The Southern Divide: Testing morphological differences among bifacial points from southern and southeastern Brazil using geometric morphometrics

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Abstract:

Bifacial points have been used to characterize the “Umbu” tradition in southern and southeastern Brazil. This archaeological tradition has been related to sites dated from the late Pleistocene-early Holocene boundary to near historical times. Such a huge temporal range and vast territory have suggested the existence of greater diversity within this tradition that has been ignored thus far due to the lack of systematic regional studies of such points. Through geometric morphometric analysis, this article aims to test the hypothesis that there are substantial differences in the Holocene bifacial points associated with the Umbu tradition in southeastern Brazil. Five landmarks were digitized in standardized photographs from 658 points from the states of São Paulo, Paraná, Santa Catarina, and Rio Grande do Sul. The results show that points made by groups from southeastern Brazil (São Paulo state) present a very distinct morphology (size and shape) in comparison to those made by the southern groups (Paraná, Santa Catarina and Rio Grande do Sul). This would indicate a regional identity shared only by some groups from São Paulo (at least regarding the projectile points). It is possible that Umbu tradition presents a more restricted range, both in chronological and spatial terms, than the one proposed so far.

Keywords: lithics; Umbu tradition; Pleistocene-Holocene boundary; projectile points

1. Introduction

Flaked lithic artifacts shaped as projectile points are quite common in the Americas, being generically called “arrowheads” or “projectile points”. Although their piercing or puncturing function is obvious, there are different ways in which such piercing or drilling can be carried out (Cattelain 1997): pressure-induced muscle strength of those handling the artifact directly transmitted via a shaft (thrusting spear), pressure-induced shock between the artifact and the target, being the kinetic energy released by either a bow or a dart thrower. It is known that stone artifacts that look like points can also be used as awls, knives, spears, harpoons, among other uses (Pitt Rivers 1906: 101, 117; Fenenga 1953; Rausing 1967: 164; Kay 1996; Greaves 1997; Erlandson *et al.* 2014). In short, the terms “arrowhead” or

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"projectile point" are inadequate, since they presuppose the use of a specific device to transmit the energy (For a recent review on the potential propulsion systems associated to bifacial points from southern and southeastern Brazil, see Okumura 2015 and Okumura & Araujo 2015a). Therefore, in this article, we will designate such artifacts as "bifacial points". An important feature of bifacial points lies in the fact they are formal artifacts, *i.e.* instruments whose manufacture aims to obtain a specific patterned form.

In the 1970s, Brazilian archaeologists tried to understand the morphological diversity observed in bifacial points through the use of typologies and the creation of archaeological phases (see Table 1). Miller (1967; 1974), working in the Sinos Valley and Maquiné region (Rio Grande do Sul), created three pre-ceramic phases that presented bifacial points: Camuri, Umbu, and Itapuí. The Camuri Phase was characterized by open-air sites, while Umbu and Itapuí Phases were associated with rockshelters. Umbu would be more ancient (6000 to 4000 years BP) than Itapuí, and the predominant bifacial point type would be stemmed points with triangular bodies, as well as lanceolated points. Itapuí Phase would be more recent than Umbu (4000 to 1000 years BP), being characterized by points with bifurcated stem and triangular body, sometimes presenting serrated edges.

Another attempt to classify sites presenting bifacial points was the creation of the Bituruna tradition (Chmyz 1981a), which was tentatively associated to Paleoindian sites, where large stemmed bifacial leaf-shaped points were abundant. This tradition was identified in the middle and low Iguaçu River, in central-southern and south-western Paraná state, as well as in the areas near powerplants in Foz do Areia, Salto Santiago and Salto Caxias (Chmyz 1969; 1981a; b; Parellada 1999). However, the alleged antiquity of this tradition still remains to be verified; thus far, dates are scarce. The only radiocarbon age concerning this tradition comes from the site Jusante UHE Salto Caxias I, in south-western Paraná, presenting a date of 4810 ± 360 BP (Australian National University-ANU 192-19; Parellada 2005: 30).

Many other archaeological phases presenting bifacial points have been identified in southern Brazil (Iguaçu and Potinga Phases; Chmyz 1969; Vinitu Phase; Kern 1981: 215-220; Schmitz 1984: 12-14; 1991a; Itaguajé Phase; Chmyz & Chmyz 1986; Itaió Phase; Piazza 1974; Capivara Phase; Schmitz 1991a). Despite these early efforts to sort out the morphological diversity observed in the bifacial points from southern Brazil, the lack of good chronologies and the unclear definitions for the bifacial point classes (*sensu* Dunnell 1971: 45) led to difficulties in assigning new sites to these "phases", resulting in a later lumping of them into a single "tradition", Umbu.

The Umbu tradition would present its oldest phase in southwestern Rio Grande do Sul with the Uruguai Phase, in the 11^{th} Millenium BP (Kern 1981: 232-8; Schmitz 1987) (see Table 1). A more recent revision of the sites and dates by Dias & Jacobus (2003) considers only ten sites with a chronology ranging from 10,800 to 8500 BP. If we accept the revised data, Uruguai Phase would be contemporaneous to Umbu, since the oldest date for Uruguai Phase is 10,985 ± 100 BP (Laranjito Site, see Table 1). According to Schmitz (1978: 108), the Uruguai Phase would be the beginning of a tradition presenting bifacial points that would continue until the 14^{th} Century with the name Umbu (while Schmitz (1978: 108) supports the idea that Uruguai Phase would represent the beginnings of Umbu tradition, other authors, like Hilbert (1991: 16), consider that Uruguai Phase would be followed by Umbu tradition. Schmitz (1978:112) also notes the similarity among bifacial points from Uruguay, Missiones (Argentina) and Southern Brazil. Schmitz (1987) draws attention to the fact that, despite the large number of sites identified as representatives of Umbu tradition very few chronological indicators have been identified so far.

This eventually generated controversy concerning the existence of such a tradition, since it would encompass a very extensive chronological range, from 11,000 to 500 years BP. Therefore, Umbu tradition poses a special problem to archaeologists because of two basic characteristics: its wide geographic distribution and, above all, the length of its chronology. Researchers have questioned whether identification of a tradition extending from the Pleistocene-Holocene period until the eve of the historical period is plausible. Such doubts have led to the discussion of the validity of the concept of "Umbu tradition" in terms of classification and organization. Given the lack of identifiable chronological markers, this tradition became, in practice, "defined" only by the presence of bifacial points, becoming synonymous with "sites presenting bifacial points", regardless of their chronology or geographic location.

