

# AGE AND PALEOCEANOGRAPHIC SIGNIFICANCE OF THE CALETA HERRADURA DIATOMITE, PENINSULA DE MEJILLONES, ANTOFAGASTA, CHILE

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## ABSTRACT

A three meters section of diatomite in the mostly siliciclastic Caleta Herradura Formation is exposed along the shore north of Antofagasta, Chile. This deposit is a lensoid erosional remnant conformably underlain by mudstone and sandstone and truncated upsection by an angular unconformity at the base of the La Portada Formation. The diatoms belong to a marine 'needle' assemblage (*Thalassionema/Thalassiothrix*) with a minor nonmarine component. The microflora is a mixture of oceanic and neritic diatoms, and is indicative of sporadic upwelling and oceanic intrusions in a nearshore environment. The co-occurrence of *Rouxia californica* Peragallo and *Nitzschia fossilis* (Frenguelli) indicates a late Miocene age for the diatomite. The diatomite formed during a major transgressive event that trapped detrital sediment shoreward of the accumulation of diatomaceous ooze. The overlying unconformity may represent the Messinian sea level regression and/or major tectonic uplift.

*Key words:* Diatomite, Ooze, Upwelling, Miocene, Caleta Herradura, Peninsula de Mejillones, Chile.

## RESUMEN

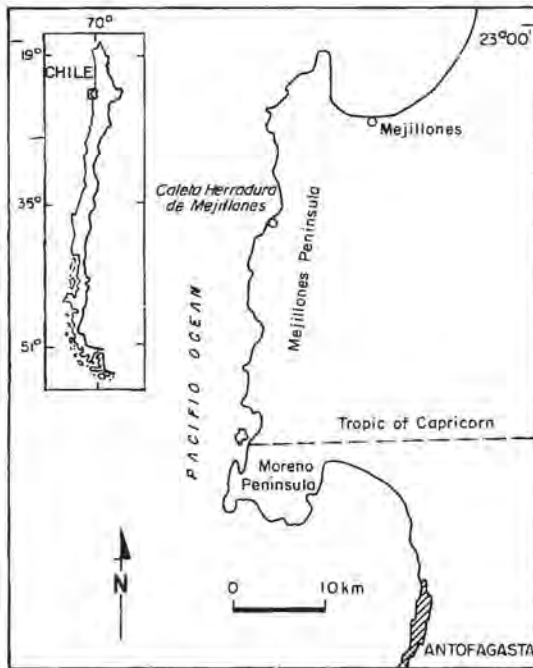
EDAD Y SIGNIFICADO PALEOCEANOGRÁFICO DE LA DIATOMITA DE CALETA HERRADURA, PENINSULA DE MEJILLONES, ANTOFAGASTA, CHILE. A lo largo de la costa, al norte de Antofagasta, Chile, aflora una secuencia de diatomitas de tres metros, dentro de estratos, en su mayor parte siliciclásticos, de la Formación Caleta Herradura. Este depósito es un remanente lenticular que sobreyace concordantemente a lodolitas y areniscas y que, a su vez, es truncado hacia el techo por una discordancia angular en la base de la Formación La Portada. Estas diatomáceas corresponden a una asociación marina, mayoritariamente acicular (*Thalassionema/Thalassiothrix*) con componentes menores de ambiente no marino. La microflora presente es una mezcla de diatomáceas de ambiente oceánico y nerítico, y es indicativa de surgencias esporádicas y de incursiones oceánicas en un ambiente nerítico. La presencia mutua de *Rouxia californica* Peragallo y *Nitzschia fossilis* (Frenguelli) indica una edad miocena tardía para esta diatomita. Ella fue depositada durante un evento transgresivo mayor, que atrapó sedimentos detríticos en la dirección de la línea de costa donde se acumulaban los lodos diatomáceos. La discordancia sobreyacente podría representar la regresión del Mesiniano y/o un levantamiento tectónico mayor.

*Palabras claves:* Diatomita, Fango, Surgencia, Mioceno, Caleta Herradura, Península de Mejillones, Chile.

