Geotemas, Pau dos Ferros, RN, Brasil
ISSN: 2236-255X, v. 15, 2025.

# MORPHOLOGY OF THE RIVER CLIFFS OF THE NEGRO RIVER, IRANDUBA-AM: AN INTRODUCTORY APPROACH

*Morfologia das falésias fluviais do Rio Negro, Iranduba-AM: uma abordagem introdutória*

*Morfología de los acantilados del Río Negro, Iranduba-AM: una aproximación introductoria*


**Kenya Correa de Souza**
Universidade Federal do Amazonas (UFAM)
E-mail: geo.kenyasouza@gmail.com

**Antonio Fábio Sabbá Guimarães Vieira**
Universidade Federal do Amazonas (UFAM)
E-mail: fabiovieira@ufam.edu.br

**Matheus Silveira de Queiroz**
Universidade Federal do Amazonas (UFAM)
E-mail: matheussilveiradequeiroz@gmail.com

**Article History**
Reveived: 24 march, 2025
Accepted: 16 june, 2025
Published: 23 july, 2025

https://doi.org/10.33237/2236-255X.2025.6943

## ABSTRACT

T This study analyzes the morphology and possible neotectonic controls of river cliffs located on the right bank of the Negro River, in the municipality of Iranduba (AM). Five cliffs were mapped using satellite images, UAVs and field surveys, allowing the characterization of their morphological and erosional features. A structural analysis, based on Digital Elevation Models and previous studies, revealed a strong tectonic control in the formation and evolution of these features, with the influence of normal faults and morphostructural lineaments. The results indicate that the dynamics of cliff evolution is influenced by the interaction between geological, hydrodynamic and neotectonic factors.

**Keywords**: Energy; Oil; Wind farm; Agriculture; Rio Grande do Norte.

## RESUMO

Este estudo analisa a morfologia e os controles neotectônicos das falésias fluviais localizadas na margem direita do rio Negro, no município de Iranduba (AM). Foram mapeadas cinco falésias utilizando imagens de satélite, veículo aéreo não tripulado e levantamentos de campo, permitindo a caracterização de suas feições morfológicas e erosivas. Uma análise estrutural, baseada em Modelos Digitais de Elevação e estudos prévios, revelou um forte controle tectônico na formação e evolução dessas feições, com influência de falhas normais e lineamentos morfoestruturais. Os resultados indicam que a dinâmica de evolução das falésias é influenciada pela interação entre fatores geológicos, hidrodinâmicos e neotectônicos.

**Palavras-chave:** Falésias fluviais; Neotectônica; Morfologia; Rio negro.

## RESUMEN

Este estudio analiza la morfología y posibles controles neotectónicos de acantilados fluviales ubicados en la margen derecha del río negro, en el municipio de Iranduba (AM). Se cartografiaron cinco acantilados mediante imágenes de satélite, vehículos aéreos no tripulados y estudios de campo, lo que permitió caracterizar sus características morfológicas y de erosión. Un análisis estructural, basado en Modelos Digitales de Elevación y estudios previos, reveló un fuerte control tectónico en la formación y evolución de estas características, con influencia de fallas normales y lineamientos morfoestructurales. Los resultados indican que la dinámica de la evolución de los acantilados está influenciada por la interacción entre factores geológicos, hidrodinámicos y neotectónicos.


**Palabras clave:** Acantilados de río; Neotectónica; Morfología; Río negro.

## 1 INTRODUCTION

The Amazon basin is the largest river basin on the planet, with an area of approximately 6,000,000 km², and its main channel also has the highest water discharge in the world (209,000 $m^3.s^{-1}$) (Molinier et al., 1996) and drains a variety of geological and geomorphological terrains. The area drained by the Andes represents 12% of the basin's total surface area (located to the west) and is home to the sources of some of the basin's main channels, such as the Amazon and Madeira rivers. In the north (Guyana) and south (Central Brazil) of the basin are the crystalline shields, which represent around 40% of the basin's total area. Some important channels, such as the Negro and Tapajós rivers, drain these regions. These shields are ancient (Precambrian) and highly weathered. Between the two shields lies the lowland region, with a lower altimetry and low slope (Filizola et al., 2009).

The Negro River basin has an estimated area of 709,000 km², spread between Colombia, Venezuela, and Brazil. The basin drains an area of equatorial forests, savannas, campinarana and igapó forests. The Negro River is the main tributary on the left bank of the Amazon River, with an estimated water discharge of 28,000 $m^3.s^{-1}$, and is considered the sixth-largest river in terms of water discharge in the world (Latrubesse, 2008). However, recent studies indicate a discharge of 35,499 $m^3.s^{-1}$ (Marinho et al., 2021), reclassifying the Negro River as the third-largest river in the world, ahead of the Madeira (Amazon basin), Yangtze (China), and Orinoco (Venezuela) rivers and behind the Amazon and Congo (Democratic Republic of Congo) rivers.

The Negro River is home to the two largest river archipelagos in the world (Mariuá, in the middle reaches, and Anavilhanas, in the lower reaches), which are considered to be great geomorphological wonders of the world (Latrubesse; Stevaux, 2015). In addition, it is possible to observe other unique features in this channel, such as the river cliffs (Franzinelli; Igreja, 2002; Souza, 2024). Suguio (1998) defines cliffs as steep-sided cliffs formed by the erosive action (abrasion) of waves on rocks. River cliffs are steep formations that develop along the banks of large rivers in the Amazon region as a result of erosion caused by fluvial and pluvial action. They have abrupt slopes and exposed walls that rise above the riverbed (Souza, 2024).

