and sierras of the Almería region.

has undergone substantial uplift since the Pliocene. The region is still tectonically active. The city of Almería was virtually destroyed by an earthquake in 1522, and the small town of Vera suffered a similar fate during the last century. The Andalucían earthquake of 25 December 1884 affected the area near Alhama de Granada and reached intensity IX on the Mercalli scale, killing 800 people (López-Arroyo *et al.* 1980). It was similar in scale to the earthquake which hit Kobe, Japan in January 1995 (7.2 on the Richter scale).

The sedimentary basins were defined during the Tortonian (late Miocene), by the development of left-lateral strike-slip faults cross-cutting the basement schists. The sedimentary infill of the basins was dominantly marine until the Pliocene, then terrestrial until the Quaternary, when regional uplift caused a switch from deposition to erosion, creating the modern landforms.

Almería Province is a superb area in which to study the relationships between tectonics, sedimentary geology and geomorphology. The basin-fills

(a)

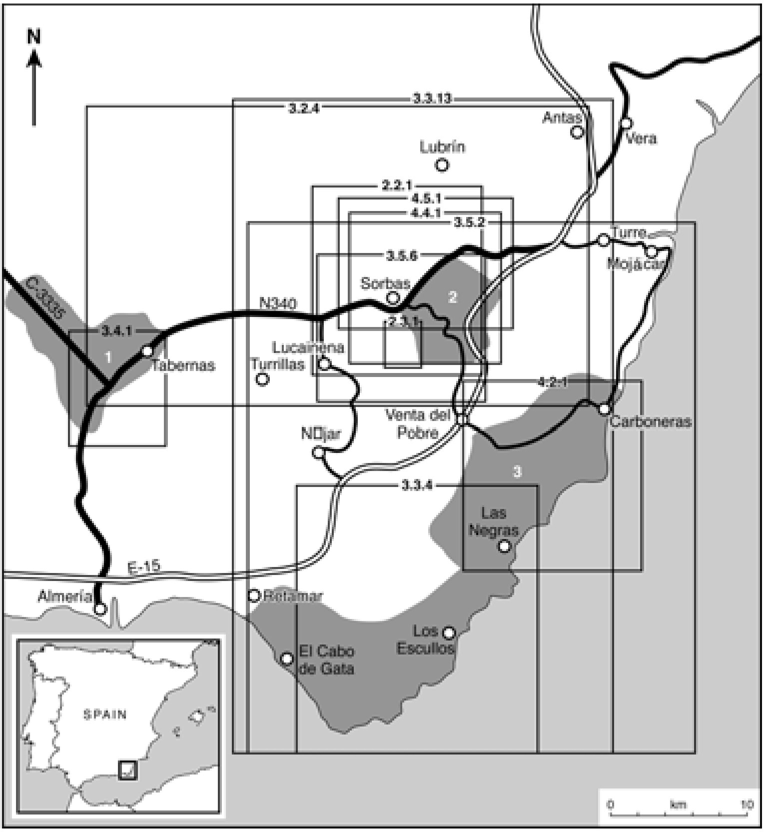


**Fig. 1.1.2.** Main excursion routes. (a) Chapters 2–5.

include an enormous variety of sedimentary rocks, reflecting the rapid environmental changes that occurred during the Neogene and Quaternary. The rocks range from deep water turbidites, through shallow marine rocks including carbonate reefs, evaporitic gypsum (related to the Messinian salinity crisis) and a whole suite of nearshore and shoreline facies, to low- and high-energy fluvial deposits. The rocks show a wide range of deformation from syn-sedimentary soft sediment deformation to brittle strike-slip faulting. The rocks are well exposed as a result of the rapid incision of the river systems during the Quaternary.

A spectacular suite of landforms has resulted from the incision of the developing drainage, under a dominantly dry Quaternary climatic regime. The erosional landforms include pediments, canyons and badlands; the

(b)

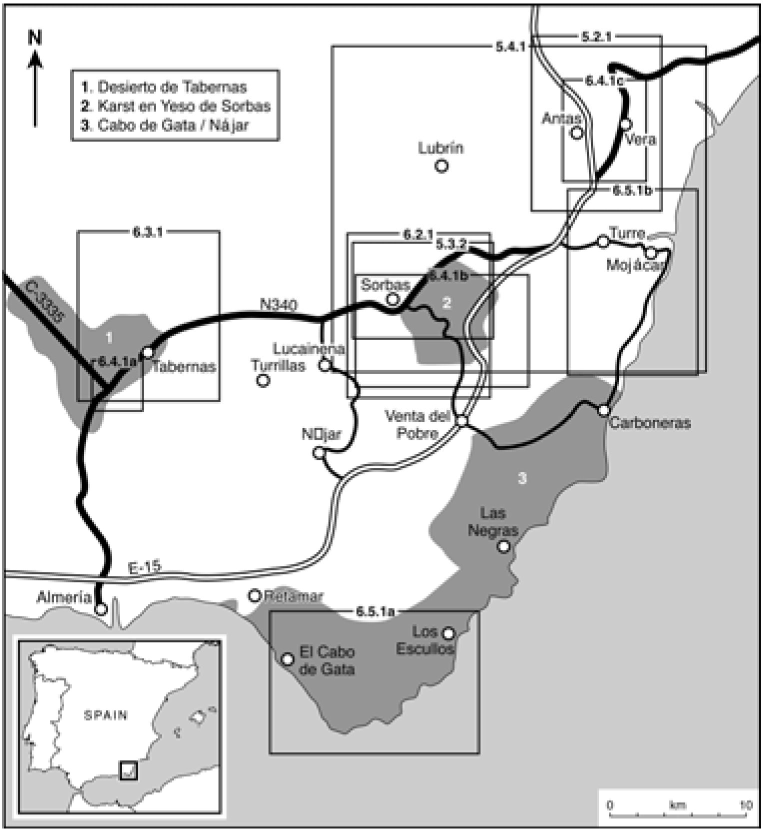


**Fig. 1.1.2.** (*cont'd*). (b) Chapters 5–6.

depositional forms include alluvial fans and braided rivers, and magnificent pedogenic calcretes. The region offers the best developed tectonically active and semiarid landscape in western Europe.

