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On Vastness and Variability: Cultural Transmission, Historicity, and the Paleoindian Record in Eastern South America

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ABSTRACT

Eastern South America, or what is today Brazilian territory, poses interesting questions about the early human occupation of the Americas. Three totally distinct and contemporaneous lithic technologies, dated between 11,000 and 10,000 ^{14}C BP, are present in different portions of the country: the Umbu tradition in the south, with its formal bifacial industry, with well-retouched scrapers and bifacial points; the Itaparica tradition in the central-west / northwest, totally unifacial, whose only formal artifacts are limaces; and the "Lagoa Santa" industry, completely lacking any formal artifacts, composed mainly of small quartz flakes. Our data suggests that these differences are not related to subsistence or raw-material constraints, but rather to different cultural norms and transmission of strongly divergent *chaînes opératoires*. Such diversity in material culture, when viewed from a cultural transmission (CT) theory standpoint, seems at odds with a simple Clovis model as the origin of these three cultural traditions given the time elapsed since the first Clovis ages and the expected population structure of the early South American settlers.

Key words: Paleoindian, Lithic technology, Umbu, Itaparica, Lagoa Santa, Cultural transmission.

INTRODUCTION

One of the most remarkable features of the debate about the origins of the First Americans is a deep lack of communication between scientists from the northern and southern portions of the continent. The reasons for this state of the art are manifold, and it is not the aim of this communication to delve into them. The main objective of this paper is to update information about the earliest human occupations that happen to be located in what is today Brazilian territory. The last effort to publish data about this issue for an English-speaking audience was made more than a decade ago (Kipnis 1998), although a more recent overview of Paleoindians in Brazil can be found in Spanish (Dias 2004). Therefore, it is time to revise old data, make new data available, and hopefully contribute to a wider debate, namely, the timing and processes that were responsible for the spread of humans into the Americas. Cultural transmission (CT) theory could be of paramount importance in this regard. Additionally, South American data can contribute to the refining of CT theory, since the empirical evidence we have surely poses some interesting problems. As proposed by Eerkens and Lipo (2007), it is important not only to borrow concepts from CT theory, but also to try to see if particular archaeological cases can have a role in theory building.

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A Question of Nomenclature

A good starting point is to determine what one could possibly mean by "Paleoindian", given that the term is used with different meanings. In northern settings, such as Canada and the United States, the meaning is usually attached to a way of life (hunting big mammals) and / or a way of doing things (big bifacial points). In Brazil, the term "Paleoindian" was originally used as a chronological marker, rather than attached to cultural or subsistence issues, mainly because, as we will see, archaeologists soon realized that many of the oldest sites lacked bifacial points and were not related to any hunting specialization. More recently, the term has been used with a strong biological meaning, since craniometric studies have suggested that there is a marked difference between early Holocene human skulls and the more recent, mongoloid Amerindian populations (Neves and Hubbe 2005, Neves et al. 2005, Neves and Pucciarelli 1991). Consequently, in Brazil the term Paleoindian is currenly applied to a population that existed in a chronological range between 12,900 and 8300 calBP[1] (or between 11,000 and 8000 14C years BP), *regardless of cultural markers*. This will be explained shortly.

Setting the Problem

The data obtained at Lagoa Santa (Araujo et al. 2012), together with archaeological information derived from other settings in Brazil, strongly suggest an abrupt and simultaneous appearance of Paleoindians in inland continental settings, about 12,500 cal BP, within a polygon whose minimum dimensions are about 800 km (500 miles) east-west and 2,300 km (1,400 miles) north-south (Fig. 1). This area is already showing a very diverse material culture. The "abruptness" and variability is most probably an artifact of archaeological visibility, since only after a threshold of population is crossed will any given area have sufficient signs of human presence.

The most striking feature of the early archaeological record in South America is, therefore, an extremely high variability in the lithic industries. I will not address such variability in a continent-wide manner (see Dillehay 2000, Bate 1990 for an overview), but will focus only on the Eastern portion of the continent, that is, Brazil, where available data are relatively recent and not very widespread. We are left with a scenario of extreme variability that could be called "variability from the onset."

When we talk about "variability", we are talking neither about different projectile point forms, nor about different ceramic decoration. We are talking about (at least) three wholly different cultural traditions[2], namely, Umbu, Itaparica and Lagoa Santa; three totally and radically different "mental templates" (Deetz 1967) or "world views" (Eerkens and Lipo 2005), resulting in different *châines opératoires* (Mauss 1967), or "recipes" (O´Brien et al. 2010).

Umbu, occurring in southern and southeastern Brazil and occupying an area of approximately 510,000 km^2, or the size of Spain, is a "bifacial" design space (O´Brien et al. 2010), that we can call symmetrical, meaning that when bisected across its major axis, each half of the artifact tends to be a specular image of the other. It can also be considered a formalized industry, since the artifact shapes show a strong pattern (Okumura and Araujo 2014). The ratio of formal (i.e., patterned shapes) to generalized (i.e., non-patterned shapes) artifacts reaches 4.75 (Table I). The bifacial points are ubiquitous, and became the "guide fossil" of this industry. The oldest age obtained was 12,660 calBP (10,985 ± 100 14C years BP; wood charcoal, site RS-

[1] All calibrated ages obtained using CalPal-2007 (Weninger et al. 2012).

[2] The term "tradition" is used in the sense of "patterned ways of doing things that exist in identifiable form over extended periods of time" (O´Brien et al. 2010, p. 3797).

