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Moving into an arid landscape: Lithic technologies of the Pleistocene–Holocene transition in the high-altitude basins of Imilac and Punta Negra, Atacama Desert

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ABSTRACT

In this work, we use taphonomic and technological analyses as a basis for study of the spatial and temporal variability of six lithic assemblages from the Pleistocene-Holocene transition (12,600–11,000 cal BP), recovered in the Imilac and Punta Negra basins (3000 m. a.s.l.), Atacama Desert (24.5°S). During the initial peopling of this area, the lithic sub-system was based on local raw material procurement and highly interconnected, complementary operative chains. This non-centralized structure resulted in even distribution of technical investment in the different stages of the reduction process, achieving great flexibility and responsiveness. We propose that this strategy allowed high mobility to co-exist with a generalized subsistence economy. Finally, we discuss the results and how they relate at the regional scale.

1. Introduction

1.1. *The peopling of South America and lithic technology*

The chronology and routes involved in the peopling of South America are still under discussion (Anderson and Gillam, 2000; Rothenhammer and Dillehay, 2009; Magnin et al., 2012; Miotti and Magnin, 2012; Bueno et al., 2013; Borrero, 2015a; Madsen, 2015). However, consensus exists that at the end of the Pleistocene and beginning of the Holocene, groups of hunter-gatherers scattered across the continent had already colonized the diversity of environments available (Borrero, 1999, 2006, 2015b; Dillehay, 1999, 2000, 2004; Politis, 1999, 2015; Aceituno et al., 2013), with varying degrees of success (Rivero, 2012).

In this process, human groups equipped with a broad spectrum of technological strategies ranked the advantages of ecological patches (Ardila, 1991; Dillehay, 1991; Politis, 1991; Kaulicke and Dillehay, 1999; Borrero, 2015b). The use of all these technologies was not uniform. Some were active over a long period and were shared across extensive regions, but at the same time new technologies appeared locally, replacing or even complementing their predecessors ("co-technologies"), while others remained hidden, only to reappear in specific contexts as "sleeping technologies" (Borrero, 2011). Far from being a single, standardized repertory, the technology of the human groups which colonized South America covered a wide range of decisions and options, forming a great geographical mosaic of technical traditions (Dillehay, 2013; Borrero, 2016).

It is quite possible that this variability resulted from different cultural units and migratory pulses (Dillehay, 1999, 2009; Madsen, 2015). From the point of view of colonization, the technological systems evolved as part of a process of learning and familiarization with the landscape. The human groups which dispersed to unknown landscapes developed new knowledge and shared different types of information (Borrero, 1994–95; Meltzer, 2002; Rockman, 2003, 2009; Ford, 2011). During the colonization of South America, their networks of interaction might reach different levels of integration, from the construction of stable niches and relations, as occurred on the Peruvian coast where greater social complexity developed (Dillehay, 2013), to small, mobile, relatively autonomous

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groups in Patagonia and the Andean highlands (Aschero, 1994).

The density and frequency of social interactions had direct repercussions on the learning and transmission of technical knowledge. When they were unstable or absent, learning by trial and error was a key factor in encouraging innovation, introducing greater technological variations (Hoguin and Restifo, 2012). Borrero for example says that "(…) *process based on learning by trial-and-error is known as guided variation* (…) *The possibility always existed that some sleeping technologies constituted Trojan horses, and maladaptation can be the result. Trial and-error is an expensive but necessary tactic, since it is difficult to be conservative when you are exploring new lands*" (Borrero, 2011:220).

Although regional models are lacking, lithic technology during this period presents characteristics which distance it from North American models (Kelly and Todd, 1988). These may be discussed under the following headings:

(1) In general, it is assumed that raw material procurement strategies focused on locally available rocks (<40 km), with a small contribution from distant sources (Nami, 1994; Borrero and Franco, 1997). However, the local/extra-local ratio can fluctuate considerably in some sites (Hajduk et al., 2012), with the balance reversed. Certainly, the management of lithic resources in each location resulted from decisions taken on the basis of various factors simultaneously. Several papers have emphasized the influence of long-distance interaction networks (Yacobaccio et al., 2005; Messineo, 2012; Flegenheimer et al., 2003), site functionality and activity planning (Flegenheimer and Mazzia, 2013; Skarburn et al., 2015; Suárez, 2015), availability of raw materials (Hajduk et al., 2010, 2012; Skarbun, 2011; Méndez and Jackson, 2012), knowledge of the landscape (Franco, 2002a, b; Paunero, 2009; Skaburn, 2012), differential transport and the use of space (Méndez, 2010, 2015; Franco et al., 2015; Méndez and Jackson, 2015).

(2) It has also been suggested that the first groups manufactured and carried toolkits appropriate to a generalized, rather than a specialized subsistence economy (Bryan, 1991; Dillehay, 2000, 2009; Lavallée, 2000; Politis and Messineo, 2008; Politis et al., 2014; Martínez et al., 2016). In this context, it has been observed that multifunctional tools were produced which could be used simultaneously in a diversity of tasks such as processing animal, vegetable and mineral resources (Aceituno, 2001; Aceituno and Loaiza, 2015; Aceituno and Rojas-Mora, 2015; Mazzia et al., 2016).

(3) Another important aspect is the co-existence of a high diversity of projectile points designs. Without doubt, fishtail points are a characteristic element of this period; they are distributed throughout South America and part of Central America (Politis, 1991; Flegenheimer et al., 2003; Suárez, 2000, 2006; Suárez and López, 2003; Nami, 2009; Castiñeira et al., 2011, 2012; Hermo and Terranova, 2012). There is some discussion as to their technological relationship with the Clovis technological tradition, particularly the "fluting" technique (Morrow and Morrow, 1999; Pearson, 2002, 2004; Faught, 2006). However, differences in the reduction sequences suggest a different but linked origin (Politis, 1991; Dillehay et al., 1992; Nami, 1997, 2003, 2014b; Borrero, 2009).