River cliffs are predominantly sculpted by the action of rivers and rainfall, but their formation and evolution are complex and influenced by a variety of factors. Souza (2024) states that in addition to interaction with the environment, lithology (whether igneous, metamorphic, or sedimentary), morphology, tectonic activity, wind patterns, human intervention, variations in water levels, and rainfall rates all play crucial roles in shaping these forms. This continuous and multifaceted interaction progressively shapes the cliffs, triggering a constant and dynamic evolution over time.

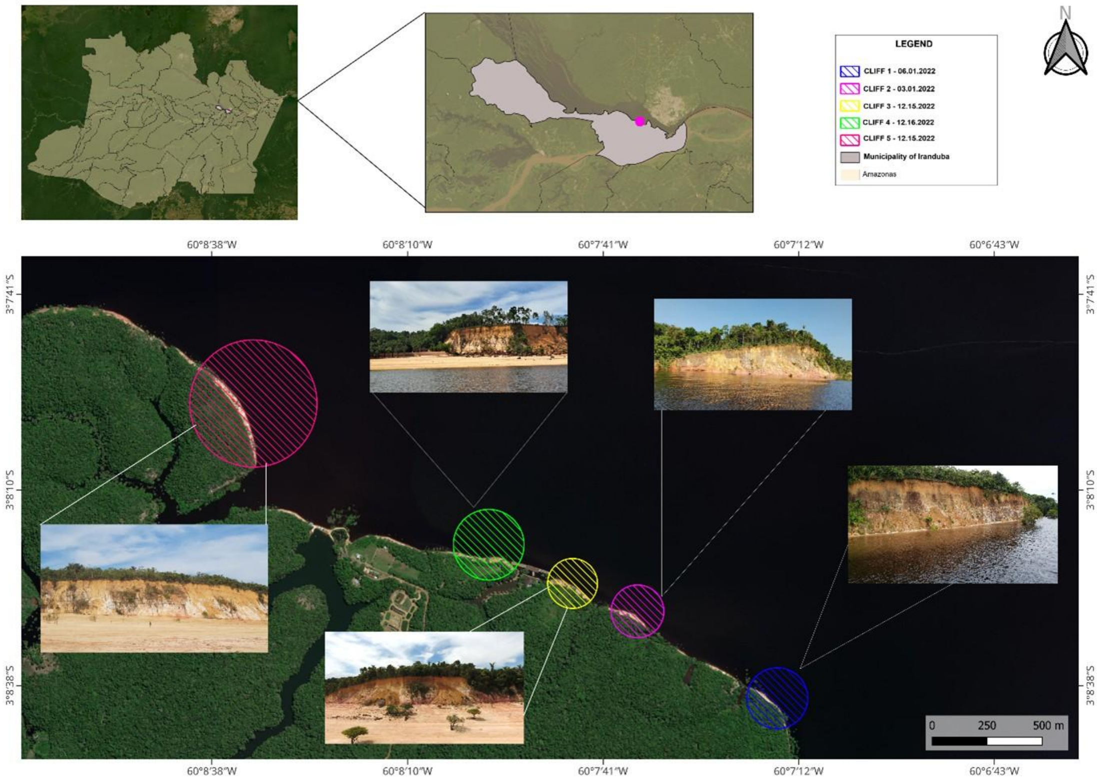
These sharp features, when exposed to water, are shaped by erosion at the base of the slope, which can result in the collapse of the upper layers. This undermining process contributes significantly to the sculpture and evolution of the cliffs over time (Souza, 2024). In view of this, this study aims to characterize the morphology and possible neotectonic controls of river cliffs in the lower Negro River.

## 2 STUDY AREA

The research area covers the analysis of five river cliffs located in the municipality of Iranduba, on the right bank of the lower Negro River, located at the following coordinates: cliff 1 ( 3° 8'39.91"S, 60° 7'17.29"O); cliff 2 (3° 8'28. 12"S, 60° 7'36.35"O); cliff 3 (3° 8'23.71"S, 60° 7'45.88"O); cliff 4 (3° 8'19.77"S, 60° 7'56.48"O); cliff 5 (3° 7'57.21"S, 60° 8'34.51"O), these cliffs were identified and mapped between 2022 and 2024 (Figure 01).

The cliffs are located in the Amazon Sedimentary Basin, where deposits of the Javari Group (Andirá and Alter do Chão Formations) outcrop, bringing together fluvial-lacustrine clastics whose geological evolution is linked to the orogenic activity of the Andes (EIRAS et al., 1994). The predominant formation of the Javari Group in the region of the cliffs is the Alter do Chão, with rocks composed of red, yellow, and white sandstones (Manaus Sandstone) and claystones dating from the Upper Cretaceous-Paleogene (Albuquerque, 1922; Kistler, 1954; Caputo, 1984; Reis et al., 2006; Hoorn et al., 2010). The sedimentary rocks of this formation are composed of layers of sandy and clayey material with cross-stratification (Reis et al., 2006).

**Figure 01** – Study Area




**Source:** Elaborated by the authors (2024).

With regard to geomorphology, according to IBGE (2024), the area of the cliffs is part of the dissected plateaus of the Negro and Uatumã Rivers, which is characterized by reliefs that include tabular interfluves and hills. Specifically in the lower reaches of the Negro River, where the area under study is located, the banks are steep.

In the region of the cliffs, latosols predominate, which are usually at an advanced stage of weathering and very evolved. They have few primary and secondary minerals, which are less resistant to weathering. These soils have a low cation exchange capacity of the clay fraction, less than 17 Cmolc.kg$^{-1}$ of clay without correction for carbon, and range from kaolinitic soils (with Ki values around 2.0) to oxic soils (with extremely low Ki). They are soils that normally vary between strongly and well drained and very deep, as observed in the cliffs (rarely less than 1 meter) (EMBRAPA, 2018).

