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Breakage Patterns on Fishtail Projectile Points: Experimental and Archaeological Cases

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Fishtail projectile points, also known as Fell 1, are dated between 11,000 and 9,500 14C yr B.P. in South and Central America and have been traditionally considered diagnostic of the early peopling of the continent. In this paper, experimental observations of impact breakage patterns on fishtail projectile point replicas are compared with archaeological points from the Cerro El Sombrero Cima site, in the Argentinian pampas, which exhibit a high breakage ratio and suggest that impact was a major cause of breakage in the assemblage. The position of these fractures is also briefly compared to patterns described by J. Bird (1969) for fishtail projectile points from Ecuador and Southern Chile.

KEYWORDS Impact fractures, fishtail projectile points, experiment, Cerro El Sombrero Cima site

Introduction

In South and Central America, fishtail projectile points (FTPP), also known as Fell 1 points, dated between 11,000 and 9,500 ^{14}C yr B.P., have been traditionally considered diagnostic of the early peopling of the continent. They attracted the attention of several researchers since Bird first discovered them (Bird 1938, 1946, 1969). Recently some issues have received special attention: manufacturing sequences (Bird 1969; Flegenheimer 2001; Gnecco 1994; Nami 1997, 2003, 2007; Suárez and López 2003; Suárez 2010), use for hunting different prey and within different weapon systems (Bird 1969; Borrero and Martin 2012; Flegenheimer *et al.* 2010; Massone 2003; Miotti *et al.* 1999; Miotti and Salemme 2005), other possible functions of some FTPP specimens (Bayón and Flegenheimer 2003; Politis

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1998; Suárez 2009, 2010), and their social role as objects of non-verbal communication (Bayón and Flegenheimer 2003; Flegenheimer *et al.* 2013; Miotti 1995). The topic that has received most attention is their morphology, discussed mainly in relation to their dispersion and place of origin (for example, Bird 1969; Castiñeira *et al.* 2011, 2012; Mayer Oakes 1986; Politis 1991; Morrow and Morrow 1999; Nami 2013).

Their morphology as described by Bird is:

> a barbless, stemmed form with and without fluting, with rounded shoulders, the stem tapering towards a concave base, the stem sides generally but not always terminating in slightly expanded, rather sharp prongs or corners ... stem sides tend to be concave in profile and minimum stem width occurs forward of or above the base (Bird 1969:56–57).

This description leaves space for some morphological variation, yet even greater variation is recognized nowadays; shoulders can be rounded or angular, the base is frequently concave but can be straight. Most researchers analyzing FTPP have recognized that the type includes great morphological and technological variability (Bayón and Flegenheimer 2003; Hermo and Terranova 2012; Mayer Oakes 1986; Nami 2013; Politis 1991). Artifacts with an outline clearly identified as a FTPP have been manufactured through complex sequences including bifacial thinning, fluting, and pressure retouch, or they may be shaped simply with a few pressure flakes, leaving most of the original flake still visible. Also, both very large and miniature specimens with a FTPP shape have been recovered; sizes range from less than 2 cm long to about 15 cm long (Bayón and Flegenheimer 2003; Meneghin and Sánchez 2009; Nami 2013). These differences are partially explained as resulting from functional variations (Bayón and Flegenheimer 2003; Politis 1998; Suárez 2010). This variability is further increased as collections include specimens at different moments of their use-life.

The patterning of breakage on fishtail points was an early issue of concern, mentioned by Bird (1969) as a useful trait in correlating FTPP from Ecuador and Southern Chile. This initial study is relevant to the information produced in the current paper. Working with other point types, several researchers have focused on different types of projectile point impact fractures, mainly with the aim of defining breakage and use wear patterns diagnostic of the use and function of artifacts characterized as projectile points, and contrasting these patterns with the archaeological record (Bergman and Newcomer 1983; Fischer *et al.* 1984; Knecht 1997; Lombard *et al.* 2004; Martínez 2001; Martínez and Aschero 2003; Odell and Cowan 1986; Titmus and Woods 1986; Truncer 1988; Woods 1988, among others).

A project with an experimental basis has recently been dedicated to understanding lithic tool breakage patterns of artifacts manufactured from orthoquartzite (Weitzel 2010, 2012a, 2012b). It originated in the need to explain fracture origins in the artifact collection recovered at Cerro El Sombrero Cima (CSC) (Figure 1), where 90% of the tools are broken (Flegenheimer 1995; Weitzel 2010). Experimental studies assessing fractures by trampling, intentional breakage, manufacture failures, and use were carried out (Weitzel 2010) and used to discuss

