Lacustrine diatomite deposits in the Madrid Basin (Central Spain)

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RESUMEN

La parte superior de la Unidad Intermedia del Mioceno en el sector occidental de la Cuenca de Madrid contiene varios niveles diatomíticos, que consisten tanto en diatomitas casi puras como en calizas y margas con contenido variable en diatomeas. Estos niveles fueron depositados en un ambiente lacustre somero caracterizado por condiciones de salinidad moderada y alcalinidad variable, tal como atestiguan la mineralogía de los depósitos y las asociaciones de diatomeas reconocidas. Dentro de éstas se ha distinguido dos asociaciones características, una con predominio de Fragilaria bituminosa *y otra constituida por varias especies de* Cymbella. *Ambas asociaciones se sustituyen entre sí en la vertical de las secciones, indicando fluctuaciones en las condiciones de depósito.*

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Introduction

The occurrence of diatoms within sedimentary deposits of the Madrid Basin (central Spain) has been pointed out only since a few years (Bustillo, 1984). Later, Pozo *et al.* (1985) and Leguey *et al.* (1985) have described true diatomite beds to the North of Esquivias (fig. 1). Here, the diatomites are interbedded within a widely chertified carbonate-clayey succession that has mostly interpreted as lacustrine deposits. Most recent studies on these sediments have been devoted to their geochemistry (Bustillo & Bustillo, 1987).

The present work deals with the sedimentological analysis of the diatomite occurrences as well as the preliminary description and paleoecological inferences suited from the study of the diatom assemblages at the Esquivias location. Hitherto, no specific attention has been paid to diatoms themselves in the Neogene record of the Madrid Basin, probably due either to their scarcity or lacking of specialists to carry out the study. Nevertheless, the analysis of diatoms reveals importance for a comprehensive design of the lacustrine systems during the Neogene.

Stratigraphic location of the diatomite beds

The Miocene formations in the Madrid Basin have been divided into

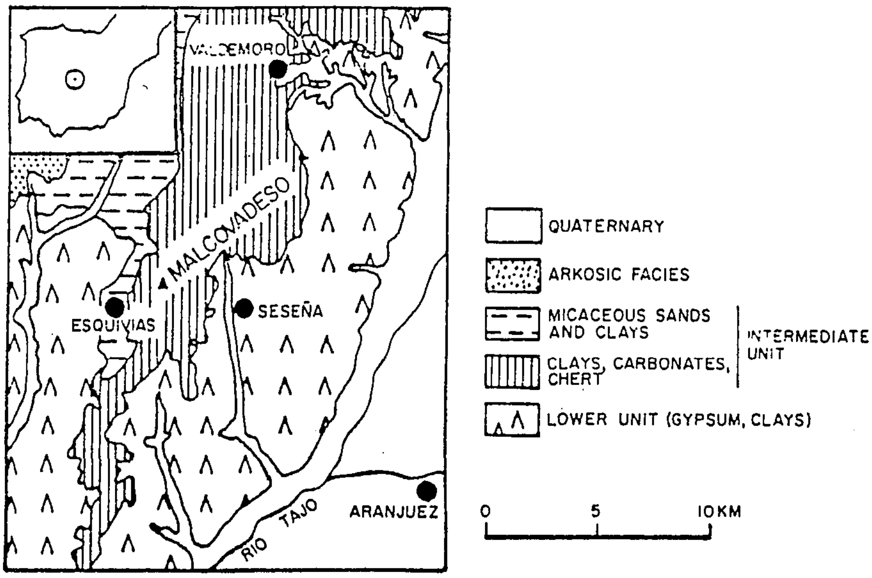

Fig. 1.—Geographic and geologic setting.

three tecto-sedimentary units (Junco & Calvo, 1983). Diatomite beds occur at the uppermost part of the Intermediate Unit (Middle Aragonian to Lower Vallesian). In the studied area (fig. 1) that unit mainly consists of basal fluvio-lacustrine sediments (micaceous sandstones and mudstones) that laterally interfinger, and are capped by, carbonates and clays of lacustrine origin. The thickness of the unit reaches up near 60 m in this area.

The diatomite beds were recognized in an extensively quarried zone (Malcovadeso). Two sections were investigated and carefully sampled for further analysis (fig. 2):

— The ESP section is made up by a 1.20 m thick sequence of roughly massive to laminar, powdery white-cream carbonates that overlies a well-defined, tabular chert bed (fig. 2).

— the ESC section consists of a 2.15 m thick sequence of soft, powdery white-cream carbonates that intercalate a thin level of green clays (fig. 2). This section is located a few tens of meters to the North of the ESP one. Although geometric continuity does not exist between the two outcrops, a similar stratigraphic position can be deduced for them by analysing similarities of the underlying sediments.