## 1.3 Climate

The region enjoys the driest climate in western Europe, with mean annual precipitation of less than 300 mm, most of which falls in autumn or winter, in relatively short duration but high-intensity storms. Daytime temperatures range from *c*. 15°C in January to *c*. 40°C in July and August. Frosts are rare, except in the sierras. The climate is most favourable for field-work in spring and autumn. June, July and August are hot (*c.* 40°C), often with poor visibility as a result of hazy conditions. Summer also has the disadvantage of being the peak tourist season with generally higher prices.

## 1.4 Accommodation, travel and general facilities

Accommodation is available in most of the key settlements (Fig. 1.1.2), with small hotels or 'hostals' in Tabernas, Sorbas and Vera, but these cannot cater for large groups. Sorbas benefits from a field centre which can handle groups of up to 40. The coastal towns, especially Almería, Mojácar and Carboneras, have hotels and other accommodation which can cater for larger parties, together with other facilities such as car hire. Some useful points of contact are included in the Appendix.

The area can be reached by train or bus to Almería. The easiest method of transport within Europe is to take advantage of cheap charter flights to Almería or Alicante. Almería is the nearest airport, but Alicante (to the north of the region, located along the Costa Blanca) has a wider range of flights and cheaper car hire. Driving time from these airports to the centre of the field area is approximately 30 min from Almería and 2.5 h from Alicante.

Coaches can be hired from tour operators, but generally greater flexibility will be enjoyed with minibuses or hire cars. Many of the tracks and minor roads are unsuitable for large vehicles and parking of such vehicles can be a problem. Suitability of access to field locations and special permission requirements for access to protected areas are given in Table 1.1.1. Figure 1.1.2 details the distribution of protected areas (both Paraje and Parque Natural) and to aid the planning of your trip. Permission to visit the protected areas can be obtained by writing to the Medio Ambiente (see Appendix for contact details), detailing the purpose of your visit, people involved and proposed itinerary.

## 1.5 Map coverage

The best topographic maps (1 : 50 000) are those of the Mapa Militar de España series. A new series of excellent 1 : 25 000 maps is available for a limited part of the area. Much map coverage is now available in CD ROM format (see Appendix for contact details). The region is also covered by at least two sets of air photos and LANDSAT Thematic Mapping imagery. The geological maps of the region are of variable quality, but undergoing revision. Maps relevant to this guide are outlined in Table 1.1.1. Addresses from where they may be obtained are given in the Appendix. Grid

**Table 1.1.1.** Details of map coverage and stop accessibility (all stops are accessible by car or minibus)

| Excursion | | Duration (days) | 1 : 50 000 Topographic/ Geology Sheets |
|---|---|---|---|
| 2.2 | Transect of the Sorbas Basin | 1 | Sorbas |
| 2.3 | A hike to Cantona view point | 0.5 | Sorbas |
| 3.2 | The basement | 1 | Tabernas<br>Macael<br>Vera |
| 3.3a | The calc-alkaline volcanics of the Cabo de Gata | 0.5 | Cabo de Gata<br>El Pozo de los Frailes |
| 3.3b | The volcanics of the Almería, Níjar/ Carboneras and Vera Basins | 0.5 | Cabo de Gata<br>Almería<br>Carboneras<br>Vera |
| 3.4 | The turbidites of Tabernas† | 1 | Tabernas<br>Almería |
| 3.5a | Plio-Pleistocene deformation: the Carboneras and Palomares Fault Zone | 1 | Mojácar<br>Carboneras<br>Cabo de Gata |
| 3.5b | Plio-Pleistocene deformation: the Sierra Cabrera Northern Boundary Fault and adjacent areas of the Sorbas Basin | 0.5 | Sorbas |
| 4.2 | Temperate water carbonates of the Agua Amarga Basin | 1 | Carboneras |
| 4.3 | Tropical carbonates of Níjar | 1 | Carboneras<br>Almería |
| 4.4 | Tropical carbonates of Sorbas | 1 | Sorbas |
| 4.5 | Evaporites and stromatolites of Sorbas | 1 | Sorbas |
| 5.2 | Late Pliocene Gilbert-type fan deltas of the Vera Basin | 1 | Vera |
| 5.3 | Mio-Pliocene marine to continental transition of the Sorbas Basin | 1 | Sorbas |
| 5.4 | Plio-Pleistocene alluvial environments of the Sorbas and Vera Basins | 1 | Sorbas<br>Vera |
| 6.2 | Drainage evolution and river terraces of the Sorbas Basin | 1 | Sorbas |
| 6.3 | Geomorphology of the Quaternary alluvial fans and related features of the Tabernas Basin† | 1 | Tabernas |
| 6.4 | Badlands† | 1 | Tabernas<br>Sorbas<br>Vera |
| 6.5 | The landforms of the coastal zone | 1 | Cabo de Gata<br>El Pozo de los Frailes<br>Carboneras<br>Sorbas<br>Mojácar<br>Garrucha |

* Permission to visit the protected areas can be obtained by writing to the Medio Ambiente (see Appendix for contact details), detailing the purpose of your visit, people involved and proposed itinerary (for A: Parque de Cabo de Gata–Níjar; B: Paraje Karst en Yeso de Sorbas and C: Paraje Desierto de Tabernas); or for D: Cortijo Urra Field Centre, Urra, Sorbas, by contacting the owner. See Appendix for correspondence addresses.