Currently, this tradition, dispersed throughout southern and southeastern Brazil, is simply characterized by the presence of bifacial points, presenting dates ranging from the Late Pleistocene to historical times (Schmitz *et al.* 1980; Schmitz 1999; Noelli 2000). Therefore, throughout the years, all archaeological sites presenting bifacial points, from Rio Grande do Sul to São Paulo (and in some cases including more northern settings, like Minas Gerais, (Koole 2007; 2014) and Mato Grosso do Sul, (Kashimoto & Martins 2009; Martins & Kashimoto 2012)), ended up being classified as belonging to the Umbu tradition. For example, in the case of São Paulo state, Miller Jr. (1972) defined the Rio Claro tradition (based on sites from Rio Claro, São Paulo state) as presenting bifacial points in some phases. Schmitz (1978: 120; 1991) also remarked the differences between the material from Rio Claro and Uruguai Phase, considering the bifacial points from Rio Claro as a regional evolution of Umbu tradition. Later, Prous (1991: 154) reports that this tradition would have been subsumed within Umbu tradition. This inclusion appears to be quite controversial since not all phases of the Rio Claro tradition presented bifacial points, and thus theoretically it could not be included in Umbu tradition. Regardless of the adequacy of this tradition, it is likely that such direct association have been obliterating important regional and local variations, either in chronological or spatial terms. To this date, regardless of the name given by archaeologists, it is possible to say there is a substantial number of archaeological sites in southern and southeast Brazil presenting bifacial points dating from the Late Pleistocene to the eve of the historical period (Table 1 and Figure 1).

Table 1: Archaeological sites from southern and southeastern Brazil presenting bifacial points dated from the Late Pleistocene to the eve of the historical period. The column "number on map" refers to the map presented in Figure 1.

Years BP	Site	Lab Number	Region	State	Reference	Map Number	Phase	Phase Reference
3100 ± 50	Gruta do Marinheiro	Beta 230979	Pains	MG	Koole 2007:107	1		
9610 ± 60	Gruta do Marinheiro	Beta 230980	Pains	MG	Koole 2007:107	1		
4650 ± 170	Camargo	-	Piraju	SP	Pallestrini & Chiara 1978	2		
1250 ± 50	BS22	Gif 9993	Bairro da Serra	SP	DeBlasis 1996:81	3		
5540 ± 120	Sarandi	Gif	Guareí	SP	Caldarelli 1983:115	4		
9540	Bela Vista I	-	Mogi Mirim	SP	Documento Ltda. 2003	5		
6090 ± 40	Capelinha I	Beta 184619	Cajati	SP	Plens 2007:74	6		
8860 ± 60	Capelinha I	Beta 153988	Cajati	SP	Neves *et al.* 2005	6		
8795 ± 100	Capelinha I	A11239	Cajati	SP	Neves *et al.* 2005	6		
8500 ± 100	Capelinha I	A11236	Cajati	SP	Neves *et al.* 2005	6		
9250 ± 50	Capelinha I	Beta 189331	Cajati	SP	Plens 2007:74	6		
10500 ± 1500	Capelinha I	Nucleo Bras/BH	Cajati	SP	Collet 1985	6		
8870 ± 50	Carcará	Beta 303991	São José dos Campos	SP	Juliani 2012:29-30	7		
7.680 ± 40	Alice Boer	Beta 320199	Rio Claro	SP	Araujo 2012	8		
7.200 ± 40	Alice Boer	Beta 320198	Rio Claro	SP	Araujo 2012	8		
3705 ± 130	Céu Azul I	SI 1575	São José dos Pinhais	PR	Schmitz 1984:47	9	Céu Azul	Schmitz 1984:47
755 ± 60	Céu Azul I	SI 1578	São José dos Pinhais	PR	Schmitz 1984:47	9	Céu Azul	Schmitz 1984:47
730 ± 50	PR-UV-02 Bogugeski	SI 142	União da Vitória	PR	Schmitz 1978	10	Iguaçu	Schmitz 1978
3110 ± 140	PR-UV-04 Kavales	SI 802	União da Vitória	PR	Chmyz 1977:197	10	Iguaçu	Chmyz 1977
990 ± 190	Fazenda Marrecas	ANU 192-26	Dr. Ulysses	PR	Parellada 2005:34	11		
4350 ± 250	Fazenda Marrecas	ANU 192-25	Dr. Ulysses	PR	Parellada 2005:34	11		
9040 ± 400	Ouro Verde 1	ANU 192-17	Boa Esperança do Iguaçu	PR	Parellada 2005:34	12		
6240 ± 250	Toninho da Recapadora	ANU 192-18	Boa Vista da Aparecida	PR	Parellada 2005:34	13		
8115 ± 80	PR-NL-8	SI 6401	Baixo Paranapanema	PR	Dias & Jacobus 2003; Chmyz & Chmyz 1986	14	Itaguajé	Chmyz & Chmyz 1986

Years BP	Site	Lab Number	Region	State	Reference	Map Number	Phase	Phase Reference
6715	PR-AP-45	SI 6498	Baixo Paranapanema	PR	Chmyz & Chmyz 1986	14	Itaguajé	Chmyz & Chmyz 1986
9630 ± 40	PR-WB-16 ASR Tunas	Beta 210872	Arapoti	PR	Chmyz *et al.* 2008	15		
7170 ± 60	PR-WB-16 ASR Tunas	Beta 210871	Arapoti	PR	Chmyz *et al.* 2008	15		
4035 ± 150	PR-FI-43	SI 5044	Foz do Iguaçu	PR	Chmyz 1983:100	16		
660 ± 80	SC-VI-10	SI 537	Presidente Getúlio	SC	Schmitz *et al.* 2009	17	Itaió	Piazza 1974
290 ± 80	SC-VI-10	SI 536	Presidente Getúlio	SC	Schmitz *et al.* 2009	17	Itaió	Piazza 1974
905 ± 95	RS-MJ-53-AyB Aleros de la Lihna Setima	SI 1196	Rio Jacuí	RS	Brochado & Schmitz 1973	18	Rio Pardinho	Schmitz 1984:47
800 ± 40	RS-SM-7 Alero de la Pedra Grande	SI 1003	São Pedro do Sul	RS	Brochado & Schmitz 1973	19		
605 ± 40	RS-SM-7 Alero de la Pedra Grande	SI 1002	São Pedro do Sul	RS	Brochado & Schmitz 1973	19	Rio Pardinho	Schmitz 1984:47
11555 ± 230	RS-IJ-68	SI 3750	São Borja	RS	Miller 1987	20	Uruguai	Miller 1987
10810 ± 275	RS-I-66 Milton Almeida	SI 2622	Uruguaiana	RS	Politis 2008	21	Uruguai	Dias & Jacobus 2003
10985 ± 100	RS-I-69 Laranjito	SI 2630	Uruguaiana	RS	Miller 1987	21	Uruguai	Miller 1987
10800 ± 150	RS-I-69 Laranjito	N 2523	Uruguaiana	RS	Miller 1987	21	Uruguai	Miller 1987
10400 ± 110	RS-I-69 Laranjito	N 2521	Uruguaiana	RS	Miller 1987	21	Uruguai	Miller 1987
10240 ± 80	RS-I-69 Laranjito	SI 3106	Uruguaiana	RS	Miller 1987	21	Uruguai	Miller 1987
10200 ± 125	RS-I-69 Laranjito	N 2522	Uruguaiana	RS	Miller 1987	21	Uruguai	Miller 1987
9620 ± 110	RS-I-69 Laranjito	SI 2631	Uruguaiana	RS	Miller 1987	21	Uruguai	Miller 1987
9120 ± 340	RS-I-70 Imbaá I	SI 2632	Uruguaiana	RS	Miller 1987	21	Uruguai	Miller 1987
10180 ± 275	RS-I-98	SI 3752	Uruguaiana	RS	Miller 1987	21	Uruguai	Miller 1987
610 ± 65	RS-314	SI 1195	Uruguaiana	RS	Brochado & Schmitz 1973	21	Uruguaiana	Schmitz 1987
9450 ± 115	RS-I-72 Palmito 2	SI 2634	Uruguaiana	RS	Miller 1987	21	Uruguai	Miller 1987

