JOURNAL OF THE GEOLOGICAL SURVEY OF BRAZIL

First *in situ* documentation of a fossil tooth attributed of †Otodus megalodon from the deep sea of Rio Grande Rise, South Atlantic Ocean

Marcos Cristóvão Baptista[1], Edgar Romeo Herrera de Figueiredo Iza[2*], José Adilson Dias Cavalcanti[1], Heliásio Augusto Simões[3], Luis Carlos Melo Palmeira[4], Jairo Cleber de Oliveira Pessoa[5], Eugênio Pires Frazão[6], Valter Rodrigues Santos Sobrinho[2]

[1]Geological Survey of Brazil - CPRM, Av. Brasil, 1731 - Funcionários, Belo Horizonte - MG, Brazil, CEP: 30140-002.
[2]Geological Survey of Brazil - CPRM, Av. Ulysses Guimarães, 2862 - Nova Sussuarana, Salvador - BA, Brazil, CEP: 41213-000.
[3]Geological Survey of Brazil - CPRM, R. Rodrigues Júnior, 840 - Centro, Fortaleza - CE, Brazil, CEP: 60060-000.
[4]Geological Survey of Brazil - CPRM, Av. Dr. Freitas, 3645 – Bairro do Marco, Belém – PA, Brazil. CEP: 66095-110.
[5]Geological Survey of Brazil - CPRM, R. Costa, 55 - Cerqueira César, São Paulo – SP, Brazil, CEP: 01304-010.
[6]Geological Survey of Brazil - CPRM, Av. Alm. Alexandrino de Alencar, 1402 - Tirol, Natal - RN,Brazil, CEP: 59015-350.

Abstract

The shark †*Otodus megalodon* is one of the main marine predators of the Cenozoic, with fossil records ranging from 15.9 to 3.6 Ma and a distribution considered cosmopolitan. However, some regions of the planet still lack unequivocal records of the species, including the South Atlantic Ocean. Although there are records of teeth on continental South America, this work presents the first record of a †O. *megalodon* tooth in the South Atlantic Ocean (offshore). The tooth was collected by the Geological Survey of Brazil (SGB), in 2012, on the Rio Grande Rise (RGR) from a dredge haul between 664–667 m depth at station 4340-IV-150-HAS and is embedded in a phosphatized ferromanganese crust. The sample exhibits a porous, botryoidal surface, with internal lamination alternating dark Fe-Mn-rich layers and light calcium- and phosphate-rich layers. The morphological description indicates a triangular tooth, with TH = 57.1 mm, CH = 45.2 mm, and CW = 36.2 mm. The cutting edges are worn due to marine abrasion. The predominant color is black (N2–N3, Munsell), reflecting Fe-Mn coating. Strontium isotope analyses performed on equivalent materials indicate ages between 21.7 and 14.5 Ma (Early–Middle Miocene). This interval coincides with the period of greatest diversity and broad distribution of †O. *megalodon*, supporting the interpretation that the tooth corresponds to this geological interval. The presence of the tooth in deep-sea settings and associated with Fe-Mn crusts is unusual, as most findings occur in coastal environments. The results presented suggest that the RGR may have served as a migratory route or feeding area for large pelagic predators during the Miocene, possibly associated with local productivity and regional paleoceanographic conditions. The record reinforces the scientific and strategic importance of the RGR and highlights the need to expand paleontological and paleoceanographic investigations in the deep waters of the South Atlantic Ocean.

Article Information

Publication type: Research Papers
Received 11 December 2025
Accepted 9 January 2026
Online pub. 12 January 2026
Editor : Rodrigo Horodyski

Keywords:
Miocene
Paleontology
Shark tooth
Offshore
Giant

*Corresponding author
Edgar Romero Herrera de Figueiredo Iza
E-mail address: edgar.iza@sgb.gov.br

Accepted manuscript – Uncorrected pre-proof

ISSN: 2595-1939
https://doi.org/10.29396/jgsb.2026.v9.n1.3
Open access at jgsb.sgb.gov.br

1. Introduction

One of the most emblematic marine predators of the Cenozoic, †*Otodus megalodon* stands out as the largest shark identified in the fossil record. According to Cappetta (2012), Boessenecker et al. (2019), and Basilos and Collareta (2019), this predator inhabited tropical and subtropical waters worldwide between 15.9 and 3.6 million years ago (Middle Miocene to Pliocene). Several authors show the wide distribution of fossils around the world, a fact that has been used as an argument that the species can be considered cosmopolitan (Uyeno et al. 1989; Purdy 1996; Purdy et al. 2001; Reolid and Molina 2015; Pimiento et al. 2016).

The largest individuals reached approximately 18 meters in length and had a body mass exceeding 50 t (Gottfried, Compagno and Bowman 1996; Pimiento and Balk 2015), making it one of the largest predators ever recorded. In any case, the fossil record consists largely of isolated teeth and, much more rarely, vertebral centra (Reolid and Molina, 2015).

Kast et al. (2022) conducted studies on the biomechanics and trophic ecology of †*O. megalodon* and concluded that the shark occupied the top of Neogene food chains. Furthermore, paleoenvironmental reconstructions and isotopic results from teeth attributed to †*O. megalodon* support migratory behavior and reproductive strategies possibly similar to those of modern great white sharks (Cooper et al. 2022).

Nevertheless, Pimiento et al. (2016) and Ferrón (2017) consider that factors such as global oceanographic changes related to cooling waters and competition with the modern great white shark were possible causes of its extinction. Thus, †*O. megalodon* represents a paleontological icon and a key case for understanding the evolution of large marine predators and the environmental transformations that occurred in the Neogene.

