Correspondence

Comment: Late Quaternary deglaciation history of the Mérida Andes, Venezuela


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Introduction

In a recent paper in the Journal of Quaternary Science (20: 801–812) Stansell et al. (2005), hereafter referred to as ‘the authors’, described the late Quaternary history of the Mucubají-Mucuñuque valley in the northwestern Venezuelan Andes, an important locality for ice age reconstructions first recognised by Jahn and others (e.g. Jahn et al., 1925) and later elucidated by Schubert (1974). In an attempt to reconstruct the palaeoclimatology of the area and especially its deglacial history, the authors analysed sediments (primarily cores) recovered from one lake and three bogs/palaeolakes in the Mucubají catchment plus six additional lakes in the region as proxy records of glacial activity. The authors claim their results build upon previously published results from the region. While it has long been recognised that the authors’ reconstruction of glacial events in the Mucubají valley, many of which have been previously documented. As discussed below, limitations also arise owing to incorrect interpretation of sedimentological evidence, especially from the upper Mucubají catchment. Finally, minor omissions in Stansell et al. (2005) fail to give a fuller picture of just how the methods used were applied to the various analyses/interpretations. For example, Munsell colour is noted as important in the methods, but no mention is made of colour analyses/interpretations. For example, Munsell colour is noted as important in the methods, but no mention is made of colour susceptibility (MS) of these sediments with glacial activity in the discussion, nor is any explanation offered as to how it may indicate glacial activity. With regard to organic content, the authors refer to loss on ignition (LOI) tests at 550°C, but over what time interval? Testing sediments for organic content may indicate glacial activity. With regard to organic content, the authors refer to loss on ignition (LOI) tests at 550°C, but over what time interval? Testing sediments for organic content at temperatures as high as 550°C is known to give erroneous results, and according to NSSC standards 400°C 15 hr⁻¹ gives values considered much closer to actual organic matter content (NSSC, 1995).

Discussion

The authors’ reconstruction of glacial events in the Mucubají valley begins with a depiction of LGM conditions during which glacier ice filled the valley to the prominent latero-frontal moraine system situated ~3500 m a.s.l. (Fig. 1). The duration of maximum ice extent is reported as 22750 cal. yr BP to 19660 cal. yr BP (ca. 19080–16500 14C yr BP) based on outwash deposits and bracketing lacustrine sediments and peats, identified by Schubert and Rinaldi (1987) in the nearby La Cañada drainage basin (Fig. 1, Site 1). While the original interpretation of these sediments (Schubert and Rinaldi, 1987) is sound, application by Stansell et al. (2005) is complicated by the fact that the outwash site described is not adjacent to the Mucubají valley. Schubert and Rinaldi (1987) believed that meltwater entered the basin as seepage or via an unidentified...
breach in the El Caballo left lateral moraine (Fig. 1). Subsequent work, including fabric analysis, on a broader cross-section of La Cancha (also referred to as the Pedregal basin) deposits (Mahaney and Kalm, 1996; Mahaney et al., 2001, 2004; Dirszowsky et al., 2005) suggests that northward directed meltwater and sediment originated in the Mucuchache valley to the west, possibly through a moraine breach identified in the field to the southwest of the basin. The ~8 km long Mucuchache valley would have supported a much larger glacier than either the El Caballo or Mucubají valleys, subject to differences in the timing of advance/retreat and meltwater production.

Given the plethora of data collected and published on the outwash ‘fan complex’ now exposed by the Quebrada La Cancha, it is rather surprising that Stansell et al. (2005) interpret the basin to have derived its water volume and sediment load from the Mucubají valley some 2.5 km distant to the east. Topographic relationships evident in the field and in Fig. 1 clearly indicate that meltwater discharge emanating from the

Figure 1  Map of the Mucubají area, northwestern Venezuelan Andes showing the correct position of Mesa del Caballo, the Pedregal basin, the recessional moraines above Laguna de Mucubají, fault strands, and sites discussed in the text: (1) Pedregal basin outwash (Schubert and Rinaldi, 1987); (2) recessional moraine bog (Stansell et al., 2005); (3) Mucubají terrace (Salgado-Labouriau et al., 1977); (4) lateral moraine bog (Stansell et al., 2005)
Mucubají valley via the (breached) west side terminal moraine could not have entered the La Cañada catchment for any length of time. Instead, rapid downcutting lead to the formation of a deeply incised spillway directed north of the Mesa del Caballo, and now occupied by Quebrada La Bejino’s.

