# Lamnoid vertebrae from the Agua Nueva Formation (Upper Cretaceous: lower Turonian), northeastern Mexico

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**ABSTRACT**

*A partial vertebral series of a lamniform shark (Chondrichthyes: Elasmobranchii) occurred in the "Vallecillo fish Member" of the Agua Nueva Formation (Upper Cretaceous: Lower Turonian) at Vallecillo, Mexico. Its taxonomic assignment below the ordinal level is tenuous, but the vertebrae closely resemble those of cretoxyrhinid sharks.This report represents the first documentation of a Cretaceous lamniform shark in northeastern Mexico. The shark could have measured slightly over 3 m in total body length. Because the vertebrae are articulated and are three-dimensionally preserved, they are thought to be deposited rather quickly on a soft oceanfloor after decomposition of most of the shark carcass.*

*Key words: lamniform, shark, vertebral series, Turonian, Vallecillo, Mexico.*

**RESUMEN**

*Una serie de vértebras de la columna vertebral de un tiburón lamniforme (Chondrychthyes: Elasmobrachii) son reportadas en el "Miembro Vallecillo" de la Formación Agua Nueva (Cretácico Superior: Turoniano Inferior), en Vallecillo, México. Aunque su determinación taxonómica no fue realizada a nivel inferior al de Orden, las vértebras semejan aquellas pertenecientes a tiburones cretoxyrhinidos. Este reporte representa la primera documentación en México de un tiburón lamniforme del Cretácico. Este tiburón pudo haber tenido una longitud corporal ligeramente mayor a los 3 m. Debido a que las vértebras están articuladas y preservadas en tres dimensiones, éstas debieron ser depositadas relativamente rápido en un sedimento suave a fluido después de la descomposición de las partes blandas del tiburón.*

*Palabras clave: lamniformes, tiburón, vértebras, Turoniano, Vallecillo, México.*

## INTRODUCTION

The Agua Nueva Formation (Upper Cretaceous) exposed at the locality of Vallecillo, State of Nuevo León in northeastern Mexico (Figure 1), contains numerous, well-preserved fossil fishes. The ichthyofauna is dominated by a taxonomically diverse osteichthyan fish fauna (particularly teleosts), but some chondrichthyans have also been found. The reported bony fish taxa include: Nursallinae (Pycnodontiformes), unidentified Pachycormiformes, Ichthyodectiformes, Dercetidae, Pachyrhizodontidae, cf. Halecoidei, Araripichthyidae, and Tselfatiidae (Blanco *et al.*, 2001; Blanco-Piñón *et al.*, 2002; Blanco and Cavin, 2003). Chondrichthyans are represented by several teeth of *Ptychodus mortoni* Mantell and some skeletal remains of elasmobranchs, including cf. *Scyliorhinus* sp. (Blanco *et al.*, 2001; Blanco-Piñón *et al.*, 2002).

In this paper, we describe a partial string of shark vertebrae from the Agua Nueva fauna, which belongs to the Paleontological Collection of the Facultad de Ciencias de la Tierra, Universidad Autónoma de Nuevo León and is catalogued as FCT-133. This specimen was discussed briefly by Blanco-Piñón *et al.* (2002), but it has not received any detailed examination. FCT-133 is attributed to the order Lamniformes, and it is significant because it represents the only documented Cretaceous lamniform shark from northeastern Mexico. Here, we discuss the paleobiologic and taphonomic implications.

## GEOLOGICAL SETTING

At the town of Vallecillo, fossil fishes from the Agua Nueva Formation occur in 6-cm thick, pink coloured, finely laminated marlstones interbedded with 30-cm thick, non-fossiliferous, brown shales. This sequence of shale-interbedded marlstones is informally known as the "Vallecillo fish Member" (Blanco, 2003). The entire member is characterized by the presence of occasional goethite nodules and the absence of bioturbation and other trace fossils (Blanco *et al.*, 2001; Blanco-Piñón *et al.*, 2002).

In thin sections, the fish-bearing marlstones show a micritic matrix with rare to abundant planktonic foraminifera. Lithologic data (Blanco *et al.*, 2001; Blanco-Piñón *et al.*, 2002) suggest that the marlstones represent low energy deposits, which were accumulated over the outer part of a shallow marine shelf under stagnant conditions, with a low concentration of oxygen (anoxic-dysoxic conditions). The presence of some ammonite taxa, such as *Watinoceras coloradoense* Henderson, indicates the rock unit was deposited during the early Turonian (Arkell et al, 1978).