Pimiento et al. (2016) state that there are still areas with no fossil occurrence records of †*O. megalodon*, notably Brazil, the Pacific coast of Central America, the northern part of the Indian Ocean, the Arctic Ocean, and the Southern Ocean. Additionally, Pollerspöck et al. (2023) corroborate Pimiento's results, not evidencing occurrences of †*O. megalodon* fossils in Brazil (onshore) and in the South Atlantic Ocean (offshore).

This work documents and describes a tooth attributed to †*O. megalodon* collected by the Geological Survey of Brazil (SGB) in the South Atlantic Ocean, during the activities of the Rio Grande Rise Project.

2. Study Area

The tooth was collected within the scope of the Rio Grande Rise Project, during which geological, geophysical, biological, and oceanographic data were obtained. The area of the Project is located on the Rio Grande Rise (RGR). The RGR represents one of the most prominent bathymetric features in the South Atlantic Ocean basins (O'Connor and Duncan 1990) (Figure 1). It is located approximately 1300 km east of the Brazilian coast, between latitudes 28° and 34°S and longitudes 28° and 40°W. Water depths range from a few hundred meters to approximately 4500 m. The area is characterized by seamounts, guyots, incised valleys, and steep escarpments (Alves 1981). The RGR is situated near the Santos and Pelotas sedimentary basins along the southern and southeastern Brazilian margins.

3. Materials and Methods

The activities of the Rio Grande Rise Project carried out between 2011 and 2012 enabled the collection of 14 tons of rock samples from 132 stations, in addition to other data. The †*O. megalodon* tooth sample was collected during Leg 4 aboard the vessel *R/V Fugro Gauss*, between January 23rd and February 19th, 2012.

The sample was identified onboard the vessel and separated for cataloging and recording procedures, including field information, provenance, and initial photographic documentation. A preliminary cleaning was then carried out using running water and air drying at room temperature, aiming to preserve the sample as much as possible and avoid damage to the fossil.

In the laboratory, the sample underwent morphological description, measurement, shape characterization, and analysis of surface features (grooves, color, structures, and type of preservation). For color description, the Munsell Rock Color Chart was used (Munsell 2010). The next step consisted of comparing the specimen with others recorded in the specialized literature, including taxonomic keys and reference collections.

Regarding the procedures for fossil identification, traditional paleontological practices were followed. The tooth measurements were taken with calipers and included cusp height and width (CH) and total tooth height (TH), crown width (CW), among other information, following the standards proposed in the literature (Hubbell 1996; Shimada 2002; Reolid and Molina 2015; Viciano et al. 2018).

Based on the aforementioned workflow, the most likely taxonomic classification was determined at the species level. The sample was then photographed, and an artistic representation was produced, both of the sample and the identified tooth. Finally, the specimen was stored at the Lithotheque of the Geological Survey of Brazil, located in Caeté, Minas Gerais.

Boessenecker et al. (2019) reviewed reports of †*O. megalodon* teeth in the eastern Pacific Ocean (California, Baja California) and concluded that many of the supposed more recent records (Pleistocene, late Pliocene) involve reworked specimens, with questionable provenance or weak stratigraphic documentation. According to the authors, this makes it "difficult to reliably assess the age and stratigraphic occurrence" of several fossils attributed to †*O. megalodon*. In Argentina, for example, De Pasqua et al. (2021) describe an isolated tooth found on a beach (Punta Médanos, Buenos Aires Province), without a clear stratigraphic context, illustrating the provenance issues in recent reports.

Thus, in order to record as much data as possible about the tooth and the rock sample in which it was found, this study includes information related to the macroscopic description of the rock, as well as geochemical and geochronological data from other similar samples from the same sampling station or nearby stations, generated by Cavalcanti and Santos (2022). Furthermore, the use of these associated data contributed to maintaining the physical integrity of the sample containing the †*O. megalodon* tooth.

4. Results and Discussions

The †*O. megalodon* tooth sample was collected at station 4340-IV-150-HAS. A dredge drag operated at depths between

664 and 667 meters was used to collect the samples. Table 1 presents the main data for this station.

At station 4340-IV-150-HAS, approximately 200 kg of samples were collected, including 142.15 kg of Fe-Mn crusts and 57.9 kg of carbonate rock with frequent crust presence. The material volume occupied nine boxes, with an average mass of 20 kg, comprising seven boxes with crusts, two boxes, and one pallet with carbonate rock. The approximate distance between the beginning and end of the dredge tow was 10.8 km. Further information can be found in Iza et al. (2025).

4.1 Morphological and Macroscopic Aspects of the Sample

The analyzed tooth is embedded in a sample of phosphate-rich Fe–Mn crust (Figure 2A, B, and C). The crust exhibits a porous, granular, and locally botryoidal surface, with a laminated internal structure and a thickness ranging from 0.2 to 2 cm. The lamination consists of dark Fe–Mn–rich layers (Munsell: N3 and N2) alternating with light Ca-rich layers, as well as cavities filled with phosphatic material (Munsell: 5YR 4/4 and 10YR 7/4). According to Cavalcanti and Santos (2022), the main mineral components of these crusts are Fe-vernadite, carbonate-fluorapatite, and calcite, all of which occur in the phosphatized samples.

