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46.2. COMPARISON BETWEEN FORMATIONS DRILLED AT DSDP SITE 372 IN THE WESTERN MEDITERRANEAN AND EXPOSED SERIES OF LAND

G. Bizon and J. J. Bizon, Bureau d'Etudes Industrielles et Coopération de l'Institute Français du Pétrole, 92500 Rueil Malmaison, France
and
B. Biju-Duval, Institut Français du Pétrole, 92500 Rueill-Malmaison

ABSTRACT

Formations penetrated at Site 372 are compared with series cropping out on land in the Balearic Islands, Southern Spain, and Sardinia. The comparison is extended to wells drilled in the Gulf of Lion. The margin at Menorca and the North Balearic Provençal Basin appear to be at least of Burdigalian age. The entire Miocene is undisturbed at Site 372 in contrast to Mallorca and continental Spain where important tectonic events occurred during middle and upper Miocene.

INTRODUCTION

Because DSDP Site 372 is located only 40 km from the Balearic Islands, it is logical to compare the series penetrated at the site with land equivalents, particularly with those on the island of Menorca. As will be demonstrated below, time-equivalent series on the Balearic Islands are characterized by a shelf facies and do not correspond to the pelagic marls penetrated in the Hole 372. The comparison will be extended to the wells drilled by the Compagnie Françise des Pétroles in the Gulf of Lion, and then to Sardinia and southern Spain. Finally, the study of a 3-meter core taken southwest of Site 372 will complete our interpretation.

Comparison with Menorca Island

Burrouilh (1973) demonstrated that the island of Menorca can be divided into two geological provinces, a tectonically disturbed northern and northeastern region, the "Tramuntana," and a platform area to the south-southwest, consisting of post-tectonic molasses, the "Mindjorn."

In the former area, the oldest outcrops range in age from Devonian to Keuper. The Keuper is unconformably overlain by lacustrine conglomerates, the cement of which contains charophytes indicating a late Oligocene to early Miocene age. Reworked components of the conglomerate are from Jurassic to late Aptian age.

By comparing these rocks with those of Mallorca, Bourrouilh considered the age of tectonism to be middle Miocene. This conclusion is questionable considering that at Site 372 the entire Miocene is undisturbed.

In the latter area (Figure 1A) the series is undisturbed except for recent faulting. The sediments are a chalky facies, cropping out in the south-southwestern part of the island. The carbonate formations are often rich in algae; echinoderms, pectens, and, locally, corals are also present. The foraminifers are esentially benthic with outer shelf (*Amphistegina, Heterostegina*) and inner shelf genera (*Borelis*). This shallow water facies was determined by Bourrouilh and Colom (1968) to be middle Miocene (Vindobonian) in age. In the southern part of the island near San Thomas, some planktonic foraminifer assemblages (*Globorotalia humerosa* Zone, Bizon et al., 1973) indicate that late Miocene sediments are present. Beyond the outcrops just mentioned, the Vindobonian molasses are, in fact, rather poorly dated, but are generally thought to range in age from Langhian to Tortonian.

To the southeast of Menorca, on Rey Island, at the contact between the tectonically disturbed and post-tectonic series and at the base of the Vindobonian molasses (Bourrouilh, 1973, p. 467), *Miogypsina* (sp. undet.) has been found in a dolomitic facies. Their presence, if they occur in situ (and there is no evidence