Stansell et al. (2005) estimate principal retreat of ice from the lower Mucubají valley to have occurred by ca. 15730 cal. yr BP (13270 14C yr BP) based on ‘incipient organic sedimentation’ within a core obtained just up-valley of the uppermost recessional moraine (~3650 m a.s.l.; Fig. 1, Site 2). It should be noted that the dated organic layer (10 cm in thickness) occurs within the upper quarter of a ~380 cm thick lacustrine or glacio-lacustrine sediment package comprising thinly bedded silts and sands (apparently deposited over till). Closely related 14C-dated palaeolake sediments exposed in the nearby ‘Mucubají terrace’ (Salgado-Labouriau et al., 1977; Mahaney et al., 2007; Fig. 1, Site 3) and similar sediments in the La Cañada basin (Mahaney et al., 2004; Dirszowsky et al., 2005) indicate early postglacial lacustrine sedimentation rates on the order of 0.35 cm yr−1, implying that glacier retreat from the recessional moraine bog site (i.e. a moraine dammed lake) occurred somewhat earlier (ca. 900 yr) than the date reported by Stansell et al. (2005). The occurrence of organic-rich clays and/or peat layers in these sediments may in part be a function of sediment influx and redistribution in the lake; however, it is just as likely related to hydro-climatic (i.e. water balance) fluctuations leading to temporary shallow water conditions (Dirszowsky et al., 2005). Therefore, while the Mucubají glacier may have fluctuated up-valley of the recessional moraine bog and terrace sites from 14859 to 13830 cal. yr BP (12650 to 11960 14C yr BP) as reported by Stansell et al. (2005), the variations in peat versus lacustrine sediments (or organic content in general) observed are not a reliable indication of glacial/nonglacial activity in this case.

The authors’ statement that the above recessional moraine bog site sediments contain ‘no evidence of erosion by subsequent glacier readvances’ (Stansell et al., 2005: 809) is important considering their later interpretations of the upper core and of additional bog sediments cored just down-valley of this site on the outer flank of the prominent right lateral moraine (Fig. 1, Site 4). Based on a transition from inorganic to organic (peat) sediments near the base of their lateral moraine core, the authors propose a glacial readvance (to) and retreat from this down-valley position just prior to 9500 cal. yr BP (8500 14C yr BP). This interpretation would require an ice mass large enough to pass sediments over the moraine crest and perhaps as substantial as that originally occupying the lower valley. Given the lack of disturbance (erosion or deformation) in the up-valley bog sediments described previously, the likelihood of such a readvance would appear to be small. It is more likely that the inorganic materials (interbedded cobbles and coarse sand) at the base of the authors’ 190 cm core simply represent a debris flow or other slope deposit (which no doubt limited coring), whereas the onset (or continuation) of peat accumulation may have been hydrologically or climatologically controlled (i.e. reduced decomposition due to increased moisture and/or decreased temperature).

The authors’ supporting evidence for a significant early Holocene glacial readvance/retreat, based on lake sediments sampled down-valley (Laguna de Mucubají) and in an adjacent valley to the east (Laguna Negra) is similarly flawed. The relatively sharp transition from thinly banded silts and sands to banded organic clays in Laguna Negra (~3473 m a.s.l.) dated to ca. 10000 cal. yr BP (8910 14C yr BP) may well indicate reduced sediment influx related to glacier retreat in the catchment, but it says nothing about the elevation reached by the ice—the inorganic sediments in their core are lacustrine not glacial. The related suggestion that glacier retreat is indicated by gradually decreasing clastic sedimentation (and MS) in Laguna de Mucubají for a time leading up to 8200 cal. yr BP (7380 14C yr BP) obviously depends on the previous interpretation of readvance and again on the assumption that inorganic sediments are glacially derived. Unfortunately this interpretation does not account for the lack of any obvious increase in clastic sedimentation at depth that might correlate with the proposed readvance itself, nor does it explain the very pronounced increase in clastic sedimentation just after 8200 cal. yr BP. The already low and decreasing inorganic content leading to 8200 cal. yr BP would seem to confirm that ice had remained up-valley of the recessional moraine bog and terrace sites and was likely continuing to shrink around this time.