Overall, the sample is not powdery to the touch, although Fe–Mn–enriched areas may locally stain the hands. Notably, samples from station 4340-IV-150-HAS show a greater degree of iron impregnation than those from other stations, a characteristic also reflected in their higher relative densities. The identified specimen consists of a single tooth with triangular morphology (Figure 2), with a tooth height (TH) of 57.1 mm, crown height (CH) of 45.2 mm, and crown width (CW) of 36.2 mm. The crown is broad, and the cutting edges do not display serration due to marine abrasion. The length of the cutting edge (lingual view) is 33.1 mm.

The lingual side is convex (high) in the apicobasal direction, whereas the labial side is relatively flat and shows a slight bulge in the central portion. It displays linear striations oriented apicobasally. At the base of the crown, a faint “chevron” shaped band is present, though only subtly visible due to Fe–Mn coating (Figure 2). This band is thicker in the medial region and becomes narrower toward the mesial and distal edges.

The root is convex in the apicobasal direction and has a smooth surface as a result of Fe–Mn coating. The lingual protuberance is slightly convex and lacks both a nutritive foramen and a groove. The tooth is completely covered by Fe–Mn–enriched dark material (manganese crust) on both the lingual and labial sides. The lower margin of the crown is partially visible when the tooth is inspected from the labial side. The root is preserved and similarly coated with Fe–Mn–enriched dark material. The predominant color of the tooth, according to the Munsell color chart, is black (N3–N2), and the total mass of the sample in which the tooth is embedded is 732 g.

Figure 3 shows an artistic representation of the sample with the tooth embedded and of the isolated tooth.

Pollerspöck et al. (2023) reported the discovery of a †*O. megalodon* tooth in the Pacific Ocean and integrated their results with the global data compiled by Pimiento et al. (2016), Eastman (1903, 1906), Séret (1987) as well as from other authors. In this study, these datasets were also integrated with the sampling point described here. The combined set of information highlights the absence of discoveries in the South Atlantic Ocean (offshore) (Figure 4).

In this work, Pollerspöck et al. (2023) further state that the deep-sea records of †*O. megalodon* refer to depths ranging from 350 to 5570 m, with distances from any land exceeding 900 km, a fact observed in this study. According to the authors, these results may be related to transoceanic migration, which has also been recorded in extant lamniform sharks (Coffey et al. 2017; Doherty et al. 2019), including *Carcharodon carcharias* (Great White Shark) (Bonfil et al. 2005).

4.2 Chemical analysis of the Fe-Mn crust

The chemical analysis performed on Fe-Mn crust collected at the same station and exhibiting macroscopic characteristics similar to the studied sample (Table 2) shows contents of Fe_3O_4 (10.67%), MnO (13.79%), P_2O_5 (11.32%), and CaO (27.47%). According to Cavalcanti and Santos (2022), the microstratigraphic succession of the RGR includes an older phosphatized Fe-Mn crust at the base and a younger non-phosphatized Fe-Mn crust at the top. The aforementioned results are consistent with the group of older phosphate-rich Fe-Mn crusts, which display higher cobalt concentrations when compared to younger crusts. The authors attribute the origin of this type of crust to diagenetic processes. Figure 5 shows a schematic profile highlighting the lithologies associated with the context of the †*O. megalodon* tooth occurrence.

Samples of Fe-Mn crusts with characteristics similar to those described above, and collected during the same project and cruise, were subjected to strontium isotopic analyses ($^{87}Sr/^{86}Sr$) for age estimation (Cavalcanti and Santos 2022). The results obtained by the authors showed ratios of $^{87}Sr/^{86}Sr$ = 0.70833 ± 2 and 0.70880 ± 2. Comparison of these values with the global curve of the oceanic Sr isotopic composition for the Cenozoic indicates ages between 21.7 and 14.5 Ma, corresponding to the Early–Middle Miocene (Figure 1).

Silva et al. (2024) studied the carbonate rocks of the RGR and identified eight microfacies. Based on the microfacies descriptions and the ages of index microfossils, they proposed a paleoenvironmental reconstruction indicating the development of an isolated carbonate platform during a period of tectonic quiescence in the Oligocene–Miocene. These results are consistent with those presented by Cavalcanti and Santos (2022), indicating that the Fe-Mn crusts formed between the Oligocene and Miocene.

The aforementioned results provide strong evidence that the tooth and associated materials correspond to the Early–Middle Miocene interval. Notably, this period coincides with the phase of greatest diversity and widest geographic distribution of †*O. megalodon* (Koch et al. 2000). The occurrence of this specimen on the RGR reinforces the hypothesis that this oceanic region functioned as a route or feeding area for large pelagic predators, possibly related to local productivity and Miocene ocean circulation (Burke et al. 1982) (Figure 6).

The recovery of the tooth in a deep-sea environment associated with phosphate-rich Fe-Mn crusts is unusual, since most records of the species come from coastal or shelf deposits. Thus, this finding contributes significantly to the understanding of †*O. megalodon* paleoecology and highlights the paleontological potential of the RGR.

5. Final Considerations

The identification of an †*Otodus megalodon* tooth on the Rio Grande Rise (RGR) represents a milestone for marine paleontology in the South Atlantic Ocean. Among other aspects, the finding constitutes direct evidence of the species presence in the region, indicating that it was part of migratory routes and feeding areas during the Early–Middle Miocene. The discovery suggests that the region hosted biologically productive ecosystems, which is consistent with records of shallow carbonate deposits and geological evidence of warm, nutrient-rich paleoenvironmental conditions.

