# High-Elevation Savanna Landscapes in the Cordillera Central, Dominican Republic, Hispaniola

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## *Dambos* in the Caribbean?



*Headwater unincised savanna (*sabana*) landscapes in the Cordillera Central, Dominican Republic, have a vegetation cover dominated by the native tussock grass,* Danthonia domingensis. *Sites occur on gentle-relief upland surfaces approximately between 2000 and 2400 m, mainly in José del Carmen Ramírez National Park (JCR) and Juan B. Pérez Rancier National Park (JBPR). Surface and subsurface data from 1 site constrain regolith age overlying granitoid saprolite to <12,570 $^{14}C$ years BP. We conclude that the savannas studied are* dambos *that developed in response to environmental change during and after the Pleistocene–Holocene transition.* Dambos *elsewhere are widely regarded as reliable indicators of major Quaternary environmental change.* Dambos *have unique hydrological, ecological, scenic, and utilitarian attributes; their importance will increase with greater tourism, as will the concerns for their sustainable use. This first publication on* dambos *in the Caribbean signals the need for more research into their origin, evolution, and state of equilibrium.*

**Keywords:** Dambo*; savanna*.

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## Introduction

Small, treeless savanna landscapes occur on low- to moderate-relief uplands between 2000 and 2400 m that occupy low-relief topographic hollows and sideslopes without incised drainage lines in the Cordillera Central, Dominican Republic, Hispaniola (Figure 1; Table 1). These features lack previous scientific study despite their present and projected potential for basic and applied research. Sites are within José del Carmen Ramírez National Park (JCR) and Juan B. Pérez Rancier National Park (JBPR). Another savanna, El Valle de Bao in Armando Bermúdez National Park (AB), which borders JCR on the north, differs in climatic and geomorphic history and will be treated elsewhere.

The JCR sites are the Sabana Macutico principal site and the savannas to the northwest and west along the mule trail between the *refugios* of Macutico and Alto de la Rosa (Table 1). Trails are the only land transportation link in this area, creating logistical limitations for research. The Macutico site and other savannas in JCR and JBPR bear striking similarities with geomorphic features described in the literature as *dambos. Dambo* is a Bantu term meaning "meadow grazing" and is extensively used to describe streamless, low-relief hollows and other low-slope-order grassland landforms in the plateau-like African uplands, dominantly south of the Equator to about 25° S (Mäckel 1974, 1985; Acres et al 1985; Boast 1990). Ackermann (1936) introduced the term *dambo* into scientific literature to describe channelless grass-covered openings in dry forest or bush vegetation that connect down-gradient to incised drainage systems. He restricted the term to headwater areas, excluding terraces but including areas inundated only during the rainy season. Classic areas occur in Malawi and Zambia (Boast 1990) and in the bordering countries. Other terms for these features include *vleis*—forms the senior author observed in The Union of South Africa. *Dambos* may also exist in southern India and in South America (Boast 1990).

With increasing tourism, Dominican savannas will assume increasing importance despite their small areal extents in these montane landscapes (<1%). Savannas provide siting for *refugios* and grazing areas for mules, and constitute a tourist attraction. Although the preponderant vegetation is *Danthonia*, additional plant species are found that are either absent in the forest or occur sparingly. Savanna preservation may be necessary for survival of rare plant species and possibly endan-