Given the previous arguments, the authors’ claim that ice retreated up-valley of the recessional moraine bog and terrace sites ca. 6280 cal. yr BP (5470 14C yr BP) is moot. The shift from inorganic lacustrine (not glacial) silts to peat in the recessional moraine bog site core at this time, once again, need not indicate glacial activity. Climatically or hydrologically induced lake-level fluctuations and eventual lake drainage as the recessional moraine dam was cut down by outflow, readily explain the observed transition (and need to be accounted for in any interpretation of these materials). The related claim that glacier retreat from the recessional moraine sites coincides with another reduction in clastic sedimentation in Laguna de Mucubají ca. 6250 cal. yr BP (5455 14C yr BP) is also problematic, since it would imply, according to the authors’ reasoning, significant glacial advance during the preceding 2000 years (based on elevated clastic inputs ca. 7380–5455 14C yr BP). While the authors do not make this inference, neither do they explain the elevated sediment inputs, which are most likely related to tectonic/geomorphic processes in the catchment. The Mucubají terrace site occurs about 80 m south (upstream) of a conspicuous splay of the Bocón Fault system (Salgado-Labouriau et al., 1977, 1992; Audemard et al., 1999; Mahaney et al., 2007) exhibiting vertical displacement of ~6 m. Relative uplift of the up-valley surface and associated increases in stream gradient have led to down-cutting and remobilisation of bog and palaeolake sediments comprising the terrace. While it is uncertain at this time whether uplift/downcutting occurred as a single event or episodically, one 14C date from upper terrace level fluvial sediments (Mahaney et al., 2007) indicates that incision was under way some time ca. 6455 ± 70 14C yr BP (7370 ± 70 cal. yr BP) (BGS-2245), coincident with increases in clastic sedimentation in Laguna de Mucubají after 7380 ± 100 14C yr BP (8200 cal. yr BP). It is possible that several observed increases in clastic sedimentation and MS in Laguna de Mucubají correspond to phases of fluvial incision of these upper catchment sediments.

It stands to reason that if Late Pleistocene/early Holocene interpretations of deglaciation are incorrect, then later Holocene interpretations based on the same evidence may be similarly faulty. Pollen records from the region have previously shown that vegetation and climate have remained similar to today through most of the Holocene (Salgado-Labouriau et al., 1988, 1992) with cold events occurring ca. 6000–5300 14C yr BP (‘La Caluta Cold/Dry Phase’; Salgado-Labouriau and Schubert, 1976) and in the 11th to 14th centuries (‘Piedras Blancas Cold Phase’; Salgado-Labouriau, 1989), and relatively warm conditions occurring ca. 2700–2500 14C yr BP (‘Miranda Warm Phase’; Salgado-Labouriau et al., 1988). The second cold phase has been correlated with the Little Ice Age (Salgado-Labouriau, 1989; Rull et al., 1987) and with moraines present at upper elevations of the Sierra Nevada de Mérida (Humboldt massif) ~40 km to the southwest (Schubert, 1972, 1998).

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While there is an apparent correlation between the two palynologically inferred cold events and elevated clastic sedimentation and MS in Laguna de Mucubají, it should be emphasised that most clastic sedimentation/MS peaks in this record occur during 'average' climatic conditions (i.e. ca. 7400–6000 14C yr BP and ca. 4100–2700 14C yr BP), and in one case (ca. 2600 14C yr BP) during a known warm period. Considering the uninterrupted records of peat (non-glacial) accumulation reported by Stansell et al. (2005) from the Páramo de Piedras Blancas and Páramo el Banco (~16 km to the northwest of Laguna de Mucubají and ranging from 4170 to 4366 m a.s.l.) since ca. 15 010–9360 cal. yr BP (12 740–8350 14C yr BP) and indicating glacial retreat/disappearance there, it would seem unlikely that ice advanced substantially below these elevations in the Mucubají valley during the Holocene.

The authors’ reference to ‘Little Ice Age moraines in the Mucubají cirque’, based presumably on Polissar et al. (2006), and their further assertion that this ‘indicates the sensitivity of this catchment to Holocene glaciation’ are particularly astounding and reveal a lack of familiarity with the physical environment of the Mucubají catchment, since no LIA moraines exist there (reconnaissances by Mahaney and Kalm between 1994 and 2001). Presumably we (Mahaney and Kalm) might have inadvertently overlooked some evidence of LIA glacier oscillations in the upper Mucubají valley, but our logs show only bedrock, associated avalanche couloirs and mass-wasted debris below the high ridge of Pico Mucun˜uque (4609 m a.s.l.), and valley floor surfaces above ~3800 m a.s.l. laced with a variety of thin discontinuous glacial meltout sediments, very inconsequential ground moraine, fluvial sediments and talus.