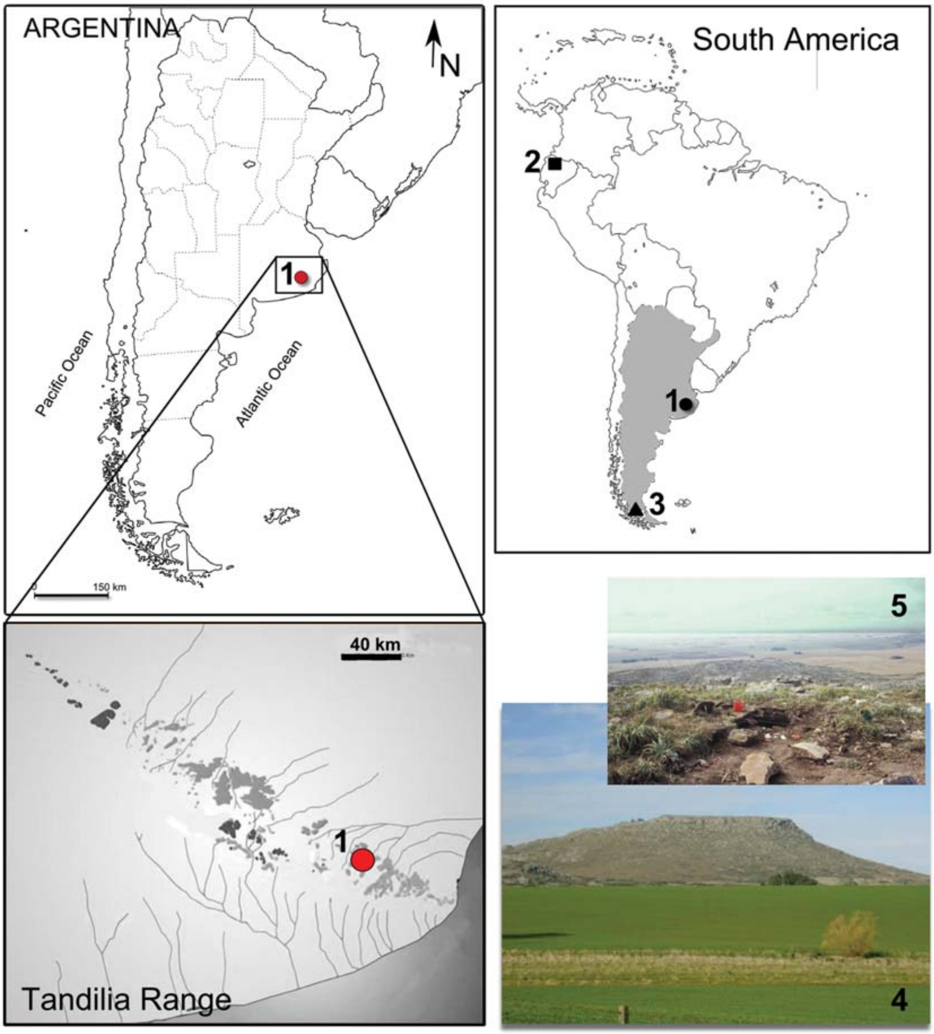

FIGURE 1 Archaeological sites mentioned in text. 1: Cerro El Sombrero Cima; 2: El Inga; 3: Fell Cave; 4: view of Cerro El Sombrero archaeological locality; 5: excavation at the hilltop of Cerro El Sombrero.

anthropic and taphonomic site formation processes. Results from the project support the idea that very specific activities were carried out at this place, including the discard of broken FTPP (Flegenheimer 2003; Weitzel 2010, 2012b). Currently this site is interpreted as a place where scouting of the surroundings, retooling, weapon refurbishing, and discarding of broken artifacts were carried out. The locality itself is considered as a place which must have been highly significant for early hunter-gatherers during the Pleistocene–Holocene transition (Flegenheimer and Mazzia 2013; Flegenheimer *et al.* 2013). Also, recently another site, known as Cerro Amigo Oeste, which exhibits a considerable number of broken FTPP, has been discovered in Patagonia 900 km away (Miotti and Terranova 2010; Hermo and Terranova 2012). Striking similarities have been registered at both sites (Flegenheimer *et al.* 2013). Both Cerro Amigo Oeste and CSC are interpreted as cases where projectile point replacement activities took place in non-domestic scenarios, and in this context the study of their material culture merits special attention.

Here we introduce those results on FTPP breakage that support some of the interpretations listed above, and present the analyses of breakage patterns on FTPP replicas from a previous experiment (Flegenheimer *et al.* 2010). This was the first experiment of its sort using FTPP and therefore has produced the only experimental collection available for comparative fracture analysis for this point type. These experimental observations are then compared with the archaeological FTPP set from CSC to assess the origin of fractures in that assemblage, and finally briefly compared to breakage descriptions by Bird (1969).

The Cerro El Sombrero Cima site is mentioned in the archaeological literature since the early 1970s (Madrazo 1972) and during this time FTPP collections from the hilltop (N=120) were deposited in three different places. Our analysis will consider 83 of these points in the collection deposited at *Área Arqueología y Antropología, Museo de Ciencias Naturales de Necochea* (Buenos Aires, Argentina).

The experiment

Experimental sample

In 2008, N. Flegenheimer, J. Martínez and M. Colombo (Flegenheimer *et al.* 2010) conducted an experiment with FTPP replicas in order to produce information concerning late Pleistocene Pampean hunter-gatherer weapon technology. The main goal was to assess the performance of the weapon systems in which FTPP could have been used. For this purpose an experimental project including a sequence of five steps was designed:

1. Projectile point manufacture: 22 FTPP were manufactured conforming to the archaeological points' metric attributes (Table 1) and outline, and using the local raw material most frequently employed in the regional assemblages, Sierras Bayas Group orthoquartzite (Bayón *et al.* 1999; Colombo 2011; Colombo and Flegenheimer 2013)
2. Production of shafts and foreshafts: 20 shafts were made from commercial woods ("palo blanco") and two were fashioned from the native woods *Celtis tala* and *Colletia paradoxa*, which could have been used in the past in the pampean region. Shafts were 14–22 mm and 33 mm in diameter and their length was 1.50 m for spearthrower darts and 1.90 m and 2.40 m for hand thrown spears. Foreshafts were 25 cm long.
3. Assembling the weapon systems: first, shafts and foreshafts were joined with glue and twine. The shafts were fletched, and points were hafted using glue and twine. Two haft configurations were tested, one with the haft ending at the distal section of the stem (Figure 2c, d, and f) and the second one with the haft extending to the middle section of the blade (Figure 2a, b,

TABLE 1

DESCRIPTION OF EXPERIMENTAL POINTS, SHOTS AND DAMAGE. TASFNP= TRANSVERSAL ACROSS STEM FORWARD OF THE NARROWEST PORTION.

Replica n° and propulsion	Stem thickness (mm)	Max. thickness (mm)	Stem Width/Stem length (mm)	Blade Length/ Blade width (mm)	Haft configu-ration*	Number of shots/hits	Position of damage	Impact surface	Damage
1 Atlatl	6	7	14/11	32/25	2	9/5	Tip	Wood	Minor Figure 3c
2 Atlatl	6	7	13/10	30/24	1	1/1	–	Bone	None
3 Atlatl	5	6	15/13	27/24	2	12/7	Tip	Wood	Minor
4 Atlatl	5	7	12/12	30/22	1	1/1	TASFNP	Wood	Broken
5 Hand thrown	6	8	19/19	51/38	2	7/2	TASFNP	Loam soil (unsuccesful shot)	Broken Figure 3c; Figure 5
6 Hand thrown	7	7	17/18	43/32	1	3/2	TASFNP	Wood	Broken
7 Atlatl	6	8	16/14	30/25	1	25/12	–	Wood	None
8 Atlatl	5	5.5	15/12	31/25	2	8/4	–	–	None
9 Atlatl	7	7	16/13	31/25	1	5/2	–	–	None
10 Atlatl	5	6	14/12.5	28/23	1	3/2	–	–	Lost
11 Atlatl	7	9	14/13	31/23	1	9/0	TASFNP	Bent by bouncing	Broken Figure 3b
12 Atlatl	5.5	5.5	15/14	29/24	2	9/4	TASFNP	Bone	Broken Figure 3b,d
13 Atlatl	8	8	15/12	31/24	2	4/3	–	–	None
14 Atlatl	5	5	14.5/11.5	29/24.5	2	3/1	TASFNP	Bone	Broken
15 Atlatl	5	6	13/12	29/23	2	12/3	–	–	None
16 Atlatl	6	6.5	13.5/12	29/23	1	10/6	TASFNP	Bone	Broken
17 Hand thrown	7	8	17/14.5	35/30	1	3/0	Prong	?	Minor
18 Atlatl	7	6	16/14	40/29	1	19/11	TASFNP + diagonally across blade	Bone	Broken Figure 3b Figure 5
19 Hand thrown	6.5	7	18/16.5	40/32	2	103/55	–	–	None