Mineralogy and petrology

In a previous work, Pozo *et al.* (1985) carried out detailed mineralogical and petrological analysis of the miocene sediments in the Malcovadeso area. Some of the diatomite beds that we study in this paper (ESP section) were included as level IV within their S-2 section.

A closed sampling in the diatomite beds of the ESC section shows that both their mineralogical and petrological characteristics fluctuate from level to level (fig. 2), this suggesting sedimentological variations during the sedimentation of the diatomites. Most important changes in mineralogy concern to relative amounts of biogenous opal, calcite, and phyllosilicates (fig. 3). Highest values of opal have been determined in samples 3, 4, 5A and 5B, where highest concentration of diatom frustules can be observed as well.

Petrographically, two main types of diatomite sediments have been recognized: 1) diatomaceous marls and limestones, and 2) clayey to nearly pure diatomites. The former consist of a rather homogeneous mixture of micrite or microsparite, and diatom frustules. The diatom frustules are frequently calcitized and/or partially dissolved. Ostracod carapaces, oogonia and stems of carophytes, and rare tests of gastropods are commonly recognized within the diatomaceous marls and limestones. The second type is seen on thin-section like homogeneous aggregates of diatom frustules showing different sizes, siliceous spicules, and probable phytolites. Variable amounts of phyllosilicates occur mixed with the siliceous skeletons. The distinction between the two types of diatomaceous sediments clearly arises after

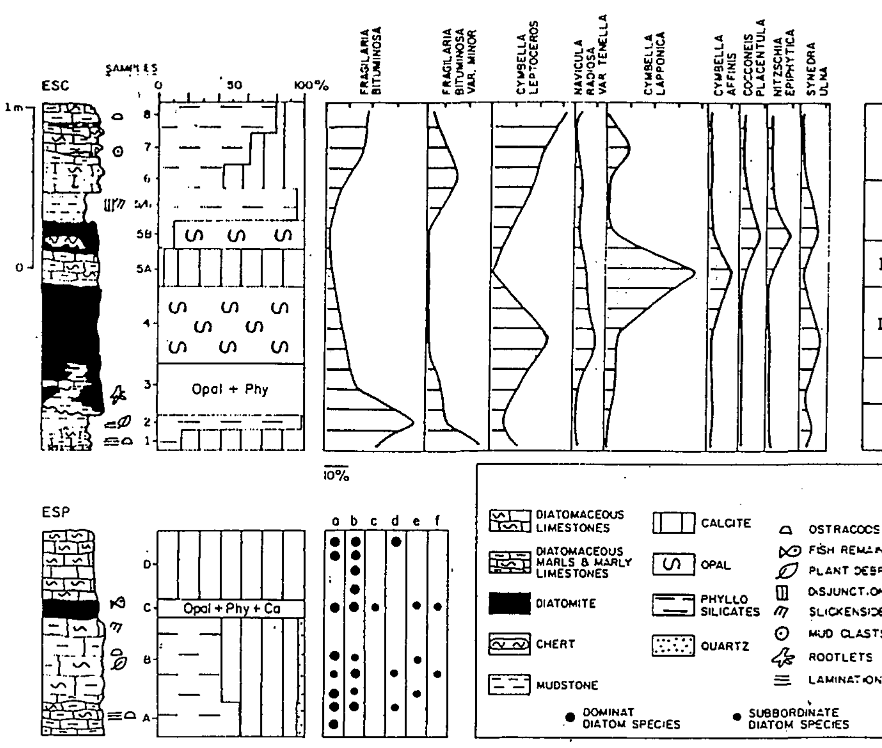

Fig. 2.—Sedimentary logs from the studied sections, with indication of mineralogy and zones defined by diatom assemblages (only for ESC section). Letters for diatom species in ESP section represent: a) *Fragilaria bituminosa;* b) *Cymbella leptoceros;* c) *Navicula halionata;* d) *Anomoeoneis sphaerophora;* e) *Amphora veneta;* f) *Navicula cuspidata.*