Years BP	Site	Lab Number	Region	State	Reference	Map Number	Phase	Phase Reference
9855 ± 130	RS-IJ-67 Pessegueiro	SI 3749	Itaqui	RS	Miller 1987	22	Uruguai	Miller 1987
8585 ± 115	RS-IJ-67 Pessegueiro	SI 2636	Itaqui	RS	Miller 1987	22	Uruguai	Dias & Jabocus 2003
9430 ± 360	RS-TQ-58 Garivaldino	Beta 44739	Montenegro	RS	Ribeiro & Ribeiro 1999	23		
8290 ± 130	RS-TQ-58 Garivaldino	Beta 32183	Montenegro	RS	Ribeiro *et al.* 1989	23		
8020 ± 150	RS-TQ-58 Garivaldino	Beta 33458	Montenegro	RS	Ribeiro & Ribeiro 1999	23		
7250 ± 350	RS-TQ-58 Garivaldino	Beta 44740	Montenegro	RS	Ribeiro & Ribeiro 1999	23		
6760 ± 50	RS-TQ-58 Garivaldino	Beta 226135	Montenegro	RS	Rosa 2009	23		
5655 ± 140	RS-C-14 Bom Jardim Velho	SI 1199	São Sebastião do Caí	RS	Dias 2003:112	23	Itapuí	Chmyz 1981b
745 ± 115	RS-C-14 Bom Jardim Velho	SI 1198	São Sebastião do Caí	RS	Dias 2012	23		Brochado & Schmitz 1973
8430 ± 50	RS-C-61 Adelar Pilger	Beta 260455	São Sebastião do Caí	RS	Dias & Neubauer 2010	23		
8150 ± 50	RS-C-61 Adelar Pilger	Beta 260456	São Sebastião do Caí	RS	Dias 2012	23		
8030 ± 50	RS-C-61 Adelar Pilger	Beta 229583	São Sebastião do Caí	RS	Dias 2012	23		
6180 ± 50	RS-C-61 Adelar Pilger	Beta 227856	São Sebastião do Caí	RS	Dias 2012	23		
3000 ± 40	RS-C-61 Adelar Pilger	UGA 02017	São Sebastião do Caí	RS	Dias 2012	23		
630 ± 205	RS-C-12 Virador	SI 1201	São Sebastião do Caí	RS	Dias 2012	23		Brochado & Schmitz 1973
7800 ± 50	RS-217 Pedro Fridolino Schmitz	Beta 204345	Bom Princípio	RS	Schmitz 2010	23		
1400 ± 40	RS-217 Pedro Fridolino Schmitz	Beta 211727	Bom Princípio	RS	Schmitz 2010	23		
2920 ± 120	RS-RP-86 Jandor Hanssen	SI 4795	Santa Cruz do Sul	RS	Ribeiro 1983	24	Rio Pardinho	
1425 ± 115	RS-RP-81 Anápio de Oliveira A	SI 4168	Vera Cruz	RS	Ribeiro 1983	24		
5950 ± 190	RS-LN-1 Dalpiaz	SI 234	Osório	RS	Miller 1974	25	Umbu	Miller 1974
5680 ± 240	RS-LN-1 Dalpiaz	SI 235	Osório	RS	Miller 1974	25	Umbu	Miller 1974
4280 ± 180	RS-LN-1 Dalpiaz	SI 233	Osório	RS	Miller 1974	25	Umbu	Miller 1974
8790 ± 40	RS-S-327 Sangão	Beta 160845	Santo Antônio da Patrulha	RS	Dias 2012	26		

Years BP	Site	Lab Number	Region	State	Reference	Map Number	Phase	Phase Reference
7390 ± 40	RS-S-327 Sangão	Beta 154353	Santo Antônio da Patrulha	RS	Dias 2012	26		
4690 ± 40	RS-S-327 Sangão	Beta 154352	Santo Antônio da Patrulha	RS	Dias 2012	26		
4610 ± 140	RS-S-327 Sangão	Beta 160847	Santo Antônio da Patrulha	RS	Dias 2012	26		
4160 ± 10	RS-S-327 Sangão	Beta 154351	Santo Antônio da Patrulha	RS	Dias 2012	26		
3970 ± 40	RS-S-327 Sangão	Beta 160849	Santo Antônio da Patrulha	RS	Dias 2012	26		
3730 ± 60	RS-S-327 Sangão	Beta 160846	Santo Antônio da Patrulha	RS	Dias 2012	26		
7240 ± 40	RS-S-337 Monjolo	Beta 165626	Santo Antônio da Patrulha	RS	Dias 2012	26		
6215 ± 30	RS-S-337 Monjolo	KIA 20841	Santo Antônio da Patrulha	RS	Dias 2012	26		
5230 ± 40	RS-S-337 Monjolo	Beta 165625	Santo Antônio da Patrulha	RS	Dias 2012	26		
520 ± 70	RS-S-337 Monjolo	Beta 165623	Santo Antônio da Patrulha	RS	Dias 2012	26		
440 ± 90	RS-S-337 Monjolo	Beta 165621	Santo Antônio da Patrulha	RS	Dias 2012	26		
1740 ± 65	RS-S-359 Aterrado	SI 2344	Santo Antônio da Patrulha	RS	Dias 2012	26	Itapuí	Schmitz 1987
920 ± 40	RS-S-360 Marimbondo	Beta 154354	Santo Antônio da Patrulha	RS	Dias 2012	26		
575 ± 80	RS-S-308 Morro da Flecha 1	SI 804	São Francisco de Paula	RS	Brochado & Schmitz 1973	27	Camuri	Brochado & Schmitz 1973