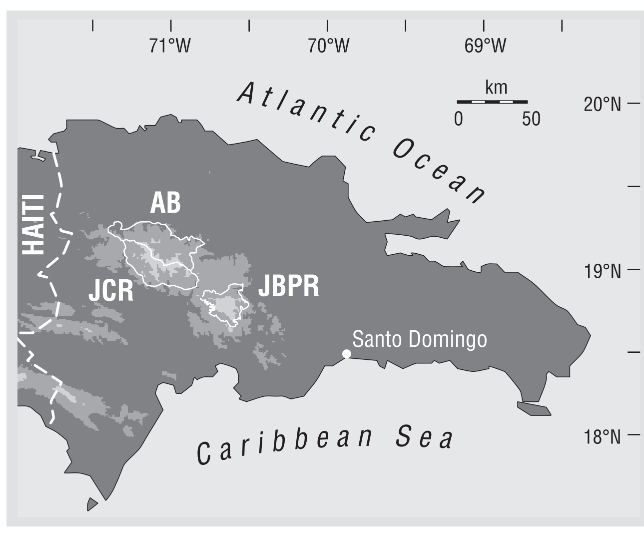


**FIGURE 1** Locations of JCR on the drier southwestern side of the topographic crest of the Cordillera Central, containing high-elevation savanna landforms. AB is on the northeastern side of the divide. The former Valle Nuevo Scientific Reserve, now Juan B. Pérez Rancier National Park (JBPR), a plateau-like upland separated from the Cordillera Central by a lowland, also contains a high-elevation savanna landscape assemblage. Elevation range shading: darkest shading = 0–1000 m; intermediate shading = 1000–2000 m; lightest shading (almost all within parks) = >2000 m.

**TABLE 1** Locations and elevations for selected savanna localities interpreted to be *dambos* on the southern flank of the Cordillera Central in JCR, and in JBPR. UTM Northings and UTM Eastings are field GPS readings except for JBPR sites Sabana Quéliz and Cerro de Sabana de la Cruz, which are from map grid data.

| Site name (see map, Figure 1) | UTM Northing | UTM Easting | Elevation (m asl, map) |
|---|---|---|---|
| JCR: Sabana Macutico | 2,105,503–2,105,640 | 281,459–281,534 | 1980–2000 |
| JCR: Sabana de los Boquerones | 2,106,565–2,107,768 | 277,721–279,059 | 2200–2240 |
| JCR: Sabana del Pino | 2,108,177–2,108,241 | 277,786–277,811 | 2320–2340 |
| JBPR: Valle Nuevo | 2,080,555 | 322,754 | 2300–2360 |
| JBPR: Sabana de los Robles | 2,080,479 | 323,645 | 2272–2360 |
| JBPR: Sabana Quéliz | 2,075,400–2,075,600 | 264,000–269,000 | 2260–2300 |
| JBPR: Cerro de Sabana de la Cruz | 2,074,500–2,074,700 | 281,000–286,000 | 2240–2260 |
| JBPR: Nizao | 2,070,791 | 330,185 | 2300–2380 |
| JBPR: La Nevera | 2,069,010–2,069,144 | 330,940–331,017 | 2260–2380 |

gered animals such as the large rodent *hutia* (Bolay 1997). Thus, the present and projected future importance of highland savannas cannot be overemphasized.

In this article we assess tectonic and climatic environments of these savanna landforms, characteristics of their landforms and regolith, and what is known of their historic, geomorphic, and ecologic environments. We then address the problems of classification and genesis and provide evidence that these features constitute two major types of *dambos*.

## Study area and description

### Introduction

The savannas have an essentially continuous vegetation cover of tussock grass (*Danthonia domingensis* Hack. & Pilger) in predominantly well-drained areas, and sedges and shrubs such as *Rubus* in poorly drained sites. Upvalley areas and sides of the treeless savannas are abruptly bordered by pure to nearly pure stands of the native West Indian pine (*Pinus occidentalis* Swartz). Down valley, savannas terminate at major topographic breaks, such as intersections with local perennial streams or small rivers.

Savannas occur in an intermediate altitudinal landscape belt between 2 other distinctive major landscape assemblages. Below 1500 m is an altitudinal belt with deeply incised, low-sinuosity, feral relief landscapes, typical of Caribbean montane environments (Ahmad et al 1993; Orvis et al 1997, figure 8, p 327). Above the savanna landscape belt are the high-peak areas with steep slopes, bedrock exposures, and blocky regolith. The intermediate savanna-containing landscape belt is composed of composite fluvial and hillslope terrains that respond dynamically to major precipitation events. Typical hillslope regoliths beneath these terrains are ancient, deeply weathered, saprolite profiles undergoing exhumation, and complex surficial diamicton deposits. Stream and small-river floodplain and terrace landforms are underlain by poorly to well-sorted coarse alluvium.

### Tectonic geology and lithology

In the Dominican Republic the Cordillera Central is within the Greater Antilles Deformed Belt (Case and Holcombe 1980) or Greater Antilles Orogenic Belt (Draper et al 1994), an active 150-km-wide strike-slip zone forming a major part of the northern Caribbean Plate boundary. Main Cordillera Central uplift phases may have occurred in the Plio-Pleistocene (Lewis et al 1991). But Lewis et al (1990, p 101) note subsurface stratigraphic evidence in Valle del Cibao (Cibao Basin), north of the Cordillera Central, that suggests rapid Cordillera Central uplift in Early Miocene time. The present combination of dynamic and erosional relief produced is extreme for the Caribbean.

