ICG2022-711, updated on 08 Jun 2023
https://doi.org/10.5194/icg2022-711
10th International Conference on Geomorphology

Geological control and processes in tropical coastal cliffs: Insights from Morro Branco, northeastern Brazil

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Coastal cliffs are short-term recession features influenced by various mechanisms, such as wave action, rainfall, groundwater, beach geometry, tectonic, and lithology. In Northeastern Brazil, the coastal morphology is characterized by extensive coastal cliffs with modest altitudes (5-25 m) and variable distances from the sea (40-100 m). Among the most representative morphologies are Morro Branco coastal cliffs, located on the east coast of Ceará state, Brazil. These reliefs are composed of the Tibau Formation (±75 Ma), and semi consolidated sandstones of the Barreiras Formation (22-17 Ma), exposed along Brazil's equatorial and eastern coastal margins. The lithological profile presents four sandy claystone sedimentary facies, recognizable from base to top cliff as gray, red, white, and orange, arranged in different degrees of lithification. The main goal of this study was to identify the influence of mechanisms controlling the morphology of coastal cliffs in tropical environments, having as a case study the Morro Branco, NE Brazil. For this purpose, UAV surveys were carried out, together with analyses of rainfall and wave impaction in relation to geological conditions. The average rainfall of the study area (900-1000 mm) is about 40% higher than of coastal cliffs in temperate climates (500-700 mm), attesting to the importance of increased precipitation in erosive processes. In addition, structural analyses of coastal cliffs rocks indicate a scarcity of failures due to the low degree of sandstone consolidation. Despite their high dip angles (80° to 88°), the orientations of cliff line fractures do not coincide with fault systems, being restricted to the area adjacent to the cliff escarpment. The correlation between rainfall and the degree of sandstone consolidation shows that more significant recessions occur at clifftop and middle, coinciding with the orange and white colorations. In these areas, gullies develop along cliff instabilities, leading to intermittent flow-type mass movements. The resulting debris is transported by rainfall to the shoreline, feeding back the beach areas. A positive repercussion is observed at the base of the cliff, represented by the gray and red-colored facies, due to the high degree of consolidation in this region. While the gray coloration is related to the Tibau Formation, the red coloration may have its degree of consolidation linked to groundwater influence. Wave action is also a critical driving mechanism, contributing to the removal of small rock blocks (< 50 cm) in the most lithified sectors, occasioning the formation of cavities (0.2-2 m high) that widen and finally collapse due to moisture. Hence, retreat rates along the cliff base, middle and top diverged, with greater retreats at the clifftop and middle and positive repercussions at the cliff base. We conclude that wave action, slight variations in lithology, and high rainfall totals can be identified as elements that govern the coastal cliff's escarpment retreat in tropical environments.