A peer-reviewed version of this preprint was published in PeerJ on 23 March 2018.

View the peer-reviewed version (peerj.com/articles/4554), which is the preferred citable publication unless you specifically need to cite this preprint.

Cadena E, Abella J, Gregori M. 2018. The first Oligocene sea turtle (Pan-Cheloniidae) record of South America. PeerJ 6:e4554
https://doi.org/10.7717/peerj.4554

The first Paleogene (Oligocene) sea turtle record of South America

Edwin Cadena Corresp., [1] , **Juan Abella** [2, 3] , **Maria Gregori** [2]

[1] School of Geological Sciences and Engineering, Yachay Tech, San Miguel de Urcuquí, Imbabura, Ecuador

[2] Universidad Estatal de la Peninsula de Santa Elena, La Libertad, Santa Elena, Ecuador

[3] Institut Català de Paleontologia Miquel Crusafont, Universitat Autónoma de Barcelona, Barcelona, Spain

Corresponding Author: Edwin Cadena
Email address: cadenachelys@gmail.com

The evolution and occurrence of fossil sea turtles at the Pacific margin of South America is poorly known and restricted to Neogene (Miocene) findings from Perú. Here we report and describe the first record of Paleogene (Late Oligocene, ~24 Ma) sea turtle remains. The fossil material corresponds to a single, isolated and well-preserved costal bone found at the Montañita/Olón locality, Santa Elena Province, Ecuador. Comparisons with other Oligocene and extant representatives allow us to confirm that belong to a sea turtle characterized by: lack of lateral ossification, allowing the dorsal exposure of the distal end of ribs; dorsal surface of bone sculptured, changing from dense vermiculation at the vertebral scute region and changing to anastomosing pattern of grooves at the most lateral portion of the costal. This fossil finding shows the high potential that the Ecuadorian Paleogene outcrops have in order to explore the evolution and paleobiogeography distribution of sea turtles by the time that the Pacific and the Atlantic oceans were connected via the Panama basin.

The first Paleogene (Oligocene) sea turtle record of South America

Cadena Edwin[1*], Abella Juan[2,3], and Gregori Maria D[2]

[1] Escuela de Ciencias Geológicas e Ingeniería, Yachay Tech, San Miguel de Urcuquí, Ecuardor.

[2] Universidad Estatal de la Peninsula de Santa Elena, La Libertad, Ecuador.

[3] Institut Català de Paleontologia Miquel Crusafont, Universitat Autònoma de Barcelona, Edifici ICTA-ICP, Carrer de les Columnes s/n, Campus de la UAB, 08193 Cerdanyola del Vallès, Barcelona, Spain.

[*] Corresponding author

Edwin Cadena, cadenachelys@gmail.com

Abstract

The evolution and occurrence of fossil sea turtles at the Pacific margin of South America is poorly known and restricted to Neogene (Miocene) findings from Perú. Here we report and describe the first record of Paleogene (Late Oligocene, ~24 Ma) sea turtle remains. The fossil material corresponds to a single, isolated and well-preserved costal bone found at the Montañita/Olón locality, Santa Elena Province, Ecuador. Comparisons with other Oligocene and extant representatives allow us to confirm that belong to a sea turtle characterized by: lack of lateral ossification, allowing the dorsal exposure of the distal end of ribs; dorsal surface of bone sculptured, changing from dense vermiculation at the vertebral scute region and changing to anastomosing pattern of grooves at the most lateral portion of the costal. This fossil finding shows the high potential that the Ecuadorian Paleogene outcrops have in order to explore the evolution and paleobiogeography distribution of sea turtles by the time that the Pacific and the Atlantic oceans were connected via the Panama basin.

INTRODUCTION

Sea turtles are iconic vertebrates that have inhabited Earth's oceans for at least 125 Ma (*Cadena & Parham 2015*). However, their evolution and fossil record in South America during the Cenozoic (~66Ma to present) is still poorly explored and understood. At present, the South American fossil record of sea turtles (Pan-Chelonioidea) is restricted to the middle Miocene *Pacifiquelys urbinai*; represented by skulls, lower jaws, cervical vertebrae, and a partial carapace and a few non-descript plastron fragments, from the Pisco Formation, Department of Ica, Peru (*Parham & Pyenson 2010*).