The Macutico site and related savannas in JCR are within the Tireo Stratigraphic Tectonic Terrane, containing Cretaceous lavas and tuffs with intercolated mudstone, siltstone, chert, and limestone. Most of these rocks have been metamorphosed to varying grades (Draper and Lewis 1991). Several large, unfoliated granitoid stocks and batholiths, mainly hornblende tonalites (Lewis et al 1990), intruded the volcaniclastic rocks and lavas between Late Cretaceous and Late Eocene times. These plutons and spatially associated rocks underlie the known savanna areas we traversed in JCR (Draper and Lewis 1991, figure 1, p 30).

The other area with savanna landforms and vegetation is JBPR, about 60 km southeast of the Cordillera Central High Peaks area (Figure 1) and separated from it by a lowland. The central part of the JBPR is a plateau-like upland, where Tireo rocks composed of tuff, limestone, and rhyolite are unconformably overlain by apparent mid-Tertiary conglomerates that are intruded by andesites and overlain by Plio-Pleistocene tuffs and basalts (Lewis et al 1991). It is unknown whether areas occupied by the main Cordillera Central to the northwest had a covermass of sedimentary rocks or sediments during the early to mid-Tertiary.

### Present-day climate

The Cordillera Central forms an orographic barrier to the northeast trade winds and to trailing midlatitude fronts in winter. Vegetation patterns on the northern, windward flank indicate that precipitation in that area increases with elevation below the trade wind inversion at 2000–2500 m, then decreases. Summits are relatively arid. On the southern, leeward flank the maximum moisture appears to narrowly coincide with the cloud belt near 2400 m and decreases rapidly downslope.

Precipitation means at foothill stations south of the Cordillera, despite a stronger tropical storm component, are about 45% of those to the north (Horst 1992). But periods of prolonged precipitation do occur, and precipitation during hurricanes can be extreme. Thus the overall geomorphic effectiveness of precipitation on the southern flank of the Cordillera Central may be very significant over time, despite low annual means.

Surface air temperature decreases markedly with increasing elevation. Horst (1992) reported an annual mean of 25.5°C at Santo Domingo (sea level), 21.5°C at Jarabacoa (529 m), and 18°C at Constanza (1164 m). Air temperatures below freezing occur in all months at all known sites approximately above 2100 m (Pedersen 1953) and at least as low as 1800 m, where cold air drainage is trapped. We are unaware of any records of snow cover, although local guides report the frequent occurrence of hailstorms, and hail may temporarily cover the land surface. Arctic air mass outbreaks reach Hispaniola on rare occasions, producing mountain temperatures at least as low as -8°C under dramatically clear skies.

## Methodology

The principal research site, Sabana Macutico JCR is an incisionless savanna in Macutico (Figure 1; 19°02′ N, 71°05′ W; 1980–2000 m), about 3–8 km west–southwest of and 1000 m lower than the High Peaks altitudinal zone (Pico Duarte, 3102 m; Loma la Pelona, 3097 m; and adjacent peaks, >2500 m). The site occupies a small, low-gradient streamless valley trending down-gradient about 200 m to the NE, then about 300 m to the

| Horizon | Depth (cm) | Color (moist) matrix | Color (moist) mottles | Field texture (moist) |
|---|---|---|---|---|
| **O** | 0–2.5 | 2.5Y/2/0 | NA | Clay |
| **$A_1$** | 2.5–15 | 7.5YR/2/0 | NA | Silty clay |
| **$A_2$** | 15–33 | 10YR/3/4 | NA | Sandy clay loam |
| **$A_3/B_1$** | 33–46 | 10YR/4/4 | 10YR/6/8 | Silty clay loam |
| **$B_2$** | 46–61 | 10YR/5/8 | NA | Silty clay loam |
| **$B_3$** | 61–86 | 7.5YR/5/6 | NA | Sandy loam |
| **$B_4$** | 86–97 | 7.5YR/5/8 | NA | Clay loam |
| **$B_5$** | 97–132 | 10YR/5/8 | 10YR/6/4 | Clay loam |
| **$B_5/C$** | 132–155 | 7.5YR/5/8 | 10YR/7/8 | Loam |
| **$Cr_1$** | 155–173 | — | NA | — |
| **$Cr_2$** | 173– | — | NA | — |

**TABLE 2** Soil pit field description for Macutico Sabana. Field soil profile descriptions follow established guidelines (Soil Survey Division Staff 1993; Schoeneberger et al 1998; Soil Survey Staff 1999).