There is also an important record from other contemporary designs. Here we may mention a broad diversity of stemmed-barbed projectile points such as "El Inga" in Ecuador (Nami, 2014a), "Rastrepo" (Ardila, 1991) and "Magdalena" (López, 1990; Cooke, 1998) in Colombia, "Tigre" in Uruguay (Suárez, 2010, 2015, 2011), "Paiján" (Pelegrin and Chauchat, 1993) on the coast of Peru, the so-called "Paiján-like" at the Monteverde site in the southern Chile (Dillehay et al., 2015), "Punta Negra" in the Atacama Desert (Grosjean et al., 2005) and "Las Cuevas" (Latorre et al., 2013) recovered at the Maní-12 site, among many others. In some cases, they have been found together with fishtail points (Chauchat et al., 1998; Cooke, 1998; Briceño, 1999; Nami, 2010, 2014b). We may also mention records of triangular (Aschero, 1984, 2010; Núñez et al., 2002; Hocsman et al., 2012) and lanceolate non-stemmed points (Dillehay and Collins, 1991; Dillehay, 2000; Gnecco and Aceituno, 2006).

(4) Perhaps one of the most discussed aspects has been the existence of an unifacial reduction technology (Bryan, 1973; Dillehay, 2000) reported in several early archaeological sites of South America (Politis and Messineo, 2008; Lourdeau, 2012; López and Cano-Echeverri, 2013; Stothert and Sánchez, 2011; Aceituno and Rojas-Mora, 2015). Although this term has been used with different connotations, the fact remains that in several early assemblages there is little or even no bifacial work (Sandweiss et al., 1998; Dillehay, 2000; Lavallée, 2000). Indeed, it has been claimed that bifacial traditions such as fishtail and Paiján, may be slightly later adaptations (Maggard and Dillehay, 2011; Maggard, 2015). Otherwise, some authors have remarked on the influence of differentiated transport and site functionality in the frequency of bifacial tools in the assemblages (Nami, 1993; Flegenheimer and Cattáneo, 2013; Aceituno and Rojas-Mora, 2015; Skarbun et al., 2015; Borrero, 2016).

In recent years, discussion on the chronology of the peopling of South America has given way to interest in understanding how colonization occurred in differing environmental scenarios (Borrero, 2015b, 2016). Thus, lithic technology has progressively been treated less as a chrono-cultural marker and more as a subject to be studied from a behavioural perspective. Despite the poor visibility of the early record (Sandweiss, 2015), there is increasing interest in micro-regional and regional scales, rather than study in isolated contexts. Today, lithic studies not only attempt to characterize technological strategies, but they contribute to discussion of cultural variability, peopling routes and adaptation processes (Aceituno and Rojas-Mora, 2015).

1.2. *The colonization of the highlands of the Southern Atacama Desert*

Far from being a restrictive bio-geographical barrier, the Atacama highlands or "*puna*" offered ideal environmental conditions for human settlement from the end of the Pleistocene and beginning of the Holocene. An environmental event known as the Central Atacama Pluvial Event (C.A.P.E.) increased rainfall on the western slope of the Andes Mountains above 2000 m. a.s.l. (Latorre et al., 2002; Placzek et al., 2009). As a result, the lakes above 3800 m. a.s.l. increased to six times their current size (Geyh et al., 1999; Messerli et al., 1993; Grosjean et al., 2001). Groundwater table levels in the pre-Cordillera (3000–3800 m. a.s.l.) rose, leading to the formation of extensive wetlands and marshes (Betancourt, 2000; Rech et al., 2002; Grosjean et al., 2005; Quade et al., 2008). Increasing aridity and rising temperatures at the end of the Early Holocene caused these formations to collapse around 9700 cal BP (Quade et al., 2008) resulting in the existing salt flats of the Andean pre-cordillera (Rech et al., 2002) (Fig. 1A).

During the Pleistocene-Holocene transition, relatively autonomous groups with low demographic density and high mobility patterns arrived from other biomes (Muscio, 1998–1999; Aschero,

