Interpreting interfluvial landscape transformations in the pre-Columbian Amazon

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Abstract

Despite evidence for the protracted presence of humans in the Amazon Basin, its vast interfluvial habitats are frequently depicted as having survived until recently as “wild” landscapes with neither human settlement nor substantial human land use. Related research interests of paleoecology and archaeology share parallel histories in the development of explanatory paradigms for understanding processes contributing to neotropical ecology, as both emerged from earlier periods dominated by models based on stability and equilibrium to a contemporary advocacy of dynamic stability and change. Recent paradigms accommodate humans as keystone species and implicate their role in past and present landscape management. This is particularly important in the Neotropics where it is argued that an extensive and ancient indigenous agroforestry employed intermediate disturbance in the management of interfluvial landscapes. This is contrasted with a critical discussion of recent paleoecological research in central and western Amazonia, which argues that interfluvial landscapes were devoid of pre-Columbian populations and survived as relatively pristine relic landscapes throughout most of the Anthropocene.

Keywords

Anthropocene, Amazon, agroforestry, paleoecology, archaeology, historical ecology

Introduction

All organisms modify their surroundings in different ways and to varying degrees; however, gregarious tool-using humans, capable of collective action and social learning are conspicuous in their ability to transform landscapes (Ellis, 2011). Novel human ecosystem engineering may have ushered in a new epoch with no geological analog, the Anthropocene, which may have started earlier with Pleistocene megafaunal extinctions or later after the persistent use of industrial chemicals (Lewis and Maslin, 2015) Whether or not we can distinguish an early or late "golden spike" for the Anthropocene's onset, some portions of the globe are regularly depicted as having remained relatively untouched by human hands. This is usually the case for Amazonia, particularly its extensive interfluvial landscapes away from the Amazon River channel and the embouchures of some of its major tributaries. Despite the clear presence of humans in the area since at least the Terminal Pleistocene, most Amazonian landscapes are depicted as "wild," with neither human settlements, agriculture, substantial land use, nor anthropogenic loss of native species and increase of exotic species (Ellis, 2011; Ellis et al., 2010; 2012).

The greatest expression of elevated biological richness, found today in lowland neotropical areas, is part of an ancient latitudinal diversity gradient with complex origins (e.g., Willig et al., 2003; Mittelbach et al., 2007). In this paper, I focus on temporally recent manifestations of this pattern that took place after humans appeared in these areas by the late Pleistocene. I am interested in localized effects of spatially and temporally intermediate disturbance on plant and animal distributions within landscapes. Here, I am concerned with the functioning and maintenance of within-habitat or alpha diversity, and between-habitat or beta diversity (Schneider, 2001) resulting from secondary succession in landscape transformation (Balée, 2006). In particular, various forms of indigenous agroforestry, which were likely ancient and pervasive throughout the forested neotropical lowlands, played a key role in shaping alpha and beta diversity since the appearance of humans in these areas. Their cumulative temporal and spatial impact on neotropical forest structure across landscapes, may have been significant. However, recent paleoecological research undertaken in some Amazonian interfluvial areas has countered this interpretation, suggesting that unlike intensively managed riverine habitats, these areas most likely retained a relatively pristine "wild" appearance throughout most of the Anthropocene.

My paper contributes some insights and commentary to this recent controversy regarding the extent of human disturbance in the interfluvial landscapes of Amazonia (Tollefson, 2013). It begins by briefly summarizing a parallel paradigm shift in paleoecology and archaeology. Each discipline emerged from a period dominated by an advocacy for stability and equilibrial adjustment to one focused on dynamic stability and change. This shift promoted the functional role of disturbance as a key process in diversification and increasingly accepted the important influence of anthropogenic activities in maintaining high biological richness. It next considers the affect of intermediate disturbance by an ancient and pervasive indigenous agroforestry landscape management on biological richness in the neotropical lowlands of South America. It then presents the results of recent research (McMichael et al., 2011; 2012a; 2012b) undertaken in the forested interfluves of western and central Amazonia, paying specific attention to the analysis and interpretation of particulate charcoal in the fossil record. It is suggested that charcoal signatures in these cores are more compatible with an interpretation of agroforestry management than they are to large scale conflagrations expected of anthropogenic disturbance. A concluding section discusses limitations and compares and contrasts differing interpretations offered by archaeology and paleoecology.