| 1 : 25 000 Topographic Sheet | *Permission required | Stops to be omitted for coaches |
|---|---|---|
| Sorbas & Polopos | none | none |
| Polopos | none | none |
| | none | 5 |
| | | |
| Fernán Pérez | all (A) | none |
| Morrón de Genoveses | | |
| El Pozo de los Frailes | | |
| Campohermoso | 1 (A) | 1 |
| | | |
| | 2,3,4,5,6 (C) | none |
| Castillo de Macenas | 4,6 (A) | none |
| El Agua del Medio | | |
| Fernán Pérez | | |
| Carboneras | | |
| Polopos | none | 2 |
| El Agua del Medio | | |
| Sorbas | | |
| Carboneras | all (A) | 3 |
| Níjar | none | none |
| Campohermoso | | |
| Sorbas | none | none |
| Polopos | | |
| Sorbas | 1,2 (B) | none |
| | none | 4 |
| Sorbas | none | 2,3,4,6 |
| Polopos | | |
| Sorbas | none | 3,5,6 |
| Polopos | | |
| Sorbas | 1,6 (B) | 2 |
| Polopos | 5 (D) | |
| | 6,7 (C) | 3,4 |
| | | |
| Sorbas | 2b (C) | 3 |
| Polopos | 4 (B) | |
| Morrón de Genoveses | 1,2,3 (A) | none |
| El Pozo de los Frailes | | |
| El Agua del Medio | | |
| Garrucha | | |
| Castillo de Macenas | | |

† Please note that excursions which visit the west of the Tabernas Basin (3.4, 6.3 & 6.4) may have restricted access to some stop localities due to the construction of the new Granada–Almería Autovia along the route of the N324. The affected stops are highlighted at the beginning of each excursion.

references throughout this guide are taken from the topographic map series. (Note that the Instituto Geológico y minero de España (IGME) geology maps use a different grid system.) Note that in the description of stop transfers KM (e.g. KM 485) is used to indicate kilometre markers along the roadside. Distance is given as km (e.g. 12 km).

# Chapter 2
# Introduction to the Neogene Geology of the Sorbas Basin

ANNE E. MATHER, JUAN C. BRAGA,
JOSÉ M. MARTÍN & ADRIAN M. HARVEY

## 2.1 Introduction

Thick, continental to marine sedimentary sequences occur throughout the Neogene basins of Almería Province (southern Spain). The Sorbas Basin retains both the most complete and well-exposed sedimentary succession and a diverse range of Quaternary landscapes. It is thus used here to illustrate the regional stratigraphy and Quaternary landscape evolution, which is less continuously or well-exposed in the adjacent Neogene basins. This section is based on a transect across the Sorbas Basin from south to north, essentially following the stratigraphy from the oldest rocks up the sequence through the basin-fill, and at the same time following the Quaternary dissection of the basin and associated landforms.

The Sorbas Basin is a narrow, east–west elongate, intramontane basin of Neogene age within the Betic Cordillera of Almería Province. It is bounded by the Sierra de los Filabres to the north and by the Sierras Alhamilla and Cabrera to the south (see Fig. 1.1.1). These reliefs comprise metamorphic rocks from the Internal Betic Zone (see Section 3.2).

The Neogene infill of the basin comprises a series of units separated by unconformities (Fig. 2.1.1). The lowermost unit consists of conglomerates and sands, probably Middle Miocene (?Serravallian) in age. The overlying upper Tortonian (Upper Miocene) unit is made up of platform carbonates—including some coral patch reefs—and conglomerates that pass basinwards into conglomerates, sandstones and silty marls deposited in submarine fans (Haughton, 1994). The Messinian sequence, in turn, consists of five units (Martín & Braga, 1994).

**1** A temperate carbonate unit (Azagador Member of Völk, 1967; Fig. 2.1.2), composed of bioclastic calcarenites and sandstones, locally mixed with conglomerates, with abundant bryozoans, bivalves, coralline algae and benthic Foraminifera, and minor brachiopods, solitary corals, barnacles and gastropods (Wood, 1996). These platform deposits grade upwards and laterally into marls (lower Abad Member of Völk, 1967) mainly dated as Messinian (Iaccarino *et al*. 1975; Serrano, 1979). The Tortonian–Messinian

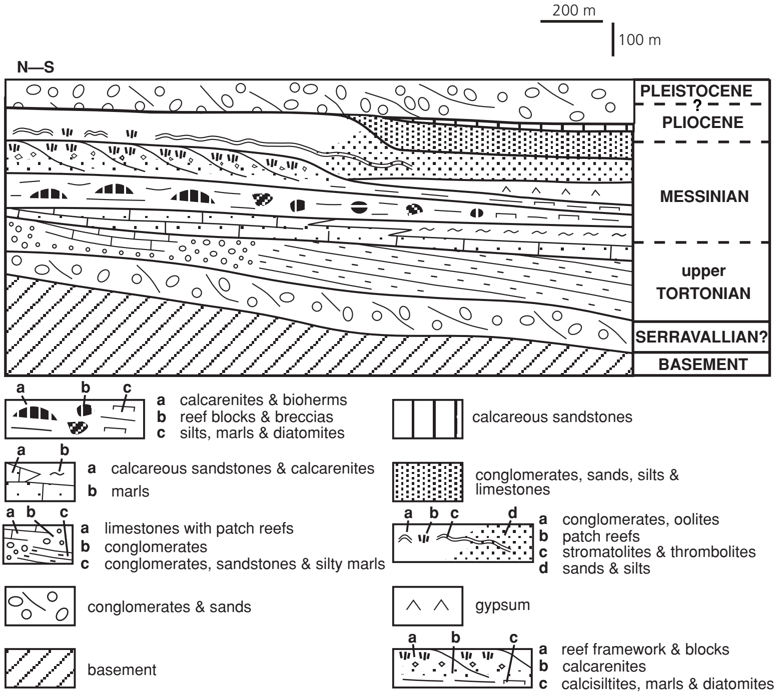


**Fig. 2.1.1.** Neogene and Quaternary lithostratigraphy of the Sorbas Basin. (Modified after Martín & Braga, 1994.)

boundary (7.1 Ma; Berggren *et al.* 1995) is recorded in the centre of the basin near the base of the marls (Sierro *et al.* 1993; Gautier *et al.* 1994). This temperate carbonate unit is considered in Excursion 4.2 but in the Agua Amarga Basin.