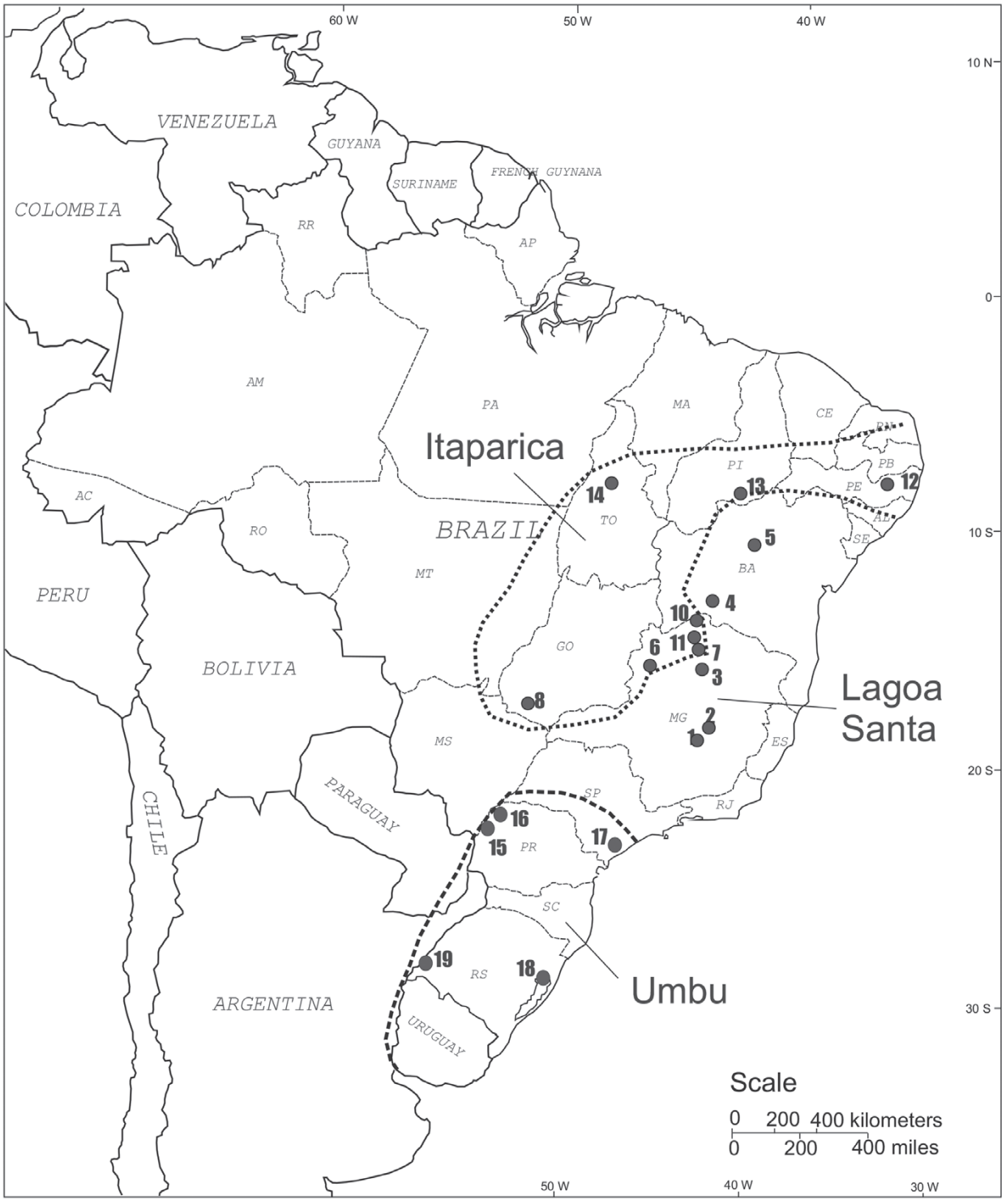

Figure 1 - Selected archaeological sites related to the eastern South America Paleoindian Traditions. Lagoa Santa: 1= Lapa do Santo, Boleiras and Taquaraçu; 2= Santana do Riacho; 3= Lapa Pequena; 4= BA-RC-28; 5= Abrigo do Pilão.
Itaparica: 6= Gruta do Gentio II; 7= Lapa do Varal; 8= GO-JA-01; 9= MT-GU-01; 10= Lapa do Dragão; 11= Lapa do Boquete; 12= Furna do Estrago; 13= Pedra Furada (São Raimundo Nonato area);14= Lajeado.
Umbu: 15= PR-FI-124; 16= PR-FI-138; 17= Capelinha; 18 = RS-C-43 and RS-S-327; 19= RS-I-69.

TABLE I
Ratios of Formal to Generalized (F/G) artifacts for some Umbu sites (from Chmyz 1978, 1979, 1980, Dias, 1994, Hoeltz 1997, Lima 2005).

Tradition/State	Site	Formal artifacts	Generalized artifacts	Ratio F/G
Umbu / Rio Grande Sul	RS-S-327	38	8	4.75
Umbu / Rio Grande Sul	RS-RP-21	49	59	0.83
Umbu / Rio Grande Sul	RS-RP-86	55	31	1.77
Umbu / Rio Grande Sul	RS-RP-88	31	25	1.24
Umbu / Paraná	PR-FI-124	634	297	2.14
Umbu / Paraná	PR-FI-138	31	25	1.24
Umbu / São Paulo	Capelinha	973	290	3.36

I-69, sample SI-2630; Noelli 2000) and supposedly this tradition was extremely long-lived, reaching the XVII century. One can have good reasons to believe that this time span is more related to a classification bias than to a real phenomenon (any site with bifacial points tends to be automatically associated to Umbu), but it nevertheless suggests a long line of "bifacial" cultural transmission in southern Brazil.

Itaparica, occurring in northeast and central Brazil, comprises a bigger area, roughly 1,280,000 km^2, almost the combined areas of France, Germany and the United Kingdom. This lithic industry has a peculiarity of presenting a *single formal artifact* in its repertoire, namely, unifacially retouched scrapers, or "limaces." The ratio of formal to generalized artifacts from Itaparica sites is shown in Table II. It is a unifacially oriented industry, and the "limaces" are considered the "fossil guide." There are *no* bifacial artifacts in this industry. It obviously represents a different design space when compared to Umbu. The oldest age obtained for the Itaparica is 12,560 calBP (10,750 ± 300 14C years BP; wood charcoal, site GO-NI-49, sample SI-2769; Oliveira and Viana 2000), and the youngest age is 9370 calBP (8370 ± 75 14C years BP; wood charcoal, site GO-JA-26, sample SI-5562; Oliveira and Viana 2000).