Recently, a fossil site at the Pacific coast of Ecuador (Fig. 1) has shown being rich in marine vertebrates, including a new genus and species of dolphin *Urkudelphis chawpipacha* (*Tanaka et al. 2017*), abundant sharks and fish teeth (*Carillo-Briceño et al.,* unpublished data) and isolated turtle remains. Here we describe an isolated costal bone belonging to a sea turtle, which

constitute the first record of Paleogene (Oligocene) sea turtles in South America. Thus, we discuss the importance of this fossil site for understanding the evolution and paleobiogeography of sea turtles in the American continent.

MATERIALS AND METHODS

Fossil material

The fossil costal bone described here is housed in the paleontological collection at the Universidad Estatal de la Peninsula de Santa Elena (UPSE), La Libertad, Santa Elena Province, Ecuador. Specimen UPSE-T0036. Comparisons of these fossils were done with some extant representatives of Cheloniidae as follow: *Caretta caretta* NMW 31531 and 1858; *Eretmochelys imbricata* NMW 1853 and MTKD D 8295; and *Lepidochelys olivacea* YT-Ver-0002. Permit for paleontological exploration of the Montañita/Olón locality was granted to J. Abella by the Instituto Nacional de Patrimonio Cultural (INPC) of Ecuador, permit Nº 0039-DR5.INPC.2015.

SYSTEMATIC PALEONTOLOGY

Testudines *Batsch, 1788*
Cryptodira *Cope, 1868*
Pan-Chelonioidea *Joyce, Parham, and Gauthier, 2004*
Gen. and Sp. Indet. (Fig. 2)

Locality and Age

Montañita-Olón locality, between the towns of Montañita and Olón, Santa Elena Province, Ecuador (1°48'50.64" S, -80°45'24.18" W). Here, we provisionally identify the source horizon for UPSE-T0036 as the Zapotal Member of the Dos Bocas Formation following Whittaker (1988). However, the age of this horizon is well constrained based on the occurrence of fossil shark *Carcharocles angustidens,* indicating that is late Oligocene in age (*Bristow 1975, Tanaka et al., 2017*).

Description. UPSE-T0036 corresponds to a right costal 4 (14.5 cm length, 3.8 cm width as preserved) (Fig. 2 A-B). We use a specimen of the extant *Eretmochelys imbricata* MTKD D 8295 to indicate the anatomical position of UPSE-T0036 in a turtle carapace (Fig. 2 C). UPSE-T0036 is a rectangular costal bone with almost the same width at the anterior and posterior margins, lacking of fully ossified lateral region, which allows the exposure of the distal end of the costal rib. On its dorsal surface the bone exhibits a sculpturing pattern that varies along its length, being of dense vermiculation at the vertebral scute region (medial portion of the costal) (Fig. 2 D), changing to anastomosing to almost parallel pattern of grooves at its lateral portion (Fig. 2 E). The sulci between pleural and vertebral scutes are well defined, indicating that the vertebral scute covered 1/3 of the total surface of the bone, ending laterally in an acute tip. The sulcus between pleurals separates the bone in two almost equal portions. On its ventral surface (Fig. 2 F-G) the outline of the costal rib is define along the length of the bone, showing a protuberant ventrally projected process for the attachment with the thoracic vertebra.

DISCUSSION

Taxonomical attribution and comparisons

UPSE-T0036 costal bone is attributed as belonging to Pan-Chelonioidea by sharing with some of the fossil and extant representatives of this clade the following characteristics: lack of lateral ossification but keeping a considerable thickness (5-7 mm), allowing the dorsal exposure of the distal end of ribs; dorsal surface of bone sculptured, changing from dense vermiculation at the vertebral scute region and changing to anastomosing pattern of grooves at the most lateral portion of the costal. Lateral reduction in ossification of costals allowing the exposure of costal ribs occur also in some other turtles as for example Chelydridae (snapping and alligator turtles), however in these turtles the bone thickness is extremely reduced and the dorsal surface is smooth and developing ridges or knobs. Other group of turtles that also exhibit reduction in lateral ossification of costals is the Tryionichidae (soft-shelled turtles), but in contrast to chelydrids and pan-chelonoidids they develop a very distinct pitted dorsal bone sculpturing and absence of sulci from keratinous scutes.