Conclusions

It appears that considerable disagreement exists between the palaeoenvironmental interpretations of Stansell et al. (2005) and various work carried out by Mahaney, Kalm, Dirszowsky and others in the same setting. Overall, the lack of terrestrial (moraine) evidence of glacial activity in the uppermost Mucubají catchment following initial deglaciation and the deposition of cross-valley moraines up to ~3800 m a.s.l., the preservation without deformation of Late Pleistocene lacustrine/glacio-lacustrine deposits, and the availability of alternative explanations for the observed variations in organic versus inorganic sedimentation in lakes, palaeolakes and bogs, argue against the authors’ belief that ice persisted in the catchment and/or readvanced down-valley long after the Pleistocene/Holocene transition or Younger Dryas climatic event. Considering also, relatively complying pollen signals in the catchment, and uninterrupted records of peat accumulation at nearby Páramo de Piedras Blancas and Páramo el Blanco sites (Stansell et al., 2005), Holocene glacial activity in the Mucubají valley would appear to be overstated.

Over-reliance on archival material gleaned from sediment cores may lead to serious misinterpretation of proxy indicators in connection with climate or environmental change. Examples of such over-reliance abound in Stansell et al. (2005), especially when one considers extrapolations made into the high Mucubají valley that are at odds with the known landform distribution. While we welcome the new data provided by Stansell et al. (2005) pertaining to the palaeoclimatology of the Venezuelan Andes, it is evident that the glacial geologic/geomorphological interpretations made therein need revision in light of what is discussed here and in other publications that were apparently overlooked as the authors prepared their results and interpretation.

References


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Reply: Late Quaternary deglacial history of the Mérida Andes, Venezuela: response to comment

We welcome the opportunity to respond to Mahaney et al.’s critique of our article on the deglacial history of the Venezuelan Andes (Stansell et al., 2005). The source of our disagreement appears to stem primarily from differences in research strategies and methodology. Our work in the Venezuelan Andes employs lake sediment archives that record continuous sedimentary sequences and can be dated using accelerator mass spectrometry (AMS) radiocarbon dating of identifiable terrestrial macrofossils. Mahaney et al. focus on temporally discontinuous deposits (moraines and glacial–fluvial sediments) and radiocarbon dates on refractory organic matter that are most likely to yield anomalously old results. The comment of Mahaney et al. is fraught with serious misunderstandings of the data we presented, and is thus misleading to readers who have not examined the original data. In our reply, we specifically address their claims regarding: (1) the local timing of the Last Glacial Maximum; (2) the chronology of the late Pleistocene–Holocene transition; and (3) Holocene environmental variability.

Lakes in previously glaciated catchments are excellent recorders of glacial variability because these systems commonly preserve uninterrupted glacio-lacustrine sequences, and contain in situ organic matter that can be isolated for 14C dating. Lake sediment cores can also be analysed at high stratigraphic resolution for an array of sedimentological parameters, which in turn can be used to infer environmental changes over a range of timescales. Lithologic transitions in peat bogs that either formed within or directly adjacent to moraines can also date significant movements of a glacier margin. Combined, these types of records are advantageous for dating glacial activity because they are less susceptible to surface processes such as erosion and weathering, and provide broadened perspectives on the attendant climatic conditions prior to, during, and after a given glacial advance.

Local timing of the Last Glacial Maximum (LGM)

Schubert and Rinaldi (1987) radiocarbon-dated a presumed LGM sedimentary sequence at the southern margin of Mesa del Caballo in the Pedregal fan complex. They interpreted the sequence as part of an outwash plain that extended from

the terminal and lateral moraines of the El Caballo and La Mucuchache glaciers. A chemically untreated organic sample from 1.5 m above the base of the section yielded a conventional age of 22 750 cal. yr BP (19 000 14C yr BP), whereas a peat sample immediately below the top of the section yielded an age of 19 960 cal. yr BP (16 500 14C yr BP). We recognise that other workers (e.g. Mahaney et al., 2001, 2004; Dirszowsky et al., 2005) have re-analysed the Pedregal fan complex. For example, the sedimentology was described in detail by Dirszowsky et al. (2005). However, the chronology in these papers is questionable and not useful for constraining the LGM. All of the recently published dates are on refractory organic matter isolated using a cellulose extraction technique which concentrates refractory carbon, resulting in ages between 47 000 and 60 000 14C yr BP. These ages include multiple reversals and are at the very edge of interpretability as finite radiocarbon ages; nonetheless, the authors have interpreted them as valid ages. Similar extraction methods for isolating the most refractory organic matter have been shown to produce ages that are much older than the age of deposition (Abbott and Stafford, 1996). Mahaney et al. (2001) described and dated palaeosols in the region; however, these data are not relevant to this discussion because the ages presented are all between 48 000 and > 64 000 14C yr BP and predate the LGM by tens of millennia. Mahaney et al. (2004) allude to the LGM without refining the chronology of its local expression, and we neither cited this paper in our analysis from lake sediments, nor have reason to believe that the original dates for the LGM reported by Schubert and Rinaldi (1987) have been refined by their recent analyses.