The Lagoa Santa industry shows a completely different cultural trend. It is a lithic industry comprised entirely of nonformal ("expedient" or "generalized") artifacts. The main purpose of flaking rocks (mostly high-quality hyaline quartz) appears to be the production of small flakes (mean size of 20 mm) and rock splinters. The larger flakes (mean size of 30 mm) sometimes do show marginal retouch (about 1% of the lithics were retouched). The ratio of formal to generalized artifacts is the

TABLE II
Ratios of formal to generalized (F/G) artifacts for some Itaparica sites (from Bueno 2005, Fogaça 2001, Schmitz et al. 1996, 2004).

Tradition/State	Site	Formal artifacts	Generalized artifacts	Ratio F/G
Itaparica / Tocantins	Miracema 1	10	9	1.11
Itaparica / Tocantins	Lajeado 18	4	0	n/a
Itaparica / Tocantins	Capivara 5	4	1	4.0
Itaparica / Goiás	GO-JA-01	482	708	0.68
Itaparica / Goiás	GO-JA-02	18	3	6.0
Itaparica / Goiás	GO-JA-03	136	476	0.28
Itaparica / Goiás	GO-JA-20	39	27	1.44
Itaparica / Minas Gerais	Boquete	17	32	0.53

lowest possible (Table III). It is interesting to note that in the older levels of three excavated rockshelters, high-quality flint (probably exotic) was also used to produce the same non-formal artifacts, ruling out explanations related to raw-material quality and availability. The oldest age obtained was 12,460 calBP (10,490 ± 50 14C years BP; wood charcoal, Lapa do Santo rockshelter, sample Beta 280489), the youngest age is 8360 calBP (7560 ± 110 14C years BP; wood charcoal, Lapa das Boleiras rockshelter, sample Beta 159243; see Araujo et al. 2012).

TABLE III
Ratios for formal to generalized (F/G) artifacts for two Lagoa Santa sites.

Tradition/State	Site	Formal artifacts	Generalized artifacts	Ratio F/G
Lagoa Santa / MG	Lapa das Boleiras	1	156	0.0064
Lagoa Santa / MG	Lapa do Santo	0	29	n/a

Here we are dealing with three different design spaces. The technological differences between these three industries are so large that it is impossible to compare them using the same paradigmatic classification (Dunnell 1971). When we say that they are "radically" different, the word means literally that they do not fit in a single cladogram.

Another important aspect is that the three industries are contemporaneous. Figure 2 shows the summed probability distributions of the ages for each of the industries, and tables SIV, SV, and SVI (Supplementary Material) show the radiocarbon database we used for Umbu (n = 91), Itaparica (n = 55), and Lagoa Santa (n = 101) sites. As mentioned previously, it is possible to regard the longevity of Umbu as an artifact of classification, although recent data point to the fact that its longevity is real (Okumura and Araujo 2014) but its onset is, nevertheless, in the same age range of the other two industries. Note that there is an overlap between the 11 Clovis ages published by Waters and Stafford (2007) and the earliest Umbu sites.

How do we explain such empirical evidence? The traditional explanation is the "Clovis-First" model. According to this model, bearers of Clovis culture spread extremely fast all the way down through South America and are, therefore, the founders of everything we find there. Let us ignore Monte Verde evidence (dated 15,200 calBP) and the rest of South America for a while, just as an exercise. Even so, would it be possible to explain the co-existence of three totally different lithic industries, contemporaneous and stretching the whole of eastern South America, already settled by 12,500 calBP? In order to explain this variation, we have to rely on a theoretical reasoning, and I believe evolutionary theory is best suited to do this, since there is no other theoretical *corpus* nowadays dealing explicitly with matters regarding cultural change across space and time (Dunnell 1980, O´Brien and Lyman 2002). The supposed rapid spread of Clovis people southward is based on plain common sense, and have no basis whatsoever on either empirical evidence or theoretical expectations.

How Do We Explain Eastern South American Paleoindian Cultural Variability?

If everything we find in eastern South America is derived from a single culture, what is the reason for such a departure from the "norm"? Why did the ancestors of South American Paleoindians give up their world views, and completely change their *chaines opératoires* or "recipes" in such a short time? Modifications in the whole structure of a lithic industry is not to be taken lightly. As put by Eerkens and Lipo (2007: 249): "structural aspects about technologies should stay relatively unchanged, although details may fluctuate greatly". A favored