**2** A bioherm unit consisting of tropical platform carbonates, locally mixed with siliciclastics, with intercalated lensoid, coral patch reefs and *Halimeda* mounds (Braga *et al.* 1996a; Martín *et al.* 1997), changing basinwards to marls that intercalate with diatomites that contain abundant planktonic Foraminifera. The coiling change in *Neogloboquadrina acostaensis* indicates an age of 6.2 Ma for this unit (using the Berggren *et al.* 1995 time-scale; Braga & Martín, 1996a). This unit is considered in Excursion 4.4.

**3** A unit of prograding fringing reefs composed of *Porites* corals encrusted by stromatolites (Riding *et al.* 1991a; Braga & Martín, 1996a). The top of these reefs is an erosional surface with signs of subaerial exposure. This reef unit passes basinwards into marls with intercalated diatomites, containing abundant calcareous nanoplankton and planktonic Foraminifera of Messinian age (Toelstra *et al.* 1980; Sierro *et al.* 1993). Magnetostratigraphy (Gautier *et al.* 1994) indicates the start of Chron 3R (5.9 Ma; Berggren *et al.* 1995) at the top of the marls. The two Messinian reef units correspond to the Cantera Member and its basinal lateral equivalent, the upper Abad Member marls (in the sense of Völk, 1967) (Figs 2.1.1 and 2.1.2). These bioherm and fringing reef units are considered in Excursions 4.3 and 4.4.

**4** Selenite gypsum deposits (evaporite unit) (Yesares Member of Ruegg, 1964; Fig. 2.1.2) overlie a basin-scale, major unconformity on top of the fringing-reef unit and laterally equivalent marls (Riding *et al.* 1991a; Martín & Braga, 1994; Riding *et al.* 1998). They onlap the eroded reef slopes (Braga & Martín, 1992), occurring as banks (up to 20 m thick) of vertically arranged, twinned, selenite gypsum crystals, separated by silt–marl interbeds (up to 3 m thick) (Dronkert, 1977). Sulphur and strontium isotope data indicate a marine origin for this gypsum (Playà *et al.* 1997). The uppermost gypsum banks intercalate with beds (up to 5–6 m thick) of marine silts and marls containing benthic and planktonic Foraminifera, including *Globorotalia gr. miotumida sensu* Sierro *et al.* (1993), *Neogloboquadrina acostaensis* and *Globigerina multiloba* that indicate a Messinian age (Riding *et al.* 1998). This unit is considered in Excursion 4.5.

**5** The last Messinian unit (Sorbas Member of Ruegg, 1964; Fig. 2.1.2) corresponds mainly with siliciclastic sands and conglomerates (Roep *et al.* 1979, 1998), with local oolitic carbonates and coral (*Porites*) patch reefs, changing laterally basinwards to silts and marls and intercalating giant (up to 15 m in diameter) microbial (stromatolite–thrombolite) domes (Martín *et al.* 1993; Braga *et al.* 1995; Braga & Martín, 2000). The marls in this unit once again contain *Globorotalia gr. miotumida sensu* Sierro *et al.* (1993), *Neogloboquadrina acostaensis* and *Globigerina multiloba* (Riding *et al.* 1998). These deposits directly onlap, at the margins of the basin, the eroded Messinian reefs.

The Pliocene to Quaternary sediments comprise two main units.

**1** The Cariatiz Formation of Mather (1991) (Fig. 2.1.2). This is composed of alluvial fan conglomerates along the northern and western margins of the basin (Moras Member of Mather, 1991) which pass basinwards to coastal plain silts and sands (Zorreras Member of Ruegg, 1964). The Cariatiz Formation sedimentation was punctuated by two basin-wide ostracod-rich carbonate units representing the deposits of a shallow, brackish-water lake (Mather, 1991) and is capped by a basin-wide marine unit. The Cariatiz Formation is considered to be Pliocene in its upper part (Martín & Braga, 1994), and Messinian in its lower part (Roep *et al.* 1979; Ott d'Estevou, 1980). These sediments are considered in Excursion 5.3.

