

New remains of *Notoemys tlaxiacoensis* from the Llano Yosobé, Sabinal Formation (Upper Jurassic, Kimmeridgian), Oaxaca, Mexico

Nuevos restos fósiles de Notoemys tlaxiacoensis de Llano Yosobé, Formación Sabinal (Jurásico Superior, Kimmeridgiano), Oaxaca, México

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Abstract

Platyhelyidae includes two genera *Platyhelys* and *Notoemys* and their fossil record spans from the Upper Jurassic to the Lower Cretaceous. The only platyhelyid described from Mexico is *Notoemys tlaxiacoensis* (Upper Jurassic, Kimmeridgian). A morphological study was carried out with a new shell fragment, collected in Llano Yosobé, Oaxaca, Mexico. The aim of this study is to present the anatomical similarities observed in the plates and scutes in this new material. Our observations suggest this new specimen represents the remains of *Notoemys tlaxiacoensis* based on the similar characteristics observed in the shape and contacts of the coastal plates and the vertebrals and pleurals scutes. The isolated shell fragment does not present any set of characters unique that indicates sexual or ontogenetic variability.

Keywords: Kimmeridgian, *Notoemys*, Platyhelyidae, shell fragment, Upper Jurassic.

Resumen

Platyhelyidae incluye dos géneros *Platyhelys* y *Notoemys* y su registro fósil se extiende desde el Jurásico Superior hasta el Cretácico Inferior. El único *Platyhelyidae* descrito en México es *Notoemys tlaxiacoensis* (Jurásico Superior, Kimmeridgiano). Se realizó un estudio morfológico con un nuevo fragmento de caparazón, colectado en Llano Yosobé, Oaxaca, México. El objetivo de este estudio es presentar las similitudes anatómicas observadas en las placas y escudos en este nuevo material. Nuestras observaciones sugieren que este nuevo espécimen representa los restos de *Notoemys tlaxiacoensis* basados en características similares observadas en las placas costales y los escudos vertebrales y pleurales. El fragmento de caparazón no presenta ningún conjunto de caracteres únicos que indiquen variabilidad sexual u ontogenética.

Palabras clave: Kimmeridgiano, *Notoemys*, *Platyhelyidae*, fragmentos de caparazón, Jurásico Superior.

1. Introduction

Platyheliidae includes five species belonging to two genera: *Platyheliys* and *Notoemys* (de la Fuente and Iturralde-Vinent, 2001; Cadena and Gaffney, 2005). Platyheliids are known from Europe, South America, North America, and Caribbean Islands, and their fossil record spans from the Upper Jurassic to the Lower Cretaceous (Cadena and Joyce, 2015).

The first described member of the Platyheliidae was *Platyheliys oberndorferi* (Upper Jurassic, Kimmeridgian–Tithonian of Germany and Switzerland) (Wagner, 1853). The Argentinian *Notoemys laticentralis* was the first platyheliid to be found outside Europe (Upper Jurassic, Tithonian) (Cattoi and Freiberg, 1961). The Cuban *Notoemys oxfordiensis* is the oldest known platyheliid (Upper Jurassic, Oxfordian), this species represents also the first platyheliid found in the Caribbean Islands (de la Fuente and Iturralde-Vinent, 2001). The Colombian *Notoemys zapatoacaensis* is the only platyheliid known from the Lower Cretaceous (Valanginian) (Cadena and

Gaffney, 2005). Lately, the last member of platyheliid was described from Mexico, *Notoemys tlaxiacoensis* (Upper Jurassic, Kimmeridgian) (López-Conde *et al.*, 2017). All the above mentioned species form a monophyletic group within the stem Pleurodira, named Platyheliidae.