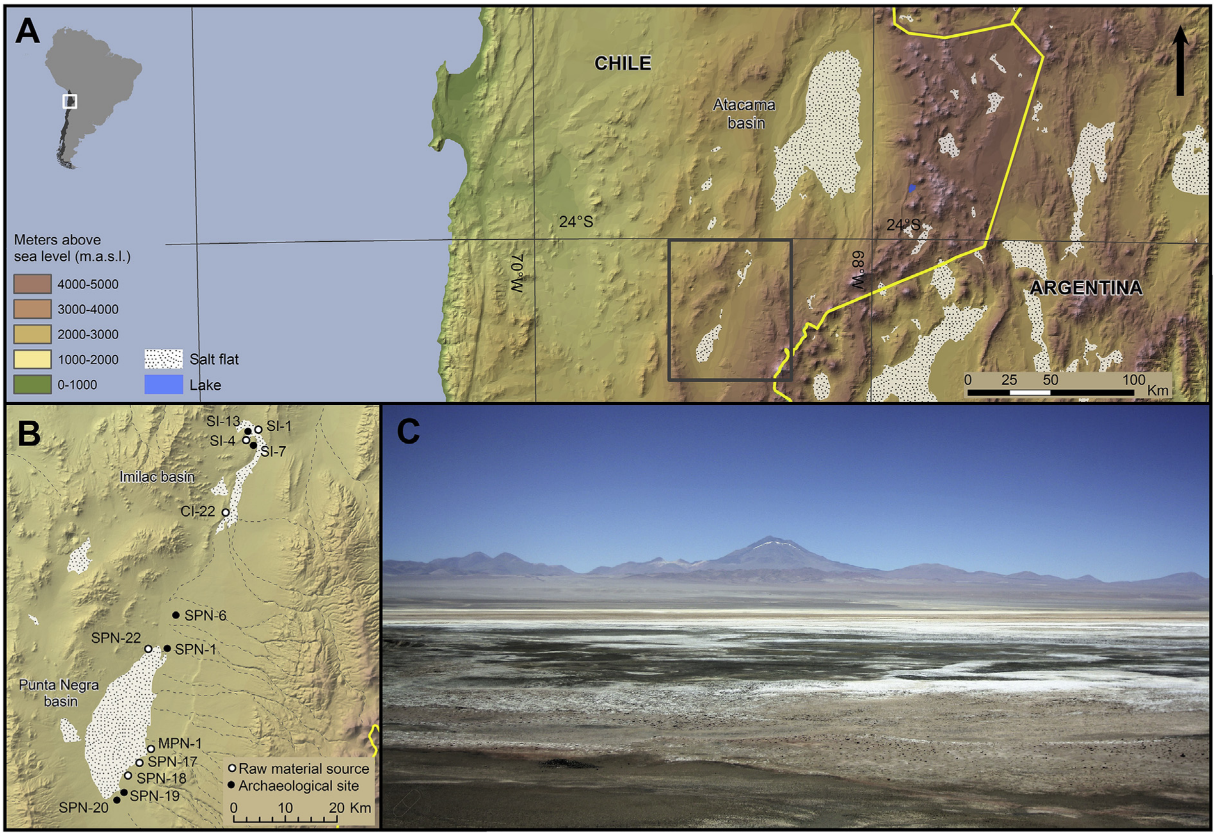

Fig. 1. Geographic Map: (A) Southern Atacama Desert, (B) Imilac and Punta Negra basins and archaeological sites, (C) Actual landscape.

1994; Yacobaccio et al., 2000, 2005) and colonized the Atacama puna on both slopes of the Andes Mountains (Aschero, 1984, 2010; Fernández Distel, 1989; Kulemeyer et al., 1999; Núñez et al., 2002; De Souza, 2004; Hernández Llosas, 2005; Osorio, 2011; Latorre et al., 2013; Cartajena et al., 2014).

In earlier works (Cartajena et al., 2014) we have proposed that the initial colonization of this area involved multidirectional leapfrogging rather than unidirectional advancesfollowing the bow and arrow model (Rockman, 2009). Human groups moving along ravines and natural routes made use of paleo-wetlands and marshes scattered in the arid landscape of the Atacama puna. These formations were exceptional habitats, home to ubiquitous, stable fresh-water sources and a great diversity of vegetable, animal and mineral resources (Núñez et al., 2002; Grosjean et al., 2005; Santoro and Latorre, 2009; Cartajena et al., 2014). On a broader scale, they formed a bio-geographical corridor which allowed fauna, plants and human groups to disperse across the desert and between different regions (Moreno et al., 1994).

As some authors have suggested, the patchy structure of resources conditioned spatially dispersed and discontinuous human settlement in different periods (Yacobaccio and Morales, 2005). It is known that locational information about resource distribution is acquired rapidly by a group (Rockman, 2003). Indeed, the ecological structure of paleo-wetlands and marshes was "familiar" (Steele and Rockman, 2003). But at some point, the colonization of these scattered micro-environments required a process of familiarization with the landscape (Rockman, 2009) and previous exploratory movements (Borrero, 2011). A reliable, shared technological platform was required during dispersal into an environment characterized by scarcity of oxygen, water scarcity and a considerable level of risk. As information accumulated on the distribution and limitations of resources, and new knowledge developed, technology in each location underwent major changes. At the same time, high mobility could have limited information transmission between localities, encouraging individual learning by imitation and the emergence of new technical skills and solutions (Hoguin and Restifo, 2012; Hoguin, 2013).

In this work, we propose a model based on the lithic technology of the human groups which inhabited the Imilac and Punta Negra basins, located in the southern *puna* of the Atacama Desert during the Pleistocene-Holocene transition. Temporal and spatial scopes are discussed in the framework of the peopling of South America.

2. Regional settings and lithic assemblages

The Imilac (23.5° S) and Punta Negra (24.5° S) basins form part of a system of closed high-altitude basins extending longitudinally from the Domeyko precordillera (3500 m. a.s.l.) to the Andes (6800 m. a.s.l.) (Fig. 1B). They cover areas of 189 and 4263 km^2 respectively, at an average altitude about 2950 m. a.s.l. The climate type known as High Desert is characterized by extremely arid conditions and cold temperatures. Mean annual precipitation is around 14 mm and mean temperatures range between 8 and 18 °C, but may drop below −20 °C. Wind is another important environmental factor, with average velocity of 14 km/h and a maximum of 90 km/h.

The basins are dissected transversally by a dendritic drainage system, formed by shallow, non-perennial ravines and streams descending from the Andes and Domyeko mountains. They are reactivated by rainfall during the summer months (known as the 'Bolivian winter'). However, high evaporation leads to the concentration of extensive saline-detrital deposits at the bottom of the basins, forming *salares* or salt flats. Shallows springs and marshes are supported by phreatic discharge to this day (Fig. 1C).