Among pan-chelonidids UPSE-T0036 resembles the sculpturing pattern of other Cenozoic fossil forms from North and South America, as for example *Ashleychelys palmeri* *Weems & Sanders* (*2014*) from Charleston, South Carolina, USA, and the Miocene *Pacifichelys urbinai* *Parham & Pyenson* (*2010*) from Peru. However differs from the first one in having a narrower covering of the costal by the vertebral scute (as indicated by the sulcus). Unfortunately, the posterior region of the carapace is unknown for *P. urbinai*, avoiding to establishing if sculpturing pattern and scutes arrangement was similar as in UPSE-T0036. Other Oligocene sea turtles from South Carolina: *Procolpochelys charlestonensis* *Weems & Sanders* (*2014*) and *Carolinochelys wilsoni* *Hay* (*1923*) differ from UPSE-T0036 by having faintly sculptured to almost smooth dorsal carapacial bones. Table 1 shows the comparisons between UPSE-T0036 and Cenozoic taxa from American continent.

UPSE-T0036 resembles in geometry, sulci and medial to lateral sculpturing pattern variation of the posterior costals of some extant sea turtles, as for example *Lepidochelys olivacea* YT-Ver-0002 (Fig. 2 H-M), differing from this particular specimen by a wider covering of the vertebral scute on the costal surface. The width of vertebral scutes exhibit intraspecific variation as we observed in specimens of *Caretta caretta* NMW 31531 and 1858; and *Eretmochelys imbricata* NMW 1853 and MTKD D 8295 (Fig. 2 C), for example in this last specimen the posterior vertebral scutes almost reach the most lateral portions of costal bones.

Importance of Montañita-Olón locality for South American sea turtle evolution understanding

The marine fossil vertebrates (cetaceans, sharks and turtles) recently discovered and described from the Oligocene, Montañita-Olón locality of Ecuador (*Tanaka et al. 2017*, *Carrillo-Briceño et al.* unpublished data and *this study*) represent the first occurrences of each of these groups in Paleogene sequences of tropical South America; and for the particular case of turtles, the first Paleogene record of marine turtles for the whole South America. Even though the material described herein corresponds to a single and isolated bone—reason why we avoid to formulate any further systematic or phylogenetic affinity hypotheses; it setups a very promising scenario for future exploration and finding of new and more complete specimens that could elucidate if for instance the already known Oligocene sea turtle taxa from North America (*Weens & Sanders, 2014*, *2017*) inhabited also the tropical Pacific coast of South America; a hypothesis that it seems to be possible considering that during the Oligocene, the Pacific and the Atlantic oceans were connected via the Panama basin (*Pindell 1994, Boschman et al. 2014*)(Fig. 3 A).

Thus, more complete sea turtle specimens from Montañita-Olón could shed light in establishing relationships with younger marine taxa from South America, as for example with the Miocene *Pacifichelys urbinai* *Parham & Pyenson* (*2010*) from Peru (Fig. 3 B), or potentially being direct ancestors of any of the five extant representatives that inhabit the Pacific coast of tropical South America (*Turtle Taxonomy Working Group 2017*) (Fig. 3 C).

The fossil sea turtle material from Montañita-Olón also increases the knowledge on the fossil turtle paleobiodiversity of Ecuador, being the first record of a marine fossil turtle in the country and an addition to the already known occurrences of Pleistocene freshwater and terrestrial fossil turtles from Santa Elena Province (*Cadena et al. 2017*).

CONCLUSIONS

The costal bone descrided herein is the first undisputable record of Paleogene (Oligocene, ~24 Ma) marine turtles of South America. This fossil finding shows the high potential that the Ecuadorian Paleogene outcrops have in order to explore the evolution and paleobiogeography distribution of sea turtles by the time that the Pacific and the Atlantic oceans were connected via the Panama basin. More complete specimens will have to be found in the Montañita/Olón in order to establish in detail the taxonomy and phylogenetic relationships of the Oligocene sea turtles that inhabited this part of South America. We hope this finding will encourage more paleontological expeditions and support for this type of studies in Ecuador and northern South America.