Models for Understanding Amazonian Landscapes: Equilibrium and Dynamism

Classic perspectives on Amazonian landscape evolution were long dominated by views advocating ecological stability and equilibrial adjustment. Accordingly, the longitudinal views of Amazonian paleoecology and archaeology incorporated paradigms emphasizing systems ecology, homeostatic regulation, human adaptation to ecologically limiting conditions, and cultural evolution. Both disciplines emerged from their respective dominant explanatory models to embrace paradigms advocating dynamic stability and change that considered disturbance as a key process in diversification along with an increased awareness of anthropogenic mechanisms responsible for landscape transformations (Goldammer, 1992).

Contemporary Amazonian landscapes are the products of ancient and complex, yet controversial processes (Hoorn et al., 2010). Colinvaux (1998) characterized two families of explanations to account for biological diversification during late Quaternary Period evolution in Amazonia. Earlier “museum” models portrayed an ancient and stable ecosystem that provided “safe storage” for tropical species in an environment where extinction was rare. Ideal growing conditions of year-round high heat and humidity, little affected by Pleistocene cooling, enabled it to accumulate larger amounts of species over geological time. These earlier explanatory paradigms were supplanted by “engine” models emphasizing continuous, but less than catastrophic change. Although the Amazon environment was impacted by variably cooler and drier Pleistocene conditions, paleoecological data suggest little substantial savanna formation and confirm that lowland areas were always forested (Bush and Oliveira, 2006; Bush et al., 2007; Colinvaux, 1998; 2001). Populations in these forests were constantly culled but never to extinction, thus one community never dominated, and resources were continuously available for speciation. High species richness is maintained in non-equilibrial states of disturbance, intermediate between the depressed richness of either large-scale catastrophic disturbance or the monopolistic domination generated in equilibrial communities (Connell, 1978).

Archaeology only recently emerged from a long and bitter debate about the nature of pre-Columbian Amazonia. A once dominant "standard" model or paradigm (Viveiros de Castro, 1996; Stahl, 2002) considered contemporary indigenous slash and burn horticulturalists as relatively recent ecological adaptations to the neotropical forests. Pre-Columbian migrants entering the Amazon basin culturally devolved to a lower level of agricultural productivity and cultural development afforded by the limiting conditions of lowland environments. Small populations of isolated shifting cultivators scattered throughout the basin were characterized as maintaining ecological equilibrium with their surroundings. This "standard" paradigm was supplanted by a "revised" counterpart with an equally old pedigree (Stahl, 2002). It advocated greater time depth of human occupation and the existence of larger and more complex indigenous populations engaged in different kinds of subsistence pursuits. The portrayal of contemporary indigenous populations as survivals of ancient patterns was dismissed as a recent characterization resulting from colonial cataclysm. Rather than treating pre-Columbian populations as adaptations to equilibrium, the "revised" paradigm focused on indigenous cultures as active manipulators and creators of humanized landscapes, serving as dynamic participants in landscape transformation through subsistence practices that formed mosaics of intermediate disturbance. Archaeological data support: a long temporal occupation; a heterogenous mix of complex large and sedentary communities along with smaller and dispersed populations; and, novel forms of agricultural production (see Denevan, 2001; Erickson, 2008; Heckenberger, 2005; Heckenberger and Neves, 2009; Roosevelt, 2014).

Amazonian historical ecology questions the existence of the “pristine” ecosystems and adopts a perspective focused on significant anthropogenic contribution to neotropical biodiversity.

Indigenous Agroecology, Disturbance, and Biodiversity Management

The long-standing equilibrium-based assumption that contemporary short-cropping/long-fallow shifting cultivation adequately characterizes pre-Columbian Amazonian agriculture is inaccurate. It is possible that this variant of slash-and-burn agriculture only became practical and widespread after the introduction of European metal (Denevan, 2001). Also, extensive shifting cultivation would have become more feasible with ample land made available through depopulation after the onset of the “Great Dying” (Heckenberger, 2005), when agriculturally regressed indigenous survivors altered their traditional subsistence options (Balée, 2013).