**FIGURE 2** Approximate lower half of length of Sabana Macutico, January 1999. View is down gradient toward termination of savanna at its truncation by the channel of upper Río Macutico (in trees, at base of near ridge, photographic center). Small fanlike features can be seen entering the savanna on the left and right sides of the view. Debris slide scars on ridges date from Hurricane Georges (22 September 1998–23 September 1998, Class IV). (Photo by G. M. Clark)

| Structure | Consistency | Boundary | Clay films | Rock fragments | Other features |
|---|---|---|---|---|---|
| Loose | Loose | Very abrupt | None | None | Charcoal dominant |
| Fine weak subangular blocky | Loose | Diffuse | None | None | — |
| Fine subangular blocky | Friable | Diffuse | None | About 1% | — |
| Fine subangular blocky | Friable | Diffuse | On ped faces | About 25%, very angular | Very abundant rock fragments |
| Fine weak subangular blocky | Friable | Diffuse | On ped faces and sand grains | None | Abundant charcoal |
| Fine weak subangular blocky | Friable | Diffuse | On ped faces and sand grains | None | — |
| Fine weak subangular blocky | Friable | Abrupt | On ped faces and sand grains | About 6% | Charcoal |
| Fine weak subangular blocky | Friable | Abrupt | On ped faces and sand grains | None | Charcoal uncal. $^{14}C$ date 12480 +/- 85 |
| Fine weak subangular blocky | Friable | Abrupt | On ped faces | Very stony, rounded fragments | Basal 8 cm very stony |
| — | Very firm | Abrupt | — | — | Soft granitoid saprolite with minor metabasaltic fragments |
| — | Extremely hard | Diffuse | — | — | Firm saprolite with minor metabasaltic fragments |

NW, then terminating at right angle to the headwater drainage of Río Macutico (Figure 2).

In March 1996 we used a tubiform root auger (Horn et al 1994) and took two 10-cm-diameter soil cores in 5-cm-depth intervals to 50 cm. Because charcoal >2 mm was present in every interval, and a radiocarbon calibrated age range from one of the cores of 11,060–10,290 cal years BP (2σ range) was obtained at the 45- to 50-cm-depth interval (Horn et al 2000), we investigated this savanna in further detail. In January 1999 a soil pit 0.75 × 2.4 × 1.75 m deep was excavated with hand tools in the medial position of the savanna. We also took an additional tubiform root auger core to a depth of 95 cm and excavated deeper samples with a soil auger. Geomorphic field procedures followed techniques given by Goudie (1990). Field soil procedures followed established guidelines (Soil Survey Division Staff 1993; Schoeneberger et al 1998; Soil Survey Staff 1999).

## Results

### Sabana Macutico

Sabana Macutico has low-gradient, concave-up cross sections and even gentler longitudinal profiles. Incision is lacking, and smoothness dominates the microtopography. With the exception of several boulders, the savanna soil surface is free of large rocks.

The 1999 tubiform root auger core segments contained charcoal in all sample intervals but one (30–37 cm) to a depth of 93 cm (Horn et al 2000, table 1: core 3). Sampling continued to greater depth with the use of spoon augering, reaching an interval of deeply weathered granitoid parent soil material (10YR/5/8) at 142–154 cm. Refusal was reached at 154–164 cm at the base of the next change in regolith to granitoid saprolite (10YR/5/8, with mottling, 10YR/8/4).

The soil pit exposed a solum overlying weakly stratified soil parent material overlying saprolite-derived grus overlying saprolite (Table 2). Soil parent material is interpreted as locally transported surficial sediment, probably emplaced by sheetwash (see Mäckel 1974). Soil profile development is moderate, evidenced by clay translocation into B-horizons. Winter soil temperature (22 January 1999) at 1-m depth averaged 13.3°C. The site's estimated mean annual air surface temperature is about 14°C at 2000 m, derived from the mean annual lapse rate (Dominican Republic temperature records, Orvis et al 1997, p 325), indicating a mesic soil temperature regime. The moderate degree of soil development at the site is consistent with drainage, the radiocarbon ages obtained, and available soil temperature and precipitation data.