## SPECIMEN DESCRIPTION

The specimen described here (FCT-133) consists of 12 partially articulated vertebral centra, which are three-dimensionally preserved and are partly replaced by calcite ($CaCO_3$). Seven vertebrae are parallel to the bedding plane whereas five are almost perpendicular to it. The centra are well calcified and amphicoelous, each measuring approximately 20 mm in width ("diameter") and 10 mm in anteroposterior length (Figure 2a). The centra are circular but are slightly compressed laterally, and their articular surfaces show well-marked concentric patterns (Figure 2b). Paired openings, where the bases of neural and hemal arches attached in life, are present in the dorsal and ventral margins in each centrum (Figure 2c). A transversely polished centrum (Figure 2d) reveals that each of these openings is bounded by a cone-shaped calcified cartilage wall, which housed the basidorsal and basiventral cartilages in life (*sensu* Welton and Farish, 1993), that narrows and points toward the center of the centrum. Several radiating lamellae are present between these cone-shaped structures and support

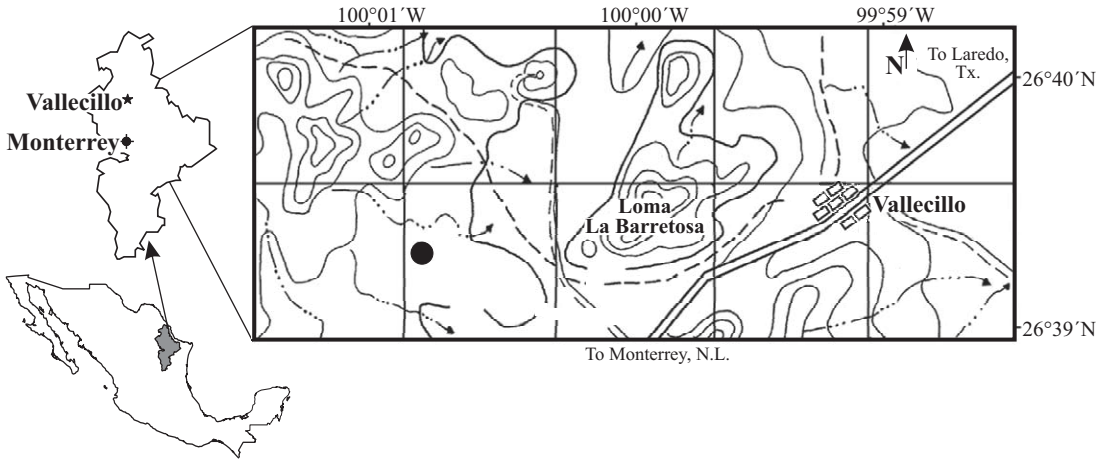



Figure 1. Geographic location of Vallecillo, northeastern Mexico. The black circle on the topographic map marks the position of the Vallecillo quarries (modified from Blanco-Piñón *et al.,* 2002).