## INTRODUCTION

Tertiary marine deposition in offshore Chile has been documented from Arica in the north (Coulbourn and Moberly, 1977) to Chiloé Island in the south (Mordojovich, 1974), and many formations of Tertiary

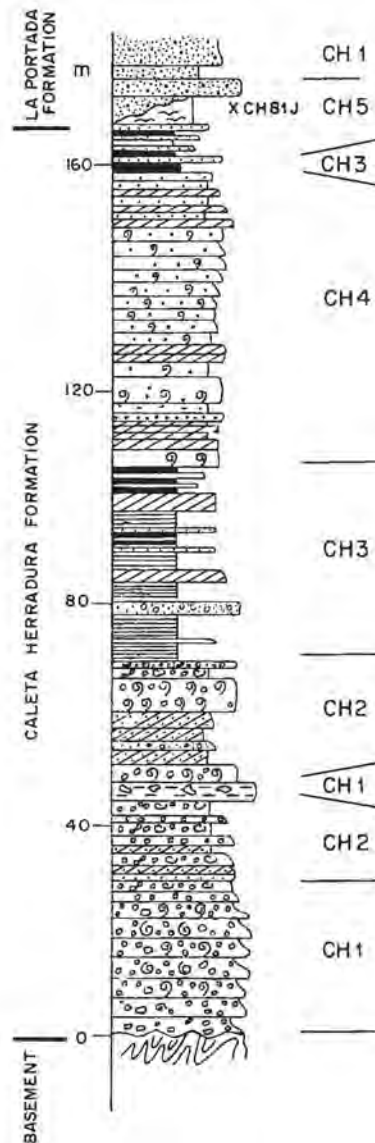
age have been reported onshore along the coast of Chile. One such deposit at Caleta Herradura was assigned a Miocene age on the basis of the occurrence of *Globorotalia peripheronda* Blow and Banner and



Text-FIG. 1. Location map.

*Orbulina suturalis* Bronnimann (Martínez, 1980). The name 'Caleta Herradura Formation' is herein proposed to describe this sequence of fossiliferous marine conglomerates interbedded with fine grained burrowed sandstones, cross bedded sandstones and silty mudstones capped by a ca. 3 m thick diatomite. The type locality is at Caleta Herradura, 50 km north of Antofagasta (text-Fig. 1). This thick (>160 m) marine sequence was previously correlated with part of the Pliocene/Pleistocene La Portada Formation (Herm, 1969; Martínez, 1980) exposed at Mejillones Bay and at the type area at La Portada. There is strong evidence, however, to suggest that the angular unconformity near the top of the Caleta Herradura section separates two distinct units. The Caleta Herradura Formation is stratigraphically beneath the unconformity and is finer grained, whereas the overlying La Portada Formation consists of breccias and fine to medium grained sandstones (text-Fig. 2). The unconformity that separates the two formations may represent the Messinian fall in sea level (Haq *et al.*, 1987) and/or major tectonic uplift. It was recognized by Ferraris and Di Biase (1978) who interpreted it as an intraformational unconformity within the La Portada Formation.

In this paper, the Tertiary marine sequence exposed along the coast north of Antofagasta is divided into three distinctive units (text-Fig. 3). The Caleta Herradura Formation unconformably rests on Paleozoic/Mesozoic rocks, and is overlain unconformably by the La Portada Formation. The latter is conformably overlain by the Mejillones Formation of Ferraris and Di Biase (1978).



Text-FIG. 2. Stratigraphic column for Caleta Herradura, Chile, showing lithofacies CH1 to CH5 and location of diatomite sample CH81J.

Herm (1969) Ferraris and Di Biase (1978) Martínez (1980)		This paper	
Quat.	Mejillones Formation	Mejillones Formation	PLEISTOCENE ? — ? — ? — ?
Tertiary	La Portada Formation	La Portada Formation	PLIOCENE
		Caleta Herradura Formation	MIOGENE
PALEOZOIC/MESOZOIC ROCKS			

Text-FIG. 3. Tertiary/Quaternary stratigraphy of the coastal region surrounding Antofagasta, Chile

### LITHOFACIES

The Caleta Herradura and La Portada formations at Caleta Herradura have several distinctive facies which may be interpreted in terms of physical processes and depositional environments (text-Fig. 2). The fossiliferous conglomerate and pebbly mudstone lithofacies (CH1) is characterized by well stratified, pebble to cobble size fossiliferous conglomerate changing upward to granular size conglomerate, often rounded to well rounded, interbedded with matrix supported breccia. This facies is interpreted to represent nearshore reworking of the toes of shortheaded fans that originated at a nearby depositional scarp.