Denevan (2001:124-127) proposes a patch pattern of pre-Columbian agriculture in which sites of dense settlement and intensive crop production in riverine and interior areas were separated by tracts of forest with smaller field and garden sites located in suitable locations. Intensive agro-ecologies exploiting Amazonian Dark Earths, nutrient-rich whitewater floodplains, and raised fields could have been managed alongside variations of permanent house gardens, intensive swiddens in clearings and second-growth forests, slash/mulch or *tapado* systems, opportunistic patch cultivation of forest clearings, and agroforestry. In particular, an indigenous agroforestry that deliberately combines crop production with trees, especially fruit trees, and woody perennials, was likely ancient and widespread throughout pre-Columbian Amazonia. Useful trees and seedlings spared during clearing and weeding, were managed, planted, and transplanted alongside crops (Miller and Nair, 2006).

A form of slash-and-burn similar to contemporaneous systems that introduce crops at the expense of removing progressively larger tracts of forests is suggested to have appeared in the neotropics by 7000 BP (Piperno and Pearsall, 1999:168). However, it is important to distinguish indigenous agroforestry production from contemporary slash-and-burn systems. Although the latter place heavier emphasis on vegetative deletion and fire, its use is highly variable and most prominent in the pioneering phases of frontier land management, after which diversification into agroforestry and reliance on vegetative processes are emphasized (Cairns, 2007; Sorrensen, 2004). Moreover, the use of fire can become impracticable in some areas, particularly in parts of the western Amazon Basin, where high precipitation can blur any distinction between wetter and drier seasons. Undertaken with stone tools, indigenous pre-Columbian agroforestry was likely opportunistic and recurring , creating “anthropic islands in a sea of forests” (Neves, 2013:379). Highly variable, indigenous agroforestry can encompass a continuum from passive to intentional forest management. It can include a “nomadic agriculture” of forest fields in cultivated gaps and trailsides, the protection, concentration, and dispersal of useful plants and forest resources, and the exploitation and manipulation of vegetative succession or “chronological ecotones” with only minimal burning and canopy disturbance (*e.g.,* Denevan et al., 1984; Hecht and Posey, 1989; Politis, 2007; Posey, 2004; Rival, 2002; Zent and Zent, 2004). Forest management promotes the emergence of new vegetational zones and ecotones (Balée, 2013) to form increasingly complex and enhanced landscapes in small and convoluted patches which can support multiple edge interactions (Porensky and Young, 2013).

From a coevolutionary perspective, agroforestry was probably a very early form of food production, as plants and humans became increasingly interdependent through intermediate and localized anthropogenic disturbance (see Rindos, 1984). Whereas the domestication of landscapes was a very old pattern in Amazonia, larger scale and intensive plant cultivation may not have been (Neves, 2013:376). As Eurasian agricultural systems emphasized cleared fields with ripening grasses, the mosaic food production of Amazonia which featured tree fruits, root crops, and oil and protein-rich annuals was comparatively underestimated in terms of its productivity and antiquity (Iriarte, 2007). Indigenous agroforestry differs from contemporary agriculture as it does not require deforestation as a starting point (Clement and Junqueira, 2010). Evidence for burning in the Amazonian archaeological record, indicated by increased fire frequency and larger-scale clearance, becomes prevalent much later in the Holocene with the appearance of large, sedentary human settlements supported by intensive agricultural, particularly bitter manioc, production (Arroyo-Kalin, 2012).

Early archaeological contexts throughout neotropical South America suggest that varying forms of agroforestry food production were quite ancient. The earliest plants recovered and identified in archaeological sites include a balanced compliment of root crops, palms and tree crops, and seed plants (Iriarte, 2007). Preserved endocarps, phytoliths, pollen, and implements, suggest that palm exploitation was extensive and ancient. Unidentified endocarp fragments appear in the record as early as 14,700 BP and palms increase in number and diversity between 9000 BP and 5000 BP, including 29 genera and 50 species of widespread, locally abundant, and highly productive palms that thrive in disturbed areas (Morcote Ríos and Bernal, 2001; Prous and Fogaça, 1999). Over two thirds of the Amazonian crop plants that were variably under some degree of domestication by AD 1492 were trees or woody perennials (Clement et al., 2010). From a coevolutionary perspective, it is important that many of these early plants are disturbance taxa (Rindos, 1984). As Amazonian food production changed through time from spatially extensive to spatially intensive fallow management (Arroyo-Kalin, 2012) it is interesting to speculate that major domesticated carbohydrate sources may have originated in seasonal regimes adapted to open and seasonally dry conditions like those found in southwestern Amazonia (Arroyo-Kalin, 2010; Clement et al., 2010; Isendahl, 2011).