Late Pleistocene–Holocene transition

Our interpretation of Late Pleistocene and Holocene glacial activity in the Mucubají valley is based on multiple sedimentary records, including a recessional moraine bog, a lateral moraine bog, a continuous record from Laguna Mucubají, and palaeoenvironmental evidence from the Mucubají Terrace (Salgado-Labouriau et al., 1977). Our methods utilised multiple proxies, including magnetic susceptibility profiles (Seltzer et al., 2002) and loss-on-ignition (LOI) measured according to standard laboratory protocols (Dean, 1974; Heiri et al., 2001; Boyle, 2004). LOI data were verified against oxidative elemental analysis of organic carbon content. The base of a 10 cm section of lacustrine sediments from the Mucubají recessional moraine bog site dates to 15 730 (15 520 to 15 920) cal. yr BP, and provides a minimum limiting age for ice being restricted far up-valley from its LGM position. The terrace site of Salgado-Labouriau et al. (1977) is down-valley of the recessional moraine bog site and contains alternating sequences of interbedded peat, clays and glaciofluvial sediments. The lower ~2.6 m of the 5 m sequence dates...
between 14 880 and 13 830 cal. yr BP (12 650 and 11 960 14C yr BP; Salgado-Labouriau et al., 1977), while the sediment lithology implies multiple glacier advances and retreats during this interval. We emphasise that the Mucubají terrace sequence of Salgado-Labouriau et al. (1977) shows absolutely no evidence of glacial activity after 13 830 cal. yr BP, in contrast to the bog site reported by Stansell et al. (2005). This does not result in a contradiction of findings because the upper 2.6 m of the Mucubají terrace was not dated by Salgado-Labouriau et al. (1977) and does not appear to preserve the upper sequence of Holocene age. The ~900 yr earlier age of glacial retreat proposed in the comment by Mahaney et al. is based on unpublished data that extrapolates deglacial ages from dated horizons using average ‘early postglacial’ sediment accumulation rates. The high clastic input during and following glacial retreat is likely to vary dramatically from site to site, implying that any extrapolation based upon ‘average’ rates is likely to be, at best, an educated guess. Regardless, a difference in 900 yr for the age of deglaciation does not affect the principal findings in our paper. We also strongly emphasise that only tentative evidence of a Younger Dryas equivalent exists from terrestrial records in the Venezuelan Andes (Salgado-Labouriau, 1989; Weingarten et al., 1991), nor is it conclusive that a widespread cooling event took place in the region during that time (e.g. Rull et al., 2005).

Our interpretation of the timing of deglaciation in the Mucubají valley is corroborated by data obtained elsewhere in the Venezuelan Andes. Radiocarbon-dated deglacial magnetic susceptibility profiles from lake sediments in the Páramo de Piedras Blancas, the Páramo el Banco, and Laguna Negra (adjacent valley to Mucubají) indicate at least two phases of widespread glacial recession at the end of the Pleistocene. The first phase occurred immediately prior to 15 010 and 14 250 cal. yr BP, as recorded in Laguna Verde Alta (4215 m) and Laguna Verde Baja (4170 m), respectively. The second phase of deglaciation is recorded in the western Páramo de Piedras Blancas and in the Paramo El Banco, where there is a sharp transition from glacial lacustrine to postglacial organic-rich lake sedimentation in three uninterrupted records. The transition at Laguna Los Locos (4366 m) dates to 9650 cal. yr BP. The transition at Laguna Grande de Los Patos (4185 m) dates to 10 000 cal. yr BP, and the transition at Laguna La Posita (4228 m) dates to 9360 cal. yr BP.