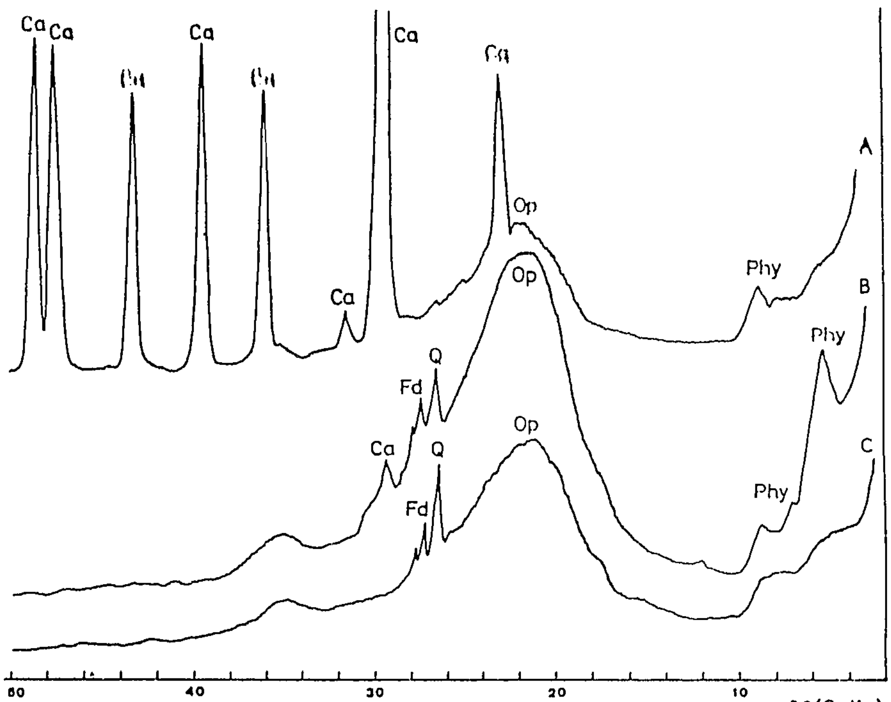

Fig. 3.—X-ray diffraction patterns from bulk samples (powder method). A) Diatomaceous limestone. B) Clayey diatomite. C) Diatomite. Symbols: CA: Calcite. Op: Opal. Phy: Phyllosilicates. Fd: Feldspars. Q: Quartz.

their recognition under the microscope or XRD analysis (fig. 3), though it is difficult to stay in outcrop.

Diatoms

Samples collected in the Malcovadeso area were analysed for determination of fossil diatom assemblages. Emphasis was done to the analysis of the ESC section because its greater diversity of flora and more frequent changes throughout the profile, the ESP section being rather homogeneous and dominated by a few species: *Fragilaria bituminosa, Cymbella leptoceros, Navicula halionata, Anomoeoneis sphaerophora, Amphora veneta,* and *Navicula cuspidata.* Anyway, a more detailed report on the total diatom content will be offered in a future paper.

The determination of diatoms was realized by standard techniques of sample concentration and further examination under microscope. For each slide, we made a census of diatom species present by counting a hundred specimens. The resulting data show that a rather high variety of diatom species (a total of 50 different species) occurs in the ESC section. However, only a maximum of ten species are present in most of our samples or occur in significant amounts in some of them (fig. 2). Figure 4 shows some selected specimens of diatoms occurring in the studied deposits.

As within section ESP, diatom flora of section ESC is characterized by the presence of *Fragilaria bituminosa* and its variety *F. bituminosa f. minor,* which are dominant both at the bottom (Zone I) and the top (Zone VI) of the section (fig. 2). In contrast, Zones III, IV, and V show a considerable decrease of *Fragilaria bituminosa,* this species being replaced by *Cymbella leptoceros, Navicula radiosa tenella* (Zone III), *Cymbella lapponica, Cymbella affinis* (Zone IV), and *Cocconeis placentula, Nitzschia epiphyitica* (Zone V). Zone II is envisaged as a transition zone, mostly characterized by a high diversity of diatom species.

Fragilaria bituminosa Pantocsek, the most abundant diatom species recognized both in ESC and ESP sections, is a fossil diatom which was found