According to Marinho (2019), the hydrographic network of the Negro River runs along the Brazil-Colombia-Venezuela-Guiana border until it reaches the confluence with the Solimões River, near the city of Manaus. As for the hydrological system of the Negro River

Basin, the flood period occurs between December and June, the ebb between August and September, and the dry period in October and November (Marinho, 2019).

Blackwater rivers, such as the Negro River, generally have little ability to remove consolidated material from the banks and little capacity to transport sediment; however, where the material on the banks is less resistant to the action of running water, it changes (Carvalho, 2006). In the case of the Negro River, as it enters the Solimões formation, the banks suffer lateral erosion by undermining, as observed in the area of this research.

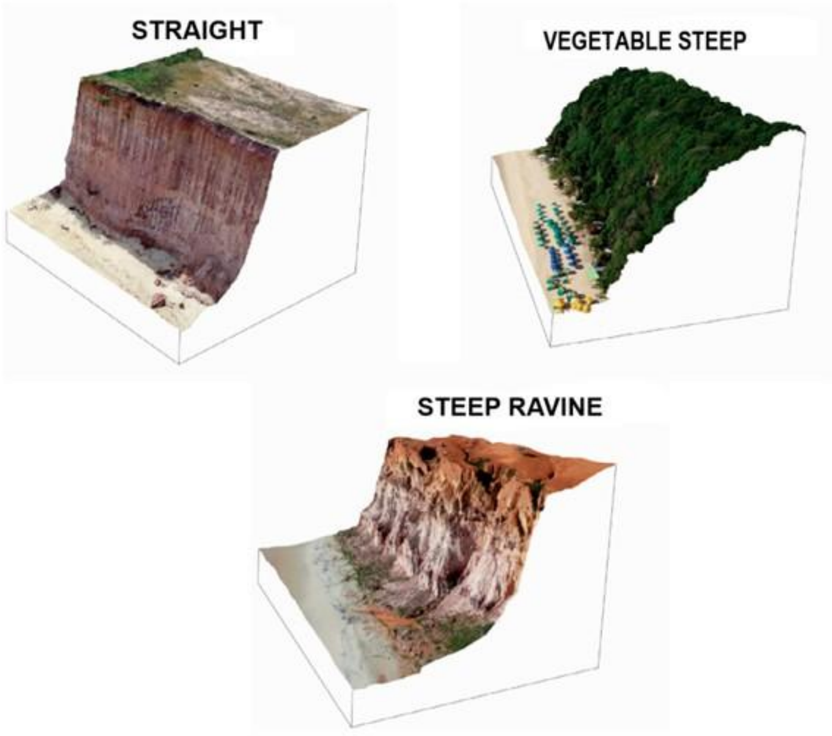
The mean rainfall in the Negro River basin is 2,620 mm.year$^{-1}$, with 54% of this volume occurring between April and July. The area with the highest volume of precipitation is located in the region of the triple border between Brazil, Colombia, and Venezuela, and the driest is between Boa Vista and Uiramutã, in the north of the state of Roraima (Marinho; Rivera, 2021). In the region of the cliffs, the lower Negro River, annual rainfall is ~2300 mm.year$^{-1}$, with the highest values in April and the lowest in August (Queiroz; Alves, 2021; Queiroz et al., 2025).

## 3 METHODOLOGY PROCEDURES

The study provides a characterization of the morphology of the cliffs under study, which involves analysis of various aspects, such as shape, height, inclinations, features present, analysis of the rocks, geological structures, formation processes, and evolution of the cliffs over time. With regard to the description of morphological characteristics and the effects of tectonics, the methodology proposed by Santos et al. (2005) was adopted. This approach included a survey of theoretical references on the geology, lithology, hydrography, and geomorphology of the Amazon region, seeking to understand the processes that occurred in the past in order to better understand the formation of the current relief.

Firstly, the five cliffs under study were identified using satellite images and the Google Earth Pro tool. Based on this identification, field visits were made on 10.11.2022 and 11.11.2022 to recognize the cliffs. During the visits, these features were mapped using a UAV (Unmanned Aerial Vehicle), where the height, erosion features, and mass movements of the cliffs were characterized. They were then classified based on their typologies according to the methodology of Maia et al. (2022) (Figure 02).

**Figure 02** - Typical cliff typologies




**Source:** Maia (2022).

Aerial photographs from the UAV were used to identify the predominant morphology and geological features that can be observed on the cliffs (Figure 03). In addition, the dimensions of the erosion features were recorded, as well as the height, width, length, slope, and orientation of the cliffs, according to the methodology proposed by Santos et al. (2005).

In order to analyze the tectonic features in the area, a survey was carried out of the tectonic workings in the region of the cliffs and a mapping of the morphostructural lineaments in the region surrounding the area. To do this, we used the Copernicus DEM Digital Elevation Model (DEM), provided by the European Space Agency (ESA), with a spatial resolution of 30 meters, suitable for regional morphostructural analysis. The use of the Copernicus DEM, as it is derived from radar and has global coverage, is essential for comparative studies in different sectors of the study area. The model's spatial resolution of 30 meters is suitable for capturing topographic variations associated with medium-sized structural features.

To interpret linear features associated with geological structures, hill shade images were generated with simulated artificial lighting at an angle of 45° and azimuths oriented to the northeast (NE) and southeast (SE). These azimuths were chosen to maximize the visibility of structural features with a NW-SE and NE-SW orientation, which are common in regions affected by multiple or complex tectonic regimes.

