STRATIGRAPHY, DEPOSITIONAL ENVIROMENTS AND FORAMINIFERA OF THE MIOCENE TORTUGAS FORMATION, BAJA CALIFORNIA SUR, MEXICO

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RESUMEN

La Formación Tortuga (Mioceno Inferior a Superior) se encuentra expuesta ampliamente en la parte noroccidental de la Península de Vizcaíno, Baja California Sur, México. Esta formación contiene un registro claro de la evolución de una cuenca localizada en el extremo austral de la provincia fisiográfica conocida como "Continental Borderland". Los sedimentos diatomáceos de esta formación se asemejan en muchos aspectos a la "Lutita Monterey" de la Alta California, con la cual se correlacionan.

El estudio integrado del contenido de foraminíferos y diatomeas, así como de las características sedimentológicas de una sección de la Formación Tortugas de 400 m de espesor, que se encuentra en un bloque afallado localizado al este de Punta Quebrada, ha permitido la subdivisión de esta unidad en cuatro miembros diferentes, cada uno de los cuales refleja cambios en paleobatimetría, ambientes de depósito y eventos climáticos y/o tectónicos. El miembro 1 (estratigráficamente el más bajo) abarca del Mioceno Inferior al Medio (Saucesiano) y consiste en 60 m de lodolitas limosas que contienen foraminíferos de ambiente batial medio. El miembro 2 está compuesto por 65 m de areniscas espiculares intercaladas con arenas tobáceas y lodolitas limosas que representan depósitos de un abanico submarino durante parte del Mioceno Medio (Reliziano y Luisiano), así como erosión de los sedimentos previamente depositados en el fondo de la cuenca; este miembro también refleja la presencia de actividad volcánica y una disminución en la profundidad de la cuenca en ese tiempo. Los miembros 3 y 4 fueron depositados durante la parte superior del Mioceno Medio y la parte inferior del Mioceno Superior (Mohniano inferior) estos miembros están compuestos por 300 m de porcelanitas (muy abundantes en los 50 m inferiores) que alternan con lodolitas diatomáceas, representando sedimentación en una cuenca sellada, anóxica, en un ambiente batial superior.

El estudio de una sección de la misma formación, localizada hacia el este de la pista aérea de Bahía Tortugas, ha permitido el dividir a esta secuencia en dos miembros. El miembro basal (A) está compuesto por 45 m de areniscas líticas que contienen pellas de fosforita y moluscos fósiles de edad Mioceno Temprano a Medio (Saucesiano Superior a Realiziano.), y que representan una facies de sedimentación nerítica que es contemporánea con la parte superior del miembro 1 y el miembro 2, los cuales representan condiciones batiales en la sección de Punta Quebrada. El miembro B consiste en 95 m de lutitas diatomáceas y limosas que contienen foraminíferos que indican un ambiente de depósito en una cuenca sellada, anóxica, semejante a la que se reconoce en los miembros 3 y 4 de la sección de Punta Quebrada.

En resumen, se reconocen tres etapas en la evolución geológica de la cuenca Tortugas: 1) Subsidencia rápida durante el Mioceno Temprano (Saucesiano) que llevó al área de un

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régimen de erosión subaérea hasta profundidades de ambiente batial medio con una acumulación lenta de sedimentos; 2) Levantamiento durante el Mioceno Medio (Reliziano–Luisiano) que originó el depósito de turbiditas en las partes profundas de la cuenca; 3) Hundimiento renovado con velocidades de subsidencia y sedimentación esencialmente iguales durante la parte temprana del Mioceno Tardío (Mohniano); estas condiciones dieron como resultado el depósito de sedimentos finos en un ambiente batial superior caracterizado por una deficiencia de oxígeno en el agua.

La secuencia depositada en la cuenca Tortugas fue levantada tectónicamenete durante el intervalo Mioceno–Plioceno. La deformación estructural del área se continuó durante el Pleistoceno.