TABLE 1 CONTINUED

Replica n° and propulsion	Stem thickness (mm)	Max. thickness (mm)	Stem Width/Stem length (mm)	Blade Length/ Blade width (mm)	Haft configu-ration*	Number of shots/hits	Position of damage	Impact surface	Damage
20 Atlatl	7	7	19/14.5	39/31	2	31/23	Tip	Bone	Broken Figure 3a
21 Hand thrown	7.5	6.5	17/14	39/30	1	7/4	TASFNP	Bone	Broken
22 Atlatl	6	6	16/19	40/32	1	3/1	–	–	None

*Haft configuration: 1=haft ending at the distal section of the stem; 2= haft extending to the middle section of the blade

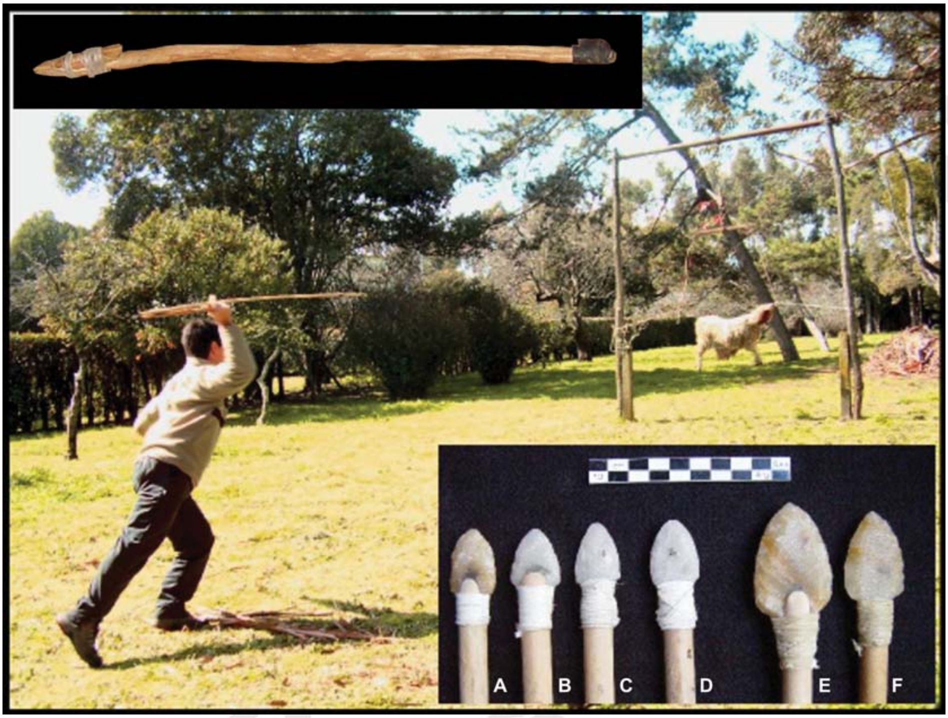

FIGURE 2 Experiments with FTPP replicas with sheep carcass target. A–F: examples of the two haft configurations.

and e). Five FTPP were hafted on hand thrown spears and 17 were hafted as darts to be propelled with a spearthrower (atlatl).

4. Use of experimental projectiles against a fixed target: Probably the FTPP under study were mainly used as part of a weapon system employed to hunt guanaco (*Lama guanicoe*). This species was not available for the experiment as it is protected by the CITES Convention in Argentina, Chile and Perú. Therefore a sheep, easily available and anatomically similar to guanaco, was chosen as target. The thick sheep wool was sheared to produce a hide similar to guanaco; the carcass was hung in the air, tying it without any artificial prop to hold it (see Figure 2). All the projectiles were thrown against the target from a distance of five meters. A single person (JM) performed all 297 shots.
5. Assessment of weapon system use damage (for more detail see Flegenheimer *et al.* 2010).

Experimental breakage

A few FTPP broke after a single shot, most broke after three to eight shots, and some of the experimental FTPP required many shots until the stone projectile fractured. Furthermore, one of the points was thrown 103 times without evident damage, even though several hits were successful, hitting and breaking bone several times, and also landing once on a pile of wood. Many projectiles suffered damage in other sections of the weapon, such as loosening of the haft or shaft breakage (Flegenheimer *et al.* 2010).

Thirteen FTPP showed some macroscopic damage. Ten experimental points broke with extensive damage beyond repair: eight of them due to impact on hard surfaces, especially target bone, and two in other circumstances (Table 1). Eight out of these ten FTPP broke near the end of the stem forward of the narrowest portion (TASFNP) and one suffered an impact fracture at the tip. The one remaining FTPP exhibits multiple fractures, one TASFNP and another diagonally across the blade. Five of these FTPP also exhibit breakage on the basal prongs. Three points suffered minor damage: two have minor fractures at the tip and could be easily reworked into functional points and another lost a basal prong.