The Sabinal Formation is exposed in the areas of Tezoatlan, Huajuapán de León, Chalcatongo, Huamuxtitlán and Tlaxiaco, in the north-eastern part of the state of Oaxaca (Meneses-Rocha *et al.*, 1994). The locality of Llano Yosobé is a small outcrop of the Sabinal Formation (Upper Jurassic, Kimmeridgian), it comprises a sequence of marine bituminous shales. This site is important because it has the highest concentration and diversity of Jurassic marine vertebrates in Mexico (*e.g.* fishes, ichthyosaurs, plesiosaurs, marine crocodyliforms and turtles) (Barrientos-Lara *et al.*, 2015, 2016, 2018; Barrientos-Lara and Alvarado-Ortega, 2018; Alvarado-Ortega and Brito, 2016; López-Conde *et al.*, 2017). *Notoemys tlaxiacoensis* is the only known taxon turtle in the Upper Jurassic (Kimmeridgian) of Mexico (López-Conde *et al.*, 2017). The presence of Jurassic turtles in other Mexican localities is unknown, leaving the Llano

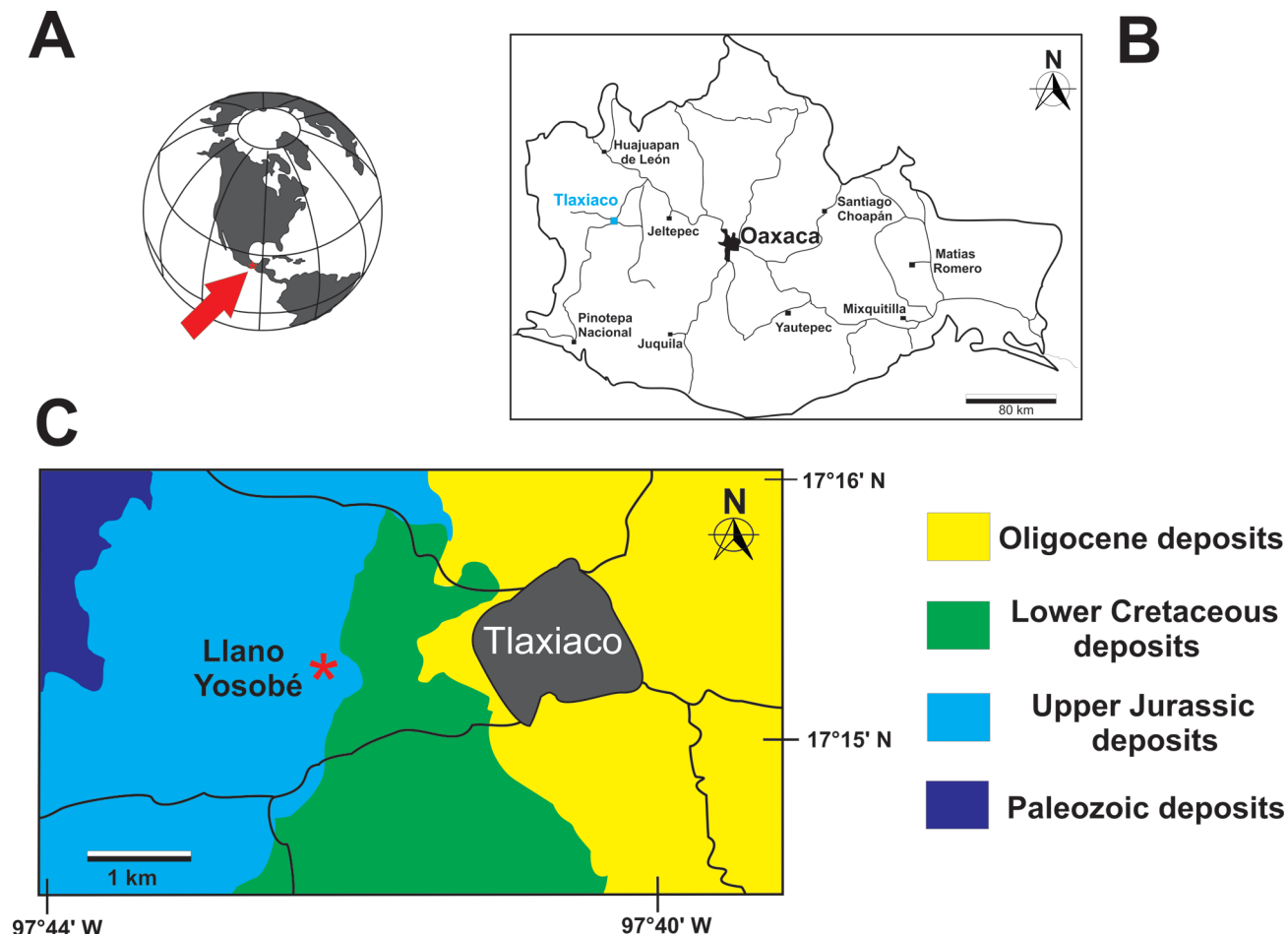


Figure 1. Map of the locality. A, general map of Mexico showing the state of Oaxaca; B, close up to the state of Oaxaca and location of Tlaxiaco municipality; C, Geological map of The Llano Yosobé. This map includes the surrounding area of this locality and deposit belonging to the Sabinal Formation (Modified from Servicio Geológico Mexicano, 2000).

Yosobé as the only Jurassic locality to continue to provide new materials. Herein, a new turtle remains from this locality is reported. It corresponds to an isolate partial shell that presents similar characteristics observed in *Notoemys tlaxiacoensis* (López-Conde *et al.*, 2017).

2. Geological setting

The fossiliferous outcrop of the Llano Yosobé (17°15'18"N – 97°42'04"W) is located 3.5 km southwest of Tlaxiaco downtown, in the Mixteca region of Oaxaca, southern Mexico (Figure 1). The fossiliferous sediments in the northern part of Yosobé are 60 m thick, at the base of which is a 30 – 40 cm thick marl layer containing trigonids, other bivalves, and ammonites (Alvarado-Ortega *et al.*, 2014; Barrientos-Lara *et al.