The implications for future research include the need to reassess the paleoceanography of the South Atlantic Ocean, develop models of ecological connectivity between continental margins and oceanic rises, and expand paleontological sampling efforts in deep waters. Additionally, this finding reinforces the scientific and strategic relevance of the region, supporting its consideration in conservation policies and in the international management of mineral resources on the ocean floor. Finally, this discovery broadens the paleontological knowledge of the RGR and highlights the importance of expanding studies on this topic using other collected samples. The geochemical and geochronological data presented were included as a way to contribute to the contextualization of the sample's collection, but it is expected that future studies will further deepen understanding and provide more precise results.

Acknowledgements

We thank the crew of the Fugro Gauss and the teams responsible for dredging operations, and Mariana Carvalho for the illustrations.

Authorship credits

Author	A	B	C	D	E	F
MCB	■		■	■	■	
ERHFI	■		■	■	■	■
JADC		■	■	■	■	
HAS		■	■		■	
LCMP		■	■		■	
JCOP		■				
EPF	■					
VRSS					■	■

A - Study design/ Conceptualization **B** - Investigation/ Data acquisition
C - Data Interpretation/ Validation **D** - Writing
E - Review/Editing **F** - Supervision/Project administration

References

Alves E.C. 1981. Estruturas da margem continental sul brasileira e das áreas oceânicas e continentais adjacentes. In: Petrobras (ed.) Estruturas e tectonismo da margem continental brasileira, e suas implicações nos processos sedimentares e na avaliação do potencial de recursos minerais; relatório final. CENPES/DINTEP, Projeto REMAC 9, 145–170.

Boessenecker R.W., Ehret D.J., Long D.J., Churchill M., Martin E., Boessenecker S.J. 2019. The Early Pliocene extinction of the mega-toothed shark Otodus megalodon: a view from the eastern North Pacific. PeerJ 7:e6088 https://doi.org/10.7717/peerj.6088

Bonfil R., Meyer M.A., Scholl M.C., Johnson R.L., O'Brian S., Oosthuizen W.H., Swanson S., Kotze D., Patterson M. 2005. Transoceanic migration, long-distance return migration and local movement patterns in the great white shark. Sci. 301(5745):100–103. doi: 10.1126/science.1114898.

Burke W.H, Denison R.E., Hetherington E.A., Koepnick R.B., Nelson H.F. Otto J.B. 1982. Variation of seawater 87Sr/86Sr throughout Phanerozoic time. Geology, 10, 516–519.

Cappetta H. 2012. Chondrichthyes – Mesozoic and Cenozoic Elasmobranchii. Handbook of Paleoichthyology.

Cavalcanti J.A.D. Santos R.V. 2022. Ferromanganese crust: is a type of Cenozoic black stromatolite in seabed? The case of the Rio Grande Rise, South Atlantic Ocean. International Journal of Paleobiology and Paleontology, 5(1). DOI: 10.23880/ijpbp-16000129.

Coffey D.M., Carlisle A.B., Hazen E.L., Block B.A.. 2017. Oceanographic drivers of the vertical distribution of a highly migratory, endothermic shark. Sci Rep. 7 (1):Article 10434. doi: 10.1038/s41598-017-11059-6.

Cooper J.A., Hutchinson J.R., Bernvi D.C., Cliff G., Wilson R.P., Dicken M.L., Menzel J., Wroe S., Pirlo J., Pimiento C. 2022. The extinct shark Otodus megalodon was a transoceanic superpredator: Inferences from 3D modeling. Sci. Adv.8, eabm9424. DOI:10.1126/sciadv.abm9424

De Pasqua J., Agnolin F., Aranciaga Rolando A. M., Bogan, S., Gambetta, D. 2021. First occurrence of the giant shark Carcharocles megalodon (Agassiz, 1843) (Lamniformes; Otodontidae) at Buenos Aires Province, Argentina. Revista Brasileira De Paleontologia, 24(2), 141–148. https://doi.org/10.4072/rbp.2021.2.05

Doherty P.D., Baxter J.M., Godley B.J., Graham R.T., Hall G., Hall J., Hawkes L.A., Henderson S.M., Johnson L., Speedie C. 2019. Seasonal changes in basking shark vertical space use in the north-east Atlantic. Mar Biol. 166 (10): Article 129. doi: 10.1007/s00227-019-3565-6.

Eastman C.R. 1903. Sharks' teeth and Cetacean bones from the Red Clay of the tropical Pacific. Memoirs of the Museum of Comparative Zoology at Harvard College. 26(4):178–189.

Eastman CR. 1906. Sharks' teeth and Cetacean bones from the Red Clay of the tropical Pacific. Bulletin of the Museum of Comparative Zoology at Harvard College. 50(4):75–98

Ferrón H.G. 2017. Regional endothermy as a trigger for gigantism in some extinct macropredatory sharks. PLOS ONE 12(9):e0185185 DOI 10.1371/journal.pone.0185185.

Gottfried M.D., Compagno L.J.V., Bowman S.C. 1996. Size and skeletal anatomy of the Giant "Megatooth" Shark Carcharodon megalodon. In: A.P. Klimley and D.G. Ainley (eds.) Great White Sharks: the biology of Carcharodon carcharias, Academic Press, p. 55–66.

Hubbell G. 1996. Using tooth structure to determine the evolutionary history of the white shark. In: A.P. Klimley and D.G. Ainley (eds.) Great White Sharks: the biology of Carcharodon carcharias, Academic Press, p. 9–18.