**Figure 03 –** UAV overflight record of the river cliff under study (1. cliff 1; 5. cliff 5)


**Source:** Elaborated by the authors (2024).

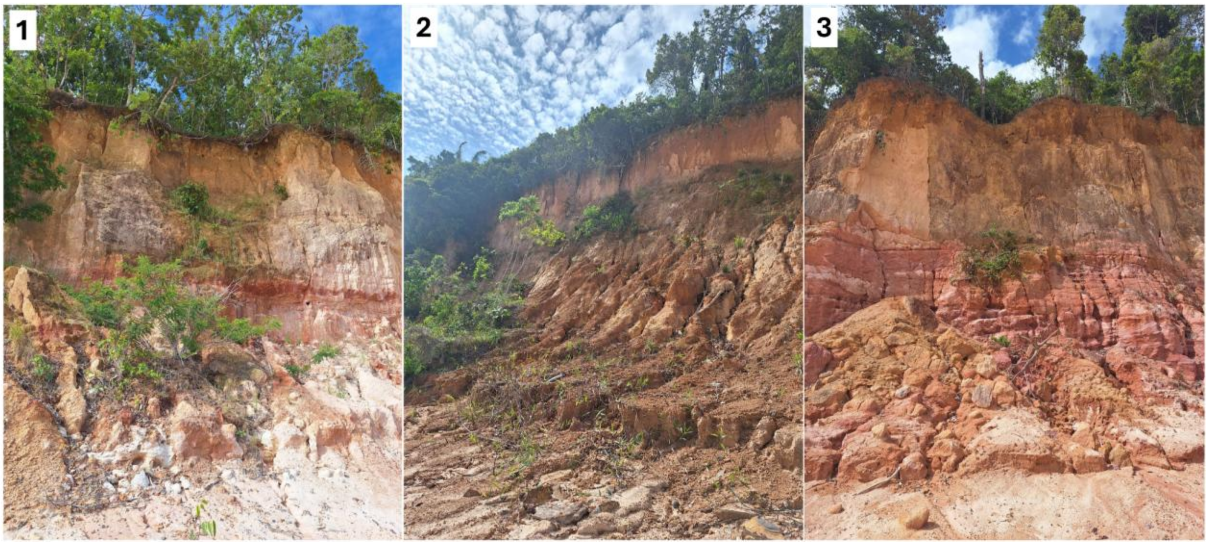
The technique of lighting with different azimuths is an efficient tool for visually highlighting topographic lineaments, since different angles of incidence of light make it possible to highlight features that could be obscured by unidirectional lighting. This methodological approach has been previously applied and tested in studies such as Sarges (2008), Sarges et al. (2011), Queiroz (2020), Queiroz and Carvalho (2021), and Queiroz et al. (2024), which showed good results in the identification, extraction, and analysis of structural lineaments in geologically complex terrain.

## 4 RESULTS AND DISCUSSION

### 4.1 Morphological Characterization of the Fluvial Cliffs of the Lower Negro River

Cliffs 1, 2, and 3 have steep profiles (Figure 04), varying between 13 and 27 meters in height, revealing distinct characteristics of fluvial undermining and obvious signs of pluvial erosion. Their lithological composition is marked by the exposure of ferruginous layers, composed of fine, dark orange sediments. According to the typology of cliffs proposed by Maia et al. (2022), the cliffs in question can be classified as steep erosive.

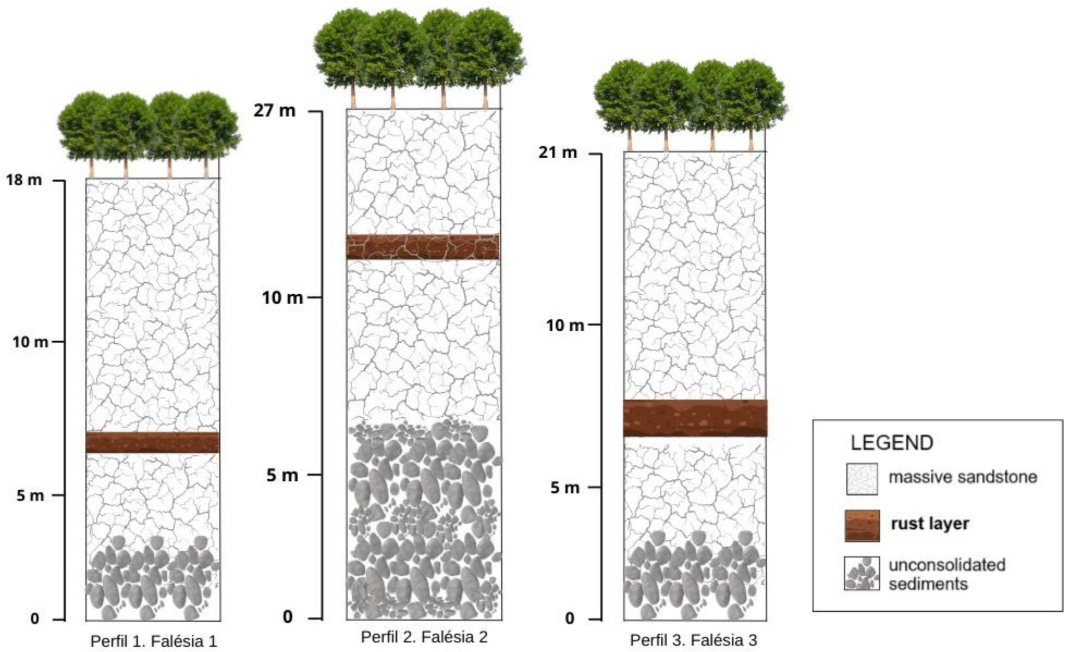
**Figure 04 -** Cliff escarpments (1. cliff 1; 2. cliff 2; 3. cliff 3)




**Source:** Elaborated by the authors (2024).

This classification suggests that the cliffs have a steep slope and are characterized by erosion processes that result in gullies and furrows appearing on their surface. Unconsolidated materials were observed at the base of the cliffs (Figure 05), often from sediments transported by mass movements. It is also possible to identify traces of vegetation that have been transported to this area.