*, 2015; Alvarado-Ortega and Brito, 2016). During the Jurassic, the Tlaxiaco Basin was active, receiving both continental and marine shelf sediments (Rueda-Gaxiola *et al.*, 2007). López-Ticha (1985) named the Sabinal Formation comprising a sequence of marine bituminous shales exposed along the north-eastern of Oaxaca State. Meneses-Rocha *et al.* (1994) described the Sabinal Formation as a sequence of mudstone and wackestone clay, marl and dark grey to black bituminous shale strata with abundant calcareous concretions and ammonites, arranged in thin laminar layers of 5, 10, and 20 cm. López-Ticha (1969) estimated the age of the Sabinal formation based on its ammonite assemblage. The fossils of Yosobé were collected primarily from shale. Some of the fossils are preserved within nodules and others occur at the contacts between shale layers. The different types of preservation suggest different diagenetic processes. All the fossils preserved in nodules, including ostracodes and wood, are three-dimensional but most of the vertebrates and invertebrates preserved between layers of shale are severely flattened and commonly carbonized. These observations suggest that the nodules were formed relatively quickly after burial. The nodules commonly contain complete invertebrate carcasses, a process that seems to have facilitated three-dimensional preservation (Alvarado-Ortega *et al.*, 2014).

Although the large vertebrates in Yosobé are commonly disarticulated, complete, or partially complete skeletons have been collected. The skeletal specimens are generally preserved by an incomplete process of nodule-formation, in which one or more adjacent nodules contains 3-D structures, but around them, the shale strata include strongly compressed structures of the same individual; therefore, it is very uncommon to obtain complete skeletons, especially when the nodules have been displaced from their original position, regardless the extent of the displacement. Vertebrate remains are generally black and relatively soft, but when weathered these can be white or red and are usually harder (Alvarado-Ortega *et al.*, 2014).