Iza, E.R.H.F., Souza, M.L., Meira, M.M., Grissolia, E.M., Simões H.A.; Cavalcanti J.A.D.; Frazão E.P.; Sobrinho V.R.S. 2025. Inventory of Geological Samples Collected from the Rio Grande Rise: Caeté Lithotheque (Minas Gerais State), Geological Survey of Brazil. Journal of The Geological Survey of Brazil, v.8, n3. https://doi.org/10.29396/jgsb.2025.v8.n3.5.

Kast E.R., Griffiths M.L., Kim S.L., Rao Z.C., Shimada K., Becker M.A., Maisch H.M., Eagle R.A., Clarke C.A., Neumann A.N., Karnes, M.E., Lüdecke T., Leichliter J. N., Martínez-García A., Akhtar A.A., Wang X.T., Haug G.H., Sigman D. M. 2022. Cenozoic megatooth sharks occupied extremely high trophic positions. Science Advances, 8(25), eabl6529. https://doi.org/10.1126/sciadv.abl6529

Koch P.L., Bassett D., Morris P.J. 2000. Sr isotopes in fossil marine teeth: implications for paleoceanography. Palaeogeography, Palaeoclimatology, Palaeoecology, 157, 1–17.

Munsell Color. 2010. Munsell soil color charts: with genuine Munsell color chips. Grand Rapids, MI: Munsell Color.

Pollerspöck J., Cares D., Ebert D.A., Kelley K.A., Pockalny R., Robinson R. S., Wagner D.; Straube N. 2023. First in situ documentation of a fossil tooth of the megatooth shark Otodus (Megaselachus) megalodon from the deep sea in the Pacific Ocean. Historical Biology, 37(1), 120–125. https://doi.org/10.1080/08912963.2023.2291771

O'Connor J.M., Duncan R.A. 1990. Evolution of the Walvis Ridge–Rio Grande Rise hotspot system: implications for African and South American plate motions over plumes. Journal of Geophysical Research: Solid Earth, 95(B11), 17475–17502.

Pimiento C., Balk M. 2015. Body size trends of the extinct giant shark Carcharocles megalodon: a deep-time perspective on marine apex predators. Paleobiology, 41:479–490. doi:10.1017/ pab.2015.16

Pimiento C., MacFadden B.J., Clements, C.F., Varela, S., Jaramillo, C., Velez-Juarbe, J., Silliman, B.R. 2016. Geographical distribution patterns of Carcharocles megalodon over time reveal clues about extinction mechanisms. Journal of Biogeography, 43:1645–1655. doi:10.1111/jbi.12754

Purdy, R. 1996. Paleoecology of fossil White Sharks. In: Kimley, A.P. and Ainley, D.G., Eds., Great White Sharks: The Biology of Carcharodon carcharias, Academic Press, San Diego, 67-78. http://dx.doi.org/10.1016/B978-012415031-7/50009-4

Purdy, R. W., Schneider V.P., Applegate S.P., McLellan J.H., Meyer R.L., Slaughter, B.H. 2001. The Neogene sharks, rays, and bony fishes from Lee Creek Mine, Aurora, North Carolina. Smithsonian Contributions to Paleobiology 90:71–202.

Reolid M., Molina, J.M. 2015. Registro de Carcharocles megalodon en el sector oriental de la Cuenca del Guadalquivir (Mioceno superior, Sur de España). Estudios Geológicos, 71:1–32. doi:10.3989/egeol.41828.342

Séret B. 1987. Découverte d'une faune à Procarcharodon megalodon (Agassiz, 1835) en Nouvelle-Calédonie (Pisces, Chondrichthyes, Lamnidae). Cybium. 11(4):389–394.

Shimada, K. 2002. The relationship between the tooth size and total body length in the white shark. Journal of Fossil Research, 35:28–33.

Silva R.O., Leite M.G.P., Krahl G., Rudnitzki I., Soares I.A.S., Souza M.L., Simões H.A., Rocha Lopes, V.H., Frazão E.P., Rojas J., Marinho M., Viana, A. 2024. Neogene isolated carbonate platform of the Rio Grande Rise (southwest Atlantic Ocean). Journal of the Geological Survey of Brazil, 145(1). DOI: 10.1016/j.jsames.2024.105044.

Uyeno T., Sakamoto, O., Sekine H. 1989. The description of an almost complete tooth set of Carcharodon megalodon from a Middle Miocene bed in Saitama Prefecture, Japan. Bulletin of Saitama Museum of Natural History, 7:73–85.

Viciano J., López-Lázaro S., D'Anastasio R. 2018. Dientes fósiles de Carcharocles megalodon: la colección del Museo Universitario de Chieti (Italia). Parte I: Análisis morfométrico. International Journal of Morphology, 36:1378–1385. doi:10.4067/S0717-95022018000401378