The FTPP experimental fractures

The types of impact fractures considered are defined and described in Table 2. The classification we follow in this paper to assess damage type is based on experimental results described by several researchers, compiled in Weitzel (2010, 2012a). Fractures considered here as diagnostic impact fractures (DIF) include: step terminating bending fractures, impact flute, impact burin, crushing, and some specific cases of spin off fractures. Hutchings (1997) and Pargeter (2011, 2013) suggested that macrofracture analysis should be used carefully when assessing impact fractures as diagnostic of projectile point use, as they were able to identify similar fractures resulting from trampling and knapping. Up to now, our experiments on trampling and knapping errors using artifacts made from Sierras Bayas Group orthoquartzites (Flegenheimer and Weitzel 2007; Weitzel 2010) have not recorded fractures like those considered diagnostic of impact. Most of the fractures we identified after trampling are transverse bending fractures (snap) with lower frequencies of hinge terminating bending fractures. Neither impact burination or fluting, nor step terminating bending fractures nor spin-off fractures were identified in our experimental samples of trampled artifacts and knapping errors. Taking into account our experimental results (Flegenheimer and Weitzel 2007, Weitzel 2010) and Pargeter's (2013) claims, in order to identify FTPP fractures as a result of use in our archaeological sample we also consider location patterning and frequency of occurrence.

As mentioned above, ten fishtail points broke during the experiments, mainly due to impact on hard surfaces (Table 1). The following is a description of these fractures.

Impact flutes and crushing

These fracture types are frequently recognized on experimental and archaeological specimens and are considered diagnostic of their use as projectiles (Bergman and Newcomer 1983; Odell and Cowan 1986; Titmus and Woods 1986). A single experimental specimen exhibits both impact fluting and crushing (Figure 3a). Two longitudinally oriented flake scars with feather termination initiated from the distal end and run along one surface of the blade. The tip of the point was removed

TABLE 2

FRACTURE TYPES THAT MAY OCCUR DUE TO IMPACT. DIF=DIAGNOSTIC IMPACT FRACTURE

FRACTURE TYPE	CAUSE	REFERENCE
BENDING FRACTURE		
(including snap terminating, feather terminating , and hinge terminating bending fractures) Fractures "initiate from a large area, having a straight or convex profile along its whole area of initiation" (Fischer *et al.* 1984:23).	Knapping errors Trampling Impact Accidental dropping	Fischer *et al.* 1984; Sollberger 1986; Whittaker 1994; Frison and Bradley 1980
STEP TERMINATING BENDING FRACTURE		
"A bending initiating fracture which before meeting the opposite surface of the specimen runs parallel to this, and which thereafter makes an abrupt change of direction to meet the surface at a right angle" (Fischer *et al.* 1984:23).		
Odell and Cowan (1986) name this fracture "snap-and-step".	Impact (DIF)	Fischer *et al.* 1984; Odell and Cowan 1986
SPIN-OFF FRACTURE		
"Cone fracture which initiates from a bending fracture and which removes parts of the original surface of the specimen" (Fischer *et al.* 1984:23). It is DIF when it is bifacial or when the cone fracture length reaches >1 mm in arrowheads and >6 mm in spear points or darts.	Impact Trampling Knapping error	Fischer *et al.* 1984
IMPACT FLUTE		
"shallow scars that often carry a distance of 5 or more millimeters from the end and terminate in either a step or hinge ... Because the principal fracture often ends a considerable distance from its initiation-point and removes much of the dorsal surface with it, it occasionally resembles intentionally manufactured fluting" (Odell and Cowan 1986:204). "...need not be represented by a single large longitudinal flake scar; multiple small flake scars can also occur" (Dockal 1997:325).	Impact (DIF)	Bradley 1982; Odell and Cowan 1986; Titmus and Woods 1986
IMPACT BURIN		
"In some cases, material is removed transversely in step or hinge terminations from the edge of the piece rather than from the surface. These are distinctive enough to constitute a separate visual phenomenon, which is here called a 'burination' because of the resemblance to intentionally-struck burin removals" (Odell and Cowan 1986:204).	Impact (DIF)	Bradley 1982; Odell and Cowan 1986; Titmus and Woods 1986
CRUSHING		
"tip damage that would technically be classified as step fracture, but the impacting force was directed so deeply into the interior of the stone that it dissipated before it could surface and remove a sizeable piece. As a result the pointed end was crushed, and the damage remained localized at the tip itself" (Odell and Cowan 1986:204).	Impact (DIF)	Odell and Cowan 1986

TABLE 2 CONTINUED

FRACTURE TYPE	CAUSE	REFERENCE
CONE INITIATING FRACTURE		
"initiates from a point or small, well-defined area, having a concave profile in the area of initiation" (Fischer *et al.* 1984:23).	Use Impact Trampling Accidental dropping	Fischer *et al.* 1984

by crushing, small bending fractures with step terminations (Flegenheimer *et al.* 2010). This specimen broke when the point penetrated the target and hit bone.

Spin-off fractures

Only some spin-off fractures can be considered diagnostic of impact (see Table 2). Four experimental FTPP points suffered spin-off fractures (Figure 3b). They all initiate from transverse bending fractures. Some cone fractures removed part of the stem surface while other flakes removed part of the blade surface. Three fractures were due to impact on bone and the fourth occurred when the projectile got caught in the sheep's wool and the haft flexed the embedded point (point n° 11). In one of