3. Material and methods

The specimen described in this paper is housed in the Colección Nacional de Paleontología "María del Carmen Perrilliat", Instituto de Geología, Universidad Nacional Autónoma de México, in Mexico City. The specimen corresponds to an isolate partial shell embedded on a shale matrix. The rocky matrix preserved on the bones was removed with pneumatic tools and dental needles. The shell fragment was hardened by applying a layer of plexyglum dissolved in cyanoacrylate. In this study, the specimen was observed and measured directly, and photographs were obtained under different conditions. A comparative study was carried out with *Notoemys tlaxiacoensis*, observing the characteristics in the plates and scutes of the carapace and plastron.

Institutional abbreviations: MACN, Museo Argentino de Ciencias Naturales "Bernardino Rivadavia", Buenos Aires, Argentina; MOZ, Museo Olsacher de Zapala, Neuquén, Argentina; MGJRG, Museo Geológico Nacional "José Royo y Gómez", Instituto Colombiano de Geología y Minas-Ingeominas, Bogotá, Colombia; MNHNCu, Museo Nacional de Historia Natural, La Habana, Cuba; IGM, Colección Nacional de Paleontología, Instituto de Geología, UNAM, Ciudad de México.

Anatomical nomenclatures: We based our comparisons on the descriptions published by López-Conde and Alvarado-Ortega, 2017 and López-Conde *et al.*, 2017.

Material reviewed: *Notoemys oxfordiensis* (MNHNCu-P), La Jagua Formation (Upper Jurassic, Oxfordian); *Notoemys tlaxiacoensis* (IGM-4861), Sabinal Formation (Upper Jurassic, Kimmeridgian); *Notoemys laticentralis* (MACN-18043 and MOZ-PV-2487), Vaca Muerta Formation (Upper Jurassic, Tithonian); *Notoemys zapatocaensis* (MGJRG IPN 15-EAC), El Caucho Formation (Lower Cretaceous, Valanginian).

4. Systematic Paleontology

Testudines Batsch, 1788
Pan-Pleurodira Joyce *et al.*, 2004
Platycheilyidae Bräm, 1965
Notoemys Cattoi and Freiberg, 1961

Notoemys tlaxiacoensis López-Conde, Sterli, Alvarado-Ortega and Chavarría-Arellano, 2017

Referred specimen. IGM-12994 (Figure 2); one partial shell.

Occurrence. Llano Yosobé (17°15'18"N – 97°42'04"W), Oaxaca, México. Sabinal Formation, Upper Jurassic (Kimmeridgian).

Description. This new material corresponds to an isolate shell fragment with the presence of elements of the carapace