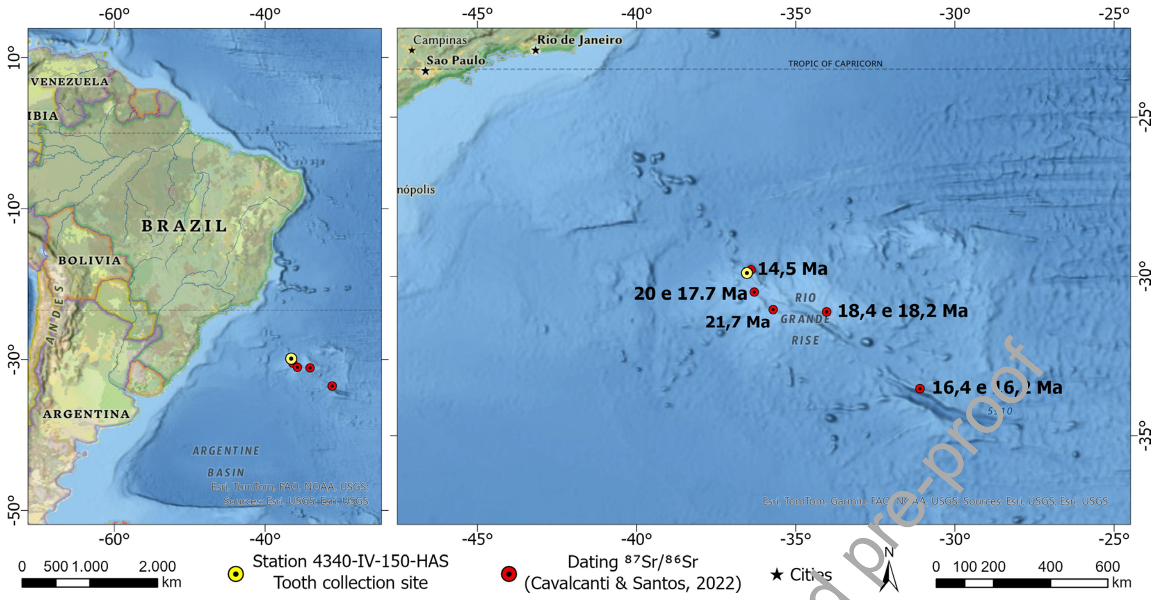

FIGURE 1. Location map of the project area (Rio Grande Rise), sample collection site, and stations with datings conducted by Cavalcanti and Santos (2022). Modified from Iza et al 2025.

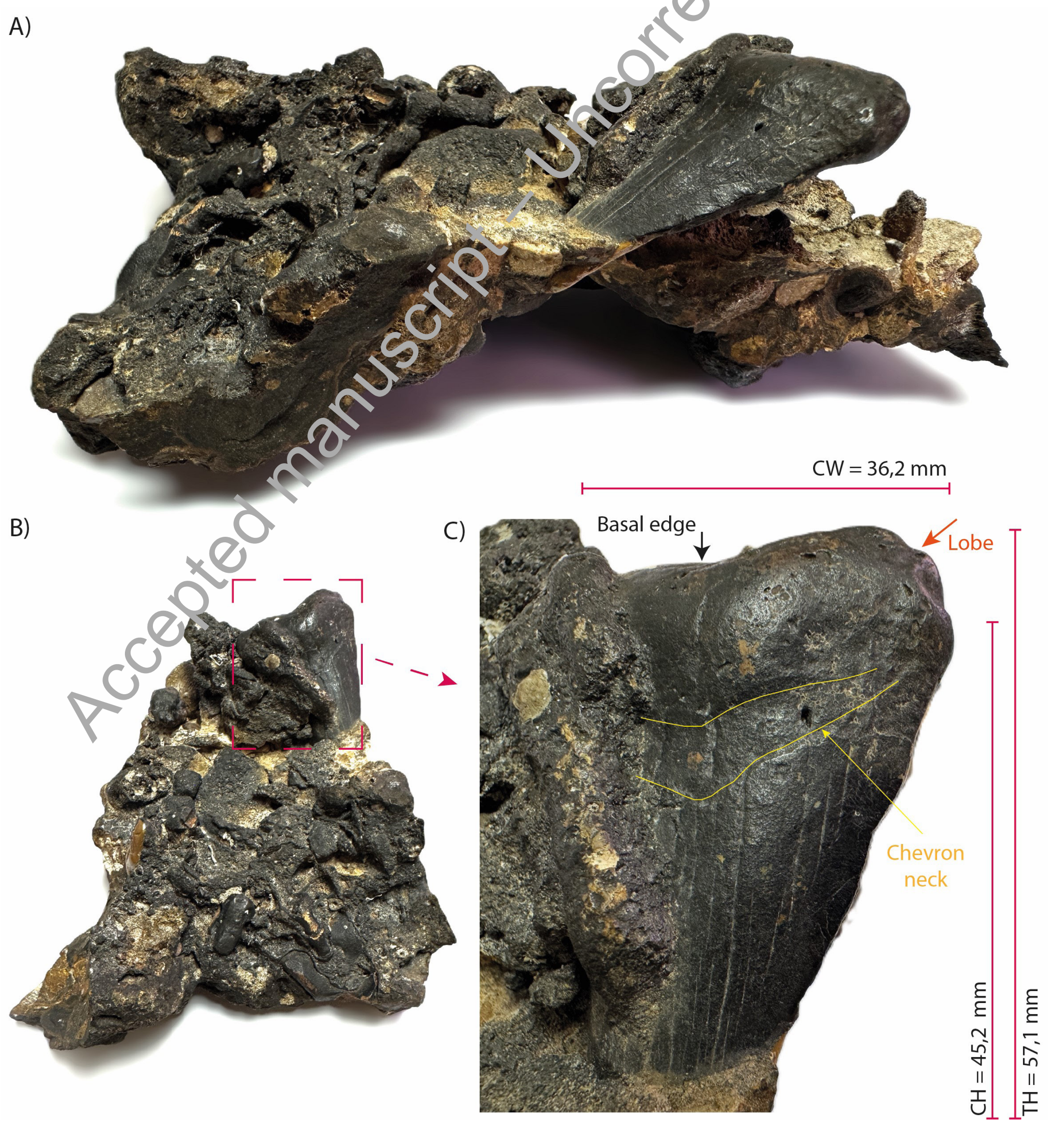

FIGURE 2. Fe-Mn crust with the presence of an †O. megalodon tooth. A) Lateral view. B) Top view. C) Detail of the tooth (Lingual view).