Paleoenvironmental research carried out at Imilac and Punta Negra (Grosjean et al., 2005; Quade et al., 2008) points to the existence of wetter conditions during the Pleistocene-Holocene transition, related to the CAPE event. It has been proposed that high groundwater levels existed during two periods: 15,000 to 13,800 cal BP and 12,700 to 9700 cal BP. During both periods, phreatic discharge supported extensive perennial wetlands with high biotic abundance and diversity, as has been observed through plant records from fossil rodent middens (Quade et al., 2008). However, the establishment of arid conditions during the Middle Holocene (9500–6500 cal BP) (Grosjean et al., 2001, 2003) led to the collapse of paleo-wetlands into low-productivity phreactic beaches (Quade et al., 2008).

Archaeological research in the area have claimed an association between paleo-wetlands and early human occupation during the Pleistocene-Holocene transition (Lynch, 1986, 1990; Grosjean et al., 2005). A large number of early sites and isolated finds have been recovered in recent systematic surveys, falling into three areas: SPN north, SI north-west and SPN south (Cartajena et al., 2014). Each contains a cluster of superficially dispersed lithic artefacts, found on fluvial terraces and phreatic beaches. In addition, seven lithic raw material sources have been documented.

3. Methodology

The lithic assemblages considered here were recovered from six archaeological sites studied in different research projects (Grosjean et al., 2005; Cartajena et al., 2014). In each site (Fig. 1B), systematic surface collections were carried out and artefacts were mapped on a 1 m^2 grid. In addition, stratigraphic excavations were carried out in 50 × 50 cm test pits, recording stratigraphic layers and artificial levels every 5 cms (Fig. 2). A summary of the radiocarbon dates is shown in Table 1 and Fig. 2G. In general, the sites excavated reveal low archaeological deposits to a depth of barely 30–60 cm (Table 2).

3.1. Taphonomic study

In order to establish the formation process and the deposit history of the assemblages, a lithic taphonomic study was carried out (Hiscock, 1985). Three aspects were included: (1) granulometric signal, (2) stability and (3) fragmentation. The granulometric signal (Bertrán et al., 2012) is defined as the differential distribution of artefact particles in the deposit, by weight, size and shape. Stability refers to changes in the position of artefacts over their taphonomic history (Borrazzo, 2004); one way in which it is measured is by the extent of weathering on the surface of the artefacts. In dry environments, wind abrasion is considered a reliable proxy (Ugalde, 2009). This is understood as wear on the surface of the artefacts produced by the action of wind-borne sediment (Borrazzo, 2004, 2006, 2007). Finally, we assess fragmentation through the macrofracture types observed (Weitzel and Colombo, 2006; Weitzel, 2009, 2010, 2012; Weitzel et al., 2014a).

3.2. Technological study

The technological study consisted in a comparative assessment of the assemblages from a techno-economical point of view (Perlès, 1991; Geneste, 1991a; b; Soressi, 2002; Meignen et al., 2009). The central object was to reconstruct the operative chains (Karlin and Julien, 1994) and their synchronic relationships within the lithic sub-system. Spatial and temporal trends are explored from a micro-regional approach. The results are presented according to four basic principles of lithic reduction: (1) raw material procurement, (2) core reduction and blank production, (3) bifacial knapping and (4) blank consumption and use.

4. Results

4.1. Lithic taphonomy and deposition history

Each artefact particle was classified in 10 g weight bands by stratigraphic level. When the distribution and frequency are compared (Fig. 3), a striking trend emerges: in the superficial assemblages, a deficit is observed in the lower weight band (<10 g). The largest number of artefacts are concentrated in band 2 (10–20 g), after which the curve falls drastically. In the stratigraphic assemblages on the other hand, the artefacts are concentrated in the lightest weight band (<10 g). This inversely proportional ratio may be interpreted as the result of a differential vertical selection process. In other words, the fragments with greater mass remained exposed on the surface, while those of lower mass became buried more quickly.

A similar situation has been reported in semi-arid wind-and-river environments in Patagonia (Borrazzo, 2004). In the case of the study assemblages, the burial of the artefacts may be associated with a range of processes such as trampling, wind sedimentation and vertical migration. The latter is important considering that vertisol soils are common around the edges of wetlands. One important consequence of this is that smaller artefacts, such as retouching flakes, would be more affected.

Without doubt wind is one of the most important taphonomic agents, and not just in the sedimentation of the assemblages. The differences in the expression of wind abrasion on the artefacts are considerable (Table 3), except in the case of SPN-6 where almost all the assemblage show no signs of weathering. In SPN-1, by contrast, abrasion is observed on only one of the faces (total and/or partial) of most of the artefacts, suggesting greater stability. In other words, the artefacts remained in the same position for most of their taphonomic history. In SI-7, SPN-19 and SPN-20, there tends to be greater abrasion on both faces (total and/or partial), suggesting horizontal migration. This trend is even more marked in SI-13, where abrasion of both faces is present in over 70% of the assemblage. Again, horizontal migration may be related to trampling, since most of the artefacts present damage and fractures around their edges which can be related to this taphonomic process.

Regardless of artefact fragmentation, the high frequency of snap fractures (Deller and Ellis, 2001; Weitzel, 2010) is striking (Table 4). According to experimental models, fractures of this kind result from an intentional blow on one face of the artefact when it is resting on a hard surface (Weitzel and Colombo, 2006; Weitzel, 2012). When the impact energy is higher, it may cause radial or complete cone fractures, however these are found only very rarely (Table 4). In the cases observed, the snap fractures seem to have been caused by controlled procedures, aimed at reconfiguring exhausted unifacial flake-tools. Accidental fractures associated with manufacture (perverse, lateral snap and end shock fractures) or use (longitudinal impact fracture) are fewer than those resulting from various causes (curved and transverse fracture).