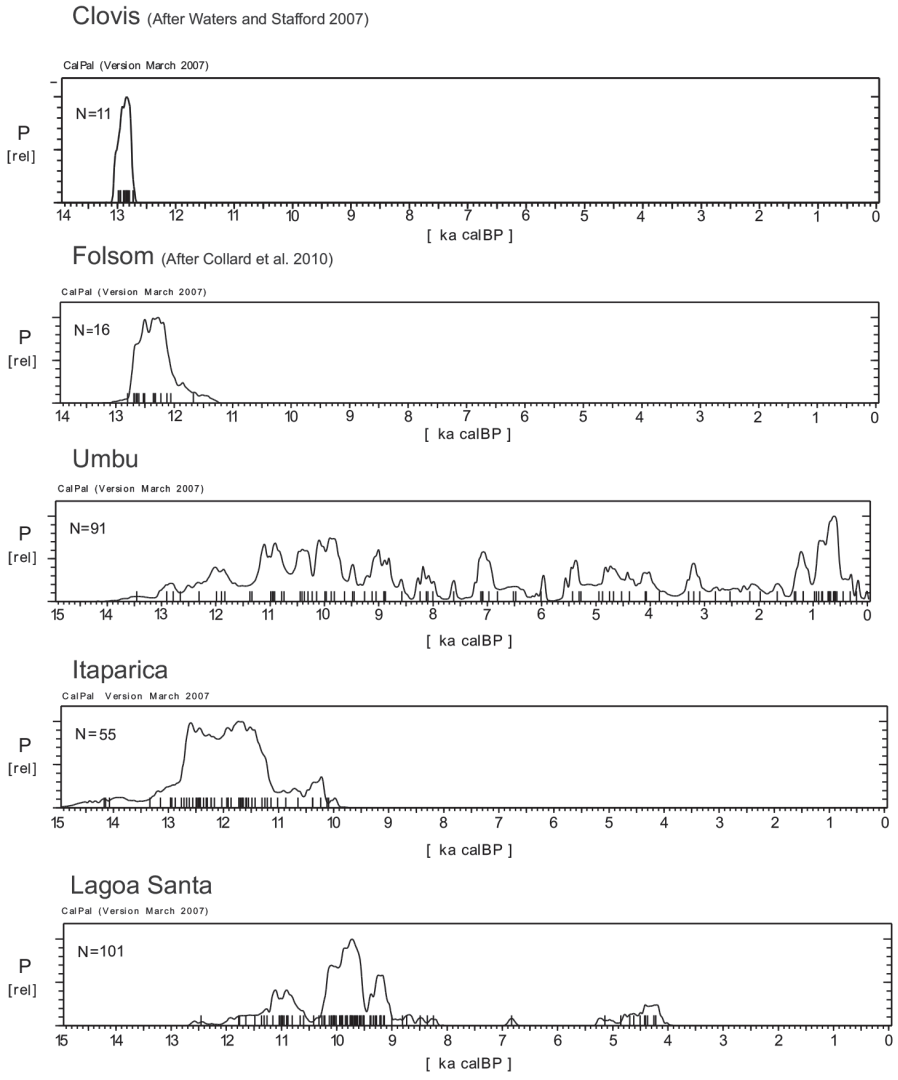

Figure 2 - Summed probability distributions of the radiocarbon ages for the Paleoindian traditions mentioned in the text.

processual explanation would say that this happened because of changes in the subsistence or environment faced by these people when they went southwards. Toolkits had to change accordingly. I believe that the strict adaptationist view of lithic industries as being directly related to environment does not reflect the empirical evidence (see also Shennan 2000: 815), again because of our Paleoindian data which will be seen. But for now, even if such was the case, why did the same not happen in North America? After all, the environmental gradient faced by Clovis people was huge. Clovis points are found everywhere, from the grasslands of the Plains through the boreal and deciduous forests of the eastern United States (Barton et al. 2004, Meltzer 2003). There is also much contention about the Clovis "specialization" in hunting megafauna. In fact, there is strong evidence that they were not specialized hunters (Cannon and Meltzer 2004). This being so, there is probably no direct relationship between Clovis bifacial points and a specific hunting activity (but see Buchanan et al. 2011 for a different opinion), or at least no "need"

to stop making bifacial points when one went south; Clovis points were most probably "all purpose" artifacts, as also suggested by microwear analysis (Kay 1996, Smallwood 2006).

The spread of humans toward the south, at an unknown age, must have been a process involving small populations. There is neither theoretical reason nor empirical data to support a mass population movement southward, since North America did not become depopulated at the beginning of the Holocene. Therefore, we have to think about cultural change involving low population levels and small communities. If this is the case, based on expectations of CT theory, we would see a *low innovation rate* (Henrich 2010, Powell et al. 2010, Shennan 2001). Innovation, or the spread of new ideas through a population, is related to the number and interconnectedness of individuals. The more people one interacts with, the more innovations will be created (Henrich 2010), and the more effectively these innovations will spread (Perreault and Brantingham 2011). This means, therefore, that these small hypothetical southbound early "Clovis-derived" populations should present a very low innovation rate. This would mean at least the persistence of bifacial industries, slightly different from the Clovis ones, due to copying errors (Eerkens and Lipo 2005, Hamilton and Buchanan 2009) and low innovation rates. Being extremely conservative, the Clovis *Bauplan* would be reproduced for a long time, as effectively happened in North America where it most probably gave rise to several "Clovis-like" points (see Bradley et al. 2010, Lipo 2006, O´Brien et al. 2001) and ultimately to Folsom (Collard et al. 2010), another bifacial fluted technology which was also very homogeneous and conservative (MacDonald 1998), and then later to a plethora of bifacial industries. However, the empirical evidence from South America shows otherwise: there must have been a very high innovation rate, indeed an explosion in innovation never recorded before in human history, in order to account for the Clovis cultural and technological package to become three totally unrelated things in less than a thousand years. Moreover, these three industries were fully established in South America at the same time that North American Paleoindians were producing Beaver Lake, Dalton, and Folsom points (Fig. 2).

Another possible outcome of small Clovis-derived populations going southward would be the *loss* of cultural traits due to decreasing (or even ceasing) contact between populations, involving a process of maintenance of simple technological skills and the deterioration of more complex ones, generating maladaptive losses (Henrich 2004), or, even if populations maintained cultural bonds, a net loss of cultural diversity is expected in the groups that are part of the advancing front due to spatial drift (Pérez-Lozada and Fort 2011). Of course, one could regard the Lagoa Santa industry as a "deterioration" of complex skills when compared to Clovis, but the same could not be said about Umbu. However, as we will see shortly, Lagoa Santa cannot be regarded as a case of maladaptive technological loss.

Explaining Variability: Shortcomings of the Traditional Way

Our point of departure is that eastern South American Paleoindians (hereafter "ESAPs") were distributed along wide territories and explored different environments, but their different material culture is less related to environment than traditional wisdom suggests. The main traditional explanations for these differences are subsistence, raw-material availability and mobility, each of which we will examine.

Subsistence

Zooarchaeological data from southern and central Brazilian Paleoindian sites (Jacobus 2004, Kipnis 2002, Schmitz et al. 2004) indicate very similar faunal contents in the Umbu and Itaparica traditions,

and the same can be said for the Lagoa Santa Paleoindians. All groups relied strongly on cervids such as the red brocket (*Mazama americana*), the Pampas deer (*Ozotocerus bezoarticus*) and peccaries (South American collared peccary, *Pecari tajacu* and white-lipped peccary, *Tayassu pecari*), as well as terrestrial gastropods (*Megalobulimus oblongus*, *Drymaeus* sp.); thus, subsistence-based explanations for differences between the material culture of these groups is not supported by empirical data. Another important point to note is the virtual absence of the largest extant South American herbivore, the tapir (*Tapirus terrestris*) in most ESAP records. At Lagoa Santa this is very clear (Bissaro Jr 2008). The most abundant species found at Lapa das Boleiras and Lapa do Santo rockshelters were small-sized mammals such as the Brazilian guinea pig (*Cavia aperea)*, the lowland paca (*Agouti paca*), and the rock cavy (*Kerodon rupestris*), amphibians, reptiles (mainly tegu, *Tupinambis* sp.), and armadillos. Among the larger mammalians, cervids (*Mazama* sp.) were the most abundant, and to a lesser extent, peccaries (*Tayassu* sp). The tapir was definitely present in the region since at least the Pleistocene / Holocene transition (Hubbe 2008), being much larger than the *Mazama* sp. cervid (*T. terrestris* mean weight is 150 kg, versus 26 kg for *Mazama* sp.); its meat is highly appreciated by extant native hunters, ruling out any difficulty in hunting or processing these large mammals (e.g., Souza-Mazurek et al. 2000). This suggests that Paleoindians were deliberately avoiding larger prey and at the same time leads us to exclude optimality reasoning from our explanatory repertoire.