Institutional abbreviations

MTKD, Senckenberg Museum of Natural History, Dresden collections, Germany; NMW, Natural History Museum of Vienna, Austria; UPSE, paleontological collection, Universidad Estatal de la Peninsula de Santa Elena La Libertad, Santa Elena Province, Ecuador. YT, Yachay Tech paleontological collection, San Miguel de Urcuquí, Ecuador.

ACKNOWLEDGMENTS

Thanks to K. Guerrero for assistance in the logistics during the visit of the first author (E. Cadena) to Santa Elena Province. JA thanks the Marine Biology students and staff from UPSE, who actively participated in the fieldwork, and the “Comuna de Montañita” and “Comuna de Olón” for their support. We thank the Instituto Nacional de Patrimonio Cultural (INPC) for the prospection and excavation permits.

REFERENCES

Alroy J. 2009. Taxonomic occurrences of Chelonioidea recorded in the Paleobiology Database. Fossilworks. http://fossilworks.org (accessed 08 February 2018).

Blakey R. 2016. Paleomaps. *Available at https://www2.nau.edu/rcb7/globaltext2.html* (accessed 08 February 2018).

Batsch AJ. 1788. Versuch einter Anleitung, zur Kinntniss und Geschichte der Thiere und Mineralien. Jena: Akad. Buchhandlung. 22p.

Boschman LM, van Hinsbergen DJJ, Torsvik TH, Spakman W, Pindell JL. 2014. Kinematic reconstruction of the Caribbean region since the Early Jurassic. *Earth-Science Reviews* 138:102–136.

Bristow CR. 1975. On the age of the Zapotal Sands of Southwest Ecuador. *Newsletter Stratigraphy 4*:119–134.

Cadena EA, Abella J, Gregori M. 2017. New findings of Pleistocene fossil turtles (Geoemydidae, Kinosternidae and Chelydridae) from Santa Elena Province, Ecuador. *PeerJ* 5:e3215; DOI 10.7717/peerj.3215.

Cadena EA, Parham JF. 2015. Oldest known marine turtle? A new protostegid from the Lower Cretaceous of Colombia. *PaleoBios* 32. ucmp_paleobios_28615.

Cadena EA, Rincon A, Bourque J, Jaramillo C, Montes C, Bloch J, MacFadden B. 2012. New Turtles (Chelonia) from the Late Eocene Through Late Miocene of the Panama Canal Basin. *Journal of Paleontology* 86:539–557 DOI 10.1666/11-106.1.

Cope E. 1868. On the origin of genera. *Proceedings of the Academy of Natural Sciences of Philadelphia*. 20:242–300.

Hay OP. 1923. Oligocene sea turtles of South Carolina. *Pan-American Geologist* 40:29–31.

Joyce WG, Parham JF, Gauthier JA. 2004. Developing a protocol for the conversion of rank-based taxon names to phylogenetically de ned clade names, as exempli ed by turtles. *Journal of Paleontology* 78:989–1013.

Parham JF, Pyenson ND. 2010. New sea turtle from the Miocene of Peru and the iterative evolution of feeding ecomorphologies since the Cretaceous. *Journal of Paleontology* 84:231–247.

Pindell JL. 1994. Evolution of the Gulf of Mexico and the Caribbean. In: Donovan S.K. and Jackson, T. A. (Eds.) *Caribbean Geology: an introduction*, University of the West Indies Press, Kingston, Jamaica, p. 13–39.

Tanaka Y, Abella J, Aguirre-Fernández G, Gregori M, Fordyce RE. 2017. A new tropical Oligocene dolphin from Montañita/Olón, Santa Elena, Ecuador. *PLoS ONE* 12: e0188380.

Turtle Taxonomy Working Grop [Rhodin AGJ, Iverson JB, Bour R, Fritz U, Georges A, Shaffer HB, Van DiJk PP]. 2017. Turtles of the world, 8th edition: annotated checklist of taxonomy, synonymy, distribution with maps, and conservation status. In: Rhodin AGJ, Iverson JB, van Dijk PP, Saumure RA, Buhlmann KA, Pritchard PCH, Mittermeier RA (Eds.). Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group. *Chelonian Research Monographs* 7:1–292. DOI:10.3854/crm.7.checklist.atlas.v8.2017.