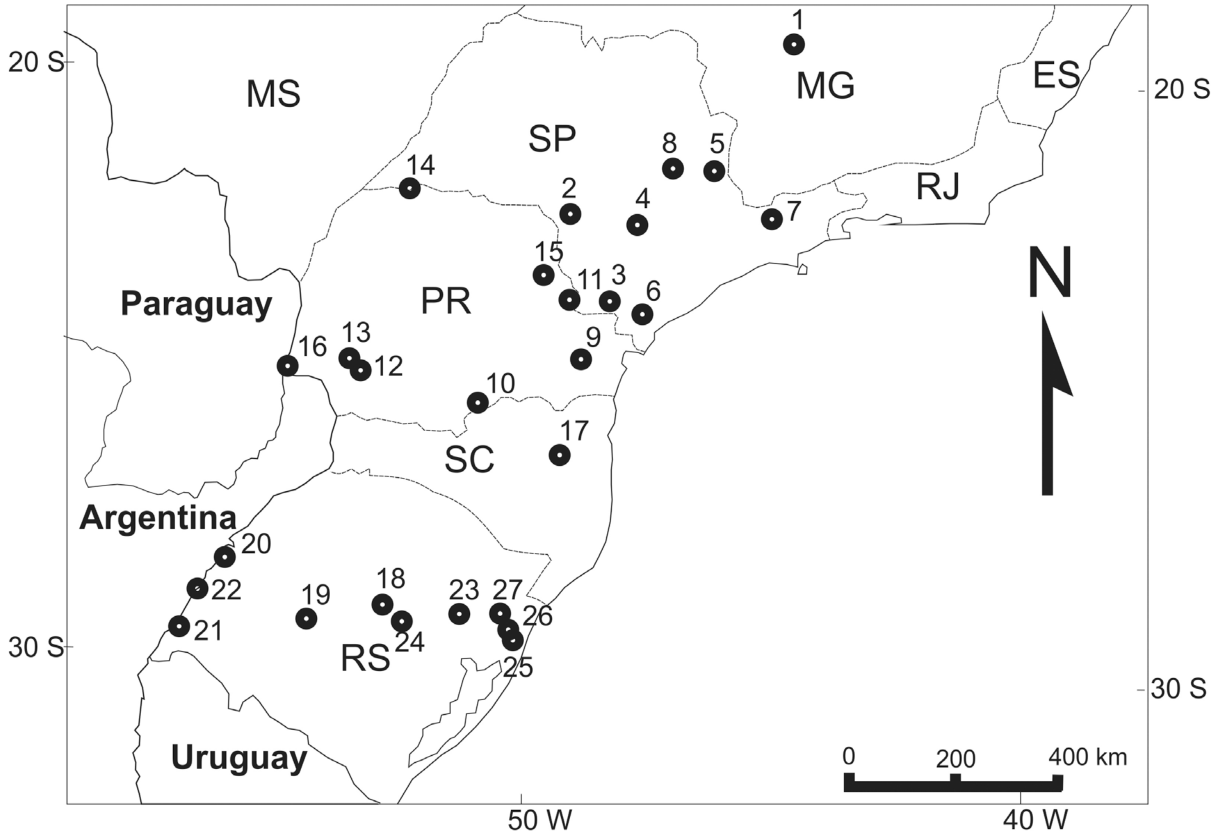

Figure 1: Archaeological sites from southern and southeastern Brazil presenting bifacial points dated from the Late Pleistocene to the eve of the historical period. The numbers refer to the column "map number" in Table 1.

1.1. Classification and the problems of assigning archaeological materials into "archaeological traditions"

The origins of the concepts of "phase" and "tradition" can be attributed to the Midwestern Taxonomic Method, by which North American archaeologists in the 1930s (McKern 1939) tried to define (or replace) the concept of "archaeological culture". Decades later, a similar system was proposed by Phillips and Willey (1953), in the 1950s and partially adopted in Brazil by "The National Program of Archaeological Research" (PRONAPA - *Programa Nacional de Pesquisas Arqueológicas*) in the 1970s. According to PRONAPA (Chmyz & PRONAPA 1976: 145), a tradition is defined as "a group of elements or techniques that are distributed with temporal persistence." In principle, this concept was totally disconnected from any "ethnographic" meaning (similar to that proposed by the Midwestern Taxonomic Method). Archaeological research pioneers aimed at defining traditions, which was often done from the study of only one or two sites. Later, phases and traditions began to be compared to "autonomous and semi-autonomous units" or "tribes" ("phases"), "tribal or linguistic entities" and "nations" ("traditions" - Meggers & Evans 1985; Schmitz 1991b).

In Brazil, criticisms of the definition and use of the term "tradition" pointed out three major shortcomings (Dias 2003: 51; Dias 2007; Dias & Hoeltz 2010; Hilbert 1994; Milder 1999): 1) a definition of such traditions was based on a few typological criteria, 2) the use of a fossil guide to determine the association of a particular site to a tradition and 3) the use of few attributes for classification of a site in a tradition. In other words, the application of the term "tradition" resulted, for example, in all sites presenting bifacial points (which are the fossil guides of Umbu tradition) being automatically classified as belonging to the Umbu tradition, regardless of the morphology, chronology, geographic location, or type of site.

After more than four decades since the initial definitions were proposed by PRONAPA, there were subsequent criticisms, followed by the remodeling of the "Pronapian" concepts, seeking stronger ties with anthropology, followed again by new waves of criticism, and finally today we have the crystallization of the concept of "tradition", simply because there is nothing better to replace it. After 40 years of controversy, perhaps we can be at peace with the term "tradition", as long as we understand it as a heuristic tool. Indeed, perhaps the best definition of tradition is the original one: simply a "group of elements or techniques that are distributed with temporal persistence". Fortunately, such definition refers to a group (a cluster of elements that can be listed) rather than a class, which would require a definition (Dunnell 1971: 45). Thus, the traditions will never be defined, only described. This may be unsatisfactory from a formal point of view, but again, perfectly serves our heuristic purposes.

Therefore, we do not propose abolishing the use of the term "Umbu tradition". However, we want to emphasize the importance of recognizing a morphological diversity present in these bifacial points that has been ignored so far. Traditions, or whatever name we give to these aggregate of phenomena, can be useful in terms of transmission of information among professionals and even among the laymen. However, they can be harmful (not to mention useless), when they ignore the observed variation by simply lumping together different classes of artifacts. In this context, we believe that the (ab)use of the term "Umbu tradition" must undergo further reflection.

1.2. Why study bifacial points? Formal artifacts and their potential statistical approaches

Binford (1977; 1979) suggested that technological organization could be seen as a continuum between cases centered on the production of highly modified ("curated") tools and cases where the tools are made from slightly modified raw materials ("expedient"). However, a quick review of the literature clearly points to a greater emphasis on characterization and study of formal lithic industries, whether in the Old World or the New World. Certainly, there is still a fascination for the formal lithic industries, reminiscent of collecting and curio cabinets, since these artifacts are more visually and aesthetically appealing, besides being more easily recognized as proper artifacts. Another important point is that, based on the discussions on style and function (Binford 1977; 1979; Dunnell 1978; Sackett 1985; among others), formal artifacts are more easily "seized" as conveying cultural transmission processes. This led to the development of various systems of classification, resulting in a greater availability of statistical analysis that can be applied in order to characterize such industries. This is the case in Europe and North America, for example, where the emphasis is on the variation between "types" of formal artifacts, which are generally considered independent of the technology. This emphasis has been the hallmark of the lithic analysis developed by François Bordes (1950), and this perspective has permeated the archaeological thought far beyond its original application in Middle Paleolithic European assemblages. Currently, many archaeologists may not share the fundamental ideas of Bordes, which sought to determine ethnicity and social interaction between different cultures, but still shape and technique are considered independent entities (Draper 1985). Thus, one cannot ignore the explanatory potential of formal artifacts, since this characteristic, the standardization of gestures and techniques aimed at producing artifacts with specific forms, allows the tracing of cultural interactions.