The highest elevations in the southeast-facing Paramo El Banco and Páramo de Piedras Blancas are around 300 m lower than the headwall of the Mucubají valley (4609 m). It is therefore possible that glaciers survived longer in the Mucubají valley relative to the El Banco and Piedras Blancas paramos. In addition, precipitation and cloud cover are much reduced on the slopes of the Paramo El Banco and Piedras Blancas relative to the Mucubají region. Therefore the geographic setting of these slopes probably drove a regional asymmetry in the elevation of glaciers (e.g. Hastenrath, 1985), and may have contributed to a deglacial lag for the higher, northwest-facing regions.

The Laguna Negra site, adjacent to the Mucubají valley, provides support for restricted ice in the region at the onset of the Holocene. Laguna Negra (3473 m) is situated at a low elevation relative to the valley headwall (4609 m), and records a lithological deglacial transition at 10 040 cal. yr BP. We agree that the change in sedimentation at Laguna Negra does not necessarily imply that the entire catchment was ice-free, but it strongly suggests that ice was, at best, restricted to the highest elevations of the valley. Likewise, the Mucubají lateral moraine bog indicates that up-valley glacier retreat was almost complete by 10 000 cal. yr BP. A core from this site preserves till capped by peat dating to 9500 cal. yr BP.

We note that these results are directly compatible with the ages for deglaciation obtained in other regions of the northern tropics, including the highlands of Mexico (Vázquez-Selem and Heine, 2004) and Costa Rica (Orvis and Horn, 2000). Thus, they add considerable new data to debates concerning the timing of tropical deglaciación, in relation to the high northern latitudes (Clark, 2002).

Holocene climate and glacial variability

Climate variability in Venezuela during the Late Pleistocene and Holocene has been highly variable as documented by a series of studies (Bradbury et al., 1981; Salgado-Labouriau, 1984; Bradley et al., 1985; Rull, 1998; Curtis et al., 1999; Haug et al., 2001; Rull et al., 2005; Polissar et al., 2006a). However, many of these studies have used pollen stratigraphic analyses at low temporal resolution, making it difficult to compare them directly to the Mucubají sedimentological record. It is noteworthy that inorganic sediment content in Laguna Mucubají is low just prior to 8200 cal. yr BP, after which the values increase until 6250 cal. yr BP. Furthermore there is also an abrupt transition from inorganic silt to peat at 6280 cal. yr BP in the Mucubají recessional moraine bog core. The coincident timing of major transitions at both sites suggests that ice was restricted to the uppermost reaches of the catchment by ca. 6300 cal. yr BP.

The published pollen records from the Venezuelan Andes provide, at best, century-scale integrations of ecosystem development and climate oscillations; short-duration events (e.g. sub-century-scale) cannot be identified. Despite these caveats, the ‘known warm period’ in the pollen record between ca. 2800 and 2550 cal. yr BP (2690 to 2500 14C yr BP; Salgado-Labouriau et al., 1988) indeed corresponds to an overall decrease in clastic sediment content in Laguna Mucubají, punctuated by an abrupt and short-lived increase in sediment around 2760 cal. yr BP. Likewise, the Mucubají record preserves evidence for at least four short-lived glacial advances during the last 400 years, which correspond to the pronounced local expression of the Little Ice Age (Polissar et al., 2006b). It is thus clear that, while broad correspondence between the palynological and sedimentological records exists, only the latter is at present sufficiently resolved to identify the numerous rapid changes that appear to punctuate the Late Holocene glacial and climate history of the Mucubají valley.

The role of seismicity in limnological systems should always be considered; however, the claim that tectonic activity caused the observed sedimentological changes in Laguna Mucubají is not supported by the data. Mahaney et al.'s single radiocarbon date bearing on the region’s seismic history remains unpublished, so that, without adequate details on the sample’s exact stratigraphic context, no meaningful inferences concerning its relevance can be made at this time. Moreover, the available evidence indicates that a strong statistical relationship exists between climate change and the observed Mucubají sedimentological record (Polissar, 2005).

More research using multidisciplinary approaches is still needed in order to refine the timing of cooling and warming events in the northern tropics. Sites with continuous, high-resolution records should be targeted for future fieldwork and improved age control should be emphasised. The evidence gathered to date suggests that the terminal Pleistocene deglaciation of the Northern Hemisphere tropics occurred later than in the Southern Hemisphere, and that multiple cooling events took place in the Venezuelan Andes during the late Holocene.
when alpine glaciers developed anew in the highest catchments. Lively discussion is an essential component of any scientific enterprise. We value the different views of Mahaney et al. and welcome this opportunity to defend our methods and results. We hope this exchange will both educate readers and further the scientific goal of understanding the timing and causes of environmental change.

References