Of course, the different lithic industries could be related to other aspects of subsistence (like vegetable processing) that are not linked to hunting practices. If so, we would expect the same lithic industry for Itaparica and Lagoa Santa, given that the environments occupied by both overlapped. Both traditions occupied the widespread areas of grassy to woody savannahs (*cerrado*).

Raw-Material Availability

One of the most striking characteristics of the Paleoindian lithic industries in Brazil is the low frequency of what could be considered good raw material for flintkanpping (i.e., flint), even in the manufacture of bifacial points and other formal artifacts. This can be observed in both the southern (Umbu) and the central (Itaparica and Lagoa Santa) assemblages (Fig. 1; Araujo and Pugliese 2009). The sites with more flint do not reach 30%; most sites barely reach 10% of flint in their industries, regardless of them being formal or generalized core reduction. The view that regards raw material quality as important in the structure of lithic industies (good quality raw material used in formal tools; bad quality raw material for generalized artifacts; Andrefsky 2005: 240) does not hold. Again, this suggests a "non-optimal" behaviour regarding the choice and economy of raw materials, leading to the use of the easiest raw-material available *regardless of the degree of formalization in the industry*.

Mobility

It is also important to note that the ESAP empirical data do not support generalizations linking mobility to technological organization (e.g. Kelly and Todd 1988, Odell 1998, Parry and Kelly 1987). Unless we regard the Paleoindians from Lagoa Santa as sedentary since 12,500 calBP, the mobility/technology model does not explain such a generalized technology without formal artifacts. The reasoning tries to explain the manufacture of formal tools (and specially bifacial cores) as an optimal strategy for mobile hunter-gatherers in terms of raw material economy and coping with uncertainty. Another recent model tries to link expediency to the advent of the bow and arrow (Railey 2010). Again, the ESAP record does not support any of these arguments, since these three early Holocene industries are most probably linked to hunter-gatherers, each of them using different technological structures.

Given the above considerations, I do not believe that these differences in lithic industries are related to issues concerning raw materials, mobility or subsistence. Rather, the differences observed appear to be three different ways of meeting basic needs, rooted in a variation that developed much earlier (Araujo and Pugliese 2009). To use an archaeological example in order to address the time interval expected to produce sufficient lithic diversification, Borrero (1989a) and Borrero et al. (1998) presented a periodization of Tierra del Fuego / Patagonia. The first appearance of bifacial points (Fishtail points) dates from 12,330 calBP (10,400 ± 80 14C years BP). Between 9500 and 7000 calBP, "discrete clusters of sites are observed (…) all characterized by stylistically similar projectile points" (Borrero 1989a: 260). Thus, we have a period of two to three millennia to see a differentiation between Fishtail points and early Holocene bifacial points. Only between 8000 calBP and 5500 calBP does the "Casapedrense" industry appear, lacking bifacial points (Cardich 1987). If we take this example as representative of the *tempo* of cultural change in hunter gatherers, it took about 4200 years to change from a flake-based bifacial industry to a blade-based unifacial industry[3]. Other things being equal (and they were probably not, since early Holocene populations were probably smaller and hence cultural change is expected to be slower), we would need at least the same time interval, and most probably a larger time interval, in order to differentiate the three ESAP industries. Another compelling example supporting very low rates of change in lithic industries comes from Brazil, where Okumura and Araujo (2014) showed that Umbu bifacial point morphology remained the same throughout at least 3100 years, or 160 generations. Therefore, I propose that these industries differ so significantly due to changes that occurred over a long period of time. This can be understood as a single culture giving rise to different ones inside the Americas (a very long period of time) or different existing cultures that enter the Americas (a shorter period but nevertheless still quite long). Both alternatives are linked to the concept of historicity in evolution.

[3] This reasoning assumes that the Casapedrense was a local development derived from bifacial industries, which is not necessarily true. See some critiques about the notion of "Casapedrense" in Borrero 1989b.

Historicity

Diversity is the product of three fundamental evolutionary influences: adaptation, chance, and history (Travisano et al. 1995a). There is an intense debate in biology regarding the role that each of these factors plays in the evolutionary trajectories of organisms (Conway Morris 2003, Gould and Lewontin 1979, Mayr 1983, Lauder 1981, 1982), and we can ask the same question regarding the evolutionary paths taken by different cultures. Therefore, we can suppose that the diversity of the ESAP record could be due to selection, drift, or history. This differentiation of three aspects is obviously an analytical tool; evolutionary paths are most likely a mixture of the three factors, but sometimes it is possible to disentangle them and at least make suppositions about which had a stronger influence.

First we will convey what is meant by "history" and "chance." The distinction between these two terms is being more appreciated, after studies of long-term experimental evolution (LTEE) using bacteria provided insights and expectations about the role that each factor (selection, chance, and history) can have upon population-level evolutionary paths (Cooper and Lenski 2010, Lenski and Travisano 1994, Travisano et al. 1995a, b). Historicity is a string of events that lead to a given state whose occurrence is dependent upon previous states; hence, it is not a matter of chance in a random sense. In other words, history can lead to an outcome that would not follow from random mutations or drift.

As another experiment with *E.coli* demonstrated, after many generations, a series of mutations gave rise to a population that was capable of feeding on citrate instead of glucose (Blount et al. 2008). The citrate-consuming population was not the product of a single mutation that occurred by chance, but of a series of previously occurring mutations.