4.2. Lithic raw material procurement

The assemblages studied reflect selection and management of a wide diversity of lithic raw materials (Fig. 4). Least common is a very small quantity of grey vulcanite (Vc-5) from a distant source located in north-western Argentina (250 km away) (Aschero et al., 2002–2004); this is the material used in the two fishtail points recorded in SPN-1 and SI-13.

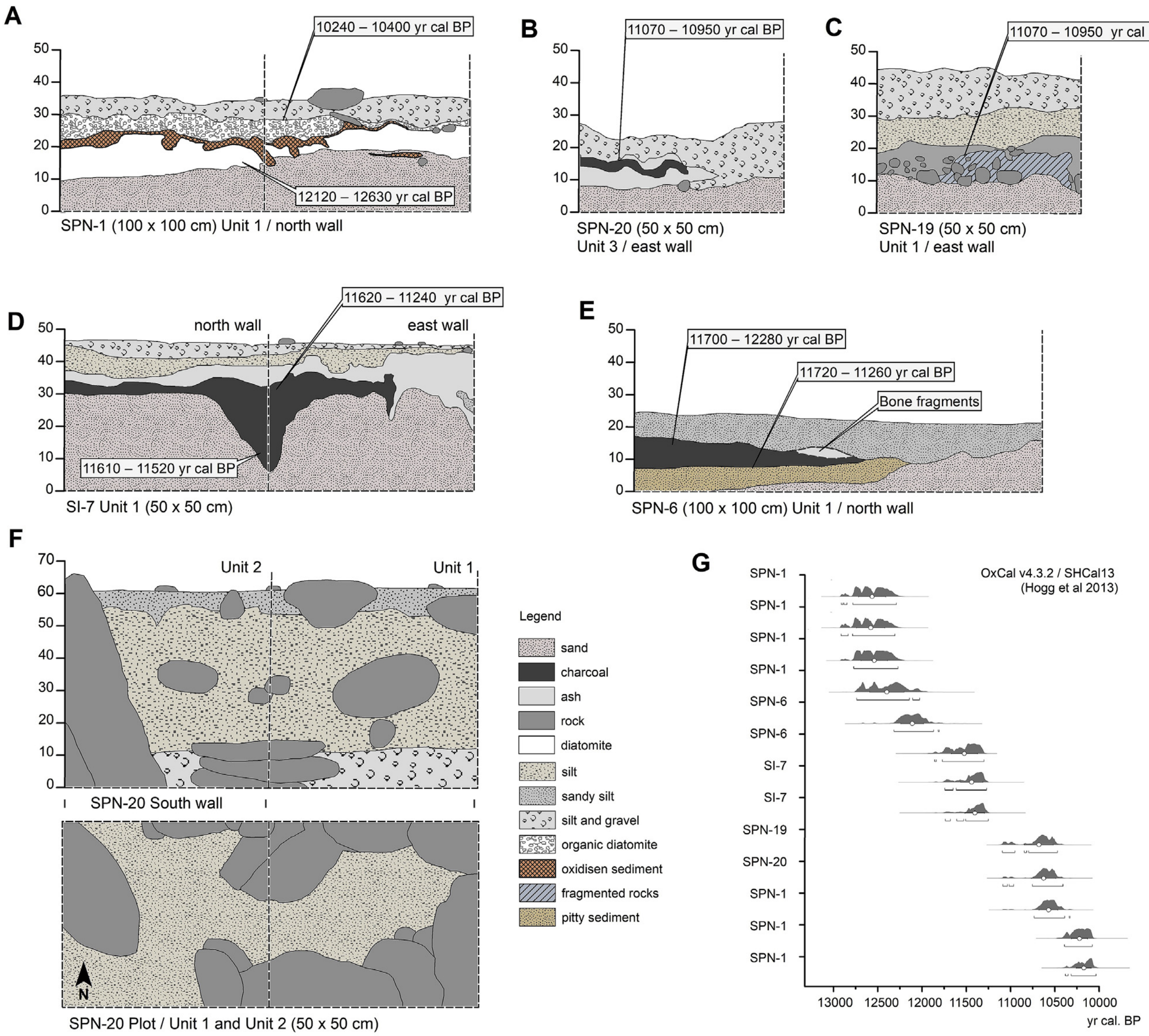

Fig. 2. Stratigraphic context and calibrated dates: (A) SPN-1 (B) SPN-19 (C) SPN-20 (D) SI-7 (E) SPN-6 (F) SPN-20 rock structure (G) Chronologic model.

Table 1
Areas, sites and ^{14}C dates (*) Grosjean et al., 2005 (**) Cartajena et al., 2014.

Area	Site	Site function	^{14}C yr BP	2-sigma cal BP (95.4% probability)
SPN North	SPN-1	Multiple task site	9450 ± 50*	10775–10443
			10460 ± 50*	12543–12035
			9180 ± 50*	10485–10206
			10350 ± 60*	12409–11830
			10440 ± 50*	12430–12020
			9230 ± 50*	10497–10240
			10470 ± 50*	12545–12050
	SPN-6	Specialized task site	10000 ± 50**	11693–11240
			10260 ± 60*	12363–11621
SI Northwest	SI-7	Multiple task site	9940 ± 50**	11601–11204
			9960 ± 50**	11604–11220
	SI-13	Specialized task site	–	–
SPN South	SPN-19	Multiple task site	9500 ± 50**	11070–10560
	SPN-20	Multiple task site	9480 ± 50**	11065–10513

The rest of the rocks come from the seven raw material sources available locally in the Imilac and Punta Negra basins (Fig. 1B). In terms of accessibility, they are "autochthonous" and "sub-local" outcrops (Turq, 2000, 2005). The autochthonous rocks include aphanitic basalts (MPN-1) and hydrothermal chalcedony (SI-3 and SI-4). Sub-alochthonous sources provide aphanitic rhyolite (CI-1

Table 2
Frequency of artefacts by stratigraphic level (every 5 cm).