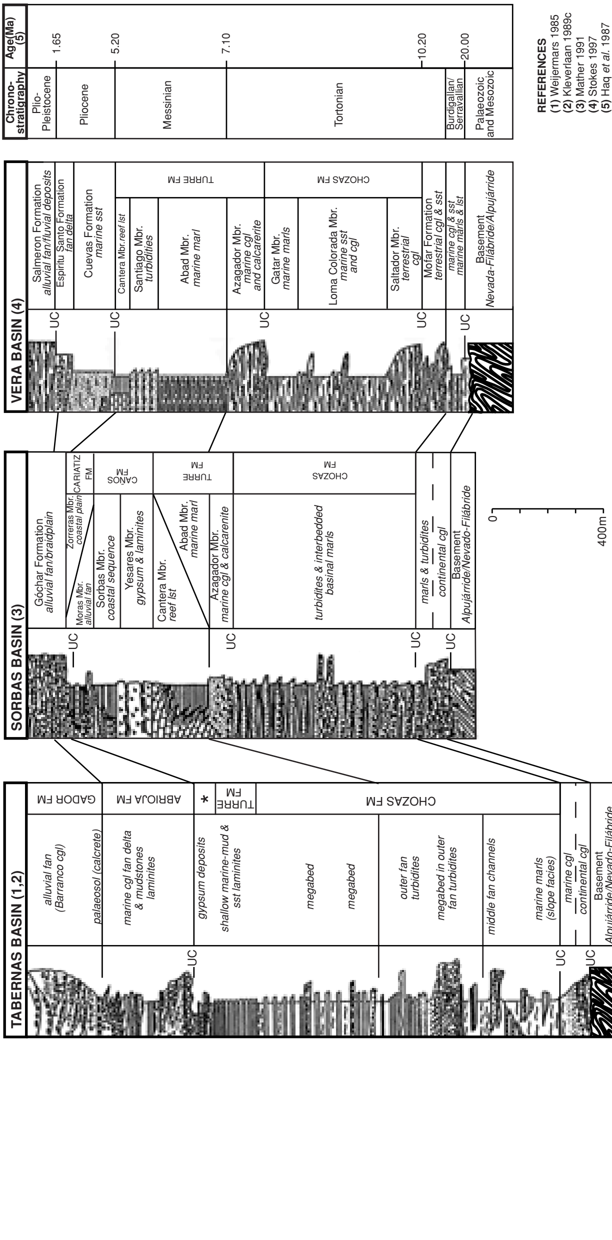


**Fig. 2.1.2.** Simplified geological sections of the Tabernas, Sorbas and Vera basins. (Modified after Weijermars, 1985; Kleverlaan, 1989c; Mather & Harvey, 1995; Stokes, 1997.)

**2** A sequence of fluviatile conglomerates, the Plio-Pleistocene Góchar Formation (Ruegg, 1964; Fig. 2.1.2). These conglomerates mark the final infill of the basin and the dominance of continental sedimentation in the form of braided fluvial systems and alluvial fan deposits (Mather, 1991; Mather & Harvey, 1995). These sediments are considered in Section 5.4.

This Neogene stratigraphy can also be recognized in the other basins in the Almería area (Fig. 2.1.2). Nevertheless, when referring specifically to single basins, some variations from this 'Sorbas stratigraphy' can be found (Fig. 2.1.2). In the case of the Tabernas Basin (the western continuation of the Sorbas Basin; Fig. 1.1.1) the upper Tortonian submarine-fan deposits are especially well represented, with scarce occurrences of Messinian deposits (temperate carbonates, reefs, evaporites; Kleverlaan, 1987, 1989a,b). In the Vera Basin, immediately to the east of the Sorbas Basin (Fig. 1.1.1), there are thick marly sequences of upper Tortonian and Messinian age (Barragan, 1997) and a large Gilbert-type delta developed in the Pliocene (Postma & Roep, 1985; Stokes, 1997). In the Almería Basin (Fig. 1.1.1) there are abundant, shallow-marine, Pliocene deposits (Aguirre, 1995). In the Agua Amarga Basin, in the volcanic Cabo de Gata area (Fig. 1.1.1), a temperate carbonate unit of lower Tortonian age is intercalated between volcanic rocks dated radiometrically as 9.6 and *c.* 8 Ma, respectively. In addition, a Messinian sequence, very similar to that of the Sorbas Basin (including the Azagador Member temperate carbonates, the reef units and a unit similar to the Sorbas Member), occurs on top of the youngest volcanic rocks (Braga *et al.* 1996b). The Tortonian temperate carbonates of the Agua Amarga Basin are considered in Excursion 4.2.

Continued uplift stimulated a change from net aggradation to net erosion in the Pleistocene, creating the landscape seen today (considered in Chapter 6). The incision of the river systems is recorded in the deep, erosional canyons developed in the more resistant lithologies, such as the Sorbas Member, and the development of badlands in the weaker lithologies, such as the Abad Member marls. Steep slopes accompanying the incision, combined with the seismic activity and the action of high-magnitude, low-frequency rainstorm events, have led to a wide range of mass movement features including rotational slips, landslides and topples.

Within the Almería region as a whole there are three groups of Quaternary deposits (Chapter 6): (i) river terrace and other alluvium; (ii) alluvial fans and other hillfoot deposits; (iii) coastal sediments. Within the Sorbas Basin, excellently exposed river terraces record the sequence of Quaternary dissection through the Neogene basin-fill succession. There are small mountain-front alluvial fans on the northern margins of the basin, but Quaternary alluvial fans are better developed in the Tabernas and Almería basins. Quaternary coastal sediments do not occur in the Sorbas Basin, as they are restricted to the modern coastal zone. For a fuller description of the Quaternary sequences and geomorphology see Section 6.1.

## 2.2 Excursion: Transect of the Sorbas Basin (one day)

ANNE E. MATHER, JUAN C. BRAGA,
JOSÉ M. MARTÍN & ADRIAN M. HARVEY

### Introduction

This excursion introduces the basic Neogene basin stratigraphy and geomorphology for the Almería region using the Sorbas Basin as a type example. The excursion starts at the south of the basin, in the Sierra Alhamilla, and follows a south–north transect, finishing in the Sierra de los Filabres which delimits the northern margin of the basin (Fig. 2.2.1).

*Transfer to Stop 1*

This stop is at KM 12.3 on the Al-104 from Sorbas to Venta del Pobre and Carboneras (Fig. 2.2.1).

***Stop 1: Peñas Negras (848 013; Polopos 1 : 25 000)***

The road-cut on the east side of the road exposes Tortonian rocks, and shows well-developed, channelled turbidites.