**Figure 05 -** Schematic profiles of cliffs 1, 2 and 3 (without scale)

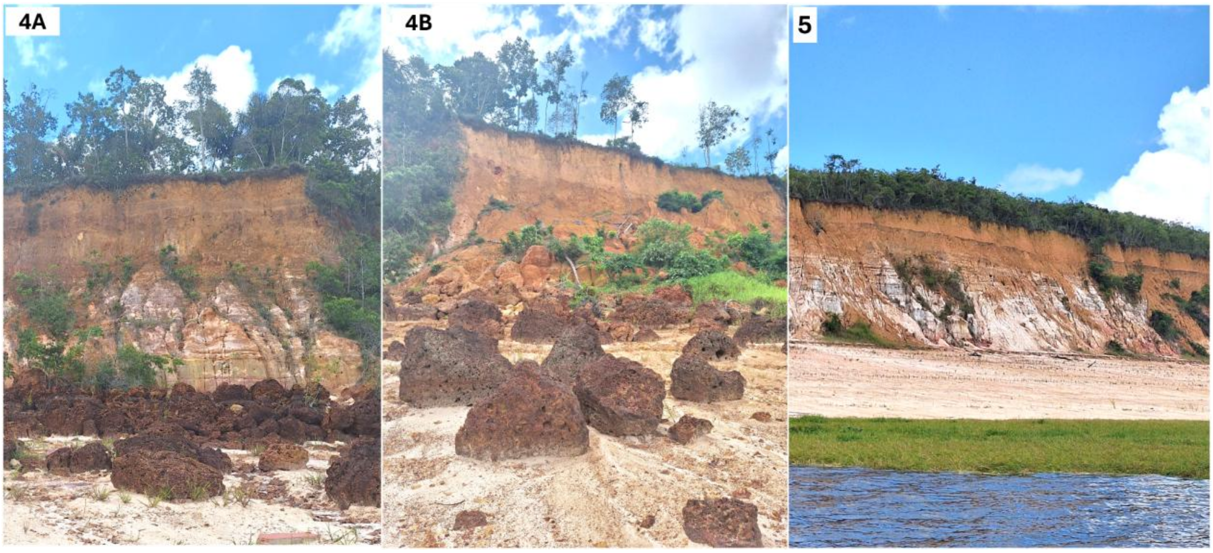



**Source:** Elaborated by the authors (2024).

In the intermediate regions of the cliffs, a fine to medium sandstone predominates, with a massive appearance and coloring that varies from yellow to whitish, being composed mainly of quartz and presenting a ferruginous layer. Closer to the riverbank, around cliff 1, reddish ferruginous layers were identified, with siltstone characteristics and plane-parallel lamination. These lithological and structural features contribute to the formation and morphology of the cliff and are influenced by the complex interaction between fluvial and pluvial processes.

Cliffs 4 and 5 are classified by the steep eroded typology and have an altimetric range from 19 to 30 meters (Figure 6). Cliff 5 has a face with little vegetation and clear evidence of mass movements. It is characterized by the steep, eroded typology, indicating a history of intense erosion and shaping by the action of natural elements. These cliffs also have an unconsolidated sediment surface at their base (Figure 06).

**Figure 06 –** Photos of the cliffs (4. cliff 4, front A and B; 5. cliff 5).

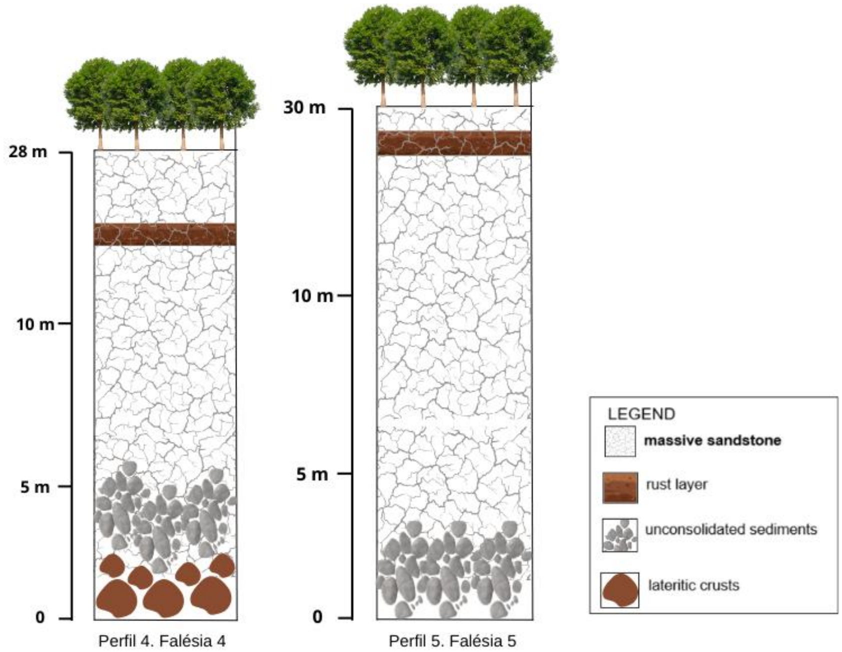



**Source:** Elaborated by the authors (2024).

Cliff 4 stands out for its uniqueness, with two distinct faces showing an exposed escarpment with sparse vegetation, revealing various stages of laterization. Collapsed blocks are also visible at the base of the cliff (Figure 07). Figure 7—Face A shows a laterized top with fine dark orange sediments.