Site	Collection	Excavation						Total
	surface	level 1	level 2	level 3	level 5	level 6	level 7	
SPN-1	1273	40	1	1	1			1316
SPN-6	23			1				24
SI-7	51	42	9	14	1			117
SI-13	1217		17					1234
SPN-19	154	7						161
SPN-20	137	44		1	2	5	3	192
Total	2855	133	27	17	4	5	3	3044

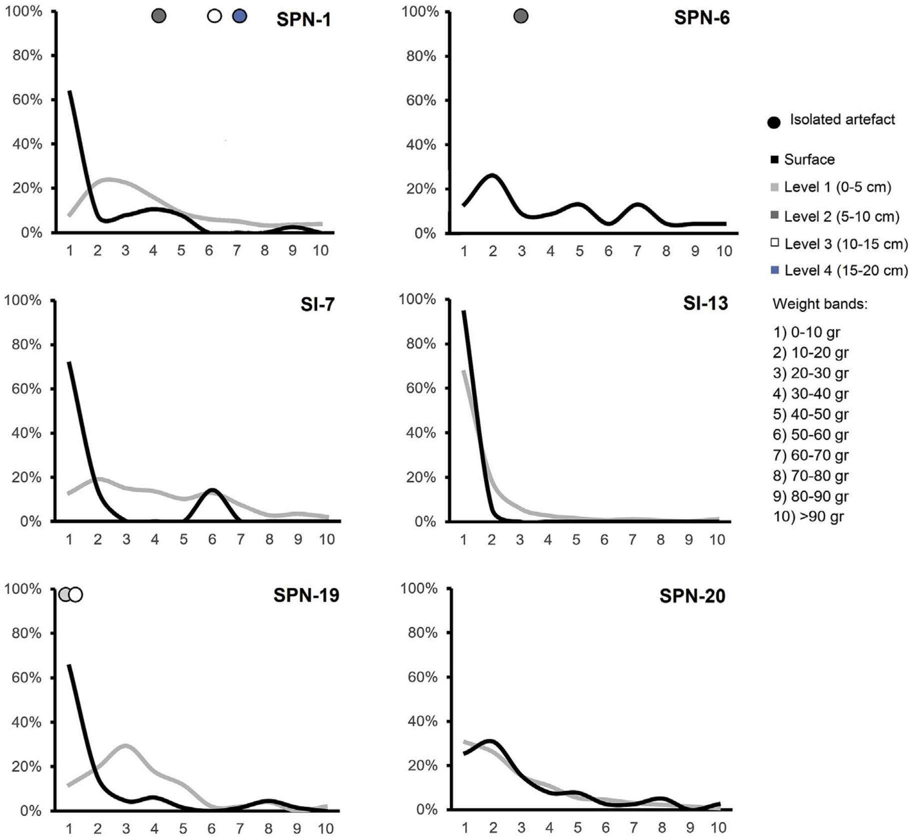

Fig. 3. Granulometry signal: Weight bands distribution by stratigraphic level.

Table 3
Wind abrasion extension by site.

Site	Non abraded		Total of one side		Partial of one side		Total of both sides		Total of one and partial of the other		Partial of both sides	
	n	%	n	%	n	%	N	%	n	%	n	%
SPN-1	277	21,05%	870	66,11%	21	1,60%	79	6,00%	57	4,33%	12	0,91%
SPN-6	22	95,65%	1	4,35%		0%		0%		0%		0%
SI-7	33	28,21%	47	40,17%		0%	37	31,62%		0%		0%
SI-13	132	10,70%	296	23,99%	31	2,51%	735	59,56%	34	2,76%	6	0,49%
SPN-19	11	6,83%	70	43,48%	3	1,86%	74	45,96%	3	1,86%		0%
SPN-20	38	19,79%	103	53,65%	4	2,08%	44	22,92%	3	1,56%		0%

and SPN-22) and silicified tuffs (SPN-17 and SPN-18). In general, sources are ubiquitous and knappable rocks are easily available. The sources are not concentrated but distributed in several points of the landscape, all in the lower parts of the basin close to potential transport routes. They offer different classes and qualities of raw materials, with blocks of different sizes and morphologies (Table 5).

The lithic assemblages present quite a similar distribution of raw materials within each area, however there are important differences between them. For example, in SPN North (SPN-1 and SPN-6), basalts and aphanitic rhyolites are the main resources. These materials are sourced from approximately 30 km away. In SI-7 on the other hand, and especially SI-13, hydrothermal chalcedony clearly predominates, sourced less than 2 km away from the settlements. On the other hand, SPN-19 and SPN-20 present a more homogeneous raw material distribution, although the sources are at widely varying distances.

4.3. *Core reduction and blank production*

The 97 cores recovered in total represent a low number per site (Fig. 5). Contextual study of these artefacts, core flakes and tool blanks allowed us to identify seven main core reduction systems:

Table 4
Macro-fracture types by site.