According to Dias (2003: 225), a lithic industry can only be fully understood with the analysis of the entire operational chain, and the typological variation observed in formal artifacts is just the tip of the iceberg (Perlés 1992: 223-224). However, what is proposed in this article is not an in-depth study of lithic technology itself, but the presentation of a complementary approach, involving the use of geometric morphometrics and multivariate statistical tests not very often used in Brazilian archaeology (but see Okumura & Araujo 2014), but whose potential has been exploited successfully in several studies abroad (Saragusti *et al*. 2005; Cardillo 2006; 2009; 2010; Buchanan *et al*. 2007; Castiñeira *et al*. 2009; 2011; 2012; Franco *et al*. 2009; Archer & Braun 2010; Buchanan & Collard 2010; Costa 2010; Lycett *et al*. 2010; Iovita 2011; Brown *et al*. 2012; Charlin & González-José 2012; Lycett & Von Cramon-Taubadel 2012; Thulman 2012; Wang *et al*. 2012; de Azevedo *et al*. 2013; Lycett & Eren 2013; Charlin *et al.* 2014; Davis *et al*. 2015; Fox 2015; Cardillo *et al*. *in press*). The use of multivariate statistical methods applied to geometric morphometrics data might help elucidate old questions about the characterization of the Umbu tradition, possibly clarifying the meanings related to changes in the morphology of bifacial points over time, the chrono-spatial relationships among different sets of points, among other issues. In this article, we will be focusing on testing the hypothesis that there are important differences in the morphology of Holocene bifacial points associated with the Umbu tradition in southeastern Brazil. Preliminary results regarding this sample have been previously published (Okumura & Araujo 2013).

2. Materials and methods

2.1. Geometric morphometrics: An overview

The analysis of the morphology has always played an important role in different areas of knowledge, including biology, arts, and engineering, among others. Differences in morphology can be briefly described through familiar objects such as geometrical shapes or letters of the alphabet. However, such descriptions are rather vague, inaccurate or even erroneous, especially when the shapes are complex (Zelditch *et al.* 2004: 1) and when an appropriate morphometric approach is not applied. Although approaches using linear measures are often used to characterize the morphology of formal artifacts, it is well known that important information, especially regarding the shape (in comparison to size) is lost (Zelditch *et al.* 2004: 5). In order to avoid losing information on the form (constituted by shape and size), we conducted an analysis using Geometric Morphometrics (GMM).

GMM “is a disparate set of techniques with a common purpose: the statistical analysis of differences in form using a quantitative description that preserves the geometry of shape variation” (Viscosi & Cardini 2011: 3). This preservation allows the visualization of group and individual differences. In this sense, taking the form, it is possible to separate size from shape, to quantify shape and to test differences among shapes (Bookstein 1991). The data obtained using GMM are coordinates of shape landmarks, whereas the traditional morphometrics deals with distances between landmarks. Therefore, GMM aims to quantify the differences in morphology through the use of landmarks (Bookstein 1991). Landmarks can be defined as “samples of discrete points which correspond among all the forms of a data set” (Rohlf & Bookstein 1990: 63) or “discrete (…) loci that can be recognized as the same loci in all specimens in the study” (Zeldich *et al.* 2004: 23). The latter definition implies landmarks in a biological context. According to Zeldich *et al.* (2004: 24), landmarks should not change their topological positions relative to other landmarks (a one-to-one correspondence in the specimens to be compared) (Viscosi & Cardini 2011), should result in a good coverage of the studied morphology, should be observed repeatedly and reliably, and should present coplanarity. The form of the structure is captured using the Cartesian coordinates of a configuration of landmarks. According to Rohlf & Bookstein (1990: 220-221), there are three categories of landmarks (but see Valeri *et al*. (1998) and Gunz *et al*. (2005) among other authors for other different types of landmarks). Type 1 landmarks are “discrete juxtapositions of tissue types”. This kind of landmark is preferred because there is no need to mention any structures far from the landmark itself. Type 2 landmarks are considered more problematic, because they are identified as "maxima of curvature or other local morphogenetic processes". In archaeology, the majority of the landmarks are Type 2. Type 3 landmarks are described as "extremal points", which renders their use very problematic, mainly because they are taken as endpoints of "as farthest" from other points. The importance of distinguishing the type of landmarks rests not only in the intrinsic quality of each type (Type 1 should be easier to be observed in a repeatedly and reliable way), but also in the amount of information that can be retrieved from each type. Because Type 1 landmarks are located in the middle of different structures, it is possible to identify the directions of forces acting upon that area. The same information cannot be obtained from the analysis of Type 2 landmarks, because they are not completely surrounded by structures (Zeldich *et al.* 2004: 31).

2.2. Geometric morphometrics applied to the analysed sample

In this article, we explore some of the potential applications of GMM in the analysis of the morphology of bifacial points. Five Type 2 landmarks were distributed in order to include the different parts of a bifacial point (Figure 2). The five landmarks satisfactorily cover half of the specimens, which is a frequently used way to reduce the time of data collection in symmetric structures (Viscosi & Cardini 2011). These five landmarks were digitized in standardized taken photographs using the software TPSDig2 (Rohlf 2015). The photographs were taken with the camera parallel to the projectile point surface. Points were laid flat with their distal ends facing to the right and a metric scale was also included. Virtually flat things like bifacial points can be reasonably analysed using a two-dimensional approach without losing much important information (Velhagen & Roth 1997; Buchanan & Collard 2010). The sample included 658 bifacial points from São Paulo, Paraná, Santa Catarina, and Rio Grande do Sul. Photographs were taken from complete and finalized bifacial points, meaning that broken points and preforms were not included in the study. The description of each group is presented in Table 2 and Figure 3 shows the geographic location of groups. Landmarks were later transformed into shape coordinates using Procrustes method. Geometric morphometric analyses were carried out using TPSRegr, TPSSmall, TPSRelw and TPSPLS (Rohlf 2015). For a detailed description of GMM principles, see Okumura & Araujo (2014).