At the base, there is evidence of coarse-grained unconsolidated sediment, accompanied by vegetation and an abundance of laterite crusts (Figure 08). These laterite crusts are very important as evidence of tectonic control in the area and act as forms of relief support.

**Figure 07** - Schematic profiles of cliffs 4 and 5 (without scale)




**Source:** Elaborated by the authors (2024).

**Figure 08** - Cliff 4


* Face A: wall of Cliff 4 facing NE; Face B: wall of Cliff 4 facing NW.
**Source:** Elaborated by the authors (2024).

The laterite crusts found in the Amazon region are mainly composed of iron and aluminum minerals. They developed during the Cenozoic in a tropical climate. The formation process of laterite crusts is related to the intense leaching of tropical soils, with the removal of soluble elements, such as silica and alkaline bases, and the accumulation of iron and aluminum oxides (SILVA, 2005).

On the other hand, Figure 08 — Face B shows evidence of intense wear of the wall, with unconsolidated materials and fallen vegetation, indicating mass movement. Although the presence of laterite crusts is notable, they are less abundant than on face A. In addition, there is little vegetation at the top of the formation, which suggests human activity in the region, possibly related to agriculture or other forms of land use. It is worth noting that climatic elements also contribute to the morphological characterization of the cliffs.

The Amazon region has a high rainfall rate, receiving heavy rains where Marques (2017) states that the high concentration of rainfall in certain months of the year causes infiltration of the sedimentary package and consequent dismantling of the material on the banks due to excess weight and disintegration of the saturated material, and this process causes the material to wear away, facilitating erosion of the bank, with the winds also contributing by creating bogs that reach the banks.

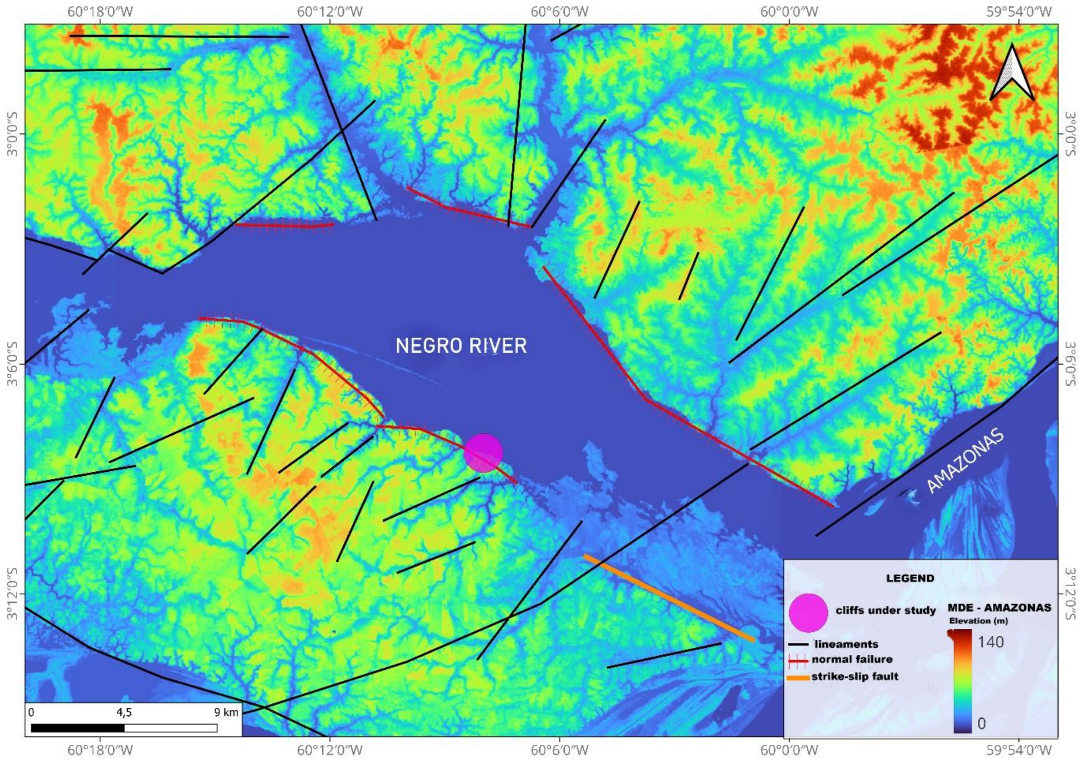
Heeps (1985) notes that the recession of a cliff is most often due to rockfalls caused by saturation after heavy rain. Sousa et al. (2020) state that the Black River exerts pressure on the base of the cliff, causing a succession of waves to undermine and carry away the material at the base. The large volumes of precipitation cause saturation of this soil package. The instability of the base and the saturation of the package cause mass movement to occur.

## 4.2 Influence of neotectonics on the formation and morphology of the fluvial cliffs of the Negro River

The five cliffs under study are on the right bank of the Negro River. Both are located in the central part of the Amazon Sedimentary Basin, where deposits of the Alter do Chão Formation outcrop. This formation consists of a sequence of clastic sediments of continental origin, weathered and unconsolidated (IBGE, 2010), inserted within a characteristic geomorphology of the Uatumã Dissected Plateau. In terms of lithology, the cliffs are made up of claystones, shales, sandstones, and siltstones.

Various authors, such as Sternberg (1950), Forsberg (2000), Franzinelli and Igreja (2002), Latrubesse and Franzinelli (2005), Silva (2005), Sarges (2008), Sarges et al. (2011), and Queiroz et al. (2024), point to evidence of a strong structural control of the main channel of the Negro River, as well as control by normal or transcurrent faults in various tributaries such as the Tarumã-Açú, Cuieiras, and Branco rivers. The river cliffs are controlled by a line of normal faults with a general NW-SE orientation (SILVA, 2005), which shows a direct interaction between the morphology and evolution of the five cliffs studied and local tectonic activity (Figure 09).