ABSTRACT

The Lower through Upper Miocene Tortugas Formation is widely exposed on the Vizcaino Peninsula of Baja California Sur, Mexico, and provides a clear record of the evolution of a southern continental borderland basin. The diatomaceous sediments of this formation are similar in many respects to the correlative Miocene Monterey Shale of Alta California.

The integrated study of foraminifera, diatoms, and sedimentologic characteristics through a 400 m thick section of the Tortugas Formation located in a faulted block east of Punta Quebrada, has allowed this unit to be subdivided into four members reflecting variations in paleobathymetry, depositional environments, and tectonic and/or climatic events. The lowermost member 1 consists of 60 m of Lower to Middle Miocene (Saucesian) silty mudstones containing middle bathyal foraminifera. Member 2 is composed of 65 m of interbedded spicular sandstones, tuffaceous sands, and silty mudstones, representing submarine fan deposition and erosion of previously deposited sediments on the basin floor during Middle Miocene time (Relizian–Luisian). Member 2 also reflects the presence of volvanic activity and an uplift event during that period. Members 3 and 4 are composed of 300 m of alternating porcellanites (mainly found in the lower 50 m) and diatomaceous mudstones representing deposition in an anoxic, middle bathyal, silled basin during late Middle and early Late Miocene (Mohnian) time.

Study of a second section through the Tortugas Formation located east of the airfield at Bahia Tortugas allowed the division of this sequence into 2 members. The basal member A consists of 45 m of lithic sandstones containing pelletal phosphorite and neritic mollusks of Early to Middle Miocene age (upper Saucesian to Relizian?) and representing a neritic facies correlative with the upper part of member 1 and with member 2 representing bathyal conditions in the Punta Quebrada section to the north. Member B consists of 95 m of silty, diatomaceous shales containing foraminifera indicative of a silled anoxic basin environment similar to the environment recognized in members 3 and 4 of the Punta Quebrada section.

In summary, three stages in the geologic evolution of the Tortugas basin are recognized: 1) Early Miocene (late Saucesian) rapid subsidence from subaerial to a middle bathyal depth of a low rate of sediment accumulation; 2) A Middle Miocene (Relizian–Luisian) uplifting event that triggered deposition of turbidites in the deeper part of the basin, and 3) Renewed subsidence and equal rate of sedimentation in the Late Miocene (early Mohnian) resulted in a low oxygen environment at upper bathyal depths.

Uplift of the Tortugas basin sequence occured during the Miocene–Pliocene interval with further structural deformation of this area during Pleistocene time.

INTRODUCTION

Neogene rocks of the Baja California Peninsula are dominated by Miocene volcanic units commonly included in the Comondu Formation (Beal, 1948; Gastil and Lillegraven, 1974). Alternately, Neogene marine units are limited in distribution and thickness, Allison, (1964). Taken together, these rocks contain a little studied record of the later development of the Baja California Peninsula and adjacent Pacific margin and Gulf of California. Significantly, Miocene marine rocks have been reported mainly from the western half of the Peninsula and assigned to the San Gregorio, Isidro, San Ignacio, Monterey Superior and Inferior, Tortugas, and Rosarito Beach Formations (Beal, 1948; Mina, 1946; Allison, 1964; Minch, 1970; Minch *et al.*, 1976; Lozano, 1975). Although the relationships between these various units are unclear in detail, they have a general similarity in age range and lithologic character with various portions of the Monterey Shale, Rincon Shale, and Vaqueros Formation of Alta California and contain a similarly valuable but little known record of Pacific borderland history. This report focuses on the depositional history of the Lower through Upper Miocene Tortugas Formation of the Vizcaino Peninsula (Fig. 1).

Miocene rocks assigned to the Tortugas Formation are widely exposed in the western side of the Vizcaino Peninsula, Robinson (1975) and in Cedros Island, Kilmer (1969). The Tortugas rocks studied for this report crop out in an area immediately north of Bahia Tortugas (Fig. 1). This stratigraphic unit represents an uplifted portion of bathyal diatomaceous sediments deposited in a subsiding Neogene basin located along the southern margin of the Southern California Continental Borderland Province, Blake *et al.* (1978).

