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A juvenile *Tuarangisaurus keyesi* Wiffen and Moisley 1986 (Plesiosauria, Elasmosauridae) from the Upper Cretaceous of New Zealand, with remarks on its skull ontogeny

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ABSTRACT

This paper presents the detailed description of a remarkable skull and partial postcranial skeleton of a very juvenile elasmosaurid referred to *Tuarangisaurus keyesi* (CD 427), from the upper Campanian-lower Maastrichtian levels of the Tahora Formation, New Zealand. The following points are discussed: i) the conspecific status of CD 427 with *T. keyesi*, ii) clarification of several cranial sutures in the adult holotype of *T. keyesi* by comparison with the clearly open sutures in the juvenile specimen; iii) morphologic changes undergone by the skull during the ontogeny of *T. keyesi*; iv) a first look at the postcranial skeleton of *T. keyesi*. The studied specimen holds a great significance because it represents one of the rarely-available juvenile elasmosaurid skulls known worldwide. As a result, we provide the first insights regarding the skull ontogeny of an austral elasmosaurid plesiosaurian.

1. Introduction

Tuarangisaurus keyesi Wiffen and Moisley 1986 is a taxonomic concept fixed to a fairly complete skull, atlas-axis and anterior cervical vertebrae, recovered from the Mangahouanga Stream, a northern tributary of Te Hoe River, inland Hawke's Bay, New Zealand (Fig. 1). The holotype comes from the Maungataniwha Sandstone Member of the Tahora Formation. Because the material was recovered from transported boulders, its chronostratigraphic provenance cannot be refined beyond the upper Campanian-lower Maastrichtian (Vajda and Raine, 2010). Along with the original description, Wiffen and Moisley (1986) illustrated few fragmentary specimens from Mangahouanga Stream. Among them, CD 427 represents a remarkable juvenile specimen, preserving both cranial and postcranial elements. The presence of skull material in CD 427 is particularly important as *T. keyesi* is the only non-aristonectine elasmosaurid from the Weddellian Province with well-known skull anatomy; in addition, CM Zfr 115 preserves few cranial elements. The other two Weddellian, non-aristonectine elasmosaurid taxa, *Vegasaurus molyi* and *Kawanectes lafquenianum* are based only on postcranial material (O'Gorman et al., 2015; O'Gorman, 2016). Here we review this particular specimen, with special focus on the skull anatomy. The latter indeed preserves more elements than those first described by Wiffen and Moisley (1986) allowing a direct comparison with the *T. keyesi* holotype skull. Several skull elements in the juvenile are similar to those preserved in the *T. keyesi* holotype (adult specimen). Osteological differences observed in the juvenile can be explained by ontogenetic changes that also occur in extant reptiles.

Specimen CD 427 provides a remarkable opportunity for studying the elasmosaurid skull ontogeny within a single species,

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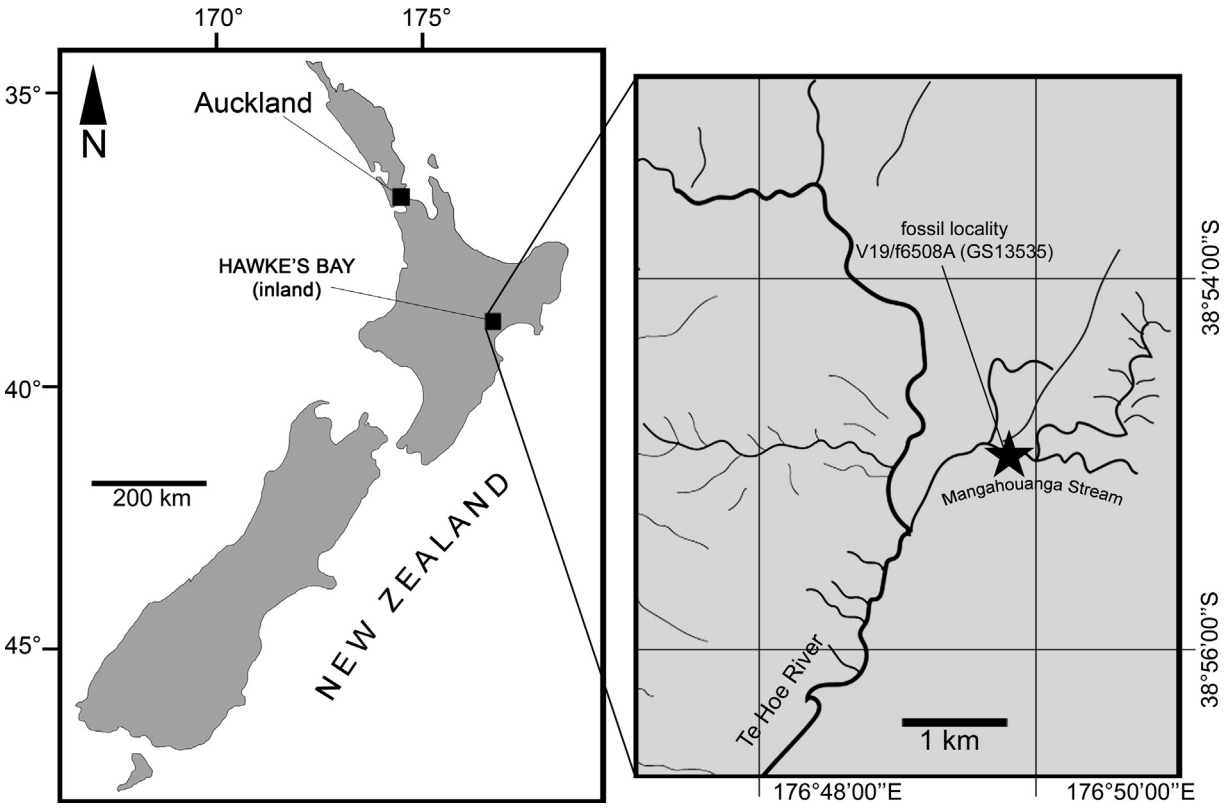