Effects of intense precipitation events on the sabana surface are minimal, to judge from the paucity of effects of Hurricane Georges (22 September 1998–23 September 1998, Class IV). Modifications to Sabana Macutico occurred at its downslope terminus with Río Macutico, with channel entrenchment and overbank deposition along the reach crossing the terminus of the sabana. Older, coarse overbank alluvium, vegetation disturbance, and coarse, poorly sorted terrace gravels in the transition zone between the lower end of the sabana proper and the near river bank indicate a similar history.

### Other savanna areas

Other savannas studied in JCR and JBPR from 1995 to 1999 (Table 1) have similar vegetation and ecotone contrast with bordering forest environments, but some landforms vary to some extent from those of Sabana Macutico. Two types of savanna landform variation occur. Valley head savannas are low-relief, gently concaving upward incisionless valleys that slope toward modern drainage lines (eg, up-gradient areas of La Nevera and Nizao, JBPR). More common are the topographically more diverse sideslope savanna landscapes consisting of interspersed nose, sideslope, and hollow landforms with somewhat steeper slope gradients (eg, Sabana de los Boquerones, Sabana del Pino, JCR). In Africa, *dambo* siting and orientation are linked to fracture patterns in the underlying bedrock (Giardino and Mäckel 1985; Whitlow 1985). Bedrock fracture effects on Dominican savanna location and orientation may exist, but the observed bedrock exposures were insufficient for evaluation. Most forms lack fluvial incision, and slope breaks and channel incisions occur only at or near down-valley ends of savannas at incised fluvial networks. Effects of Hurricane Georges that were visible in January 1999 were confined to such preexisting fluvial channels and their margins.

The additional savannas observed on the dry southern flank of the Cordillera Central in JCR are of the sideslope type (Orvis et al 1997, figure 7, p 327). Bedrock underlying these savannas is mapped as the granitoid Macutico Batholith complex and related rocks (Draper and Lewis 1991, figure 1, p 30). Where exposed or sampled by tubiform root auger coring, augering, and shallow soil pits, the underlying regolith is of local provenance, although not residual until massive subsoil and saprolite are reached. Typical sections of the modern soil have histic surface and near-surface soil horizons underlain by mineral soils. Where reached, the underlying parent material is weathered granular rock.

Both valley head and sideslope savannas occur in JBPR. Mineral soil underlies histic surface and near-surface horizons, and deeper soil parent material typically is cobbly to bouldery regolith ranging in weathering state from moderately weathered to totally decomposed.

## Discussion

The following synopsis emphasizes African *dambo* properties as described in the literature and comparisons with and contrasts against savanna characteristics in JCR and JBPR.

Most of the reported climates in African regions with *dambo* morphology exhibit pronounced seasonality with average annual precipitation of 800–1500 mm and a high recurrence interval of intense precipitation events (Bond 1967; Mäckel 1974) with resultant geomorphically effective sheetfloods (Thorbecke 1973). Except in areas where *dambos* are increasing their areal extent (usually headward), abrupt demarcation lines exist between bordering arboreal vegetation and grassy near-level *dambo* floors. Although other factors are cited, sharp contacts between grassland and the surrounding woodland are most commonly attributed to poor soil drainage in the *dambos* (Meadows 1984; Acres et al 1985; Whitlow 1985), as evidenced by the surface wetness and widespread existence of organic-rich horizons (Mäckel 1974; Meadows 1984). Wide soil texture variations are reported in African soil descriptions and reflect underlying and bordering rock types. Sandy textures are characteristic of *dambo* soil profiles derived from quartzite, granitic, and gneissic parent rock materials derived from bedrock beneath many African *dambos* (Meadows 1984; Acres et al 1985; Whitlow 1985).

Acres et al (1985) gave a 4-fold geomorphic classification of *dambos* that emphasized landscape position. These categories are headwater *dambos* with extremely gentle gradients; slope *dambos* that extend up the valley sides with greater slope gradients; hanging or scarp *dambos* on plateau edges; and river *dambos*, with flanking terraces due to subsequent fluvial incision. Savanna features in JCR and JBPR best fit their models of headwater *dambos* and slope *dambos*. Sabana Macutico is an excellent fit with the headwater *dambo* type, whereas several other savannas such as the Sabana de los Boquerones and Sabana del Pino in JCR fit descriptions of the slope *dambo* category. We, therefore, interpret these savannas to be *dambos*.