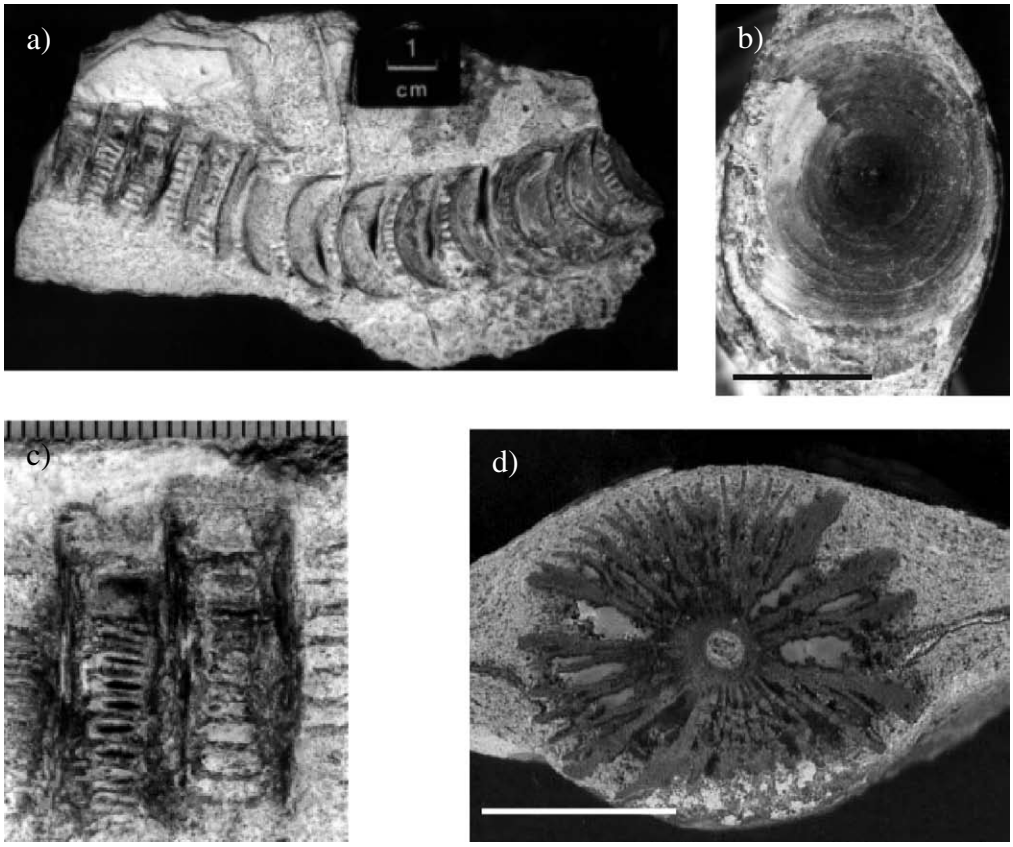



Figure 2. String of caudal vertebrae of cretoxyrhinid(?) shark from Vallecillo, Mexico (FCT-133). a) overall view; b) close-up view of articular surface showing the concentric lamellae (scale bar = 1 cm); c) close-up view of two centra in dorso-lateral view showing the longitudinal disposition of the radial lamellae and the pits for the archus haemalis (scale in mm); d) close-up view of transversal section of centrum exposing the radial lamellae (scale bar = 1 cm).

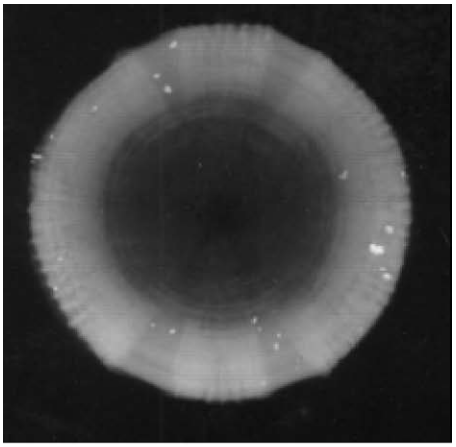
the two disk-shaped calcified cartilages that constitute the amphicoelous articular surfaces.

## DISCUSSION

The presence of several well-calcified radiating lamellae indicates that FCT-133 belongs to Lamniformes (*e.g.*, Compagno, 1990; Shirai, 1996). The extent of morphological variation of vertebrae in extinct (and extant) sharks is poorly known. Thus, like the case with a gigantic lamnoid vertebra found in the Albian of Kansas, USA (Shimada, 1997a), the exact taxonomic placement, even at the familial level is difficult for FCT-133. However, it should be noted that the centra in FCT-133 closely resemble those referred to Cretoxyrhinidae (taxonomy *sensu* Cappetta, 1987), including *Cretolamna appendiculata* Agassiz (Applegate, 1970) and *Cretoxyrhina mantelli* Agassiz (Eastman, 1895; Shimada, 1997b; Figure 3) from the Upper Cretaceous deposits of the USA.

Lamniform sharks are known from the Aptian to the Recent marine deposits worldwide (Cappetta, 1987; Siverson, 1996, 1999). Vertebrae of lamniforms are very rare in the fossil record compared to their teeth, but they do occur occasionally (*e.g.*, in Texas, USA, which is adjacent to Mexico; Welton and Farish, 1993, fig. 26). In northeastern Mexico, some teeth of Late Cretaceous lamniforms, including *Cretolamna* Glickman, and *Cretoxyrhina* Glickman, have been collected from the Boquillas Formation (Upper Cenomanian – Turonian) at Ocampo in the State of Coahuila (González-Barba, unpublished data), but they remain undescribed. Therefore, although its taxonomic assignment below the ordinal level is tenuous, FCT-133 is important because it constitutes the only documented remain of Cretaceous lamniform vertebrae from northeastern Mexico.