In historical perspective, the cumulative impact of passive, small to medium-scale and localized disturbance can be greater than slash-and-burn (Zent and Zent, 2004:86). Although artifacts used for forest clearance are neither prevalent nor early in the archaeological record (Piperno, 2006:292), the footprint of generations of agroforesters survives today in the structure of Amazonian forests. This contemporary legacy endures as hyperdominant palm, bamboo, liana, brazil nut, and various fruit forest formations (Balée, 2013; Clement, 2006; Levis et al., 2012; Roosevelt, 2014; Scoles and Gribel, 2012; Shepard and Ramirez, 2011; ter Steege et al., 2013).

Recent Disagreements about the Extent of Human Impact in Pre-Columbian Amazonia

In a series of recent articles, McMichael and associates (McMichael et al., 2011; 2012a; 2012b) report on their interpretation of as many as 247 soil cores extracted from 55, mostly interfluvial and highly clustered, locations in central and western Amazonia. Based upon their analyses of particulate charcoal, phytolith, and soil nutrient data, they report that past anthropogenic disturbance in the interfluves was “small, infrequent, and highly localized,” “light and shifting,” “spatially heterogenous,” “patchy and localized,” or “not consistent with widespread, extensive agriculture.” They conclude that where evidence for past fire history was identified, it was produced mainly by ground fires confined to the forest floor that rarely, if ever, penetrated the canopy. These interpretations are based on core samples with small amounts or erratic distributions of charcoal, low concentrations of soil nutrients and black carbon, the absence of burned phytoliths, especially of major crop plants, and/or the presence of phytolith evidence for existing forest canopy.

A critical focus of their research rests on the analysis of particulate charcoal preserved in sampled cores. Cautioning that an absence of charcoal does not necessarily signal an absence of fire, McMichael et al. (2011:135-136) nonetheless attach significance to finding "no extraordinarily enriched layers of charcoal" despite observing that even modern agricultural sites in their sample area usually contained only low quantities of charcoal. They advocate the sampling of each site with multiple, spaced cores in order to overcome the commission of false negative (Type II) error; however, they also "down-weight" the presence of smaller charcoal particles in order to overcome the commission of false positive (Type I) error (McMichael et al., 2012a:74). They propose a "novel method" for soil charcoal analysis that "filters" or "cancels out" background noise by distinguishing "trace" (<0.25 mm^3/cm^3) from "present" (>0.25 mm^3/cm^3) particles.

A perusal of the data published by McMichael et al. (2011; 2012a; 2012b, and supplementary material, www.sciencemag.org/cgi/content/full/336/6087/1429/DC1) clearly reveals the presence of charcoal particles in most sampled cores. By their own admission, they point out that "trace" charcoal was present at every site, and "present" charcoal occurred at most sites in their study at Los Amigos and Gentry-Parker in the western Amazon (McMichael et al., 2012a:76). They indirectly admit that 87% of the soil cores contained charcoal; however, their core data clearly show that over 90% contain charcoal (McMichael et al., 2012a:Figure 4).

Moreover, it is interesting to note the lack of internal consistency and highly variable results obtained from separate cores extracted at the same site.

It is particularly disappointing that the authors chide archaeologists for only reporting evidence of human impact while disregarding negative evidence (McMichael et al., 2011:138; 2012a:81). Although their admonition may hold some truth, it is alarming that the "novel methodology" that they introduce to avoid erroneous false positive results can create false negative results. Despite most of their sampled cores clearly showing evidence of particulate charcoal, they explicitly base their conclusions on the occurrence of "present" (>0.25 mm^3/cm^3) charcoal (McMichael et al., 2012a;80). Their rationale is based on the study of a high intensity Norwegian boreal forest ground fire that suggests that larger (>0.50 mm) charcoal particles in forest soils are "solid and reliable evidence for local fire influence." However, the authors of this study also add that larger particles must be carefully interpreted as their deposition is highly variable and at times non-existent inside burn areas (Ohlson and Tryterud, 2000:523).