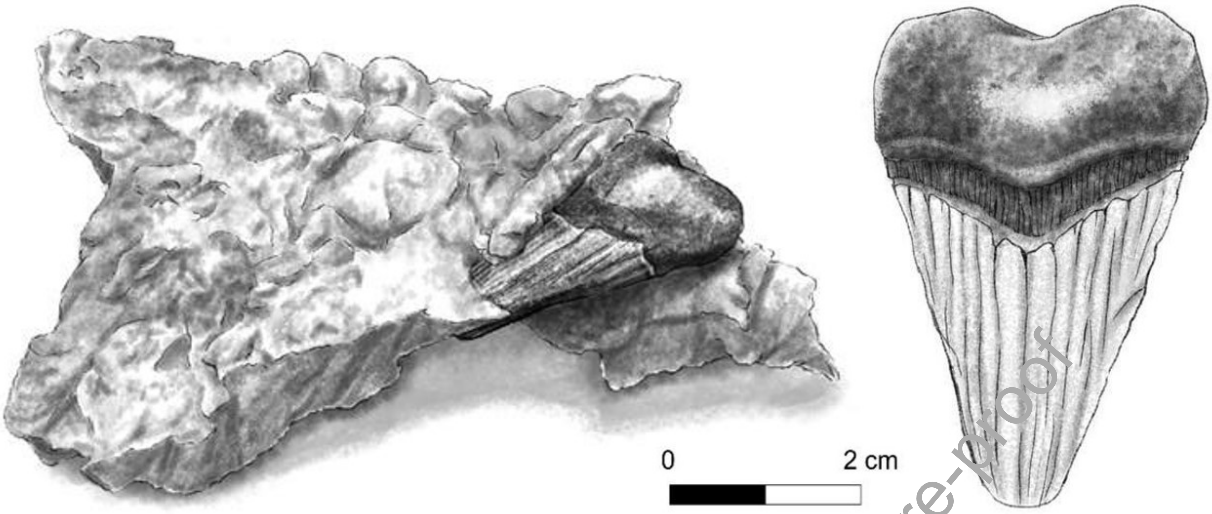

FIGURE 3. A) General aspect of the sample containing the tooth. B) †O. megalodon tooth from a ferromanganese crust of the RGR (Illustration by Mariana Carvalho), in lingual view.

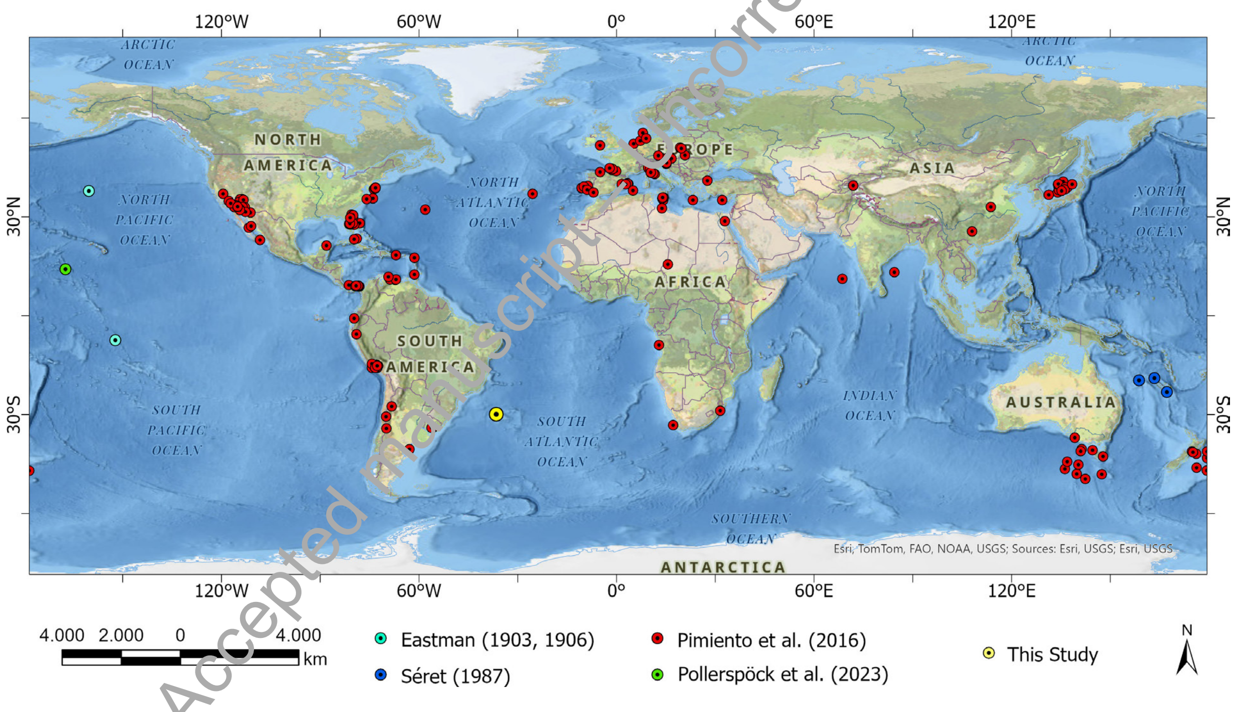

FIGURE 4. Fossil occurrences of †O. *megalodon*, as cited in the literature.