The two sections studied were displaced by post–Miocene faulting. This action brought these sequences closer together relative to their original locations.

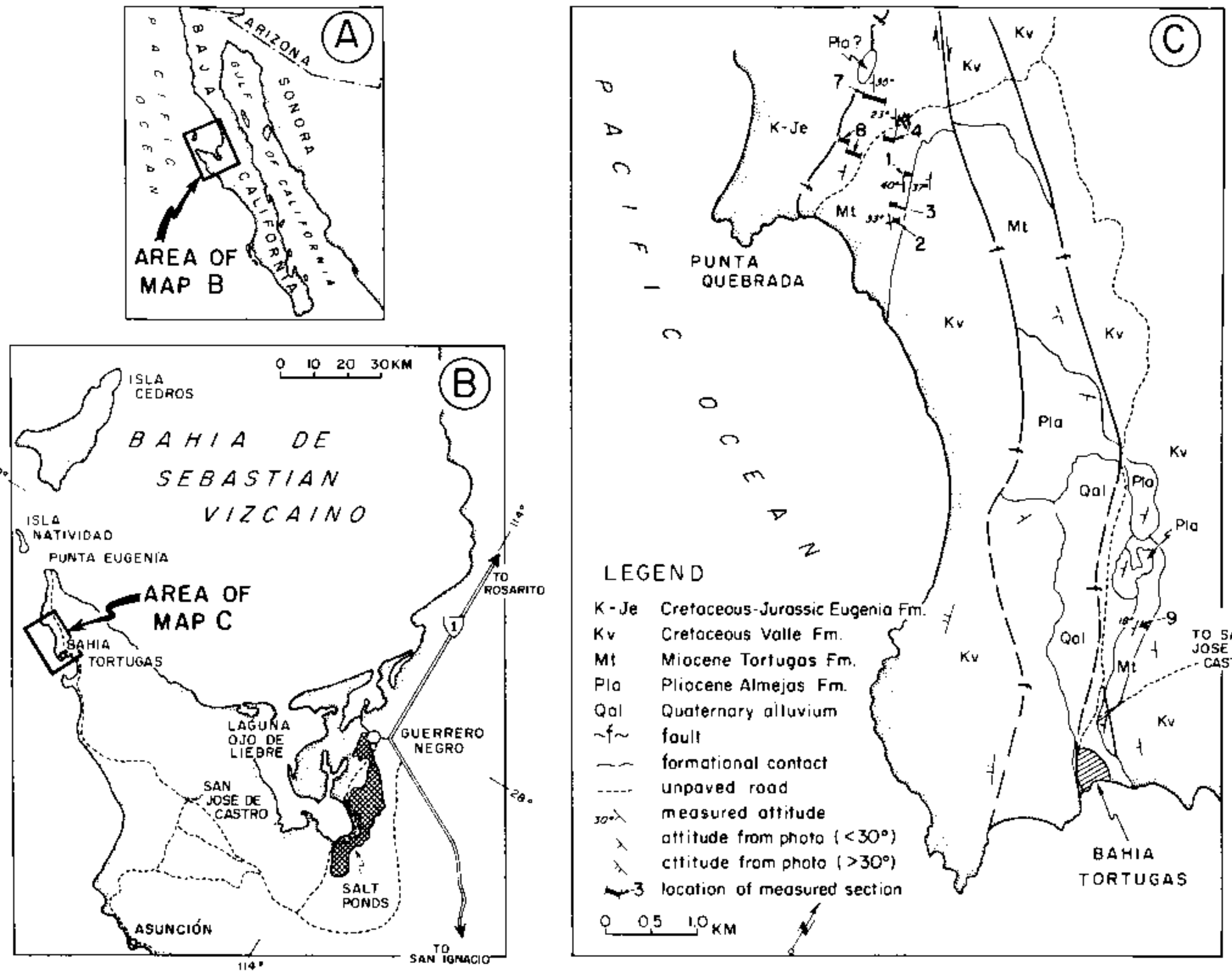

Fig. 1. Location and geology of the Bahia Tortugas area, Baja California Sur, Mexico (geology by J. Helenes, 1979).