To the west there is a general view of the southern margin of the basin. To the south and SW are the mountains of the Sierra de Alhamilla comprising low-grade, blackschists of the upper part of the Nevado–Filábride nappe complex, overlain by brown/purple Triassic metacarbonates and phyllites of the Alpujárride nappe complex. The mountain front faults can be identified by slivers of red, purple and other brightly coloured Triassic lithologies. The mountains are faulted against the Tortonian marls and turbidites, which dip steeply towards the north, and are exposed in the foreground and at the base of the large escarpment to the NW. The steep, low ridges to the west and NW are formed by the more resistant sandstone and conglomerate units within the Tortonian.

Looking northwards (Fig. 2.2.2) the Messinian deposits are visible above the upper Tortonian marls, comprising bioclastic, temperate carbonates (Azagador Member), followed by marls, the upper part of which are the lateral, basinal equivalents of Messinian reefs (Cantera Member). In the highest hill (Cerrón de Hueli) Messinian gypsum (Yesares Member) occurs on top of these marls. The gypsum is capped by the Sorbas Member (Fig. 2.2.2), which contains stromatolites.

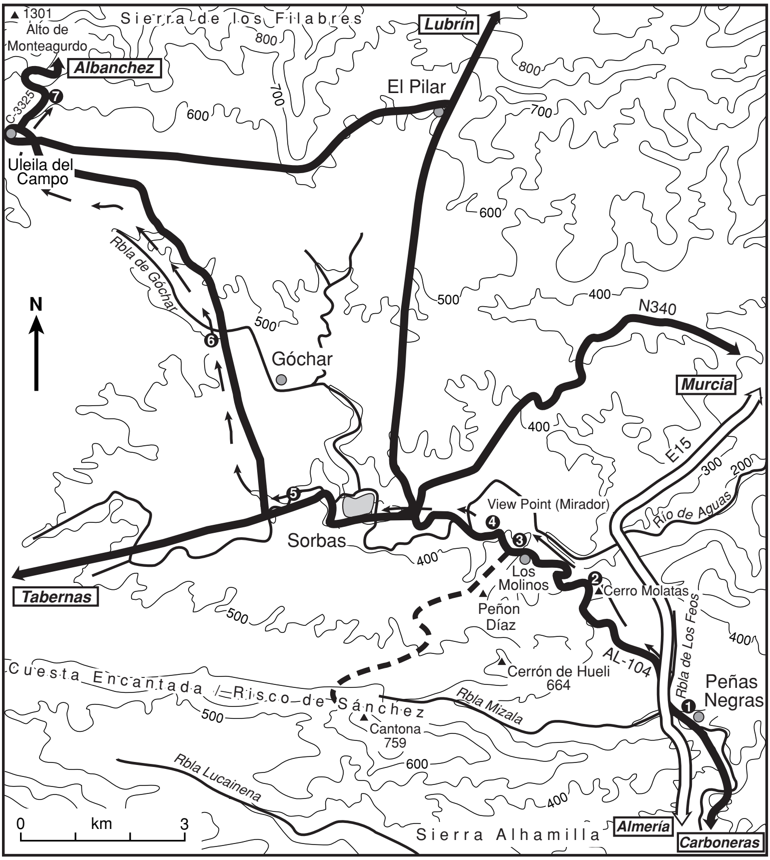


**Fig. 2.2.1.** Location map of the field-trip stops for Excursion 2.2.

The ancestral Aguas–Feos valley flowed south from here across the mountains; this course is today exploited by the route of the motorway. Terrace fragments record the Pleistocene evolution (Harvey & Wells, 1987; Harvey *et al.* 1995) south of Peñas Negras; the modern Río Aguas now flows to the east into the Vera Basin. The Rambla de Mizala, a tributary from the west, now forms the main headwater of the Feos. It developed as a subsequent stream, exploiting the strike of weak lithologies in the Tortonian rocks, and capturing earlier north-flowing basinal drainage. The continuation of this process can be observed from Cantona, at the head of the valley (788 016), where steep, east-draining gullies are about to capture a less steep, north-flowing drainage. This is explored further in Excursion 6.2.

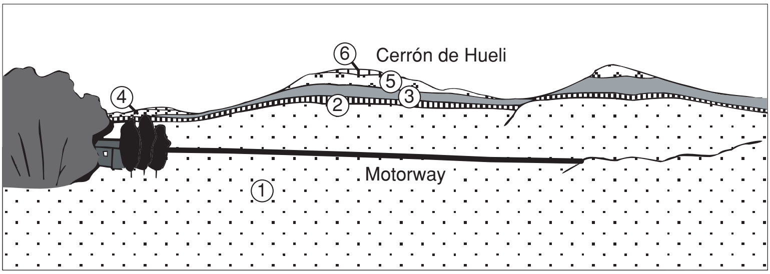


**Fig. 2.2.2.** Stop 1, Peñas Negras view to the north of: 1, Upper Tortonian silty marls, turbidite sandstones and conglomerates; 2, Azagador Member temperate carbonates; 3, Abad Member marls (undifferentiated); 4, Cantera Member reefs; 5, Yesares Member gypsum; and 6, stromatolitic carbonates and sands from the Sorbas Member.