Weems RE, Sanders AE. 2014. Oligocene pancheloniid sea turtles from the vicinity of Charleston, South Carolina, U.S.A. *Journal of Vertebrate Paleontology* 34:80–99.

Weems RE, Sanders AE. 2017. More-complete remains of *Procolpochelys charlestonensis* (Oligocene, South Carolina), an occurrence of *Euclastes* (upper Eocene, South Carolina), and their bearing on Cenozoic pancheloniid sea turtle distribution and phylogeny. *Journal of Vertebrate Paleontology* 34:80–99.

Table 1 (on next page)

Comparison of the morphological characteristics of costal bones

of *Ashleychelys*, *Carolinochelys*, and *Procolpochelys*, with crown Cheloniidae (*Trachyaspis*, *Natator*, *Lepidochelys*, *Caretta*, *Chelonia*, *Eretmochelys*), with the addition of *Pacifichelys Parham & Pyenson* (*2010*) and UPSE T-0036 Pan-Chelonioidea (Gen. and Sp. Indet.) described herein. Table taken and modified from *Weens & Sanders* (*2014*).

Table 1. Comparison of the morphological characteristics of costal bones of *Ashleychelys*, *Carolinochelys*, and *Procolpochelys*, with crown Cheloniidae (*Trachyaspis*, *Natator*, *Lepidochelys*, *Caretta*, *Chelonia*, *Eretmochelys*), with the addition of *Pacifichelys* Parham & Pyenson (2010) and UPSE T-0036 Pan-Chelonioidea (Gen. and Sp. Indet.) described herein. Table taken and modified from Weens & Sanders (2014).

Character	*Carolinochelys*	*Procopochelys*	*Ashleychelys*	UPSE-T-0036	*Pacifichelys*	Crown Cheloniidae
Costal bones surface texture	Sculptured and uniform along the entire bone surface	Faintly sculptured to smooth	Strong sculptured and uniform along the entire bone surface	Strong sculptured, pitted-vermiculate medially, anastomosing grooves laterally	Sculptured and uniform along the entire bone surface	Faintly to strong sculptured, uniform or with variation from the medial to the lateral portions of the bones.
Carapace thickness	Moderate	Thick	Moderate	Moderate	Moderate	Moderate
Vertebral scutes	Narrow	Narrow	Wide	Narrow	?	Narrow to wide

Figure 1

Map of Ecuador showing Santa Elena Province.

Location and outcrop of Montañita/Olón locality from where UPSE-T0036 described herein was found.