The coquina and cross bedded sandstone facies (CH2) is characterized by thick beds of fossil debris interbedded with planar, cross bedded, coarse grained sandstones. The coquinas range in thickness from 0.5 to 3 m and the sandstones vary in thickness from 0.35 to 0.55 m. This lithofacies is interpreted to represent a high energy, nearshore to upper shoreface environment.

Fossiliferous mudstone interbedded with cross bedded sandstone and fossiliferous conglomerate constitute lithofacies CH3. The mudstones are yellow

brown, silty, fossiliferous, and contain calcareous concretions. The conglomerates consist of well stratified, imbricated pebble sized clasts. The sandstones are coarse grained, well sorted, with planar cross bedding. This lithofacies is arranged in well defined thickening and coarsening upward cycles interpreted as shoaling upward cycles representing several pulses of offshore bar construction.

Lithofacies CH4 consists of fine grained burrowed sandstones interbedded with cross bedded sandstones. The sandstones are graded, with thick shell fragments at the base followed by fine to very fine grained, highly burrowed sandstones. There are also some discrete cross bedded fine to medium grained sandstones. This lithofacies is interpreted to have been deposited in the lower and upper shoreface environment.

The diatomaceous mudstone lithofacies CH5 consists of medium to dark brown, silty diatomaceous mudstone interbedded with white laminated diatomite toward the top. This facies is interpreted to represent an offshore pelagic facies formed by sporadic upwelling during a maximum marine transgression.

### DEPOSITIONAL ENVIRONMENTS

The Caleta Herradura Formation documents several pulses of sea level change in a nearshore shelf environment during a period of intense tectonic

activity. The lower 45 m (lithofacies CH1) represent almost total reworking of the toes of shortheaded fan facies by nearshore processes. The sediments at the

toes of the fan, derived from nearby active fault blocks, reached the shoreline and were partially or totally reworked by waves and currents. The interbedded coquina and cross bedded sandstones (CH2) represent the nearshore to upper shoreface facies which is followed upward by several relatively small thickening and coarsening cycles (CH3). These sequences, formed during transgressive/regressive cycles, are interpreted to represent offshore bar

facies. This facies was followed by burrowed fine grained sandstones interbedded with discrete cross bedded sandstones (CH4) deposited during a regressive cycle and representing the lower and upper shoreface. The distinctive diatomaceous mudstone at the top represents the offshore facies deposited during a period of maximum marine transgression.

## PALEONTOLOGY

One sample of the diatomite at the top of the Caleta Herradura Formation was collected for micropaleontological analysis. Sample CH81J is an extraordinarily pure diatomite. It contains two important biostratigraphic markers: *Nitzschia fossilis* (Frenguelli) emend. Kanaya (Pl. 1, Fig. 1) (middle late Miocene to middle Pleistocene), and *Rouxia californica* Peragallo (Pl. 1, Fig. 2) (early middle Miocene to the Miocene-Pliocene boundary) (Barron, 1985). The diatomite is therefore late Miocene in age, which agrees with the age determination of Tsuchi *et al.* (1988) based on the co-occurrence of *Asterolampra acutiloba* Frenguelli and *Nitzschia miocenica* Burcke.

The diatom assemblage of sample CH81J consists primarily of thin, long fragments of *Thalassiothrix longissima* Cleve and Grunow, and *Thalassionema nitzschioides* Grunow (Pl. 1, Fig. 3), and has been called the 'needle' assemblage (Shipboard Scientific Party, 1988). In addition, the genera *Thalassiosira*, *Dictyochoa* (silicoflagellate), *Actinoptychus*, and *Chaetoceros* (spores) are present as well. This assemblage appears to belong to Schrader's phase 2 category of coastal upwelling-sporadic and with an oceanic-temperate influence. The preservation of the microflora in CH81J, however, is excellent - better

than the 'good' expected beneath phase 2 upwelling. The unusual purity of this diatomite may be explained by entrapment of detrital sediment in more shoreward basins during a period of maximum transgression, thus producing starved basins offshore where pelagic sediments, i.e., diatomaceous ooze, accumulated. Although upwelling may have been sporadic, biogenic silica must have been the most significant source of sedimentation.