Fig. 1. Map indicating the Mangahouanga Stream, east of Te Hoe River, inland Hawke's Bay, in the North Island of New Zealand. The studied specimen (CD 427) comes from the fossil locality V19/f6508A (collected by Joan Wiffen and William Moisley in 1976) indicated with the star.

being the first skull ontogenetic series available for a Late Cretaceous taxon from the southern hemisphere. Furthermore, the material preserves several postcranial elements that allow us a better understanding of the trunk and anterior extremities of *T. keyesi*, previously unknown in its holotype.

2. Locality and geologic setting

'Bill's Baby', the nickname given to the very juvenile specimen CD 427 found by William L. Moisley, was collected from the locality V19/f6508A (GS1535) NZMS 260 Map Sheet V19, Grid Reference 419 470, as pointed out by Wiffen and Moisley (1986). This is placed in the course of the Mangahouanga Stream, 200 m upstream from the forestry road bridge, inland Hawke's Bay, North Island, New Zealand (Fig. 1, Fossil Record Electronic number V19/f6508A, GS 13535). Rocks cropping out in this locality are part of the Maungataniwha Sandstone Member of the Tahora Formation. This represents the basal unit of Late Cretaceous age in northeastern New Zealand (Isaac et al., 1991; Cutten, 1994). The Maungataniwha Sandstone Member is a ca. 400 m thick unit mostly comprised of poorly bedded sandstones. Its depositional environment has been interpreted as a fully marine, near-shore, shallow water setting with moderate to high energy, possibly within an estuary, bay, or inlet. Deposition occurred during several minor transgressive – regressive cycles (Crampton and Moore, 1990). Fossil assemblages include marine invertebrates and tracefossils (Glaessner, 1980; Crampton, 1990; Crampton and Moore, 1990; Feldmann, 1993; Eagle, 1994), indicating at least three different habitats. Vertebrates found in the unit include chondrichthyans and osteichthyans (Keyes, 1977; Wiffen, 1983) plesiosaurs, mosasaurs, turtles (Wiffen, 1980, 1981, 1990a,b; Wiffen and Moisley, 1986), as well as continental vertebrates represented by fragmentary remains of dinosaurs and pterosaurs (Wiffen and Molnar, 1988; Wiffen and McKee, 1990; McKee and Wiffen, 1998). The terrestrially-derived fauna suggests the presence of a nearby river mouth or delta (Crampton and Moore, 1990).

In the lower Mangahouanga Stream (Fig. 1), the age of the Maungataniwha Sandstone Member has been assigned to the upper Piripauan-lower Haumurian New Zealand stages, equivalent to the Campanian-Maastrichtian (Warren and Speden, 1978). Microfossils and palynomorphs suggested that the lower 100 m could be refined to the Piripauan, and the upper 200–250 m to the Haumurian (Crampton and Moore, 1990). Most marine reptile remains from the unit have been recovered from the calcareous and phosphatic concretions in the float of the river bed. Dinocyst assemblages indicate that the concretions may derive from at least two horizons (Young and Hannah, 2010), while plesiosaur-bearing concretions indicate different stages between the lower to upper Haumurian (lower Campanian to lower Maastrichtian). Based on the assemblage of pollen taxa, dinocysts and megaspores, Vadja and Raine (2010) proposed an upper Campanian-lower Maastrichtian age for the plesiosaur-bearing boulders.

3. Material and methods

The material examined is part of the National Paleontological Collection (NPC) held at GNS Science, Lower Hutt, New Zealand. CD 425 and CD 426 (holotype of *Tuarangisaurus keyesi*) and CD 427 ('Bill's Baby') are part of a collection of 31 partial elasmosaur specimens, recovered by W.L. Moisley, T. Crabtree, M.A. Wiffen and J. Wiffen, over 10 years of summer fieldwork in the Mangahouanga Stream, before 1986 (Wiffen and Moisley, 1986). According to these authors, each specimen was reduced on site by mechanic means, using cutting saw, hammers and chisels for facilitating their transport within