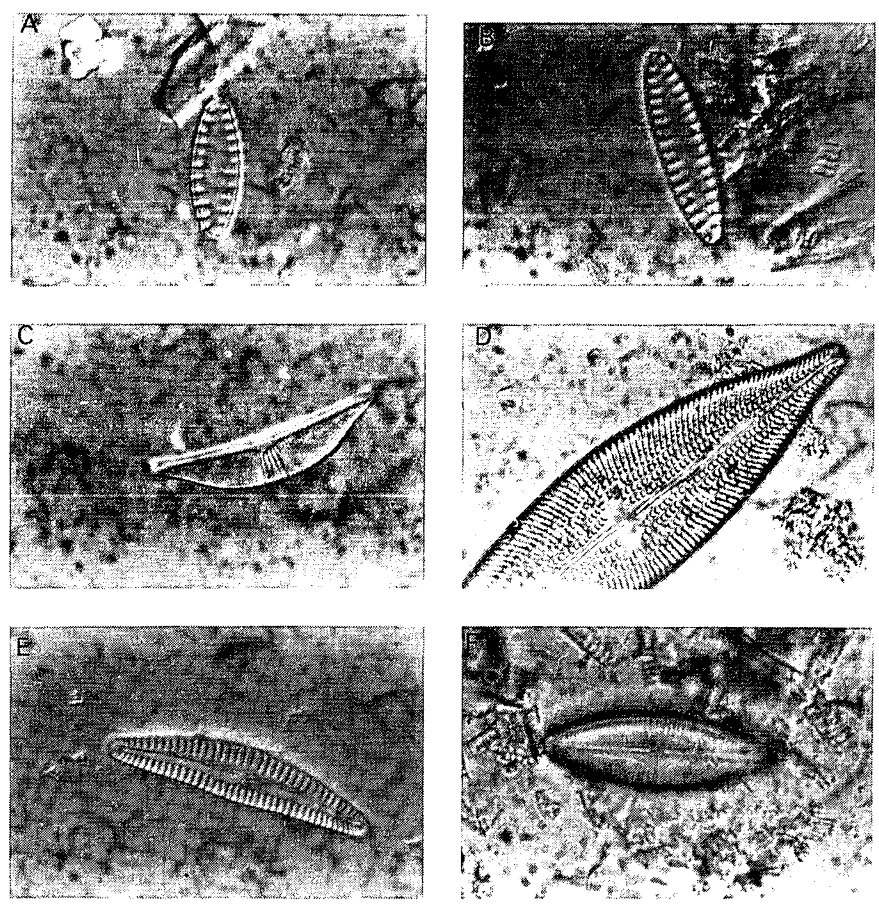

Fig. 4.—Microphotographs of diatom species. A) *Fragilaria bituminosa* Pantocsek (f. *minor*). B) *Fragilaria bituminosa* Pantocsek. C) *Amphora veneta* Kützing. D) *Navicula tuscula* (Ehr) Grunow. E) *Cymbella leptoceros* (Ehr) Grunow. F) *Navicula brasiliana* (Cleve) Cleve. Magnification, x1000.

initially in Brackwasser Sarmatian deposits in Hungary (Pantocsek, 1889). Its presence serves to attest the Miocene age of the diatomite deposits in the Madrid Basin.

Paleoenvironment of diatomite sedimentation

The continental character, inferred from regional geology, of the miocene formations, is also attested by diatoms provided a complete absence of non-continental diatom species in the studied samples. The sedimentation of the Intermediate Unit in the Esquivias area began with fluvio-lacustrine deposits that vertically gave pass to a complex mosaic of clays, carbonates, and siliceous sediments that were deposited in lacustrine environments. According to this scheme, diatomites would be deposited during stages of maximum regional enlargement of the lake areas.

Sedimentological data as well as evidence provided by diatoms strongly suggest that, as a whole, deposition took place in shallow lakes and surrounding paludal areas. Probably, the lacustrine sedimentary sequence resulted from small, more or less permanent shallow lakes that shifted, and sometimes coalesced, through time. In this picture, diatomite beds should be deposited into most stable lake areas. Evidence of very shallow conditions, such as root holes, suggest that the lake experienced some oscillations of the water level. Further evidence of shallowness is provided by diatoms. The whole of the diatom specimens that we have recognized in our samples is constituted by epiphytic and/or epilithic species. Living forms of these species are commonly found in shallow waters, frequently in littoral lake environments.

A closer view of the distribution of diatoms in vertical sequence (Zones I to VI in section ESC) allows to infer that Zones I and VI, both of them characterized by *Fragilaria bituminosa*, reflect slightly higher salinities in lake water. This circumstance is clearer in Zone VI, where *Fragilaria bituminosa* occurs asociated with mesohalobien species, such as *Anomoeoneis sphaerophora, Navicula cincta, Amphora veneta,* and *Amphora coffaeformis.* On the other hand, Zones III, IV, and V are characterized by *Cymbella* species, which are oligohalobien and alkaliphilic species, and they are indicative of fresh-water, shallow lake environments. In this context, Zone V displaying the highest occurrence of *Cocconeis placentula,* represents a more marked lowstand in water level. Finally, the transitional Zone II would represent an episode of progressive freshening between Zones I and III.

It follows from the previous paragraph that diatoms in the miocene formations of the Malcovadeso area are mostly freshwater or tolerant of moderately saline conditions. This seems to fit well with the commonly observed low-Mg calcite composition of the carbonate phase in the diatomite beds. In addition, diatom ecology indicates that the observed species were adapted to somewhat alkaline waters, which in turn favoured the formation of authigenic clays such as palygorskite and sepiolite (Leguey *et al.,* 1985) within the shallow lake. Authigenesis of these clays could be related to the colloidal silica provided from dissolution of diatom frustules.

Finally, main diagenetic features in the diatomites concern to corrosion or even total dissolution and later calcitization of the diatom frustules. Nevertheless, the definite paths of these processes have not been yet evaluated. It does not seem unreal to assume that diatom dissolution mostly accounted for the formation of the opaline levels widely extended within the miocene formations in the studied area.

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