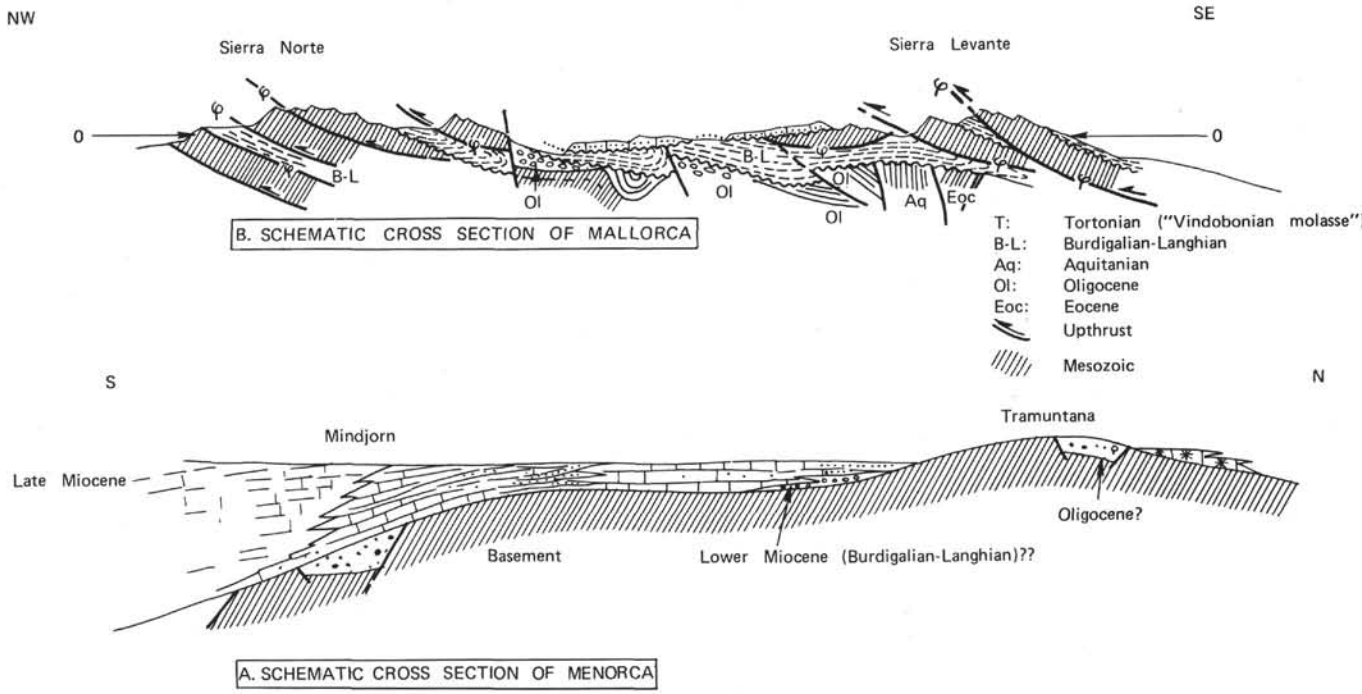

Figure 1. *Schematic geological cross sections of the Balearic Islands.*

of reworking), would indicate that the Menorca molasse began locally in the Burdigalian.

Late Miocene evaporites are not known from outcrops. A new marine transgression began at the end of the Pliocene or at the beginning of the Pleistocene which deposited littoral limestones containing *Amphistegina, Miliolidae*, and other benthic foraminifers (Bourrouilh and Magne, 1963). In summary, shelf facies dominated on Menorca during the Miocene and Pliocene-Pleistocene, and consequently a direct correlation with the pelagic facies encountered in the formations penetrated at Site 372 is not possible.

Comparison with Mallorca Island (Figure 1B)

The complex geological framework of Mallorca is rather well known, as a result of investigations by Fallot, (1930) Rangheard, (1969) and Bourrouilh, (1973). It comprises:

1) The Sierra Norte in the north-northwest in which Mesozoic and lower Miocene rocks were thrust to the north-northwest resulting in imbricate structures.

2) A central region with outcrops of the "Vindobonian molasse" and, locally, some inliers in which older formations appear.

3) The Sierra de Levante, an intensely imbricated Mesozoic, Paleogene, and lower Miocene series.

The Tertiary outcrops are discontinuous, poorly exposed, and badly faulted; precise age determinations of the series is difficult.

Tectonically Disturbed Series

The oldest Tertiary formations known on Mallorca consist of conglomerates, unconformably overlying rocks of Cretaceous age, followed by Eocene nummulitic limestones; they outcrop near San Arbos, in the Sierra Levante, and near Santa Margaritae, in the central part of the island.