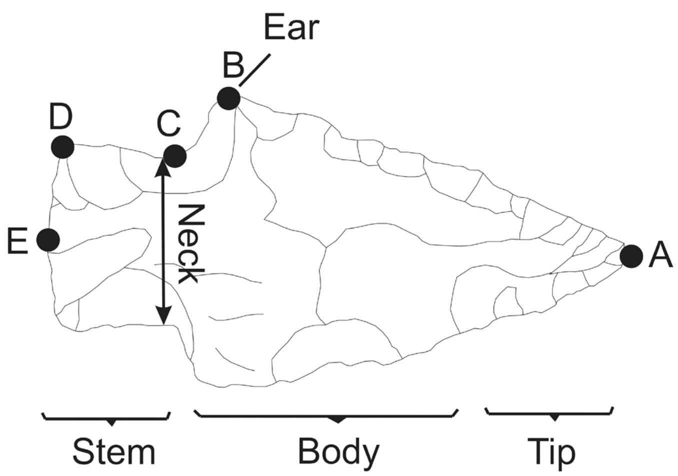

Figure 2: Drawing presenting the different parts of a bifacial point and landmark configuration used to characterize the different parts of a bifacial point. (A) the apex of the body in the longitudinal line (distal end), also defined as the junction of the two blade edges, (B) the most extreme point in the shoulder curve, (C) the point where the neck meets the body, (D) the meeting of the lateral and the basal parts of the stem, and (E) the most extreme point of the stem in the longitudinal line.

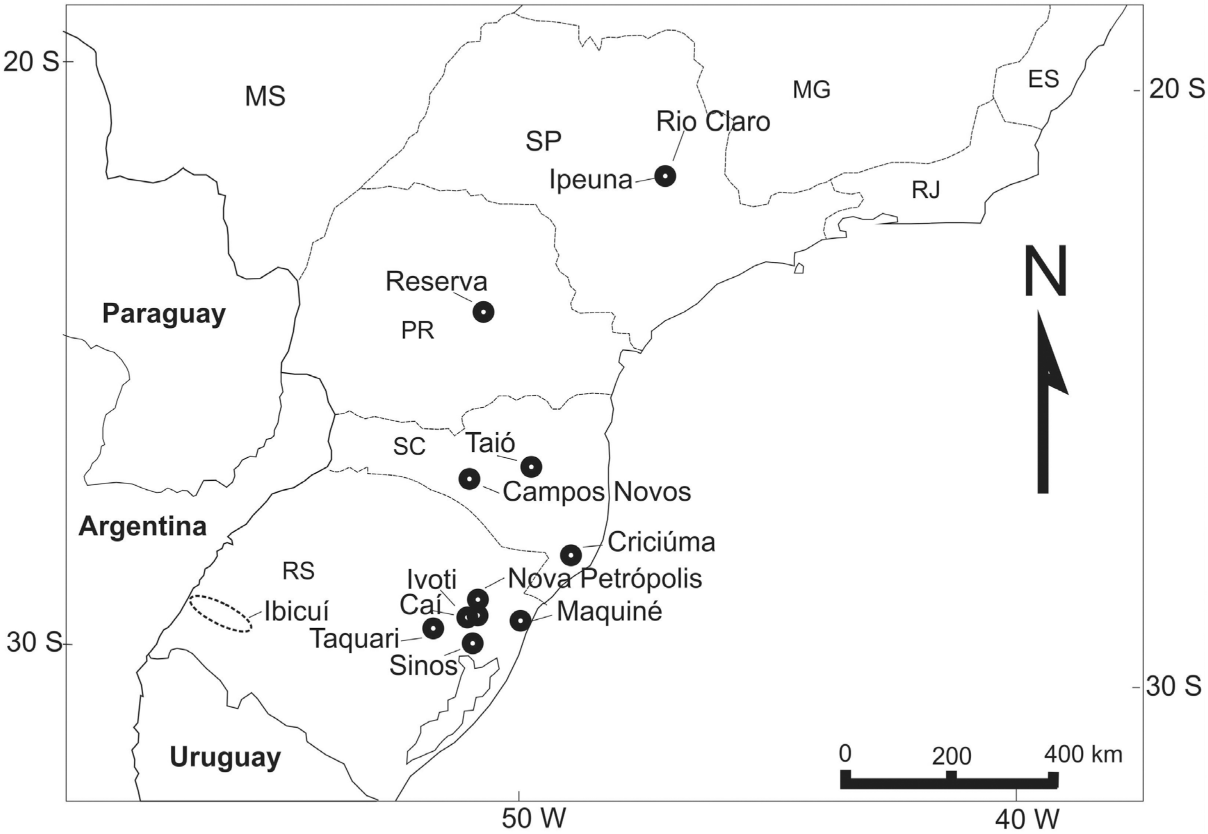

Figure 3: Map presenting the geographic location of the analysed groups.

Table 2: Geographic origin and number of points included in the analysis. Group names in bold refer to groups composed exclusively of points of a single archaeological site, in this case, it was decided to name the group according to the name of the archaeological site.

State	Group	Abbreviation	Regions	Number
São Paulo (SP)	**Alice Boer**	Ali	Rio Claro	47
	Ipeúna	Ipê	Ipeúna	28
Paraná (PR)	Reserva	Res	Reserva	108
S. Catarina (SC)	Taió	Tai	Taió	43
	Criciúma	Cri	Criciúma	35
	Campos Novos	Cpo	Campos Novos	9
Rio Grande do Sul (RS)	Caí	Cai	Caí	35
	Capivara	Cap	Ivoti	99
	Dalpiaz	Dal	Maquine	75
	Garivaldino	Gar	Taquari	101
	Ibicuí	Ibi	Ibicuí	15
	N. Petrópolis	Npe	N. Petrópolis	9
	Sinos	Sin	Sinos	17
	Toca Grande	Toc	Sinos	37
Total				**658**

3. Results

In GMM, the centroid size measures the dispersion of landmarks around the centroid of the configuration. Centroid size is a measure of size that is *mathematically* independent of shape (Zeldich *et al.* 2004: 13) and it was computed using the five landmarks described in the

Materials and Methods section. An ANOVA indicated significant differences among groups (F = 10,081). A post hoc Bonferroni test (Table 3) shows that the two groups of São Paulo (Alice Boer and Ipeúna) are similar to each other and significantly different from the others, with the exception of Campos Novos (SC), Ibicuí (RS), and Taió (SC). Figure 4 shows that points from São Paulo are, in general, bigger than those from the south.

Table 3: Results from Bonferroni *post hoc* test for centroid size. * = p≤0.05, ** = p≤0.01, *** = p≤0.001, ns = not significant.