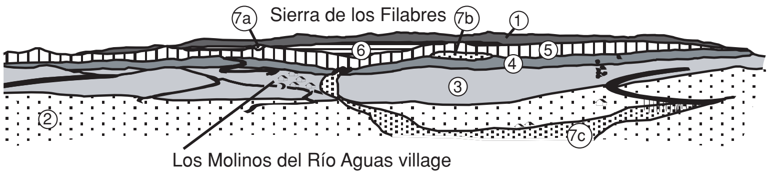


**Fig. 2.2.3.** Stop 2, Cerro Molatas view to the north: 1, Nevado–Filabre basement of Sierra de los Filabres; 2, Azagador Member temperate carbonates; 3, grey marls from the lower Abad Member; 4, yellow marls with intercalated diatomites from the upper Abad Member; 5, Yesares Member gypsum; 6, post-evaporitic Messinian (Sorbas and Zorreras Members undifferentiated); and 7, fluviatile Quaternary deposits: (a,b) ancient river terraces; and (c) present-day, Río de Aguas alluvial deposits (see also Fig. 4.1.3).

### *Transfer to Stop 2*

Take the road north towards Sorbas. At Cerro Molatas (832 045), on the apex of a right-hand bend, is a dramatic view down the lower Aguas valley. This is Stop 2.

### ***Stop 2: Cerro Molatas (832 045; Polopos 1 : 25 000)***

The view south from Stop 2 takes in the southern part of the basin and includes the older part of the basin-fill observed at Stop 1. Towards the NW the outcrop of the gypsum can be traced, forming an escarpment (Fig. 2.2.3). To the north and east the same escarpment can be seen across the canyon of the Río Aguas. The gypsum has a maximum thickness of 130 m and crops out over an area of 25 km$^2$ in this part of the Sorbas Basin.

Below the gypsum, in a belt stretching from the east, through Los Molinos below you, and to the west is the lower ground of the Abad

Member marl. This terrain is deeply dissected by gullies and badlands. Note also the topple failures where the underlying Abad Member marls have been eroded from beneath the gypsum.

To the east of the motorway at 836 054, the Azagador Member can be seen dipping into the lower Aguas valley. At this point the Azagador Member consists of locally conglomeratic, bioclastic, calcareous sands and calcarenites with abundant bivalves, coralline algae, bryozoans, echinoids and brachiopods. The upper yellowish marly sequence (Abad Member) is the basinal lateral equivalent of the Messinian reefs (Cantera Member). The Azagador Member rests unconformably on Tortonian marls, exposed in the hillside below Cerro Molatas. Note the planar slides and associated tensional failures where the Azagador Member calcarenite has moved down-dip over the Tortonian marls. For a fuller description of the Quaternary geology and landform development see Excursion 6.2, Stop 6.

*Transfer to Stop 3*

Continue in the same direction along the road, after passing through the village of Los Molinos del Río Aguas. Climbing the hairpin bends on to the top of the gypsum escarpment you will come to a cross-roads where the road flattens out. Take the dirt track to the right (the turning to the left leads to the gypsum quarry). If in a coach, park here. If in a car or minibus, proceed down the dirt track to the first grove of sparse olive trees. To the south is a hill. Stop 3 is at the top of this hill.

***Stop 3: Los Molinos Mirador (819 056; Sorbas 1 : 25 000)***

This site provides panoramic views north into the centre of the basin, and south across the Los Molinos area and the site of the Aguas–Feos river capture (Figs 6.2.5 and 6.2.6). In the Pliocene and earlier Pleistocene this river flowed through the gap to the north of Cerro Molatas, but was captured by the lower Aguas at *c.* 100 ka (Harvey *et al.* 1995), eroding headwards from the east along the outcrop of the weak Abad Member marl. For a fuller description of the Quaternary geology and landform development see Excursion 6.2, Stop 1.

The ridge here is formed by the Yesares Member gypsum. A little down the ridge to the SW are exposures of *in situ* selenite crystals in growth position. At the top of the hill, resting unconformably on the gypsum, are two conglomerate units. The older unit, resting on brecciated marl, is not in depositional position and contains dewatering structures (reorientated clasts). These features probably reflect deformation, associated with underlying gypsum cave collapse. This resembles similar disturbed deposits, which occur on a larger scale at Peñón Díaz, 2 km to the SW (810 045). We interpret these rocks to represent the preserved base of the Góchar Formation. The second conglomerate unit is *in situ* within a channel, cut into the first set and the underlying gypsum. We interpret these to be an eroded remnant of a Quaternary gravel terrace (Terrace A, Harvey *et al.* 1995).

The view north from Stop 3 takes in the central part of the Sorbas Basin and includes the upper part of the basin-fill sedimentary succession. The low ground in the foreground, the valley of the Río Aguas, follows the strike of the Sorbas Member. Beyond, the reddish rocks with the two thin, white carbonate units are the Zorreras Member. This is capped by the Góchar Formation conglomerates. The mountains in the distance are the Sierra de los Filabres.

*Transfer to Stop 4*

Rejoin the road and turn right. As you drive north you will drive down off the gypsum escarpment. At KM 3 park at the stone-built view point (Mirador). At 813 060 (on the south side of the road) you can observe deformed sections of Pleistocene river terraces (Terrace B, Harvey & Wells, 1987). This theme is followed in Excursion 6.2.

***Stop 4: Urra Mirador (813 061; Sorbas 1 : 25 000)***

Here the Sorbas Member consists of siltstones, claystones and marls, with lesser amounts of sandstones. The Zorreras Member, visible in the distance (Fig. 2.2.4), is made up of red clays and silts, with minor sands, that are locally quarried. Interbedded with the clays and silts are two beds of white, ostracod-rich limestones of lacustrine origin.