Although used as a tool in paleoecology for years, charcoal analysis has been hindered by problems associated with particle transport and preservation (Clark, 1988; Figueiral and Masbrugger, 2000; Patterson et al., 1987). Observation of natural fire events and controlled study of experimental fires provide important criteria for interpreting past fire histories; however, they have generally involved intense, large-scale, stand-replacing crown fires with strong convection plumes that can transport materials over vast areas (*e.g.,* Clark, 1988; Clark et al,. 1998; Gardner and Whitlock, 2001; Lynch et al., 2004; Ohlson and Tryterud, 2000). Although highly variable, vegetation fires like those expected in indigenous agroforestry are most commonly surface fires spread by flaming combustion on or near soil surfaces that rarely or never subsequently ignite into the crown or ground fires (Scott et al., 2000) typical of these experimental studies. They are more likely similar to low intensity and small-scale surface fires with low convective columns that move along the ground surface. These fires are characterized by a very different form of charcoal particle production with few large fragments, no significant distribution between particle size classes, and deposition of the smallest particles in the immediate vicinity of the fire (Pitkänen et al., 1999).

Discussion: Digging with Spoons

Archaeological data have contributed to a general consensus that large, sedentary, and complex populations existed in Amazonia before the arrival of Columbus (see Heckenberger and Neves, 2009; Roosevelt, 2014). This is not disputed by paleoecologists, who concur that supporting evidence is certainly found along the major river channels during the two millennia before AD 1492. Archaeologists, however, have penetrated farther into different portions of Amazonian terra firme, uncovering increasing evidence that similar conditions existed there as well (see Heckenberger and Neves, 2009; Roosevelt, 2014). Some claim that an Amazonia once considered to be pristine "Uhrwald" is in all likelihood substantially anthropogenic. This "revised" notion of a humanized Amazon is an extreme departure from "standard" orthodoxy, and although a somewhat new idea for this area of the world, it has roots that can be traced at least to the mid-nineteenth century writings of Marx (Marx and Engels, 1970:63).

"Polarities are falsehoods that focus debate" (De Boer, 2011:75). Although the argument's dialectical pendulum appears to have swung to an opposing extreme (Tollefson 2013), it might be a less drastic swing to the middle. Some paleoecologists acknowledge what was once denied, yet object to the death of the pristine by suggesting that it persists in the Amazonian interfluves. They chide archaeologists for not publishing negative data (McMichael et al 2012a:81), yet more to the point it should be underscored that archaeologists tend to study archaeological sites where they are most interested in cultural accumulation and deposition. However, paleoecological criticism is well taken; if archaeologists wish to infer the nature of past landscapes then they should adopt a less site-centric approach and study landscapes with methodological tools (e.g., archaeobotany and zooarchaeology) that can detect landscape alteration.

Many years ago when I was a graduate student participating on an archaeological project in a remote area of interior British Columbia, an elderly indigenous gentleman approached my boss at the local watering hole and asked, "how can you know so much by digging with a spoon?" We have techniques and methodologies to extract data that provide what we hope are reliable answers to valid questions. Nevertheless, we problematically dig with spoons and attempt to explain what happened over at least 12000 years in an area almost as large as the contiguous United States. McMichael et al.'s interpretations from six sampled areas of central and western Amazonia are based upon no more than 1.9402 m^3 of excavated deposits, less than the sampled volume of two small archaeological test pits. However, after the selected sampling points along their cores are extracted, prepared, deflocculated, wet sieved, concentrated and microscopically scanned, only a shot-glass or less of extract is analyzed to project inferences about thousands of years of human occupation in a vast and poorly known area.

Moreover, exactly what are we looking for? The analyzed core data are used to support an inference that pre-Columbian interfluvial landscapes of western Amazonia were "not subjected to continuous or large-scale forest clearing or intensive agriculture" (McMichael et al., 2012b:1430). Regardless of one's perspective, these samples cannot be used to deny anthropogenic management. McMichael and colleagues' search for "wholesale clearance" is more applicable to the intensive fire regimes associated with a contemporary short-cropping and long fallow slash and burn agroecology that is alien to indigenous agroforestry. The latter, by the author's own admission is a form of landscape management that may lie beyond the methodological reach of their studies (McMichael et al., 2011:138).