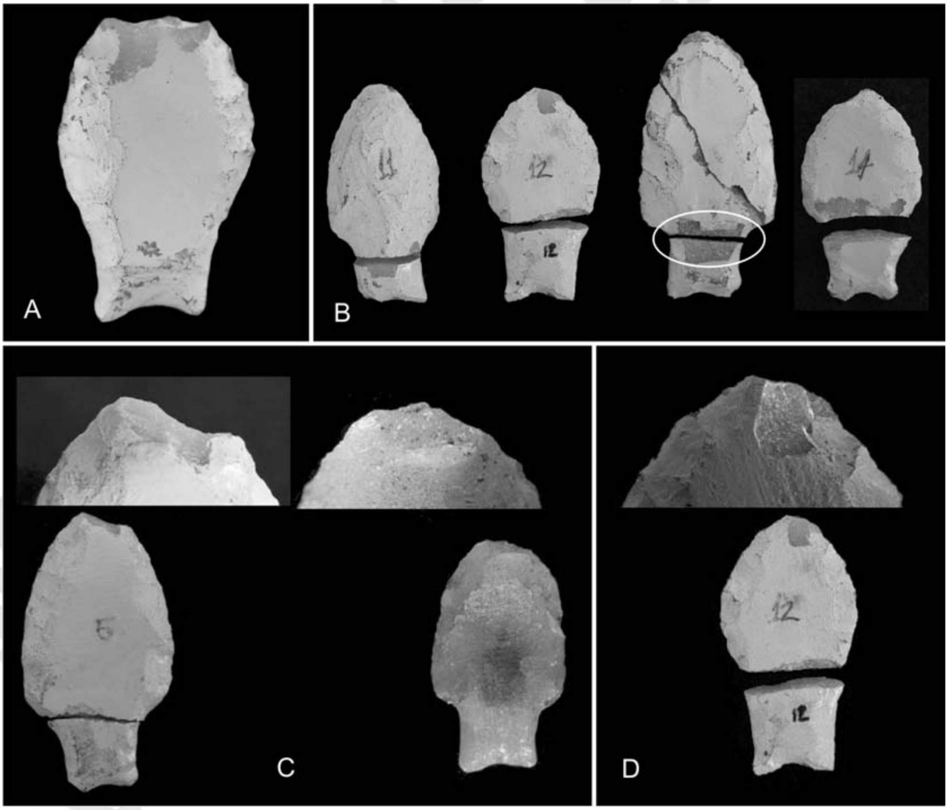

FIGURE 3 Impact fractures on experimental FTPP. a: Impact flute and "crushing"; b: Spin-off fractures; c: Step terminating bending fractures; d: cone initiating fracture.

the points, the spin off fractures occupy both faces and are 5 mm long, this is the only spin-off fracture considered diagnostic of impact. In the other three points they are situated on a single face and measure 2 mm, 3 mm and 4 mm long. As these experimental cases are few, further experiments including other fracture causes and raw materials would be useful to discuss diagnostic flake scar lengths in orthoquartzite FTPP.

Step terminating bending fractures

This fracture type is also described by Fischer *et al.* (1984), who consider it diagnostic of projectile point impact. This kind of breakage may occur at the tip of the point, with the removal of one or more flakes with step terminations and it may also occur in other sections of the point (such as the mid portion or stem). Two experimental FTPP show this type of fracture on their tips (Figure 3c). One of the fractures occurred as a result of impact on a wooden surface. The second FTPP broke when hitting bone after the point penetrated the target. Afterwards the spear hit the ground and the stem broke by bending.

Cone initiating fracture

Described by Fischer *et al.* (1984) as a fracture that initiates from a point and has a concave profile where it initiates, this type of damage is not diagnostic of impact breakage as it may occur due to many accidental factors including trampling, dropping, and using an artifact as a knife. Two experimental FTPP show this type of damage. One of them has two flake scars on either side of the tip as a result of missed shots that hit wood and a sheet of corrugated iron. The other (Figure 3d) is one of the broken points with a spin-off fracture on the stem, and also has a cone initiating fracture on the tip.

Six FTPP, including four broken points, also have cone initiating fractures at the basal prongs, mostly small (2–3 mm long). One of these fractures broke off the prong (Figure 4a), while the others did not produce major morphological modifications (Figure 4b–d). A cone initiating fracture of larger size (7 mm length) eliminated another prong and partially covers the stem (Figure 4e).

Bending fractures

This type of breakage is not diagnostic of the use of the stone tip as a projectile point as it can also be produced by trampling (Fischer *et al.* 1984), manufacture, or use (Truncer 1988). Dockall (1997) includes them as distal or transverse fractures and Johnson (1979) calls them haft snap when bending fractures are located in the hafted portion of the point. This was the most frequent type of fracture in the experimental FTPP. A total of seven bending fractures were recorded (Figure 5). Six are fractures located near the distal end of the stem and the other is diagonally across the blade. An important feature is their position on the point as they are repeatedly located transversely across the stem forward of the narrowest portion (TASFNP, Bird 1969).

Snap terminating bending fractures in our experimental FTPP have no association with a specific impact surface. Nonetheless, most broke due to impact after shots that reached and penetrated the target carcass, hitting bone, and others

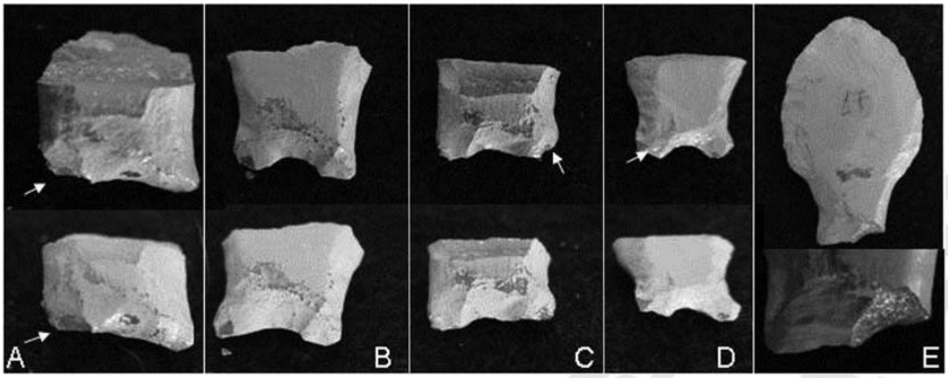

FIGURE 4 Fractures of the basal prongs in experimental FTPP. a: missing prong; b–d: fractured prongs with minor damage; e: missing prong removed by major cone initiating fracture.

resulted from bad shots in which the projectile hit wood. One of the fractures occurred when the spear fell to the ground after bouncing off the target.

Experimental results discussion

In the FTPP experiment most of the types of damages known to result from projectile point use were observed, with the exception of impact burination. At least three of the types registered are considered diagnostic of impact: impact flute, step terminating bending fractures, and spin-off fractures. Points on both hand thrown spears and darts broke during use, but darts propelled with the spearthrower exhibited more damage, a combination of fracture types related to impact and a higher frequency of fracture types usually considered diagnostic of impact.

The most frequent type of fracture was bending. An important observation in the experimental FTPP refers to the position of bending fractures; about 90% of them (6 of 7) are transverse across the stem forward of the narrowest portion (TASFNP). We suggest that as this was a recurring pattern with breakage occurring in very specific portions of the experimental points, it can be associated with impact in some cases; but to assess impact more accurately we also need to consider context, remaining fragments of FTPP, and the presence or absence of conjoinable fragments. Further tests with experimental knapping and trampling of FTPP would help evaluate the occurrence of bending fractures with this position due to activities other than the use of FTPP as projectiles.