The Oligocene is generally represented by continental red-beds, although marine intercalations are known from the central part of the island (Randa area). The Puig de Santa Gloria series, an overturned and faulted sequence, consists of lower Oligocene nummulitic limestones, middle Oligocene *Lepidocyclina* limestones and marls with *Almaena* sp., *Globigerinoides primordius* and *Globorotalia kugleri* of Aquitanian age. The lower Miocene (Burdigalian) series rests unconformably on the tectonically disturbed Aquitanian series. The lower Burdigalian rocks, containing *Miogypsina*, grade into a pelagic facies of Langhian age (*Praeorbulina glomerosa* Zone) in the Santa Margarita section in the center of the island. This marine series in turn grades gradually into brackish and lacustrine formations which contain laminated limestones. The Charophyta, *Planorbis,* and fresh-water ostracodes and diatoms are present in some intervals. The formations, accurately described by Colom (1967) are conformably overlain by the "Vindobonian molasses." In the Sierra Norte and in the Sierra Levante, Burdigalian-Langhian marls are strongly affected by tangential tectonics.

Post-Tectonic Series

The "Vindobonian molasses" are shelf sediments comprising white chalks with oysters, pectens, and echinoderms. Benthic foraminiferal faunas consist mainly of near shore genera (*Borelis, Amphistegina, Heterostegina,* Miliolids). In 1947, G. Colom described highly diversified benthic foraminifers from the Vindobinian of Mallorca. These earlier investigations need

revision; recent sampling of the outcrop of San Vari d'Aix Llumachor has shown that the planktonic foraminiferal assemblages belong to the early Pliocene *Globorotalia* Zone (= *Globorotalia margaritae evoluta* of Cita, 1973) (Bizon, 1972 IFP, unpublished reports). Accurate age determination of other sections could not be achieved because the "Vindobonian molasse" mostly underlies the agricultural regions on the island where the contacts are obscured.

The late Neogene generally consists, as on Menorca, of calcarenites with *Amphistegina* and Miliolids.

In summary, on Mallorca the Burdigalian-lower Langhian is a transgressive sequence deposited on a tectonically disturbed series and shows a facies of pelagic marls with local occurrences of *Miogypsina* at the base. The series, in turn, is tectonically disturbed, and hence its thickness is difficult to evaluate. Nevertheless, it is similar to the pelagic marls in the lower part of the section penetrated at Site 372, with the exception that, on Mallorca, benthic foraminifers are generally present and indicate deposition at shallower water depths than at Site 372. Precise correlation between the pelagic Serravallian marls of Site 372 and the "Vindobonian" shelf formations on Mallorca is not possible.

Comparison with the Wells in the Gulf of Lion (Figure 2)

We have seen that the stratigraphic correlations between the formations penetrated at Site 372 and those cropping out in the Balearic Islands are not simple; the same is true for correlations with formations penetrated in the wells drilled in the Gulf of Lion by the Compagnie Française des Pétroles (Cravatte et al., 1974). The environment of deposition deduced from the populations of foraminifers recovered from these wells is different from the one that prevailed at Site 372. In Mistral 1, Tramontane 1, Sirocco 1, and Autan 1, benthic foraminifers are generally well represented and indicate the presence there of a rather shallow basin. Miocene plankonic foraminifers are seldom present and are often badly preserved. Some intervals in Mistral 1 are very poor in microfauna, even counting contaminants. In Mistral 1, the age of the nearly barren sediments which separate the marine lower Pliocene from the marine lower Serravallian cannot be determined precisely. Fossiliferous samples of Aquitanian, Burdigalian, Langhian, and lower Serravallian sediments are impoverished in characteristic species; marker horizons that are defined on the basis of the extinction of a species (such as *Globorotalia fohsi peripheroronda*) contain too few specimens for adequate correlation with the formations penetrated at Site 372, where planktonic foraminifers are abundant. Large benthic outer shelf foraminifers occur in Tramontane 1 and Autan 1 which indicates the presence of sediments of Aquitanian age. These overlie in Autan 1, red-brown clays which cannot be easily be dated. These shelf deposits were not found at Site 372 where the lowest core from the well contained a pelagic microfauna of lower Burdigalian age.