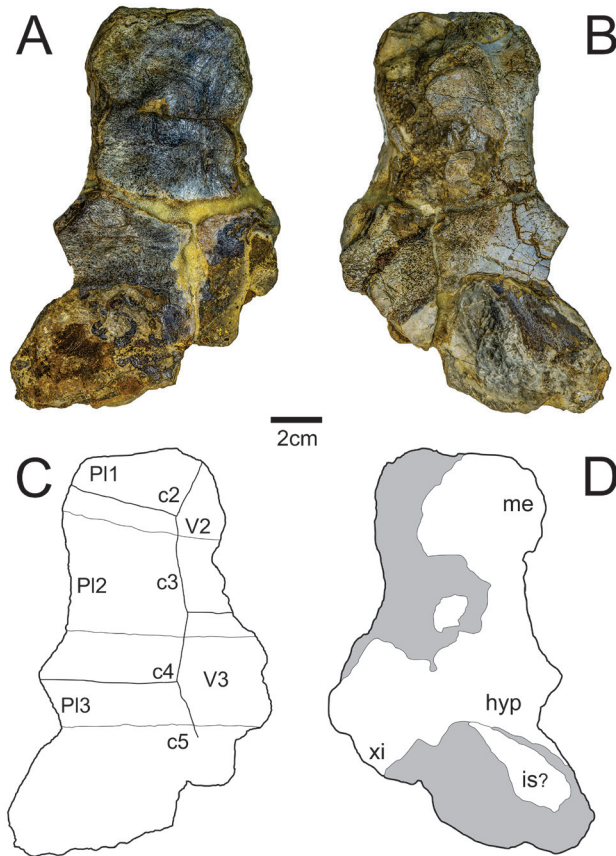


Figure 2. IGM-12994 corresponding to shell fragment of *Notoemys tlaxiacoensis*, from the Upper Jurassic (Kimmeridgian), from Llano Yosobé, Oaxaca, Mexico. A, dorsal view; B, ventral view; C, drawing of the dorsal view; D, drawing of the ventral view. Abbreviations: c, costal; hyp, hypoplastron; is, ischium; me, mesoplastron; Pl, pleural; V, vertebral; xi, xiphioplastron. Grey areas: sediment. Scale bar equals 2 cm.

and plastron. Only four costals (costal two to costal five) are preserved. They are wider than long and the remaining part of these plates are rectangular in shape, in the same way as all *Notoemys* species. The preserved scutes in the carapace are two vertebrals and three pleurals. Vertebrals 2 and 3 are similar in shape to those of *Notoemys tlaxiacoensis* (hexagonal), and they are wider than long. The vertebral 2 covers the costals 2 and 3; contacts laterally with the pleurals 1 and 2. The sulcus between pleurals 1 and 2 is on the costal 2, and the sulcus between the vertebrals 2 and 3 is on the costal 3. The vertebral 3 covers the costals 3, 4 and 5; contacts laterally with the pleurals 2 and 3; and the sulcus between the pleurals 2 and 3 is on the costal 4. The preserved plates of the plastron are the hypoplastron, mesoplastron, and xiphioplastron; these plates are damaged and the most part were not preserved. We can observe the inguinal area. The ischium can be observed, but no further description of this element can be made.

Remarks. *Notoemys* is an enigmatic group of Upper Jurassic-Lower Cretaceous turtles, and has four representatives: *Notoemys oxfordiensis* (de la Fuente and

Iturralde-Vinent, 2001) from the Upper Jurassic (Oxfordian) of Cuba; *Notoemys tlaxiacoensis* (López-Conde *et al.*, 2017) from the Upper Jurassic (Kimmeridgian) of Mexico; *Notoemys laticentralis* (Cattoi and Freiberg, 1961) from the Upper Jurassic (Tithonian) of Argentina and *Notoemys zapatoacaensis* (Cadena and Gaffney, 2005) from the Lower Cretaceous (Valanginian) of Colombia (Figure 3). These species are known mainly for their shells, and they were collected in transitional and marine stratigraphic sequences, with abundant marine invertebrates and reptiles (Bräm, 1965; Fernández and de la Fuente, 1994; de la Fuente and Iturralde-Vinent, 2001; Cadena-Rueda and Gaffney, 2005; López-Conde *et al.*, 2017). With the description of *N. tlaxiacoensis*, a gap was filled in the Kimmeridgian (Upper Jurassic). The fossil record of this taxon shows one gap in the Berriasian (Lower Cretaceous) (Figure 3).

Notoemys tlaxiacoensis, is the oldest turtle from Mexico. With the description of this new taxon, the stratigraphic reach of turtles was extended, previously the oldest record corresponded to the Lower Cretaceous (Albian) from the Tlayúa quarry (Reynoso, 2006).

5. Discussion and conclusions

The specimen IGM-12994 was recovered from the vicinity of the occurrence of *Notoemys tlaxiacoensis* the isolated shell fragment does not present any set of characters unique. Our observations suggest that the specimen IGM-12994 represents the remains of *Notoemys tlaxiacoensis* based on the similar characteristics observed in the shape and contacts of the costals plates and the vertebrals and pleurals scutes. The following diagnostic character supports our taxonomic assignment of IGM-12994 as a new *N. tlaxiacoensis* specimen: neural 3 hexagonal (being slightly octagonal in *N. laticentralis* and *N. zapatoacaensis* and rectangular in *N. oxfordiensis*). The isolated shell fragment does not present any set of characters unique that indicates sexual or ontogenetic variability.