The position of bending fractures in our experimental collection is not related to where the haft ends, as FTPP with the two different haft configurations tested exhibit the same fracture location (see Table 1). Also, point size or the impact surfaces do not seem relevant to the position of these fractures (Flegenheimer *et al.* 2010). We therefore suggest that the position TASFNP may be associated with a weak area due to the FTTP design.

FIGURE 5 Bending fractures on experimental FTPP.

Even though the position of breakage and other features of the fracture are not associated with a specific impact surface, all those fractures that can be considered diagnostic of projectile point impact occurred when the point hit a hard surface, mainly bone. This is consistent with other experimental results concerning impact damage (Martínez 2001; Odell and Cowan 1986; Titmus and Woods 1986). On the contrary, bending fractures resulted both from impacting hard surfaces and from bad shots that made the point fall to the ground, even though the latter were scarce (n=2).

In agreement with the results obtained by other researchers (Fischer *et al.* 1984; Odell and Cowan 1986; Truncer 1988) breakage in the FTPP replicas was observed at the tip and at the bases. Our experimental points most frequently exhibit proximal damage in the stem (TASFNP), while those in other researchers' experiments are mainly broken at the tip. It was also common that points suffered a combination of damages of different types in different portions of the same specimen.

These results allowed us to recognize in the experimental FTPP almost all of the diagnostic fractures of projectile impact that have been previously assessed in other projectile point types. Also, these experiments provide a data base to compare to the types of breakage exhibited by broken archaeological FTPP.

Archaeological fishtail projectile points from Cerro el Sombrero Cima

Cerro El Sombrero Cima is an archaeological site assigned to the Pleistocene/Holocene transition. It is located at the hilltop of a butte in the Tandilia Range surrounded by the pampean plains (Buenos Aires, Argentina) (Figure 1). It has been proposed that at this place the refurbishing and maintenance of FTPP was carried out along with the final stages of point manufacture. The complete assemblage includes other flaked tools (n>1400), unifacial as well as bifacial, and ground, and abraded artifacts (n=11). The hilltop is a 25000 m^2 surface partially covered by pampean loess. Stratigraphy at the site varies among different sectors. Archaeological remains are found within the A soil horizon at a maximum depth of 50 cm. Two main concentrations have been identified, and artifacts are scattered throughout the hilltop both as surface and buried remains. Both the surface and excavated collections are similar in raw materials, tool types, technological characteristics, debitage, and to a certain extent fracture ratios (Flegenheimer 2003; Weitzel and Flegenheimer 2007). This site has yielded one of the largest known collections of FTPP. The sample is highly fractured and consists of points at different stages of their use life, mainly represented by stems, a few blades, and some whole points. Preforms, highly maintained points and recycled items were also identified. These points exhibit great variability in size. Most are manufactured from Sierras Bayas Group orthoquartzite (77%), some from quartz (16%), and the remaining (7%) from phtanite and silicified limestone (Flegenheimer 2003; Flegenheimer and Mazzia 2013; Flegenheimer *et al.* 2013).

Here we consider 83 FTPP including both surface (n=52) and excavated (n=31) artifacts that were analyzed for breakage types (Weitzel 2010, 2012b). This sample has a fracture frequency of 84%. Diagnostic fractures other than impact were recognized; Figure 6 shows the types of fracture identified and the causes which originated those fractures. Knapping errors such as perverse fractures were identified both in FTPP considered as preforms (Figure 7c) and on stems with macroscopic evidence that they had been hafted (Figure 7a and b). Another diagnostic manufacture breakage identified is lateral snap as defined by Rondeau (1981) (Figure 7d).

The most frequent fractures are bending breaks which, as mentioned above, can result from knapping errors, trampling or impact. Most of these fractures (n=14) are TASFNP (Figure 7e, f, and g). Another three are located transversely across the stem but beneath the narrowest portion. There is one located transversely across the middle of the stem and one diagonally across the stem. The remaining are: diagonally across the blade (n=1), transversely across blades (n=6), transversely