Note the extensive flat topography with red soils of Terrace C to the east. This is an extensive terrace level related to the ancestral Aguas–Feos, which used to flow through the Aguas–Feos gap at this stage. To the north, in the middle, near distance, note the extensive brown sediments which make up Terrace D surfaces inset into the yellow marls of the Sorbas Basin. The large, white building to the NW (Cortijo Urra Field Study Centre) sits

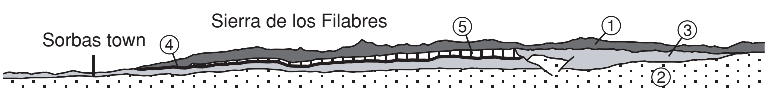


**Fig. 2.2.4.** Stop 4, Urra Mirador view to the north: 1, Nevado–Filabre basement of Sierra de los Filabres; 2, sandstones, siltstones and claystones from the Sorbas Member; 3, clays, silts, sands and limestones from the Zorreras Member; 4, marine bioclastic sandstones from the Lower Pliocene; and 5, Plio-Pleistocene Góchar Formation conglomerates. Vertical scale is exaggerated by 1.5.

on top of one such surface. These sediments (examined in Excursion 6.2, Stop 5) represent low-energy, ponded sediments of Terrace D of the Río Aguas (Mather *et al.* 1991) which may relate to deformation along an active strike-slip structural lineament, the Infierno–Marchalico lineament (described in Excursion 3.5b, Stop 2).

*Transfer to Stop 5*

From the Mirador proceed north along the road for *c.* 2.5 km to the junction with the N340. Turn left along the main road. Drive past the town of Sorbas, which sits on coastal deposits of the Sorbas Member. The road follows an abandoned (post river capture, Terrace D) meander of the Río Aguas. Follow the road for *c.* 1 km past the main entrance to Sorbas Town (on the right). Park on the right-hand shoulder adjacent to the 'Taller Mecánico'.

***Stop 5: 'Taller Mecánico', west of Sorbas village (768 064; Sorbas 1 : 25 000)***

Along the bed of the Rambla de los Chopos, which is an upstream tributary of the Río de Aguas, at *c.* 1 km to the west of Sorbas there is an excellent section of prograding beach/barrier deposits (Roep *et al.* 1979; 1998; Dabrio *et al.* 1985; Fig. 2.2.5). The lower part consists of trough cross-bedded calcareous sandstones. They correspond to shoreface deposits. The upper part of the section is made up of low-angle, parallel-laminated calcareous sandstones burrowed at their top. They constitute the foreshore and backshore sediments which prograde to the east on top of the

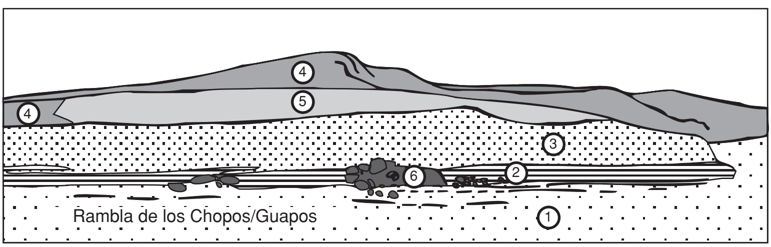


**Fig. 2.2.5.** Stop 5, Rambla de los Chopos view to the north: 1, beach deposits (low-angle, seaward-dipping, parallel-laminated and trough cross-bedded calcareous sands); 2, lagoonal deposits (laminated clays with mudcracks and bird-foot imprints); 3, aeolian dune deposits (low-angle, landwards-dipping, parallel-laminated fine sands); 4, Plio-Pleistocene Góchar Formation conglomerates; 5, Quaternary river terrace; and 6, fallen blocks from the cliff (collapse instigated by the 1973 flash flood in the region; see Thornes, 1974 for details on the regional impact of the flood event).

shoreface deposits. Locally they include calcareous breccias interpreted as fragments of eroded beachrock (Roep *et al*. 1979). These deposits are overlain by fine-grained sands and laminated clays with mud cracks and bird-foot tracks (Roep *et al*. 1979; Dabrio *et al*. 1985). They represent aeolian dunes (Fig. 2.2.5).

To the west the sequence is unconformably overlain by conglomerates which appear to thicken and crop out down to the river bed, displaying intercalated red sands and showing evidence of deformation. These sediments are part of the Góchar Formation.

The top of the section is capped unconformably by a well-cemented conglomerate of Sierra de los Filabres provenance (amphibole–mica schists—see fallen blocks in the river bed). The conglomerate is well imbricated and fluvial in origin and includes blocks derived from the Góchar Formation. This conglomerate marks one of the Quaternary terraces (level C, precapture terrace of Harvey & Wells 1987; Harvey *et al*. 1995) set into both the Góchar Formation conglomerates and the Sorbas Member.

What is interesting to note is the lack of the Zorreras Member at this locality. This in part can be accounted for by erosional loss. However, careful tracing of the Góchar–Zorreras contact which occurs in the section on the north side of the river, although partially obscured by large block topples of Góchar Formation conglomerates, indicates that the Zorreras Member thins to zero in this vicinity as a function of palaeorelief (see Excursion 5.3).

*Transfer to Stop 6*

Continue along the N340 to the west. Take the first turn on the right towards Uleila del Campo. Follow the road for 5 km. After crossing a bridge over the Rambla de Góchar, park at the side of the road. Note the conglomerates exposed in the apex of the meander bend to the west. This is Stop 6.

### *Stop 6: Rambla de Góchar-type locality of the Góchar Formation (753 110; Sorbas 1 : 50 000)*

Stop 6 exposes a succession of Góchar Formation conglomerates, overlying Messinian reef limestones (Cantera Member), exposed east of the bridge, and shoreline facies of the Sorbas Member, exposed west of the bridge. The top of the section forms approximately the end-Góchar Formation depositional surface, the final stage of basin-filling. Since the end-Góchar the rambla has trenched only *c.* 25 m into this surface, which represents the total Quaternary dissection in this part of the basin (contrast this with the greater incision at Stops 2 and 3). The dissection stages are marked by