The paleogeography importance of this taxon corresponds to that it has only been collected until now in America. The fossil record of platychelyids on both continents during the Upper Jurassic and Lower Cretaceous reinforces the proposed connection between the Tethys and the Palaeopacific through the Hispanic Corridor. *Notoemys* inhabited shallow waters with tolerance to marine environments which helped them to disperse along the coastline through the Hispanic Corridor (López-Conde and Alvarado-Ortega, 2017) (Figure 4).

The discovery of turtles from other Jurassic localities is required to improve our knowledge about fossil turtles from Mexico. New remains of turtles collected in Llano Yosobé will be revealed, other materials of Jurassic turtles are collected and according to a preliminary result, they could correspond to a new Jurassic turtle. Therefore, it is

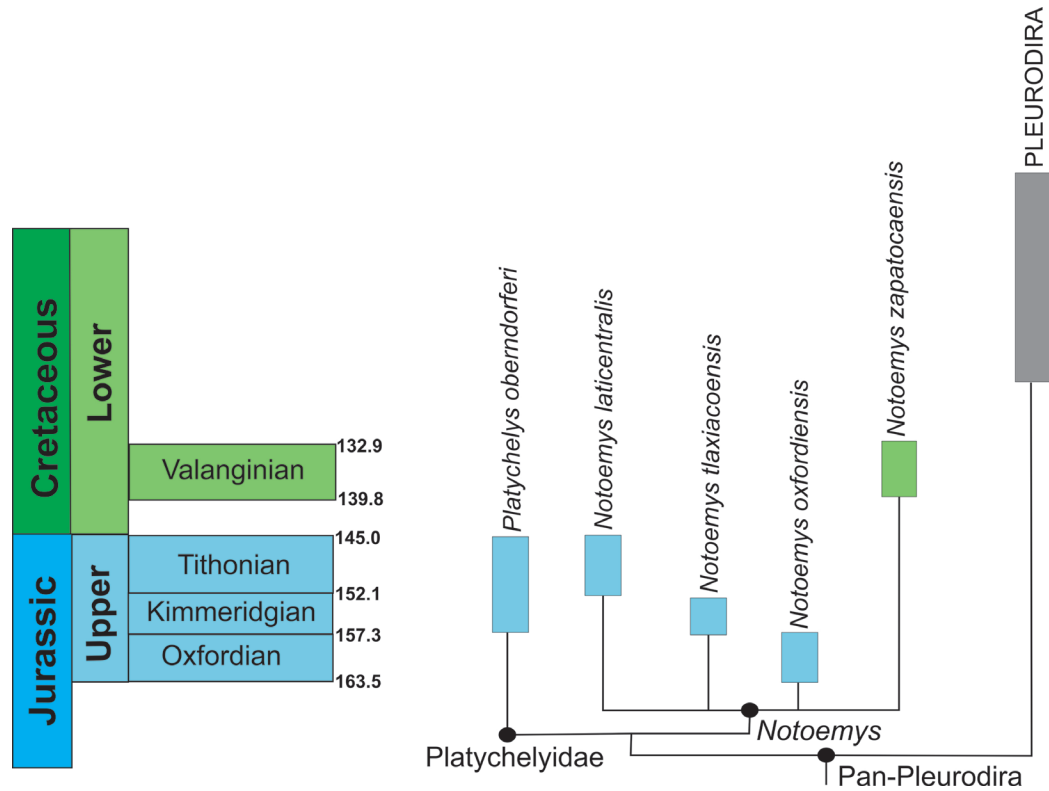


Figure 3. Stratigraphic reach of *Notoemys* calibrated in time showing the relationships within Platycheilyidae (Modified from López-Conde *et al.*, 2017).