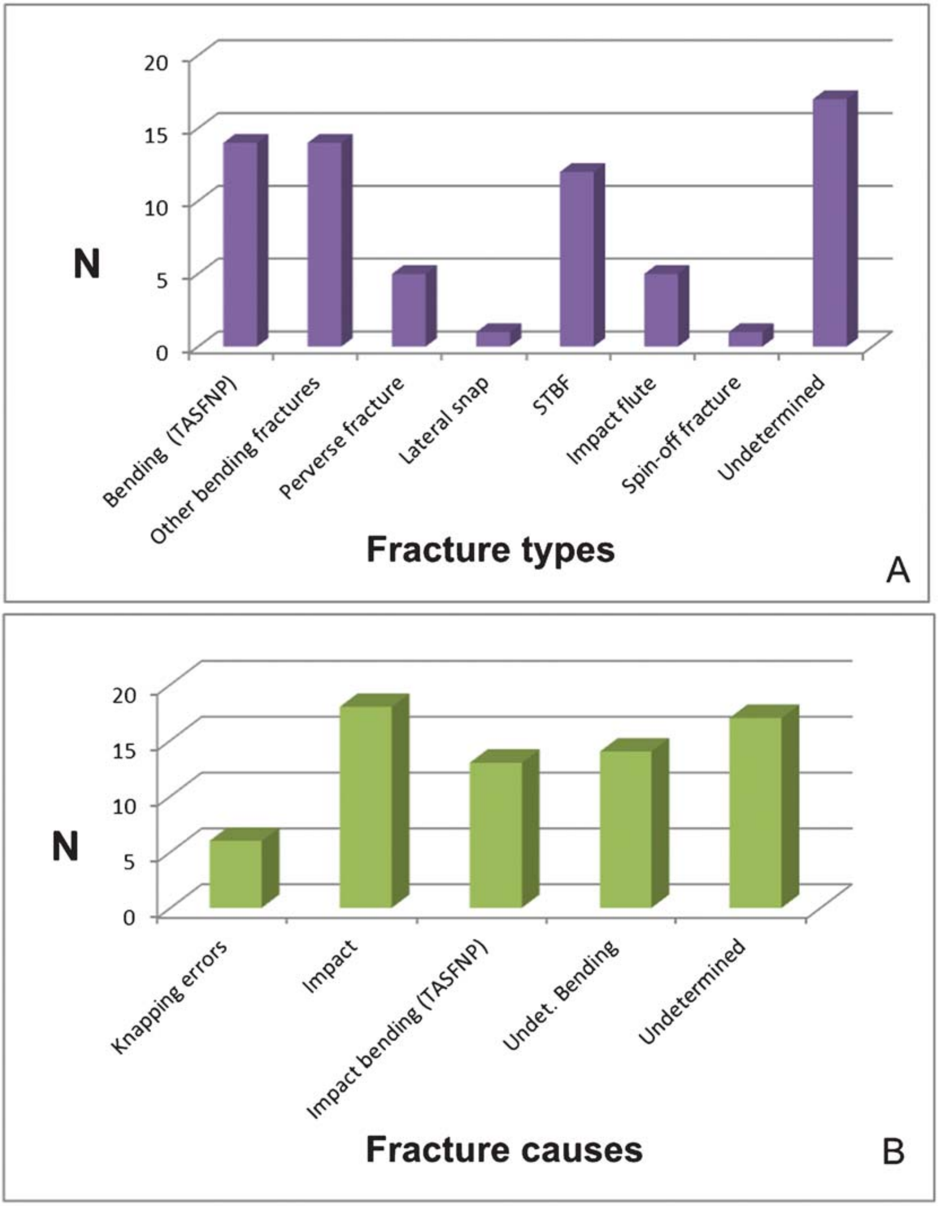

FIGURE 6 A: Fracture types on archaeological FTPP from Cerro El Sombrero Cima (STBF=step terminating bending fracture. B: Fracture causes on archaeological FTPP from Cerro El Sombrero Cima.

where stem widens to shoulder (n=1) and diagonally across blade and into stem (n=1).

We propose that the bending fractures located transversely across the stem forward of the narrowest portion may be considered as probably due to impact

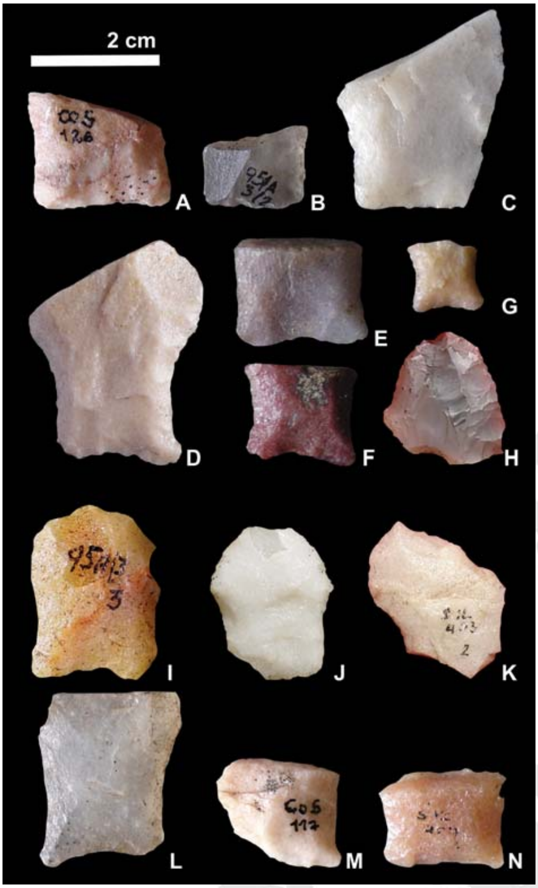

FIGURE 7 Fracture types in fishtail points from Cerro El Sombrero Cima site. A, B: perverse fracture (stems); C: perverse fracture (preform); D: lateral snap; E, F, G: bending fractures (TASFNP); H, I, J, K: impact flute; L: spin-off fracture; M and N: step terminating bending fracture.

during the use of FTPP for hunting. This interpretation is based on the high frequencies of TASFNP in experimental results and the similar patterning of the position of breakage in the archaeological collections of CSC, Ecuador, and Southern Chile (Bird's position 1 in Table 3). If that is the case, 13 bending fractures should be added to the impact breakage column in Figure 6b. The remaining bending fracture with this position is not considered an impact fracture because it appears to be on a preform. Other bending fractures located on the stem (positions 9 and 10 in Table 3) among the archaeological points were not considered impact fractures as they were not replicated during the experiment, so they might have occurred by impact or other incidental causes such as knapping errors, trampling, etc.

Breakage with these positions also includes one bending fracture on a preform, which resulted from a production failure during fluting, six incidental fractures on points that were probably used, and the two perverse fractures mentioned above. These last occurred on points with indications of hafting such as ground edges on the stems, suggesting that some points were removed from the shaft for maintenance. Other evidences for the use of these points are residues of hafting (mastic and wood) obtained by fatty acid analysis, found on two points with impact fractures (Figure 7l and n) along with two recycled points (Mazzia 2011; Mazzia and Flegenheimer 2014). The only indicator of impact still comes from macrofracture analysis.

Diagnostic impact fractures at Cerro El Sombrero Cima

We identified 18 fractures of different types that can be considered diagnostic of FTPP impact in the Cerro El Sombrero Cima assemblage. Step terminating bending fractures were the most frequent type of impact breakage identified (Figure 6, Figure 7m, n). They are located mainly transversely across the stem but they were also recorded on blades. One of these FTPP was recycled after breakage by a few flake removals. Also, in one of these points a prong was broken off with this type of fracture.

Impact fluting was recognized on five FTPP (Figure 7h–k), two of them with size greatly reduced by maintenance (Figure 7i and j). Another point fragment showed extensive damage, probably due to impact (Figure 7k).

Finally, a spin-off fracture was present on a single specimen. The fracture position is transversely where the stem widens to shoulder (Figure 7l). The damage consists of three flake removals on both faces of the point, so following Fischer and colleagues (Fischer *et al.* 1984) it can be considered diagnostic of impact.