	SPN-1		SPN-6		SI-7		SI-13		SPN-19		SPN-20	
	n	%	n	%	n	%	n	%	n	%	n	%
Perverse	8	1,55%		0%	2	6,45%	11	2,63%		0%	1	1,47%
Lateral Snap		0%		0%	4	12,90%	18	4,30%	7	12,07%	12	17,65%
Longitudinal Impact	7	1,36%		0%	2	6,45%	11	2,63%	1	1,72%	1	1,47%
Radial	27	5,23%		0%		0%	10	2,39%	3	5,17%		0%
Snap	249	48,26%	2	50%	4	12,90%	64	15,27%	22	37,93%	17	25,00%
Complete Cone	1	0,19%		0%		0%	2	0,48%	1	1,72%		0%
Curved	159	30,81%	2	50%	7	22,58%	74	17,66%	5	8,62%	14	20,59%
End Shock		0%		0%		0%		0%		0%	2	2,94%
Transverse	64	12,40%		0%	12	38,71%	229	54,65%	19	32,76%	21	30,88%
Other	1	0,19%		0%		0%		0%		0%		0%
Total	516	100%	4	100%	31	100%	419	100%	58	100%	68	100%

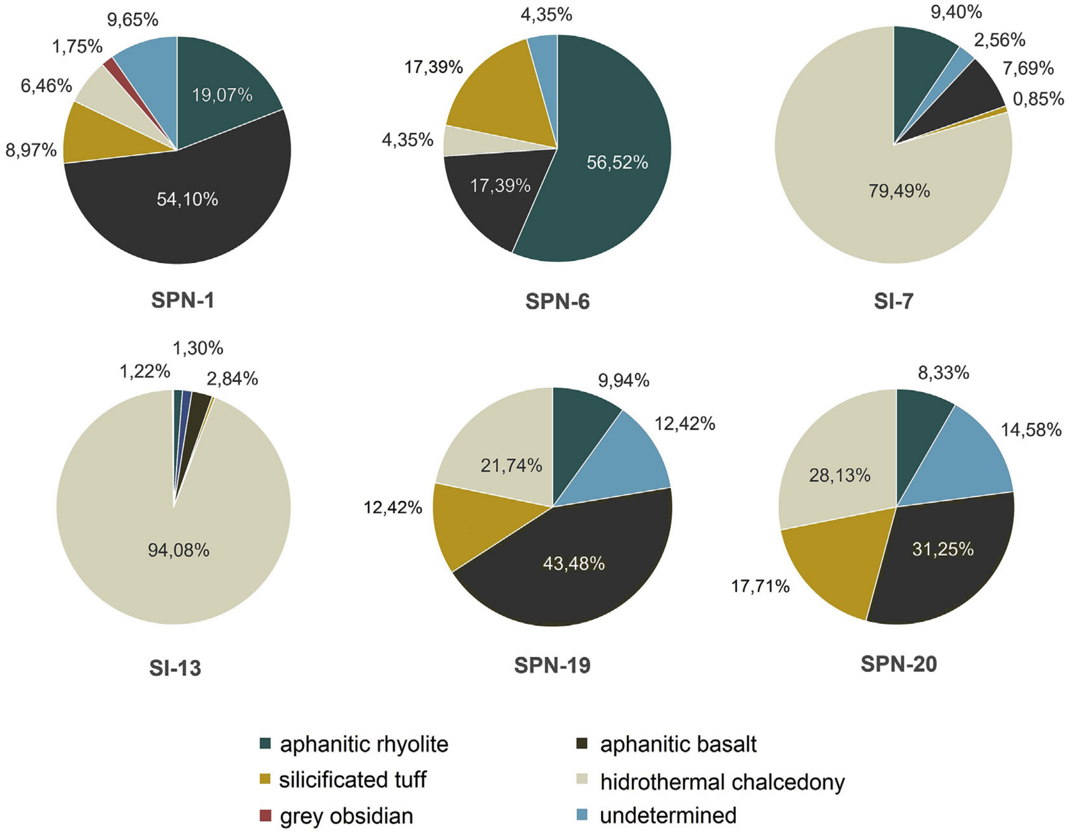

Fig. 4. Distribution of lithic raw materials by site.

(1) peripheral secant, (2) centripetal bisecant, (3) facial on slice, (4) facial sub-parallel on flake, (5) unipolar secant on flake, (6) centripetal mixed platform and (7) parallel slices (Table 6). No differential management of lithic resources was observed, except in the case of the facial on slice system, which predominates on hydrothermal chalcedony.

The peripheral secant system is based on unidirectional cores with a single platform (Fig. 6A). The products are medium and large sized angular flakes. The centripetal bisecant system (Fig. 6B) provides medium and large sized angular flakes. In both cases, the core architecture is adapted to the morphology of the nodule without the need for significant shaping. Neither involves standardized procedures for maintaining the surfaces or predetermined extraction for defining blanks.

The facial sub-parallel (Fig. 6C) and unipolar secant on flake (Fig. 6D) systems involve 'ramified' (or branching) operative chains (Bourguignon et al., 2004). The former was used to produce small flat flakes with sub-circular morphology; the latter provide small angular flakes. In both cases, the frequency is much higher if we include the recycled tools in this core type. We recorded a total of 47 unifacial exhausted tools recycled as facial sub-parallel cores, and 17 as unipolar secant cores. No shaping is required in either case, since they take advantage of the morphology of the blank. No maintenance of the surfaces or predetermination of the extractions was observed.

The parallel slices system (Fig. 6E) was recorded in only one core, however, it makes a significant contribution to tool blank variability. The products are thick, cortical-backed slices with axial (complete slices, Fig. 6E and 1) or wedge (partial slices, Fig. 6E and 2) ends. Some works stress the large number of blanks that can be

Table 5
Outcrops and lithic raw materials.