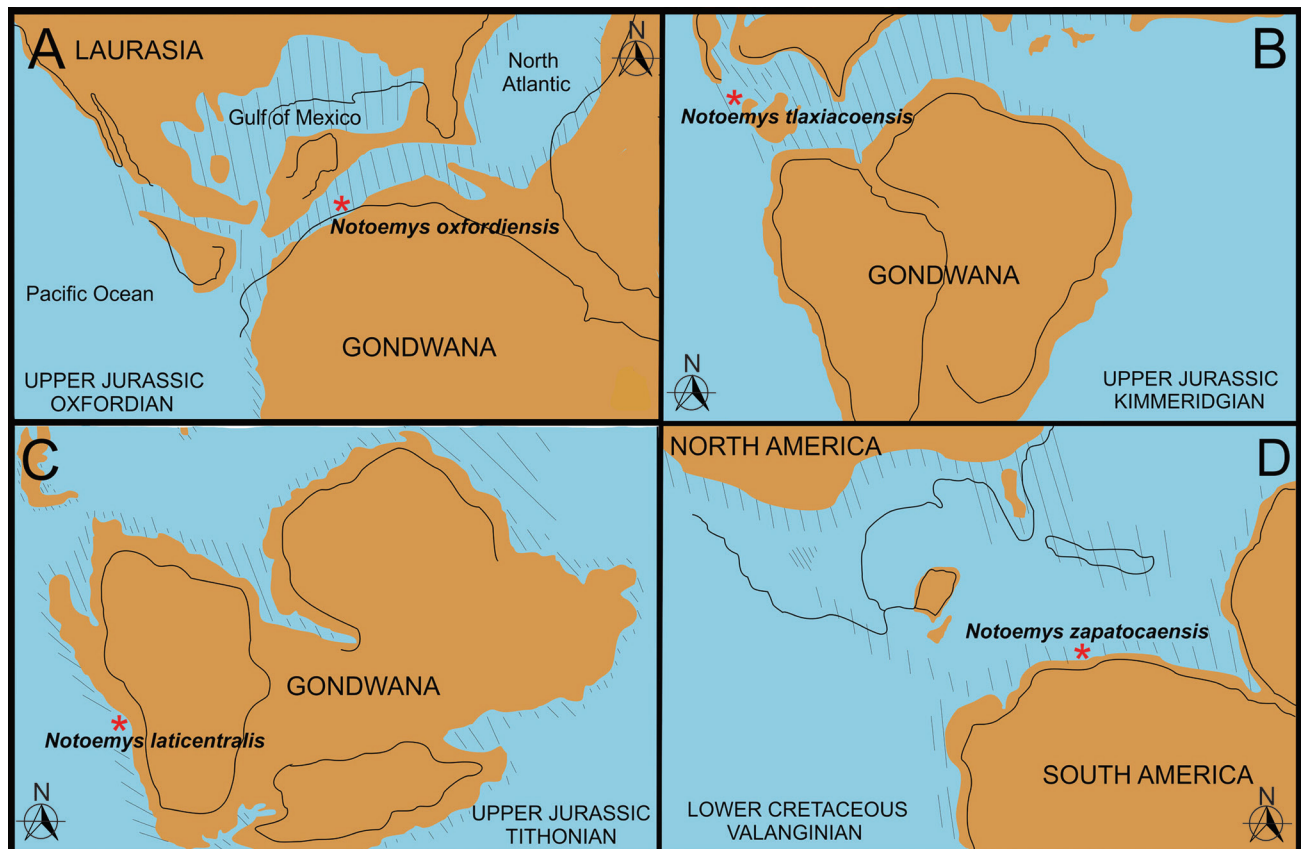


Figure 4. Distribution of *Notoemys* during the Upper Jurassic and Lower Cretaceous. A: *Notoemys oxfordiensis*. B: *Notoemys tlaxiacoensis*. C: *Notoemys laticentralis*. D: *Notoemys zapatoensis* (Modified from López-Conde *et al.*, 2017).

important to continue the studies in this locality, to increase the knowledge of Jurassic vertebrates in Mexico.

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