CH81J also has the oceanic 'warm water' species *Coscinodiscus asteromphalus* Ehrenberg (Pl. 1, Fig. 4) and *Coscinodiscus radiatus* Ehrenberg (Pl. 1, Fig. 5) (DeVries and Schrader, 1981), thus attesting to the influence of the open ocean. Benthic diatoms, too, are well represented in this sample. Sample CH81J appears to have formed in a neritic environment characterized by sporadic upwelling and warm-temperate oceanic water. The diatomaceous ooze probably accumulated during a period of maximum marine transgression, so that the detrital influx was trapped shoreward of the accumulation of pelagic sediments. The unconformity that truncates this diatomite may be attributed to the Messinian sea level regression and/or a major tectonic uplift.

## CONCLUSION

Sample CH81J from the Caleta Herradura Formation diatomite is late Miocene in age. It is a very pure diatomite that formed during a period of maximum marine transgression. The unconformity at its top

may represent the Messinian fall in sea level and/or major tectonic uplift. The diatom assemblage is indicative of sporadic upwelling and oceanic influence on the continental shelf.

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## PLATE 1

## Figures

- 1 *Nitzschia fossilis* (Frønguelli) emend. Kanaya  
Length: 33  $\mu\text{m}$ .
- 2 *Rouxia californica* Peragallo  
Length: 64  $\mu\text{m}$ .
- 3 Sample CH81J showing 'needle' assemblage composed of *Thalassionema/Thalassiothrix*, and *Rouxia californica* as a lesser component. Diameter of centric diatom in middle field is 67  $\mu\text{m}$ .
- 4 *Coscinodiscus asteromphalus* Ehrenberg  
Diameter: 171  $\mu\text{m}$ .
- 5 *Coscinodiscus radiatus* Ehrenberg  
Diameter: 69  $\mu\text{m}$ .

PLATE 1

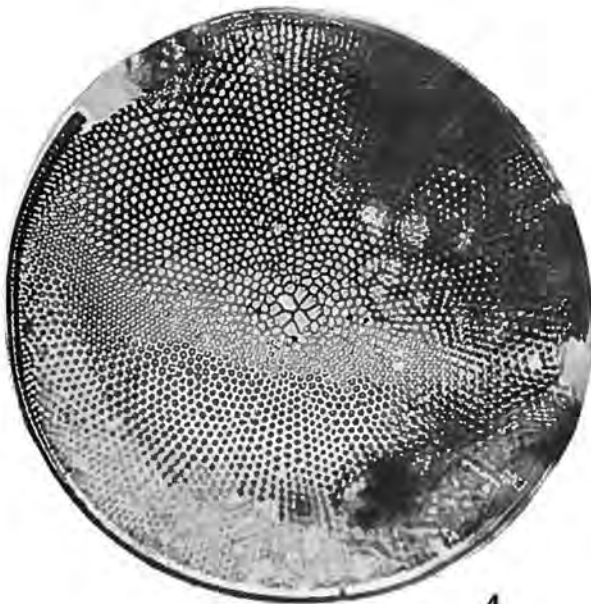


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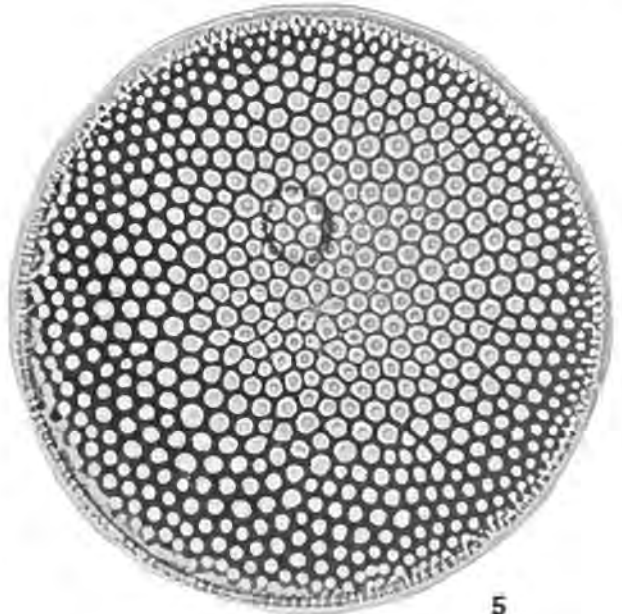
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