Their novel methodology of filtering out the background noise of particulate charcoal is used to deny past episodes of intensive fire, but it cannot be used to claim the absence of recurrent historical fire management (McMichael et al., 2012a:77). The ubiquitous charcoal data in their study sites probably suggest pre-Columbian landscape manipulation in the form of a "low impact cultivation" not associated with "wholesale clearance." Their study found no artifacts, but why would valued and normally curated stone artifacts necessarily have been deposited at interfluvial agroforestry sites? Non-stone tools would likely not preserve. Little soil modification was detected, but what kind of soil modification should be expected other than the patchy yet ubiquitous charcoal evidence that was found? Few crop phytoliths were recovered, but crop plants are not necessarily deposited and burned in production areas of interfluvial forest management. When phytoliths were recovered, they indicated presence of forest canopy, and none of these were burnt. Why would trees be burned? The point of indigenous agroforestry management is to integrate trees and their canopies into an agroecological system. Furthermore, many phytoliths are not reliably identifiable below the taxonomic level of botanical family. How many culturally useful plants are included within these broader taxonomic categories? Indigenous agroforesters regularly use and actively manage many different tree species for food, fuel, tools, adornment, medicine, and ritual (*e.g.*, Balée, 1994; 2013).

When they mention that “wholesale conversion of landscapes for agriculture…could have led to a ‘parkland’ or ‘manufactured landscape’” McMichael and colleagues (2011:131) are not using agroforestry as a model for pre-Columbian agriculture in off river areas. In closing, they claim that although humans may have contributed to alpha-diversity in some places, long-term non-cultural processes were the primary reason for hyperdiversity (McMichael et al., 2012b:1431). This is particularly curious as some of their major study areas are located in the midst of high concentrations of Brazil nut trees which can be important indicators of anthropogenic disturbance (Scoles and Gribel, 2012; Shepard and Ramirez, 2011). In this regard, it might be speculated that pre-Columbian forest management and the development of anthropic, oligarchic, or cultural forests may have been a key reason for explaining the hyperdominance of tree species in Amazonia today (compare Roosevelt, 2014 and ter Steege et al., 2013).

Whether we practice paleoecology or archaeology, we cannot know the true extent of ecosystemic manipulation in the pre-Columbian Amazon because we dig selectively preserved samples with spoons. We should, however, consider what we sample and how. Archaeologists are site-centric; if they want to infer past landscapes then they should focus on techniques and methods that generate reliable answers to valid questions about anthropic biodiversity manipulation and management in pre-Columbian landscapes. Similar cautions apply to paleoecologists. It is likely correct that the inferences based upon analyses of archaeological sites are neither systematic nor randomized (Bush and Silman, 2007:460), but it is naïve to believe that those based on minuscule core data are. Charcoal analysis may not be a useful methodology for developing inferences about indigenous agro-ecology; it is possible that there was less human activity in the interfluves, but it may have been greater than charcoal would detect (Levis et al., 2012:7).

It is important to remember that agrarian systems in the pre-Columbian Amazon undoubtedly changed in time and space (Arroyo-Kalin, 2012). Recourse to images of the "ecologically noble Indian" in the Amazon's past or present (Denevan, 2011) is a pejorative straw man argument that reflects an ignorance of indigenous land management. However, for Europeans who have been historically uncomfortable in the forests and whose agricultural development always begins with forest clearance (Clement and Junqueira, 2010:535), indigenous agro-ecology has had a better track record than the woeful history of the past 500 years. Indigenous populations have been manipulating landscapes since their first appearance at least as early as the Terminal Pleistocene. They have been doing so in ways creatively different from the destructive agricultural systems that remove canopy and create open grasslands. We should be interested in learning how indigenous practices, whether sustainable or not, extract a living from neotropical lowland contexts, but certainly not couched in outdated neoevolutionary notions. Was there a pre-Columbian "tipping point" marking the beginning of an Anthropocene which may have also resulted in irreparable harm to neotropical ecosystems? Was this associated with the appearance of intensive food production and technology associated with large, complex polities in the millennia before Columbus (Arroyo-Kalin, 2012)? Regardless, comments like those made by Barlow et al. (2012:48) that understanding the environmental impacts of indigenous Pre-Columbian agro-ecology in the Amazon may be fascinating but of little practical value for conservation, are both arrogant and reckless.

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