**Figure 09** - Structural lineaments in the study area




**Source:** COPDEM (2024); Sarges (2008); Silva (2005); Latrubesse e Franzinelli (2005); Queiroz et al. (2004). Elaborated by the authors (2024)

In addition, morphostructural lineaments with a predominantly NE-SW orientation can be seen in the main tributaries on the right bank of the Negro River (around the cliffs), which may indicate a greater tectonic influence on the morphology and evolution of the cliffs in the study area.

Silva (2005) observes that in the western part of Manaus, these lineaments are marked by a continuous N30-35W orientation, associated with the fault scarp on the left bank of the Negro River. Franzinelli and Igreja (2002) emphasize that the straightness and steepness of the banks are characteristics that show the tectonic orientation of these river valleys.

The right bank of the lower Negro River has a general N45W direction, suggesting a normal fault dipping to the northeast, which is in line with other well-defined normal faults on the left bank. These two fault regions (right and left banks of the Negro River) may indicate control of the channel by a graben or half-graben, with the river channel representing a lowered block. This dynamic was observed by Latrubesse and Franzinelli (2005) for the middle Negro River, in the Mariuá archipelago.

The normal faults that form the cliffs of the Negro River are fundamental to its morphology, dynamics and genesis. Normal faults occur when blocks of the crust move vertically in response to distensional stresses, creating the "lapa", which is the block of rock that lies below the fault plane and the "capa" is the block above (FOSSEN, 2017), which creates a steep "wall" above the water mirror of the Negro River, increasing the vulnerability to erosion of these forms.

This relationship also forms a deeper area in the Negro River due to the lowering of the block (Marinho et al., 2022) which increases the hydraulic pressure of the Negro River on the cliff (uplifted block), which increases erosion, especially in flood (Carvalho, 2012; Queiroz; Alves, 2021). In addition, the presence of normal faults can increase the instability of slopes by creating discontinuities in the rock mass, and the reactivation of faults is one of the conditioning factors of fluvial erosion in Amazonian rivers (Carvalho, 2012).

## 5 CONCLUSIONS

River cliffs are predominantly sculpted by the action of rivers and rainfall, but their formation and evolution involve a complex interaction of geological, environmental, and anthropogenic factors. This study contributes to a detailed understanding of the influence of geological structure and rock resistance on the morphology of these features, showing how these elements act as essential determinants of morphological evolution over time. In addition, by analyzing the role of tectonic activities, wind patterns, human interventions, variations in water levels, and rainfall rates, the research broadens the understanding of the multiple factors that control the dynamics of the cliffs.

The results reinforce that the continuous interaction between these processes shapes the cliffs in a progressive and dynamic way, with emphasis on the erosion process at the base of the slopes, which causes the upper layers to undermine and collapse, accelerating the transformation of these natural structures. This contribution makes it possible to identify potential areas at risk of landslides, providing important input for environmental monitoring strategies and the sustainable management of these regions.

## REFERENCES

ALBUQUERQUE, O. R. **Reconhecimentos geológicos no vale do Amazonas.** Boletim do Serviço Geológico e Mineralógico do Brasil, Rio de Janeiro: DNPM, n. 3, p. 84, 1922.

CAPUTO, M. V. **Stratigraphy, tectonics, paleoclimatology and paleogeography of northern basins of Brazil.** 1984. 583 f. PhD Thesis (Doctor of Philosophy) – University of California, Santa Barbara, 1984.

CARVALHO, J. A. L. **Erosão Nas Margens do Rio Amazonas: o Fenômeno das Terras Caídas e suas Implicações na vida dos moradores.** Tese - Programa de Pós-Graduação em Geografia. Niterói/RJ: Universidade Federal Fluminense, 2012.

EIRAS, J. F. et al. **Bacia do Solimões.** Boletim de Geociências da Petrobras, Rio de Janeiro, v. 8, n. 1, p. 17-45, 1994.

EMBRAPA – EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. **Sistema Brasileiro de Classificação de Solos.** 5. ed. Brasília, DF: Embrapa, 2018.

FILIZOLA, N. P. et al. **Variabilidade hidrológica na Amazônia: uma perspectiva para a elaboração do balanço hídrico regional.** In: ZAMUDIO, H. B. et al. (org.). Amazônia e água: desenvolvimento sustentável no século XXI. [S. l.]: Serviço Editorial da Unesco Etxea, 2009.

FOSSEN, H. **Geologia Estrutural.** Oficina das Letras, 2017.

FRANZINELLI, E.; IGREJA, H. L. S. Modern sedimentation in the Lower Negro river, Amazonas State, Brazil. **Geomorphology**, v. 44, p. 259–271, 2002.

FRANZINELLI, E.; IGREJA, H. Utilização de sensoriamento remoto na investigação da área do Baixo Rio Negro e Grande Manaus**.** In: Simpósio Brasileiro de Sensoriamento Remoto, 6., 1990. **Anais [...].** p. 641-648.

HOORN, C. et al. The Amazonian Craton and its influence on past fluvial systems (Mesozoic–Cenozoic, Amazonia). In: HOORN, C.; WESSELINGH, F. (ed.). **Amazonia:** Landscape and Species Evolution. Chichester: Wiley-Blackwell, p. 103–122, 2010.

IBGE – INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Cidades.** 2018. Disponível em: https://cidades.ibge.gov.br/brasil/am/iranduba/panorama. Acesso em: 21 jul. 2023.

KISTLER, P. **Historical Resumé of the Amazon Basin.** Belém: PETROBRAS–RENOR, 1954. (Relatório Técnico Interno, 104-A).