The slightly laterally compressed outline of the centra in FCT-133 suggests that the vertebrae are from the caudal region (compare the two images of *Cretoxyrhina mantelli* vertebrae in Figure 3). However, the size of vertebrae and the fact that terminal vertebrae are not preserved suggest that FCT-133 does not come from the posterior-most part of the vertebral column. Its exact position within the caudal region is uncertain, so the exact total body length (TL) of the shark cannot be determined. However, by using its vertebral width of approximately 20 mm, a crude TL estimate may



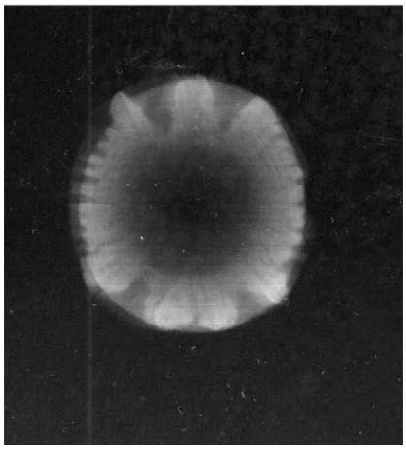


Figure 3. Radiographs of vertebral centra of *Cretoxyrhina mantelli* from the Niobrara Formation of western Kansas, USA [specimens in Sternberg Museum of Natural History, Fort Hays State University (FHSM), Hays, Kansas, USA]. 1: trunk vertebra (FHSM VP-2184; width = 70 mm); 2: caudal vertebra (FHSM VP-2187; "v-185" in fig. 2A of Shimada, 1997b; width = 31 mm).

be possible: 1) if one assumes that FCT-133 comes from *C. mantelli* or a lamnoid with similar anatomical proportions to *C. mantelli*, including morphometric relationships between the TL and vertebral size; and 2) if one assumes that FCT-133 represent vertebrae from a similar region of the vertebral column where the caudal vertebra illustrated in Figure 3 comes from (*ca.* 185th vertebra if they are *C. mantelli*). The vertebra in Figure 3, which has a width of 31 mm, comes from a *C. mantelli* individual (FHSM VP-2187) that measured about 500 cm TL (Shimada, 1997b). The width of the vertebrae in FCT-133 is 65% of the vertebra illustrated in Figure 3, so the estimated TL for FCT-133 is 323 cm.

The observation made by Schäfer (1972) provides some insights into the taphonomic history of FCT-133. Schäfer (1972, p. 56) observed the following sequence of events through his experiment on decomposing a small (*ca.* 40 cm TL) shark carcass (*Galeorhinus gales* Linnaeus: Carcharhiniformes) in 18°C, low energy seawater for 20 days: 1) carcass sank to the oceanfloor, but then briefly floated and sank again; 2) the carcass began to disintegrate rapidly, and pieces of "skin" began to hover for a while and then sank to the substrate on the leeward side of the carcass; and 3) parts of the skeletal elements became disarticulated, while others remained articulated (*e.g.*, forming many short segments of vertebral column).

The oceanic conditions between Schäfer's experimental setting and the waters where Agua Nueva Formation was deposited were probably not identical but similar; the lithologic data and the paleogeographic position of Vallecillo during the Turonian suggest that the Vallecillo sea was relatively warm and calm. Upon the death of the lamnoid individual, the carcass probably sank to the bottom of the oceanic basin. Although it is uncertain whether or not a temporal floating event took place (FCT-133 was apparently a much larger shark than that in Schäfer's experiment), the absence of dermal denticles in the specimen matrix possibly indicates that the integument became disassociated from the rest of the body through decomposition and was transported elsewhere. Because the preserved vertebrae are articulated, their burial probably took place relatively quickly. The three-dimensional preservation of the vertebrae could indicate semi-fluid, "soup ground" substrate, which permitted the penetration ("sagging") of the vertebrae within the soft sediment (*e.g.*, Martill, 1997) and avoided their total flattening as the next set of sediment accumulated over them. Then, the decay process apparently ceased possibly because the sediment and water were anoxic-dysoxic (Martill, 1997). Subsequently, the vertebrae were partially replaced by calcite through diagenesis.

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