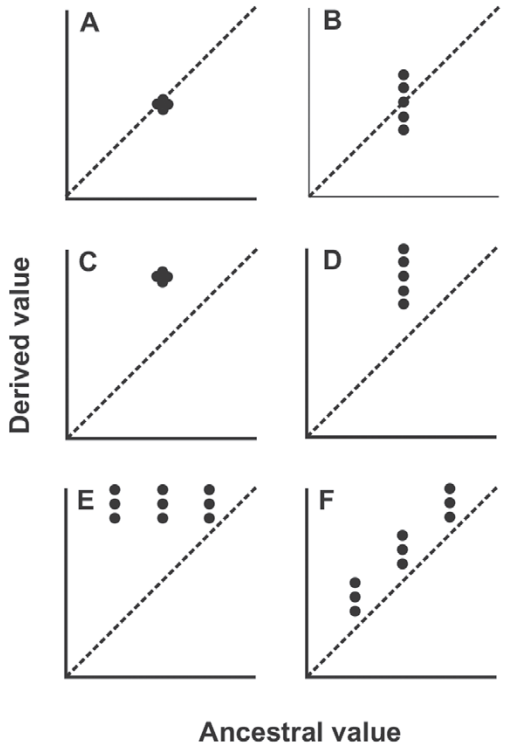

Figure 3 - Schematic representation of changes related to adaptation, chance, and history in the evolutionary paths (Travisano et al. 1995a: 87). A) No change, no evolution; B) Chance plays a major role, the mean of the derived values are around the same value as the ancestral; C) Adaptation plays a major role, the derived values are higher and closely associated; D) Adaptation plays a role, but is combined with chance to spread the values; E) An initial effect due to history is eliminated by subsequent adaptation and chance effects; F) An initial effect due to history is maintained, chance and adaptation are superimposed.

Figure 3 shows the effects of adaptation, chance, and history on evolutionary change and diversification (Travisano et al. 1995a: 87). Building on the LTEE data, Desjardins (2011: 348) made explicit some conditions that must be obeyed in order to claim that history matters in a given evolutionary path:

1. Multiple possible past states; 2. Multiple possible outcomes; 3. Causal dependence between the two; the probability that a given outcome occurs must change as a function of the historical conditions realized on a given occasion.

A further distinction was drawn between two forms of historicity: *dependence on initial conditions* and *path dependence*. The former states that differences "from the onset" would be responsible for different evolutionary trajectories, even if the subjects under evolution were placed in the same environment. The latter begins with a single population, and the "past states" of condition 1 are related to different paths, or chains of stochastic events, and not to different original sets of traits. Of course, the difference between the two kinds of historicity is arbitrary and will depend on where the researcher draws the line in order to define the initial conditions, if beginning the study with a single set of traits or with multiple sets.

In summary, if history matters, a given set of traits will maintain its differences from another set of traits in a manner that they will be still recognizable as different sets. An alternative to this is chance, eventually leading to a scattering of traits across the evolutionary space. The third alternative is convergence, or different initial states reaching the same final state due to strong selective pressures. Convergence means that history and chance are erased[4]. It is interesting to note that, in theoretical terms, the three ESAP traditions cannot be linked to a historical path. In fact, they are so different that they will not obey the third condition proposed by Desjardins (2011), namely, the causal

[4] This is the argument underpinning the New Archaeology approach to material culture: differences between toolkits or material culture in general would be adaptations to the environment; this means that history (especially cultural history) does not matter.

dependence, because "history will matter as long as the derived populations diverge *and* that the initial similarities are sufficiently maintained" (p.347).

Another important aspect of the LTEE results is related to the fact that the 12 bacteria populations, originated from a single individual (cloned) and living in the same environment, evolved in different ways. The expected outcome is shown in Figure 4a, but it was realized that these populations diverged or took different evolutionary paths. The outcome of 4a being ruled out, there was still the possibility that they diverged in an early phase but that the same selective pressures would make them reach the same fitness level after enough time (Fig. 4b). However, the outcome of the experience showed that the paths were actually divergent, akin to Figure 4c, even after 50,000 generations. The authors of the experiment believed that this happened because *each population reached an adaptive peak*. In order to test this hypothesis, Cooper and Lenski (2010) grew seven *E. coli* populations in both stable and fluctuating environments, their results showing that after 2000 generations the ones that were subjected to environmental fluctuations were more diverse than the ones in stable environments, again suggesting that they reached different adaptive peaks because *heterogeneous environments produce rugged adaptive landscapes*. This is roughly the same idea proposed by Shennan (2000) following Rosemberg (1994), in which the emergence of a new cultural *Bauplan* as a result of fission and expansion of populations in new environments is explained. In such cases, stochastic elements such as founder effects and drift would have a strong influence on the structure of derived cultures. Here we regard founder effect as a case of historicity dependent on previous conditions.

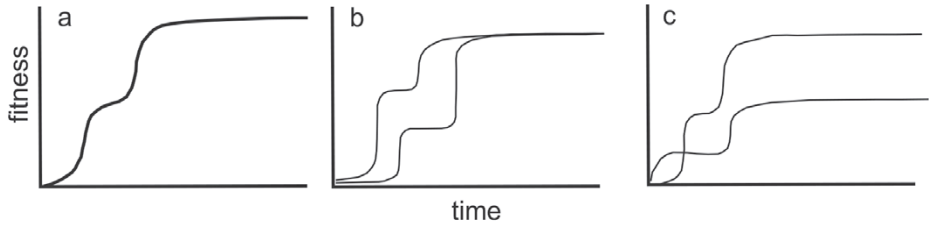

Figure 4 - Schematic evolutionary paths taken by different populations: **a)** parallel evolution; **b)** transiently divergent evolution; **c)** sustained divergent evolution. From Desjardins (2011: 343).

Before proceeding it is important to make it clear that the LTEE results bear importance not because they are directly applicable to humans, since we are not dealing either with genetic transmission or with huge generational spans, but because they show the major role that historical paths can play in evolutionary processes.

There are several implications of the preceding discussion for our understanding of the ESAP record:

1) The (at least) three different sets of material culture that we refer to as traditions (as in O´Brien et al. 2010) could be regarded as three different ways of meeting basic needs, probably not equally efficient in absolute terms, but efficient enough to maintain viable human populations, what is enough in evolutionary terms. This could be regarded as the outcome of the occupation of different peaks in a rugged adaptive landscape (heterogeneous environment). The three traditions can be schematically represented by the points in Figure 3F.