The strata of the Tortugas Formation are Early to Late Miocene in age, and resemble the well known Monterey Shale of California and similar deposits around the Pacific margin. The similarity in lithology, age, and depositional history of these deposits suggests a similar origin, in turn implying regionally widespread Miocene tectonic, paleoceanographic, and paleoclimatic events, Ingle (1973).

OBJECTIVE AND METHODS

The purpose of this report is to describe the lithology and fossil content of the Miocene Tortugas Formation exposed at two localities of the Bahia Tortugas area (Fig. 1) in order to define the age and depositional history of this important unit. A firm correlation of these strata with regional tectonic and sedimentological events is proposed for at least one of the sections.

In order to achieve these objectives, a reconnaissance geologic map of the area was prepared and two key sections through the Tortugas Formation were measured and sampled (Fig. 1). Samples were collected at irregular intervals with regard for changes in microfossil content and preservation, as well as lithologic characteristics.

Lithologic variations through the Tortugas Formation were determined on the basis of field observations together with limited petrographic descriptions in the laboratory.

Emphasis in the study is placed on quantitative analysis of fossil foraminifera within the Tortugas Formation. Samples were mechanically broken and then boiled in water with Quaternary–O. Washed samples were sieved using a No. 230 mesh (opening in mm = 0.063) screen to eliminate silt and clay sized material. The remaining coarse fractions were then scrutinized for foraminifera. Generally, 250 or more specimens of fossil foraminifera were randomly picked from 32 of the prepared samples found to contain these microfossils. However, due to the low numbers of foraminifera in some of the samples, the mean number of specimens picked is 192.

Approximate boundaries between the various paleoenvironments identified in this report represent the top or the base of important water mass boundaries commonly impinging along continental margins, including the surface layer and the oxygen minimum layer, Ingle (1975). Thus, the assignment of species to an environment or biofacies implies an approximate depth range. The depth ranges indicated by the use of qualitative environmental designations are the following: Upper Neritic, 10–50 m; Lower Neritic, 50–150 m; Upper Bathyal, 150–500 m; Middle Bathyal, 500–2000 m; Lower Bathyal, 2000–4000 m.

A paleobathymetric curve was constructed (Fig. 5) using the deepest dwelling forms present in each sample, yielding a minimum depth of deposition (Ingle, in press) for each portion of the Tortugas Formacion exposed at Punta Quebrada.

PREVIOUS WORK

The earliest references to Miocene rocks in the Bahia Tortugas area are those by Hanna (1926) who described thick deposits of "light, gray–colored shales" overlying "a sandy layer in which we found numerous shark teeth, some sea lion teeth and pectens". He correlated these layers with the Upper Miocene of Kern County, California. Jordan and Hertlein (1926) also described Miocene strata in the Bahia Tortugas area "which are several hundred feet thick. The base of the Miocene is a layer containing bones and shark's teeth". The rest of the series was reported to be composed of white siliceous shale and soft fine grained sandstone, ashes and impure diatomite. Later, Hertlein and Jordan (1927) described several localities of Miocene exposures near Bahia Tortugas, and assigned these rocks to the Middle Miocene (Temblor stage) on the basis of mollusks and shark teeth.

In 1933, Hertlein collected a diatomite in the northern end of Bahia Tortugas bay, and according to Dr. G. D. Hana's identification of the diatoms, the sample was placed in the Upper Miocene.

The Tortugas Formation as such, was first named by Mina, (1956) for the Miocene rocks exposed abouth three kilometers north of Bahia Tortugas (Locality 9 in Fig. 1). He assigned to this unit a Middle to Upper Miocene age on the basis of questionable faunal content.

In 1960, Durham and Allison mentioned diatomaceous and tuffaceous rocks of the Tortugas Formation that contain Middle Miocene foraminifera and gastropods. In addition, Allison (1964) described the Tortugas Formation as composed of cherts and diatomaceous rocks, and assigned the unit to the Middle Miocene Luisian stage of Kleinpell (1938).