In sum, in our archaeological sample we have recorded 13 complete specimens, 6 specimens with fractures diagnostic of knapping errors, and 18 with impact

TABLE 3

COMPARISON OF BREAKAGE PATTERNS ACCORDING TO BIRD (1969) BETWEEN EXPERIMENTAL FTPP RESULTS, CERRO EL SOMBRERO CIMA (ARGENTINA), EL INGA (ECUADOR) AND FELL CAVE (SOUTHERN CHILE). WE ADDED POSITIONS 9 AND 10 TO ACCOUNT FOR FRACTURES IN CSC COLLECTION.

Position of breaks (according to Bird 1969)	Experimental FTPP	Cerro El Sombrero Cima	Fell Cave (Bird 1969)	El Inga (Bird 1969)
1. Transversely across the stem forward of the narrowest portion	8 (40%)	28 (27.45%)	3 (25%)	9 (34.6%)
2. Transversely across blades in the area from near the maximum width back to the shoulders	–	10 (9.8%)	5 (41.6%)	4 (15.4%)
3. Two fractures in both of preceding areas, i.e., two breaks per specimen	1 (5%)	1 (0.98%)	1 (8.3%)	1 (3.8%)
4. Transversely where stem widens to shoulder behind forward turn of shoulder outline	–	6 (5.8%)	1 (8.3%)	3 (11.5%)
5. Diagonally across blade	1 (5%)	5 (4.9%)	1 (8.3%)	3 (11.5%)
6. Diagonally across blade and into stem	–	1 (0.98%)	–	3 (11.5%)
7. Basal corner section of stem	5 (25%)	34 (33.3%)	1 (8.3%)	2 (7.7%)
8. Tip missing	5 (25%)	4 (3.9%)	–	1 (3.8%)
9. Transversely across the stem before the narrowest portion	–	6 (5.8%)	–	–
10. Diagonally across stem	–	3 (2.9%)	–	–
Other	–	4 (3.9%)	–	–

fractures. Bending fractures total 28, 13 of which are located TASFNP. The origin of bending breaks is difficult to identify as they may have several causes. An initial assessment of the breakage frequencies in the CSC lithic assemblage showed that post-depositional processes such as trampling could account for the difference of breakage ratios between surface and excavated assemblages (Weitzel and Flegenheimer 2007). However, further experiments on trampling showed that the usual orthoquartzites are hard, tenacious rocks and overall breakage due to intense human trampling was low (19%) and therefore could hardly account for the high breakage frequency of the assemblage (Flegenheimer and Weitzel 2007; Weitzel 2010). Some bending and undetermined fractures might have originated from trampling, but the lack of conjoinable fragments in the archaeological assemblage and the experimental results leads us to propose that most of these fractures on FTPP—those located TASFNP—can be explained as a result of impact. Thus impact fractures should total 31 if bending fractures located TASFNP are included. Finally, 17 FTPP have undetermined fractures and 4 points were recycled after breakage.

Considering the above, we suggest impact has been an important factor in the breakage of FTPP at Cerro El Sombrero Cima. This information is in agreement with the initial interpretation of CSC as a place where one of the activities carried out concerned projectile point replacement and repair, along with the final stages of manufacture of fishtail points and other artifacts (Flegenheimer 1986, 1991, 2003). That is, information is consistent with a scenario where people at the Pleistocene–Holocene transition climbed the hill with their broken weapons and repaired them on the hilltop (Flegenheimer and Mazzia 2013; Weitzel 2010).

Bird (1969) considered the pattern of breakage as a relevant feature to establish relationships between FTPP from distant sites. Table 3 shows the comparison made by Bird (1969) between the position of breakage in FTPP from Fell Cave (Chile) and El Inga (Ecuador) (Figure 1), with the addition of our experimental results and the FTPP from CSC. The most common position of breakage in the archaeological specimens from CSC is position 7 which is related to breakage of the basal prongs. This may be related to hafting choices and post-depositional processes such as trampling, given that the surface assemblage exhibits more broken prongs (52% vs. 22. 6%). With this exception, the data show a strong similarity in the position of breakage between the FTPP from El Inga and CSC. At both sites the most frequent location of fractures is position 1; this was also the most recorded position in the experiment. In descending order, both El Inga and CSC fishtail points show breakage at positions 2, 4, and 5. The rest of the positions are variable, with a higher frequency of missing tips at CSC than at El Inga. The pattern shared between CSC and El Inga differs from that seen in the FTPP from Southern Chile, where the most frequent position of breakage is transversely across blades. We suggest that the difference in positions of breakage may be related to the design of points: FTPP from CSC have an outline that has a closer resemblance to El Inga fishtail points, while points from Southern Chile have a more elongated shape. Variation in morphology between both regions has recently been analyzed (Castiñeira *et al.* 2012), yet detailed studies of use life are required to establish a correlation between shape and breakage patterns. A breakage experiment specifically designed for the purpose would be useful.

Final comments

The main goal of this paper was to present impact breakage patterns identified in FTPP replicas after an experiment using them on projectiles. This paper describes the first observations of experimental impact macrofractures on FTPP. Most of the impact fractures considered diagnostic in the literature were recorded in the FTPP replicas.

The Fishtail Projectile Point replicas with impact fractures were compared to the breakage patterns exhibited by the archaeological FTPP from Cerro El Sombrero Cima. Fracture pattern analysis proved to be useful for correlating archaeological FTPP breakage patterns with the use of these artifacts. In the case of CSC it reinforced the initial proposition that stems found at the site are the result of impact fractures (Flegenheimer 1986). This information is also relevant for understanding the life histories of these points as well as discussing the hilltop as a place where specific activities, such as point replacement and discard, were repeatedly carried out (Flegenheimer 1991, 2003). Another site in Patagonia, Amigo Oeste, was also interpreted as a case where projectile point replacement and discard took place in non-domestic scenarios (Miotti and Terranova 2010; Hermo and Terranova 2012). Strong similarities between these two sites reinforce the idea that this particular landscape was meaningful for the early hunter gatherers in a large area (Flegenheimer *et al.* 2013).

Also, the experimental results obtained and the comparison with different archaeological samples, suggest that variations in FTPP point morphology and design might be relevant in the study of breakage patterns and that this issue needs to be further investigated. For instance, the archaeological collection at CSC shows some positions of breakage (7, 9, and 10) that are not frequently found in the other collections. These issues merit further studies including both the analysis of other archaeological collections and more experiments designed for this specific purpose.

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