2) Historicity probably explains most of the observed variability for two reasons. In spite of producing different toolkits, the three populations showed very similar patterns for foodstuff acquisition. Moreover, Lagoa Santa and Itaparica occupied similar environments but had different toolkits. Therefore, regarding the lithics as adaptations to different environments is not a robust

explanation. On the other hand, once visible in the archaeological record, i.e., once the archaeological visibility threshold was surpassed, the three traditions showed remarkable persistency in time. Umbu and derived bifacial industries remained in the same area during the whole Holocene. Lagoa Santa certainly endured from 12,500 calBP to 8400 calBP, and after a hiatus in the occupation of the rockshelters[5], the same sites were reoccupied between 5000 and 4000 calBP, suggesting cultural continuity for at least 7000 years. The ages for Itaparica suggest a shorter time span, from 12,600 calBP to 9400 calBP, but still a three millennia interval. These data suggest that stable, novelty-avoiding cultural mechanisms were active, and does not leave much room for cultural drift as the only or major generator of diversity.

3) It is an open question whether the observed diversity is related to historicity as "dependence on initial conditions" or "path dependence." In other words, if we focus our interest on the Americas, do the ESAP traditions derive from (at least three) different cultural stocks that entered the continent at different times, as strongly suggested by bioanthropological (Neves and Hubbe 2005, Neves and Pucciarelli 1991) and genetic data (Bortolini et al. 2003, Lell et al. 2002), a scenario of dependence on initial conditions, or are they due to diversification operating over an original single cultural stock, a case of path dependence? Either of these two possibilities rules out that such changes occurred upon a Clovis cultural background in less than 500 years.

4) The "simplicity" of Lagoa Santa industries should be regarded as a major cautionary tale. The idea that generalized industries are linked to environmental factors or group mobility does not hold in this case. Moreover, it is tempting to see the Lagoa Santa culture as a case of maladaptive loss, given the simplicity of the lithics. However, it must be stressed that they probably outlived and replaced the Itaparica tradition. The same rockshelters which show Itaparica industries from 12,600 calBP started to show flake-based industries without any formal artifacts about 9500 calBP, what is regionally called "Serranopolis phase". We do not yet have enough data to affirm that Serranopolis is linked to the same Lagoa Santa population, but given the fact that Lagoa Santa was still active as a cultural system up to 8400 calBP, and perhaps up to 4,000 calBP, as we just saw, the idea seems plausible.

[5] Probably a change in the focal area of occupation, by means of a northward migration.

If Not Clovis, What Then?

Having exposed my motives for thinking that the Clovis-First model falls short of explaining the empirical evidence when taking into account the expectations and simulation models based on CT theory, let us now show other independent reasons for abandoning the model.

Firstly, let us consider dispersion rates. Mathematical models for the spread of humans into the Americas generally go in two basic ways: either they assume that humans crossed the Behring Strait at a given date, and then calculate the necessary expansion and population growth rates to ensure that the population would have reached Patagonia at the assumed date (e.g. Lanata et al. 2008); or they use the location and ages of known sites to estimate rates of dispersion (e.g. Hamilton and Buchanan 2010, Haynes 2006). These models tend to work with high population growth rates and even higher expansion rates.

Much time and effort has been devoted to calculating the speed at which these supposed Clovis hunters would have travelled. Table VII shows some scenarios; of course, the Clovis dispersion scenarios by Fiedel (2004) and Haynes (2006) are totally discrepant in relation to other archaeological and ethnographic data and do not deserve further comments. In our view, the most reliable, empirical data available is for northeastern Europe, and we have to bear in mind that the reoccupation of that area by humans after the Last

TABLE VII
Estimates of dispersion rates for modern humans spreading in different settings.

Author/setting	Dispersion rate
Barton et al. (2004) / Northeastern Europe after glacier retreat	0.3 to 0.9 km / year
Pinhasi et al. 2005 – Neolithic spread	0.6 to 1.1 km / year
Webb and Rindos (1997) / Sahul (Tasmania + New Guinea)	2 to 3 km / year
Hamilton and Buchanan 2007 / Clovis advance front	5.1 to 7.6 km / year
Webb and Rindos (1997) / Model of South America colonization	7 to 10 km / year
Barton et al. (2004) / Model of colonization of the Americas	10 to 20 km/ year, decreasing to 8 km/year
Fiedel (2004) / Thule in Northern Canada	16 to 21 km / year
Haynes (2006) / Clovis in North America	2,270 km / year
Fiedel (2004) / Clovis traversing the Ice Free Corridor	2,000 km in 80 days = 25 km / DAY

Glacial Maximum (LGM) was done by a population already used to the north European climate and resources. Even so, it occurred at a much slower rate than proposed by any of the models.

Another strong evidence of slower dispersion rates is provided by Pinhasi et al. (2005). The spread of agriculture from the Middle East towards Europe was calculated by means of the radiocarbon ages of 735 early Neolithic sites, and the rate of dispersal fell between 0.6 and 1.1 km/year. Based on genetic and craniometric data, this spread is considered by the authors to be predominantly a demic expansion, rather than the transmission of a cultural novelty. It can be argued that agriculturalists move slower than hunters, and also that they encounter people already living in the areas they move into, but at the same time the adoption of agriculture is responsible for much higher population growth rates and, therefore, entails an aggressive territorial expansion (Rindos 1980). So, even taking into account that agriculture is a fast spreading subsistence system, driven by its inherent instability, and that at the same time it promotes a strong evolutionary advantage to people who adopts it, the spread of farmers into Europe, probably one of the fastest events of human expansion in prehistory, is much slower than what is proposed by the models.

If we forget not only all tenets of cultural transmission discussed earlier but also the rest of the South American archaeological record, and simply trace a least-distance path between the United States / Mexico border and eastern South America, it gives us a distance of about 8,270 km. Table VIII shows the time necessary to cover this distance for different expansion rates. The table shows that a minimum expansion rate of 15 km /year would be necessary to cover this *linear* distance in less than 500 years[6]. Based again on empirical data, such rate is highly improbable.