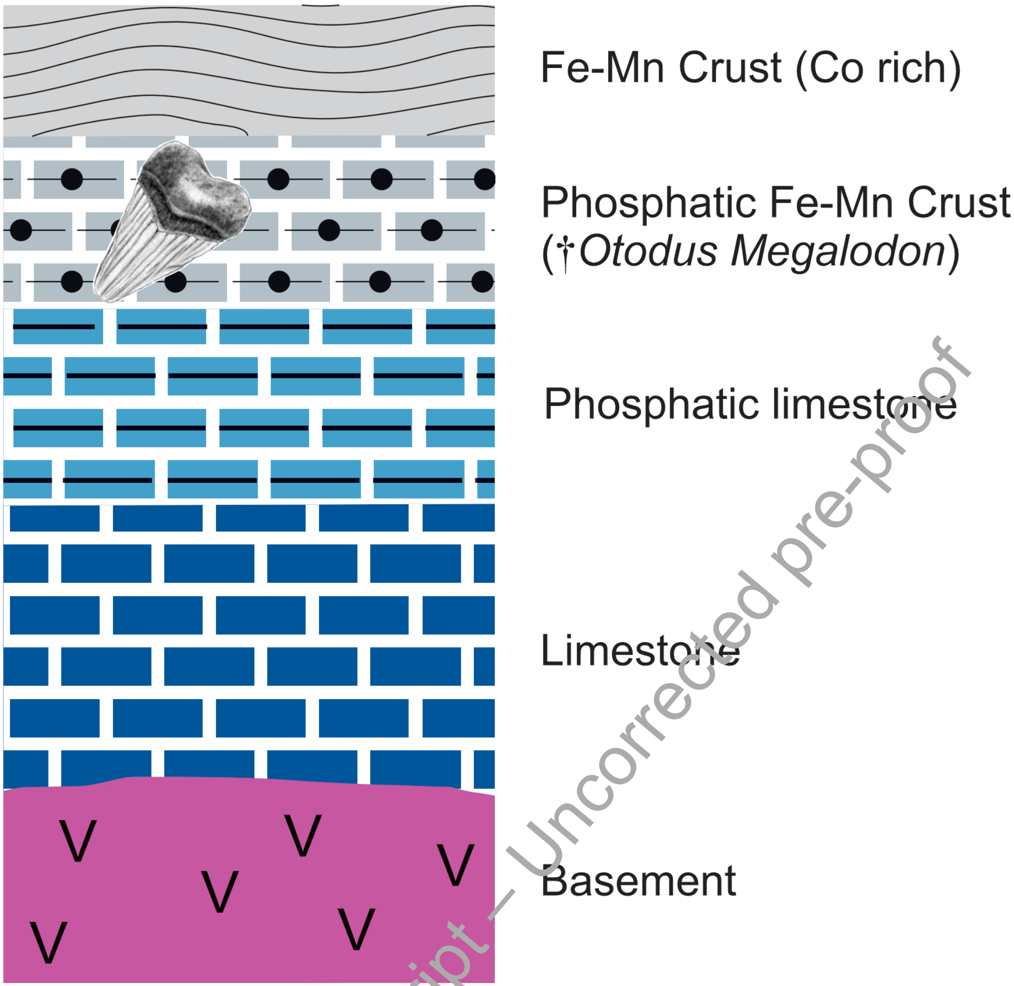

FIGURE 5. Schematic cross section (not to scale) showing the relationships between the main lithologies and the Fe-Mn crusts on the RGR.

FIGURE 6. Reconstruction of †O. *megalodon* in the vicinity of the RGR (Illustration by Mariana Carvalho)

TABLE 1. Data from Station 4340-IV-150-HAS

Leg	Data	Start	End	Deep (I)	Deep (F)	Lat.(init)	Long.(init)	Lat(final)	Long. (final)
IV	14/02/2012	20:30	22:02	-670	-664	-29.89522	-36.53373	-29.8793	-36.425537

TABLE 2. Geochemical data from a phosphate-rich Fe-Mn sample collected at station 4340-IV-150-HAS

	%		ppm		ppm		ppm
Al2O3	3.83	Ba	342	La	117.4	Ag	<0.1
CaO	27.47	Be	4	Ce	197.4	As	215.9
Cr2O3	0.016	Co	1230.2	Pr	21.77	Bi	4.1
Fe2O3	10.67	Cs	0.3	Nd	104.6	Cd	5.0
K2O	0.22	Ga	19.8	Sm	20.11	Cu	416.2
LOI	23.2	Hf	2.8	Eu	4.56	Hg	<0.01
MgO	5.34	Nb	24.7	Gd	25.32	Mo	305.6
MnO	13.79	Ni	7055	Tb	3.54	Pb	297.7
Na2O	0.73	Rb	5.0	Dy	22.61	Sb	19.0
P2O5	11.32	Sc	7	Ho	5.04	Se	<0.5
SiO2	1.29	Sn	7	Er	15.61	Tl	43.0
Sum	99.11	Sr	1250.2	Tm	2.00	Zn	426
TiO2	0.31	Ta	0.5	Yb	12.13		
		Th	6.7	Lu	1.79		
		U	10.1				
		V	653				
		W	193.6				
		Y	222.5				
		Zr	112.6				

Method 4A–4B was used. For the elements from Ag to Zn (last column), method 1DX was applied.