Most *dambo* sites in both major areas of the Dominican Highlands were not waterlogged during our observation periods (February 1995; March 1996; February 1997; May 1997; July 1998; January 1999–February 1999). Exceptions include small blockages behind levee-like features (Valle Nuevo site, JBPR) and small fans (Macutico site, JCR). But good drainage for pine forest growth may not always have existed or may not exist the year round. Histic surface horizons are common and may partly be relicts from earlier wetter conditions, raising an unanswered question about whether or not some *dambo* features are relict.

Given its long history and apparent frequency (Horn et al 2000), fire is likely a major influence on savanna vegetation development and its interactions with the surficial geomorphology. Several prehistoric charcoal dates and common historic occurrences of lightning strikes and droughts in the pine forest suggest that many fires may be natural. Macroscopic charcoal (>2-mm sieve catchment) is present in all but 2 depth intervals in the 3 Sabana Macutico soil cores, and one of these intervals is at the base of the deepest core (93–95 cm, Horn et al 2000). During recent widespread fires in JCR and JBPR, complete burning of *Danthonia,* but with little mortality, occurred in many sites—bogs and other wet areas excepted. Abundant charcoal was produced during burns, and the *dambos* have burned in the past, as evidenced by abundant subsurface charcoal in the Macutico *dambo* and other investigated sites (Horn et al 2000). Frost may also inhibit pine invasion into the *dambos*. In the Haitian savannas of Acani, Boujcan Pierre, Phillipe, and Pistache between 1524 and 1829 m, frost killed seedlings and injured saplings of *P. occidentalis* during the winter of 1950–1951 (Pedersen 1953). Severe effects occurred in open low-slope gradient areas in pine plantations with poor air drainage and were rare on land with intermediate to high slope gradients. A Forest Division meteorological station at 5500 feet (1676 m) reported temperatures of 24°F (-4°C) in January and 27°F (-2°C) in February (Pedersen 1953). Temperatures as low as -8°C are reported in the Dominican Highlands, and we observed morning frost on *Danthonia* in savannas on several occasions during 1999. Human effect on *dambo* development is probably minimal–highland activity comprised only cattle grazing and lumbering, and in JBPR, limited agriculture immediately before park establishment.

## Conclusions

Dominican savannas that we interpret to be *dambos* have an abrupt contrast in vegetation—from bordering pine forest cover on hillslopes to grass-dominated vegetation—that is remarkably similar to the reported characteristics of African *dambos*. Topography upslope from the ecotone does not markedly differ from that at the boundary. Judging from surface and near-surface rock fragments, soil parent rock material is visually identical to that in the savannas. Other factors, for example, ponding of cold air drainage and subsurface hydrology, apparently have dictated formative savanna environments, and those processes must have differed markedly from conditions in the bordering forest. Hillslope expression is more variable. Gentle concave-upward transverse profiles and low longitudinal gradients characterize most savannas, but more complex shapes occur. In map view, straight trends and sharp angular bends suggest the influence of bedrock fracture patterns.

*Dambos* are widely regarded as strong indicators of major Quaternary environmental change, and their origins may be linked to such instability (Meadows 1985; Thomas 1994). A speculative chronology has the Late Pleistocene–Holocene transition open with rain-shadow montane aridity, enhancing the prospects for fire, slow vegetation recovery, and slopewash. Abundant evidence of prehistoric fires is preserved in Dominican *dambo* sediments, although definitive links to climatic variation are not yet established (Horn et al 2000). Recolonization of *dambo* floors by pine seedlings on open areas could be inhibited further by severe frost accompanying outbreaks of northern cold air masses.

The present and projected future importance of highland *dambos* cannot be overemphasized and must be brought forth in Dominican National Park plans for sustainable mountain development. Research will be necessary for further understanding of the origin, evolution, and present state of stability of *dambos* in the Cordillera Central. Subsurface information is especially needed to assess the 3-dimensional nature of the regolith-weathered bedrock surface and to study the effects of *dambo* formative process mechanisms that operate underground.

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