Comparison with Sardinia (Figure 2)

The Monte Santo section (Pomesano-Cherci, 1970) in the northwestern part of Sardinia shows a stratigraphic succession that is similar to the one observed at Site 372, ranging in age from Burdigalian, with *Globigerinoides bisphericus* to Serravallian, with *Globorotalia praemenardii* and *Globorotalia miozea*. The middle Miocene seems incomplete towards the top and the author does not mention the interval with abundant *Globigerinoides obliquus* which generally characterizes the top of middle Miocene in the Mediterranean. The marls with *Globorotalia praemenardii* are overlain by neritic limestones and by basalt flows.

The facies of the Burdigalian, Langhian, and Serravallian are generally sandy with neritic limestone intercalations, again indicating shallow water deposits and differentiating them from the deeper water facies encountered at Site 372.

Comparison with Southern Spain (Figure 2)

Lower and middle Miocene deposits exist to the northwest of Alicante, near Alcoy (Montenat, 1973). Here the planktonic microfauna is similar to that at Site 372. The sequence consists of white, silty marls with more calcareous intercalations, ranging in age from late Burdigalian (*Globigerinoides bisphericus*) to Langhian (*Orbulina suturalis* and *Globorotalia fohsi peripheroronda.)* The Serravallian overlies this sequence with an angular unconformity and consists, as for the lower series, of silty marls with more calcareous intercalations. *Globorotalia praemenardii* occurs at the base of this sequence. At the top, planktonic foraminiferal assemblages are similar to those observed in Core 13 at Site 372. The sequence ends with a neritic limestone bed.

Although the planktonic foraminiferal assemblages found at Alcoy and at Site 372 are similar, the environment of deposition is definitely different. The Alcoy beds are always rich in benthic foraminifers which constitutes about 50% of the total benthos + plankton. The genera *Elphidium* and *Amphistegina* indicate sediments laid down on the outer shelf; the planktonic foraminifers although sometimes abundant, are often badly preserved. Fragments of echinoderms and pelecypods abound.

Upper Miocene sediments (*Globorotalia acostaensis* and *Globorotalia humerosa* zones) are represented in several areas of southern Spain (Montenat, 1973). In the Venta la Virgen section, marly beds belonging to the *Globorotalia acostaensis* and *Globorotalia humerosa* zones (600 m) are overlain by near shore sediments with *Ostrea, Elphidium, and Ammonia* (Bizon et al., 1972). Several tectonic disturbances are known to have affected these rocks between upper Serravallian and lower Tortonian times, but the boundary between *Globorotalia acostaensis* and *G. humerosa* zones is always conformable and represented by continuous open marine sediments.

A type of sediment similar to the laminated interval which occurs in the upper part of Core 9, Section 2,