Secondly, let us analyze population growth rates. This aspect is somewhat linked to expansion rates, since population pressure would be a prime-mover of group fission and, therefore, expansion. Lanata et al. (2008) worked with several population growth rates and the simulations showed that the minimum rate for a viable population (i.e., reaching

[6] Using the oldest age for a credible Clovis site, Lange-Ferguson, of 12,980 calBP (11,080 ± 40 14C years BP, Waters and Stafford 2007).

TABLE VIII
Number of years to cover the 8,270 km (5,200 mi) between USA/Mexico border and eastern South America.

Rate (km/year)	Years
0.9	9188.9
1.1	7518.2
2	4135.0
3	2756.7
7	1181.4
8	1033.8
10	827.0
15	551.3
16	516.9

Tierra del Fuego) would be 2% growth rate, but to fit the colonization of South America inside the desired chronological range (entrance post-LGM), the growth rate should be 3%. However, as stated by the same authors, extant hunter-gatherers show growth rates between 1 and 1.5%. Of course we can reason that these extant groups were heading for extinction, but it is also reasonable to think that perhaps the mathematical model is inadequate[7]. Even if it is not, is there any reason to suppose that the first people to colonize the Americas would show a growth rate that is two to three times higher than the one observed for extant hunter-gatherers? A recent simulation for the population growth of Australian hunter-gatherers, taking into account the radiocarbon ages, points to much lower rates, ranging between 0.09% and minus 0.05%, with an average of 0.01% (Williams 2013).

Anyway, by using the (probably inflated) 2% growth rate, Lanata et al. (2008) found that "the complete colonization of the Americas was possible, but required more than 12,000 years to arrive at northern South America and more than 20,000 years to reach Tierra del Fuego" (Lanata et al. 2008: 523). That is a very interesting statement.

[7] The authors used Fisher´s model for population growth that includes K or carrying capacity. This parameter, by itself, is extremely difficult to estimate with paleoenvironmental data. Moreover, an anisotropy coefficient was added.

CONCLUSIONS

Summing up all the evidence, it seems clear that the best hypothesis to explain the cultural diversity in South America and the time-depth necessary to explain it, is contrary to the Clovis-First model. Meltzer (2003) schematically arranged the hypothesis of peopling of the Americas in terms of timing (pre or post-LGM) and number of migrations (one or multiple), as seen in Table IX.

Given all the available data, hypothesis H2 is the best suited to explain the empirical record: multiple migrations, the earliest of which was in pre-LGM times. This hypothesis allows enough time to have distinct cultural lineages developing and establishing territories in eastern South America, following some basic assumptions anchored in CT theory, namely, expected rates of cultural change involving small populations and heterogeneous environments.

TABLE IX
Four hypotheses of the peopling of the Americas (from Meltzer 2003: 546).

Timing	Number of Migrations	
	Single	Multiple
Pre- LGM	H1: Single migration in pre-LGM times	H2: Multiple migrations, earliest of which in pre-LGM times. Subsequent migrations could occur then on post-LGM.
Post-LGM	H3: Single migration in post-LGM times	H4: Multiple migrations in post-LGM times

Clovis is probably the most visible component of a much more complicated scenario involving time-depth. There is no reason to expect that every population entering the Americas used stone bifacial points, since these artifacts are but one of several ways of hunting, and the persistence in manufacture and use of this specific class of artifacts is most probably strongly linked to cultural lineages. Bifacial points made of stone were persistently used in some parts of South America, for example, Umbu; and not used at all in others - Lagoa Santa and Itaparica; or even abandoned, for example, the Casapedrense

in Argentina who were hunters specialized in a big mammal, the guanaco (*Lama guanicoe*) and did not use stone points (Cardich 1987).

The South American Paleoindian record comprises, therefore, a scenario that seems incredibly rich, making the North American record seem a quasi-unilinear thread of cultural transmission as observed in the Paleoindian bifacial industries (e.g., Buchanan and Collard 2008), where Clovis (and probably other similar biface-thinning technologies) seems to originate Folson, that seems to originate Archaic forms. In contrast, we are here presenting a case where evolutionary mechanisms provided a boom in cultural lineages and, therefore, in lithic traditions. Our data contradicts the idea that reticulation, or the intermingling nature of culture, acts as a blurring agent (e,g., Dewar 1995), erasing the phylogenetic signatures of different cultures (see O´Brien et al. 2008: 48).

That the empirical record of South America cannot be explained by a southbound migration of Clovis people is an old claim. What I tried to show here is that it is also not feasible when viewed under the light of cultural transmission and evolutionary theory.

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RESUMO

O Leste da América do Sul, ou o que é hoje o território brasileiro, coloca questões interessantes sobre a ocupação humana no início das Américas. Três tecnologias líticas totalmente distintas e contemporâneas, datadas entre 11.000 e 10.000 ^{14}C AP, estão presentes em diferentes partes do país: a tradição Umbu no sul, com sua indústria formal bifacial, com raspadores bem retocados e pontas bifaciais; a tradição Itaparica no centro-oeste e nordeste, totalmente unifacial, cujos únicos artefatos formais são os raspadores plano-convexos; e a indústria de "Lagoa Santa", com ausência completa de quaisquer artefatos formais, composta principalmente por pequenas lascas de quartzo. Nossos dados sugerem que estas diferenças não estão relacionadas à subsistência ou restrições de matéria-prima, mas sim a diferentes normas culturais e transmissão cultural de cadeias operatórias fortemente divergentes. Essa diversidade na cultura material, quando abordada do ponto de vista da teoria da transmissão cultural (TC), parece em desacordo com um modelo simples de origem Clovis destas três tradições culturais, dado o tempo decorrido desde as primeiras idades Clovis e da estrutura populacional esperada para os primeiros colonizadores da América do Sul.

Palavras-chave: Paleoíndios, tecnologia lítica, Umbu, Itaparica, Lagoa Santa, Transmissão cultural.

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SUPPLEMENTARY MATERIAL

TABLE SIV - Radiocarbon ages for Umbu sites, calibrated using CalPal-2007 Hulu calibration curve (Weninger et al. 2012).
TABLE SV - Radiocarbon ages for Itaparica sites, calibrated using CalPal-2007 Hulu calibration curve (Weninger et al. 2012).
TABLE SVI - Radiocarbon ages for Lagoa Santa sites, calibrated using CalPal-2007 Hulu calibration curve (Weninger et al. 2012).