	Ali (SP)	Ipe (SP)	Res (PR)	Tai (SC)	Cri (SC)	Cpo (SC)	Cai (RS)	Cap (RS)	Dal (RS)	Gar (RS)	Ibi (RS)	Npe (RS)	Sin (RS)
Toc	***	***	ns	**	ns	***	ns	ns	ns	ns	**	ns	ns
Sin	**	ns	ns	ns	ns	**	ns	ns	ns	ns	ns	ns	
Npe	***	***	ns	**	ns	***	ns	ns	ns	ns	**		
Ibi	ns	ns	ns	ns	ns	ns	ns	*	ns	ns			
Gar	***	***	ns	*	ns	***	ns	ns	ns				
Dal	***	ns	ns	ns	ns	*	ns	ns					
Cap	***	***	ns	*	ns	***	ns						
Cai	ns	ns	ns	ns	ns	ns							
Cpo	ns	ns	**	ns	**								
Cri	***	*	ns	ns									
Tai	ns	ns	ns										
Res	***	*											
Ipe	ns												

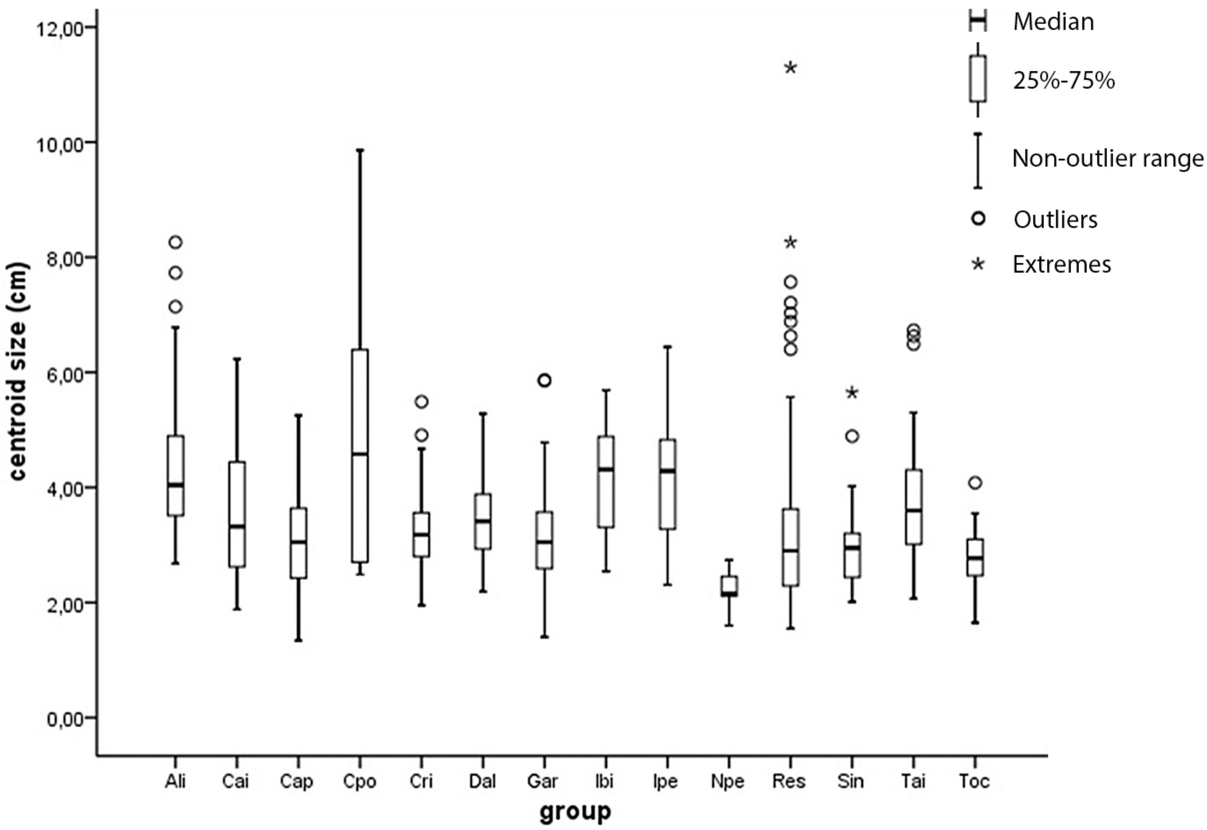

Figure 4: Box-plot graphs based on centroid size.

Figure 5 presents the Principal Component Analysis applied to the shape coordinates. There is a considerable overlap among the groups. In this case, the consensus shape presented in the upper corner would be located in the center of the chart (coordinates 0,0). It is possible to verify that there are points whose body is long and stem is tapered (points from the upper portion of the graph); points whose body is short and the stem is tapered (points from the right side of the graph); points whose body is short and the stem is forked (lower portion of the graph); and points whose body is long and the stem is forked (left portion of the graph). A higher frequency of short bodies observed in some samples possibly indicates episodes of resharpening. The importance of resharpening, which relates to an allometric relation between shape and size is also indicated through the high correlation observed between the aligned data and centroid size (0.50721).

From the Relative Warps Score Matrix, we performed a Canonical Analysis using the entire matrix. The graph representing the two functions of this canonical analysis (Figure 6) shows that the two groups of São Paulo present a different shape compared to the southern groups. It is also possible to verify an association between Paraná and Santa Catarina, especially Reserva (PR) and Taió (SC). The morphological similarity between points from these two regions was also observed in the analysis of linear measurements (Okumura & Araujo 2015b).

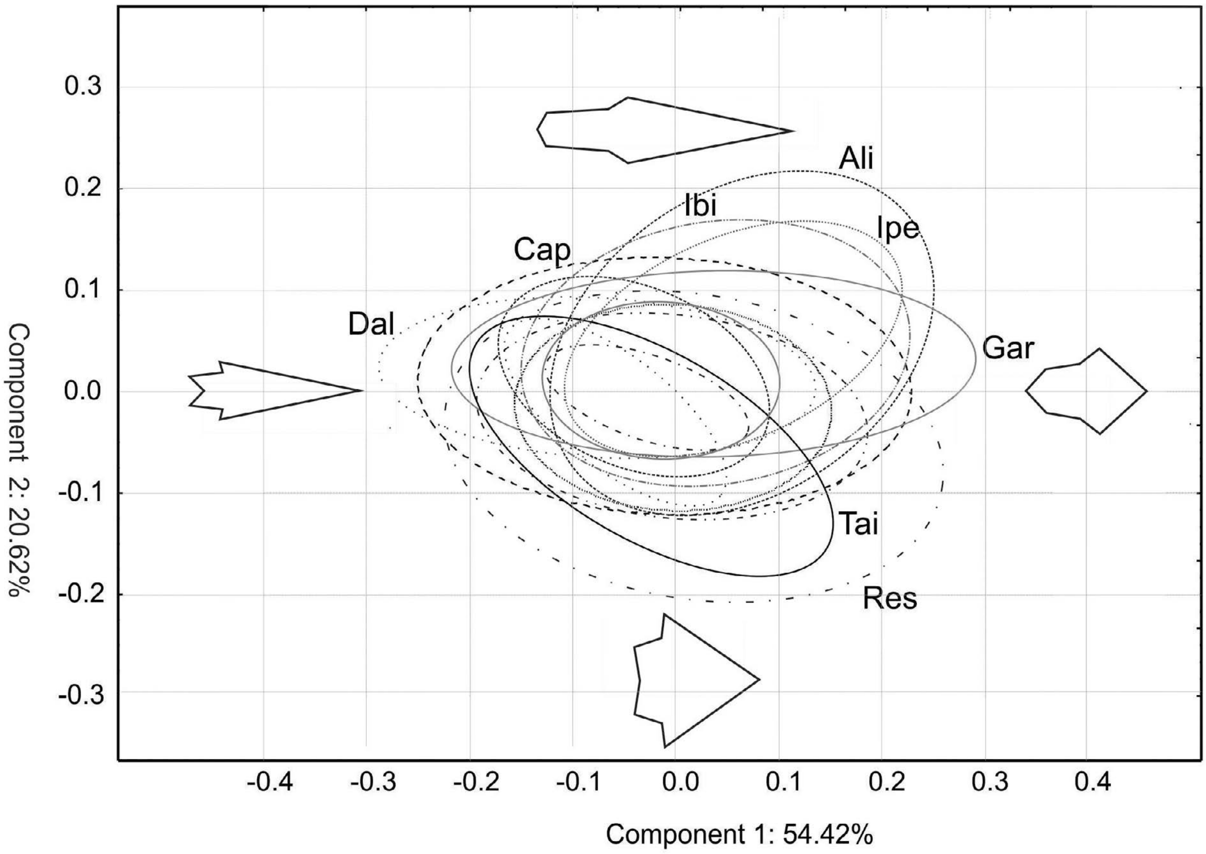

Figure 5: Principal Component Analysis applied to the shape coordinates. Upper corner: consensus shape (note that the program output represents half of the point).