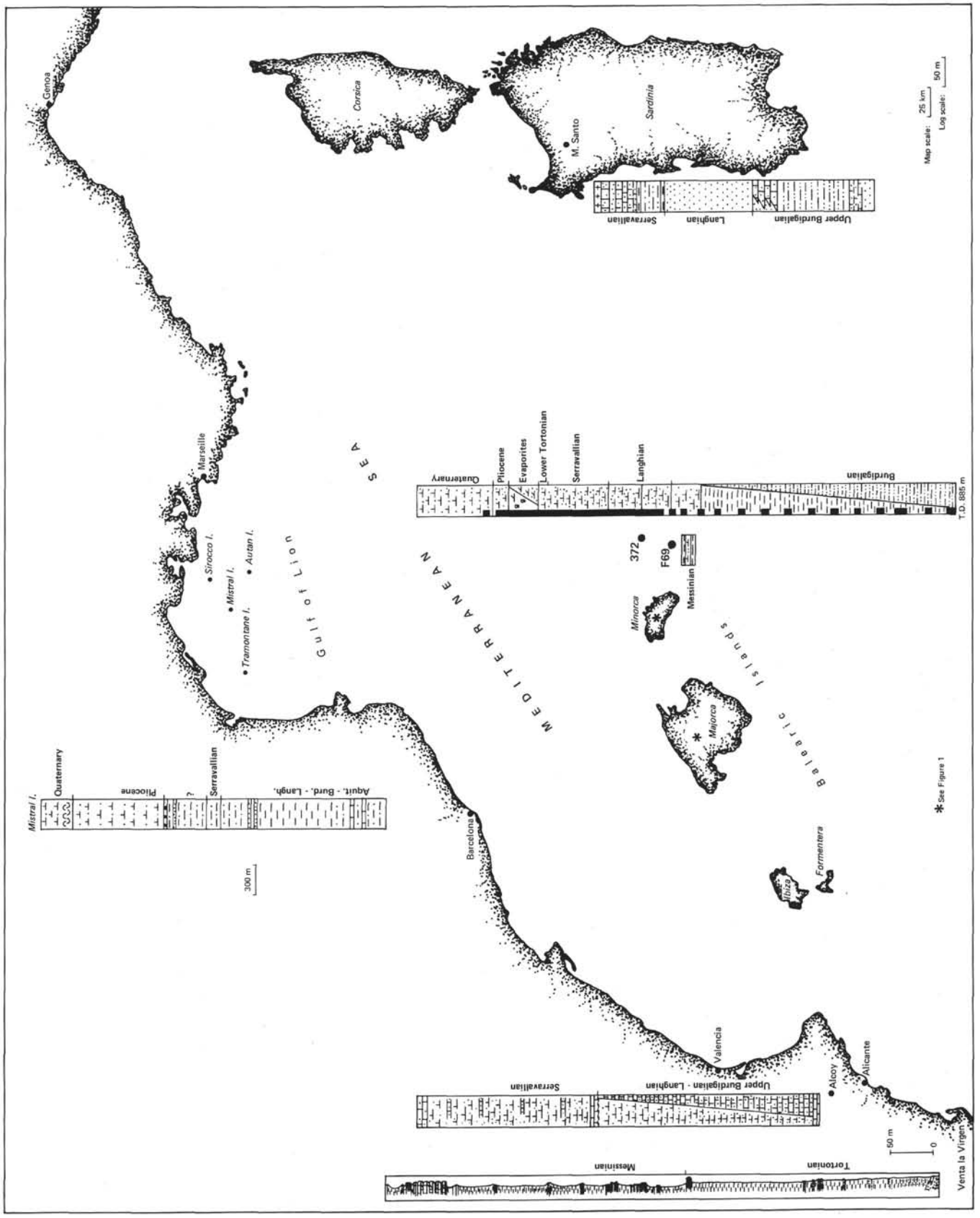

Figure 2. *Comparison between Site 372 other drillsites and exposed series on land.*

and in the lower part of Core 9, Section 1, is known in the Guadalquivir Basin in the Valenzuela present (*Globorotalia acostaensis* Zone, Tjalsma, 1971) and Chaves (lower and middle Miocene, Verdenius, 1970) formations. Laminated limestones are also known in from the upper-most Miocene of the Murcia-Alicante basin where they contain coccoliths and diatoms. These younger sediments are generally barren of any foraminifers.

Comparison with Piston Core FOM 69

A piston core recovered on the continental shelf, east of Menorca, south-southwest of Site 372, reveals the presence of marine marls with a planktonic microfauna of late Miocene age (*Globorotalia humerosa* Zone, *Globorotalia mediterranea* Subzone), with intercalation of dolomitic beds (Bizon et al., 1975). Similar beds occur in the upper part of Core 4, Section 2, at Site 372, above the evaporites. Marine Quaternary sediments overlie these beds in Core FOM 69, with reworked lower Pliocene and upper Miocene microfauna.

CONCLUSIONS

The pelagic marls of Miocene age, at Site 372 were certainly deposited in a deeper marine environment than on Menorca or Mallorca where shelf facies predominate. Towards the east, in Sardinia, the lower middle Miocene becomes sandy and toward the west, the sequence becomes more calcareous. To the north, in the Gulf of Lion, the Miocene series is rich in benthic foraminifers, indicating an environment of deposition in water shallower than at Site 372. Thus, the margin at Menorca and the North Balearic Provencal Basin appears at least as old as Burdigalian and at that time the basin was deeper. furthermore, in spite of more or less well-defined gaps or condensed sequences in sedimentation recorded in the hole, the entire Miocene is undisturbed at Site 372. This may also be true in Menorca where Miocene tectonism is not definitely proven. In contrast, Mallorca and continental Spain were affected by significant tectonic events during middle and upper Miocene time (see Biju-Duval et al., this volume).

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