LATRUBESSE, E. M. Patterns of anabranching channels: The ultimate end-member adjustment of mega rivers**. Geomorphology**, v. 101, p. 130–145, 2008.

LATRUBESSE, E. M.; FRANZINELLI, E. The late Quaternary evolution of the Negro River, Amazon, Brazil: Implications for island and floodplain formation in large anabranching tropical systems**. Geomorphology**, v. 70, p. 372–397, 2005.

LATRUBESSE, E. M.; STEVAUX, J. C. The Anavilhanas and Mariuá Archipelagos: Fluvial Wonders from the Negro River, Amazon Basin. In: VIEIRA, B. C.; SALGADO, A. A. R.; SANTOS, L. J. C. (ed.). **Landscapes and Landforms of Brazil**. Dordrecht: Springer, p. 157–169, 2015.

MAIA, R.; AMORIM, R.; MEIRELES, A. **Falésias:** origem, evolução e risco. Fortaleza: Imprensa Universitária UFC, 2022.

MARINHO, R. R. **Integração de dados de campo e sensoriamento remoto no estudo do fluxo de água e matéria no Arquipélago de Anavilhanas, Rio Negro – Amazonas, Brasil.** 2019. Tese (Doutorado em Clima e Ambiente) – Universidade do Estado do Amazonas; Instituto Nacional de Pesquisas da Amazônia, Manaus, 2019.

MARINHO, R. R.; RIVERA, I. A. A precipitação estimada por satélite na bacia do Rio Negro, Noroeste Amazônico (1981–2017). **RAEGA –** O Espaço Geográfico em Análise, v. 50, p. 44–61, 2021.

MARINHO, R. R.; ZANIN, P. R.; FILIZOLA, N. P. The Negro river in the Anavilhanas Archipelago: streamflow and geomorphology of a complex anabranching system in the Amazon. **Earth Surface Processes and Landforms,** v. 47, p. 1–16, 2021.

MARINHO, R. R.; FURTADO, A. R.; SANTOS, V. C.; ZUMAK, A.; FILIZOLA, N. P. Riverbed morphology and hydrodynamics in the confluence of complex mega rivers - A study in the Branco and Negro rivers, Amazon basin. **Journal of South American Earth Sciences**, v. 118, p. 103969, 2022.

MARQUES, R. O. **Erosão nas margens do Rio Amazonas: o fenômeno das terras caídas e as implicações para a cidade de Parintins–AM.** 2017. 153 f. Dissertação (Mestrado em Geografia) – Universidade Federal do Amazonas, Manaus, 2017. Disponível em: http://tede.ufam.edu.br/handle/tede/5826. Acesso em: 7 jun. 2025.

MOLINIER, M. et al. Les Régimes Hydrologiques de l'Amazone et de ses Affluents**.** In: CHEVALLIER, P.; POUYAUD, B. (org.). **L'hydrologie Tropicale:** Géoscience et Outil Pour le Développement**.** Paris: IAHS, p. 209–222, 1996.

QUEIROZ, M. S. et al. Arquipélago de Anavilhanas: uma revisão das suas formas, processos e origem. **Revista Geonorte**, v. 15, p. 166, 2024.

QUEIROZ, M. S. Evidências de Neotectônica na Bacia Hidrográfica do Mindu – Manaus – Amazonas. **Revista Tocantinense de Geografia**, v. 9, p. 130–142, 2020.

QUEIROZ, M. S.; ALVES, N. S. Conditioning Factors of "Terras Caídas" in Lower Solimões River – Brazil. **Caminhos de Geografia**, v. 22, p. 220–233, 2021.

QUEIROZ, M. S.; CARVALHO, J. A. L. Geomorphological Characterization of the Tarumã-Açú Basin, Amazonas, Brazil. **Brazilian Geographical Journal**, v. 11, p. 113–125, 2020.

QUEIROZ, M. S.; SOUZA, K. C.; SILVA, G. M. Análise do microclima urbano do bairro do Coroado, Manaus, Amazonas. **Revista da Casa da Geografia de Sobral (RCGS),** v. 27, p. 42, 2025.

REIS, N. J. et al. **Geologia e recursos minerais do Estado do Amazonas.** Brasília, DF: CPRM – Serviço Geológico do Brasil, 2006.

SANTOS JÚNIOR, O. F. dos. Estabilidade de encostas e erosão. In: **Geotecnia do Nordeste**. 1. ed. Recife: Editora Universitária da UFPE, 2005. v. 1, p. 181–203.

SARGES, R. R.; SILVA, T. M.; RICCOMINI, C. Caracterização do relevo da região de Manaus, Amazônia Central. **Revista Brasileira de Geomorfologia**, v. 12, n. 1, 2011.

SILVA, C. **Análise da tectônica cenozoica da região de Manaus e adjacências.** 2005. Tese (Doutorado em Geociências) – Universidade Estadual Paulista – UNESP, Rio Claro, 2005.

SILVA, C. L. **Análise da Tectônica Cenozóica da Região de Manaus e Adjacências.** PhD Thesis – Universidade Estadual Paulista – UNESP, Rio Claro, 2005.

SOUZA, K. C. de. **Evolução morfológica das falésias fluviais da margem direita do Rio Negro – Iranduba, AM.** 2024. 110 f. Dissertação (Mestrado em Geografia) – Universidade Federal do Amazonas, Manaus, 2024.

STERNBERG, H. Vales tectônicos na planície Amazônica? **Revista Brasileira de Geografia**, 1950.

SUGUIO, K. **Dicionário de geologia sedimentar e áreas afins.** Rio de Janeiro: Bertrand Brasil, 1998.

***