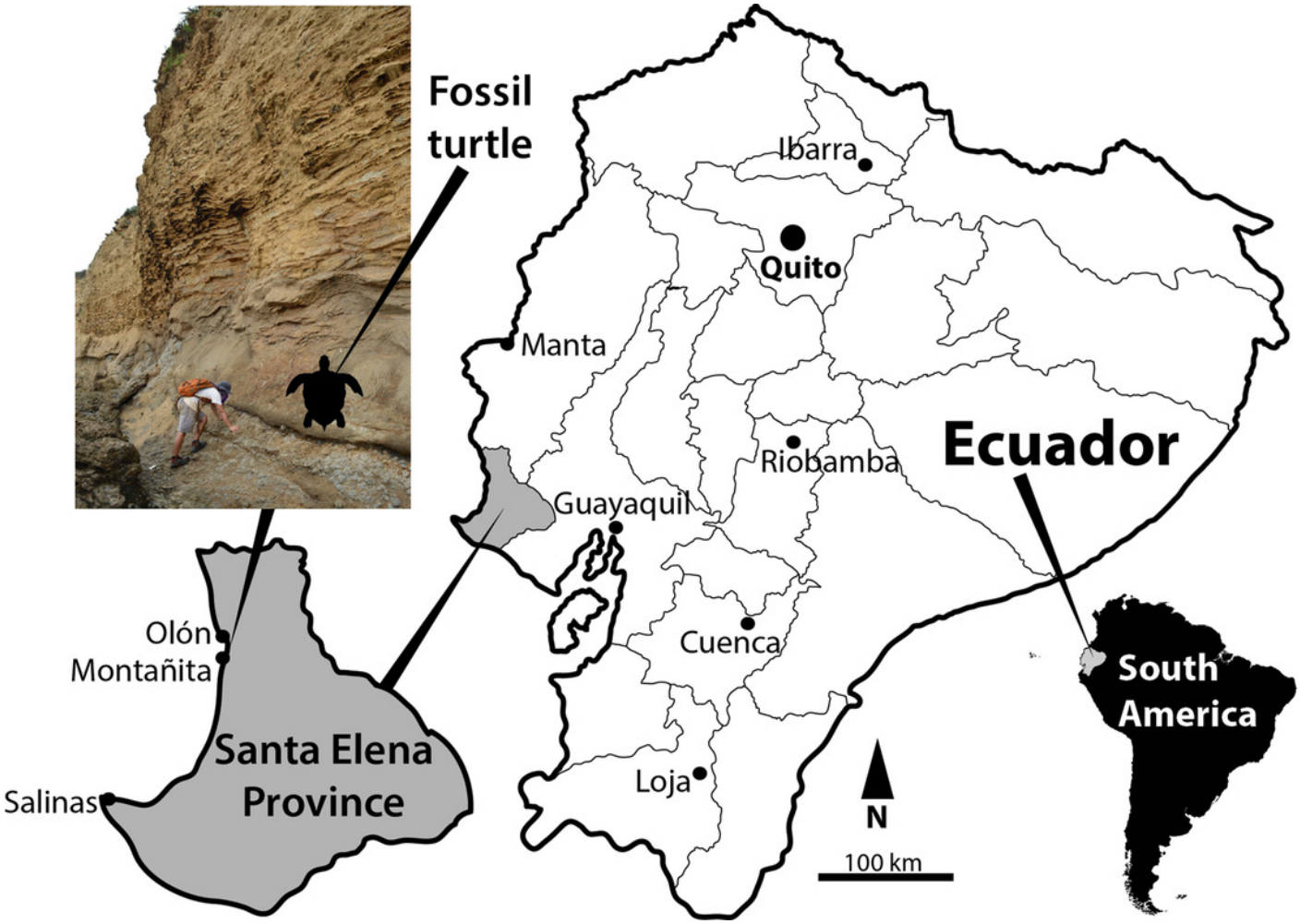

Figure 2

Pan-chelonoidid (Gen. and Sp. Indt.) from Montañita/Olón locality compared with some extant marine turtles.

(A-B). UPSE-T0036 right costal 6 in dorsal view. (C). Carapace of *Eretmochelys imbricata* MTKD D 8295, right costal 6 in yellow shadows. (D). Close-up of the medial region of UPSE-T0036 showing the pitted-vermiculated bone surface sculpturing (see circle D in B). (E). Close-up of the lateral region of UPSE-T0036 showing a bone surface sculpturing of anastomosing grooves (see circle E in B). (F-G). UPSE-T0036 right costal 6 in ventral view. (H-I). Right costal 6 of the extant *Lepidochelys olivacea* YT-Ver-0002 in dorsal view. (J-K). Right costal 6 of the extant *Lepidochelys olivacea* YT-Ver-0002 in ventral view. (L). Close-up of the medial region of *Lepidochelys olivacea* YT-Ver-0002 showing the pitted-vermiculated bone surface sculpturing (see circle L in I). M. Close-up of the lateral region of *Lepidochelys olivacea* YT-Ver-0002 showing a bone surface sculpturing of anastomosing grooves (see circle M in I). Top scale bar applies for (A-B) and (F-G), bottom scale bar applies for (H-I) and (J-K). Abbreviations: co, costal bone., cr, costal rib., P, pleural scute., rh, rib head., V, vertebral scute.