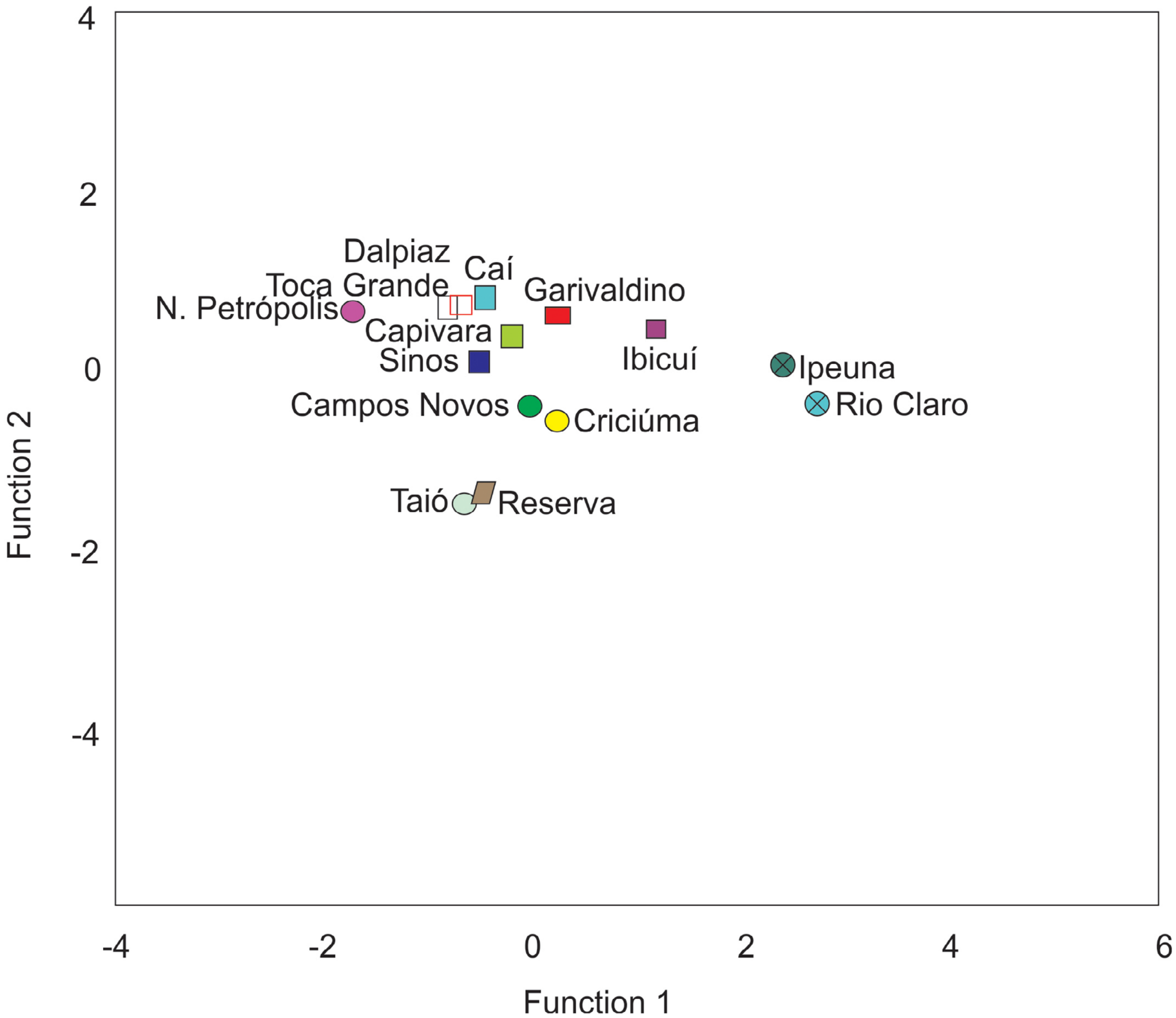

Figure 6: Graph representing the two canonical functions. Crossed circles: São Paulo state, parallelogram: Paraná state, circles: Santa Catarina state, and squares: Rio Grande do Sul state. The first function explains 53,4% of total variance and the second function explains 35,5%.

4. Discussion and conclusions

The GMM analysis point to the presence of significant differences in the size and shape of the bifacial points from São Paulo compared to the southern region. The bifacial points from the two groups from São Paulo (Rio Claro and Ipeúna) presented high morphological similarity. In general, the bifacial points from São Paulo seem to be larger than the other groups (with the exception of two groups from the south: Campos Novos and Ibicuí). Such results have been previously observed through the analysis of linear measurements of points from Rio Claro and southern states (Okumura & Araujo 2015b). Although we believe it is not necessary to revive the category "Rio Claro tradition", our preliminary results point to an important difference in the morphology of the points from São Paulo in relation to the southern points of the country. Since Umbu tradition was defined based on the material found in southern sites, the points from São Paulo could not be considered part of this group. It may be possible that the points from Minas Gerais and Mato Grosso do Sul are also distinct from the points of the southern region.

There is evidence of similarity between the points from Paraná and Santa Catarina, as well as between some groups in Rio Grande do Sul (Okumura & Araujo 2013; 2015b). Such similarities could be exacerbated due to the huge difference between the points from São

Paulo and the rest of the sample, which makes southern Brazil materials appear more homogeneous (Okumura & Araujo 2015b). Further analysis, considering only southern Brazil will aim to explore the diversity within this region.

Our data shows, therefore, a very intriguing pattern, where differences in point morphology seem to reflect territorial and probably identity group differences between southern and southeastern hunter-gatherer groups in Brazil. These differences were not formerly recognized, due to the lack of both an explicit comparison between points of different regions, and of statistically based studies as well. Far from being definitive, our data can be considered an initial effort in approaching this diversity, and could be used as a guide for future research, that should involve the study of more specific themes related to bifacial points, including raw material types, resharpening and artifact life histories, as well as the analysis of other categories of artifacts, the technology behind the point manufacture, and subsistence issues.

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