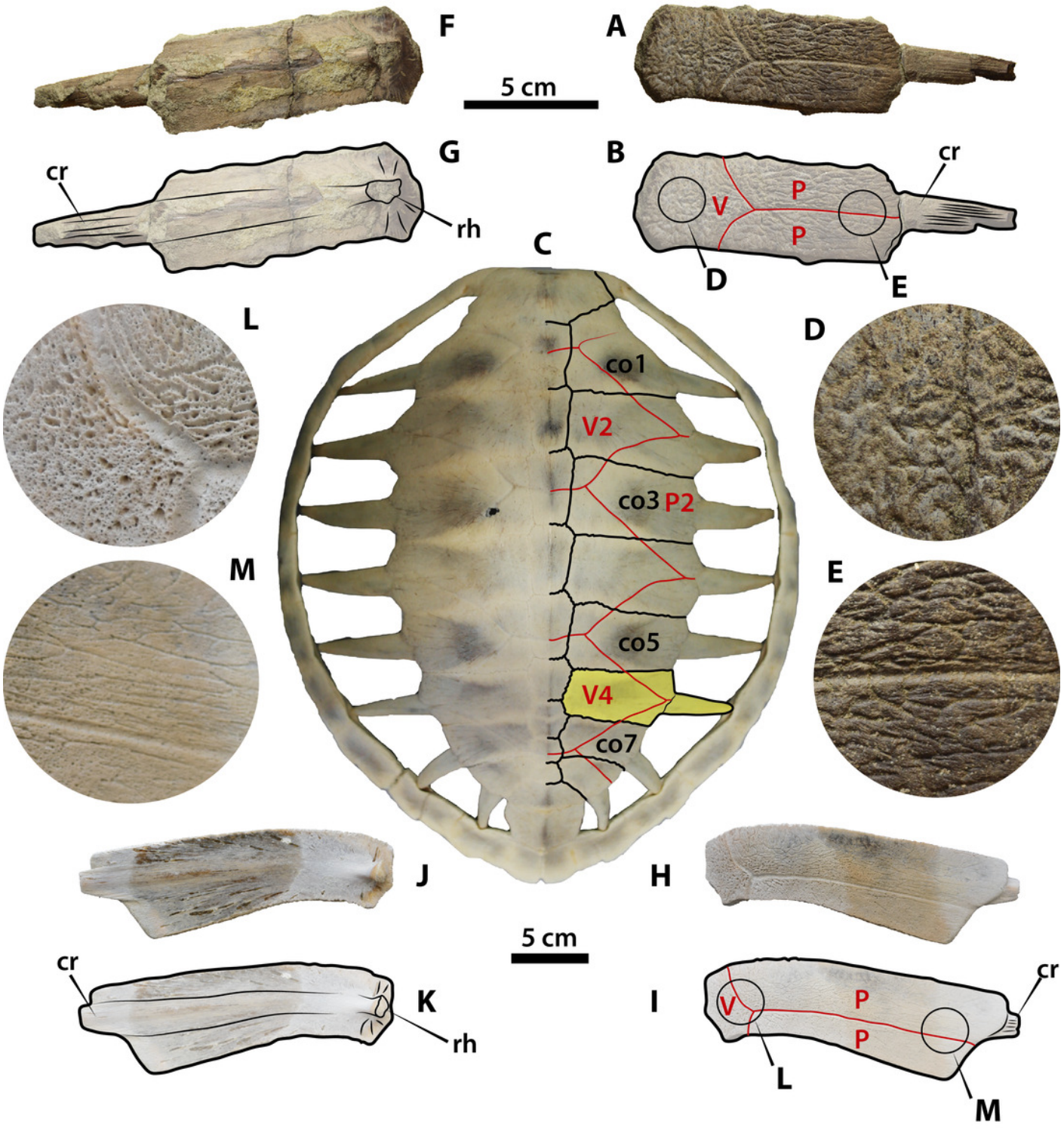

Figure 3

Paleogeographic reconstruction of South America and the fossil and extant distribution of chelonioidid marine turtles.

(A). Oligocene fossil occurrences of chelonioidid turtles, including the first record of South America described here (UPSE-T0036). (B). Miocene, fossil occurrences of chelonioidid turtles, adding the record from Panama basin (*Cadena et al. 2012*). (C). Present biogeographic distribution of marine turtles (Chelonioidea) based on *Turtle Taxonomy Working Grop* (*2017*). Red dots indicate fossil occurrences based on Fossilworks paleobiology database (*Alroy 2009*). Paleogeography taken and modified from *Bakley* (*2016*). Abbreviations: F, Foraging., N, Nesting., V, Vagrant.