Source	Accessibility	Availability	Outcrop dimensions (m^2)	Rock class	Mophology	Clast size range (cm)	Quality
SI-3	Secondary allochthonous	Middle	155096	Hidrothermal Chalcedony (opaline nodules)	Spheroidal-rounded nodules	5–15	Good
SI-4	Primary allochthonous	High	38629	Hidrothermal Chalcedony (phreatic breccia)	Irregular-subrounded boulders and pebbles	10–150	Good
CI-1	Sub-allochthonous	Middle	–	Aphanitic rhyolite	Tabular-rounded pebbles	10–25	Regular/ Good
SPN-22	Sub-allochthonous	Low	–	Aphanitic rhyolite	Irregular-subrounded pebbles and cobbles	5–15	Regular
MPN-1	Primary allochthonous	High	4104215	Aphanitic basalt	Tabular-subrounded boulders and pebbles	10–150	Regular/ Good
SPN-17	Sub-allochthonous	Middle	100	Silicificated Tuff	Tabular-subangular boulder (isolated block)	140	Regular
SPN-18	Sub-allochthonous	Middle	37408	Silicificated Tuff	Spheroidal-subrounded pebbles	15–30	Regular

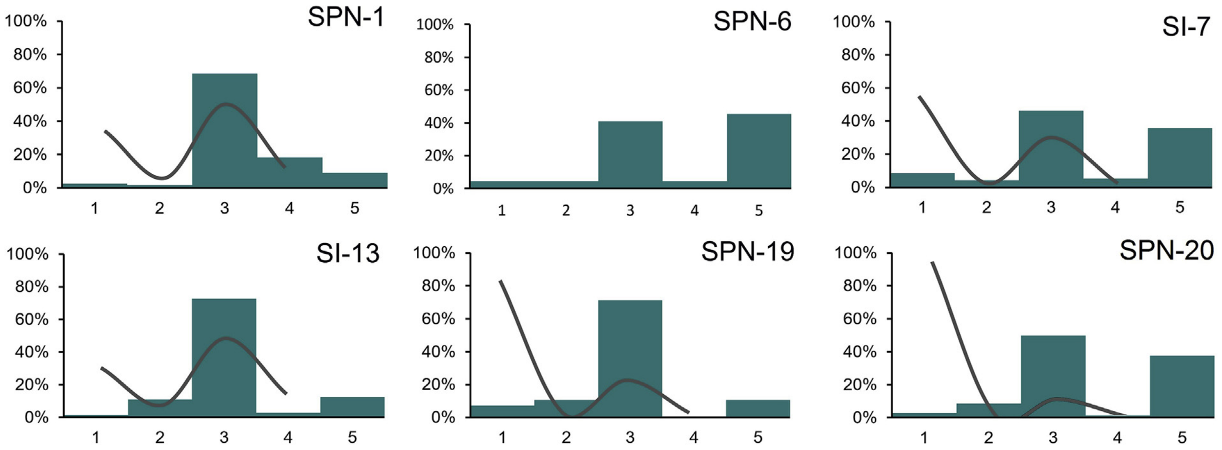

Fig. 5. Technological variability: Bars: 1 = Core, 2 = Bifacial tool, 3 = Flake-tool, 4 = Recycled tool, 5 = Used flake. Lines: 1 = Core reduction flake, 2 = Bifacial reduction flake, 3 = Tool retouch flake, 4 = Tool recycling flake.

Table 6
Core frequency by site.

Core category	SPN-1		SPN-6		SI-7		SI-13		SPN-19		SPN-20	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Peripheral secant	3	13,64%	1	100%		0%		0%	3	27,27%		0%
Centripetal bisecant	2	9,09%		0%		0%	2	3,85%	4	36,36%		0%
Facial on slice		0%		0%		0%	27	51,92%		0%		0%
Multidirectional	5	22,73%		0%		0%	6	11,54%	1	9,09%		0%
Centripetal mixed		0%		0%		0%		0%		0%	1	50%
Parallels slices		0%		0%		0%	1	1,92%		0%		0%
Unipolar secant on flake	3	13,64%		0%		0%	3	5,77%	1	9,09%		0%
Subparallel facial on flake	4	18,18%		0%		0%	7	13,46%	1	9,09%	1	50%
Non-patterned	5	22,73%		0%	1	100%	5	9,62%	1	9,09%		0%
Undetermined		0%		0%		0%	1	1,92%		0%		0%
Total	**22**	**100%**	**1**	**100%**	**1**	**100%**	**52**	**100%**	**11**	**100%**	**2**	**100%**

extracted from one core, representing intensive use of the volume.

The facial on slice system (Fig. 6F) is an exceptional case of a compound and ramified operative chain. It involves two closely-linked but independent core reduction systems. First, parallel slices flaking is applied to obtain long, thick slices. These blanks are then reduced by a sub-parallel facial system to provide three different kinds of blanks: flat flakes, small angular flakes (Fig. 6E and 1) and asymmetrical flakes with cortical or often prepared back (Fig. 6F–2 and 3). Higher technical investment is observed in shaping and surface maintenance. This core reduction system has been recorded exclusively in Imilac sites and related with hydrothermal chalcedony. Finally, multidirectional cores are very frequent, but most correspond to reworking of unipolar secant cores.

At least one core may represent a centripetal mixed platform system (secant/sub-parallel) (Fig. 6G). Unlike the bisecant centripetal cores, this one shows functionally hierarchized management of the surfaces, with a predominant sub-parallel platform on one secant leading to differentiated blank production (Fig. 6G 1 and 2). More systematic maintenance and shaping procedures were

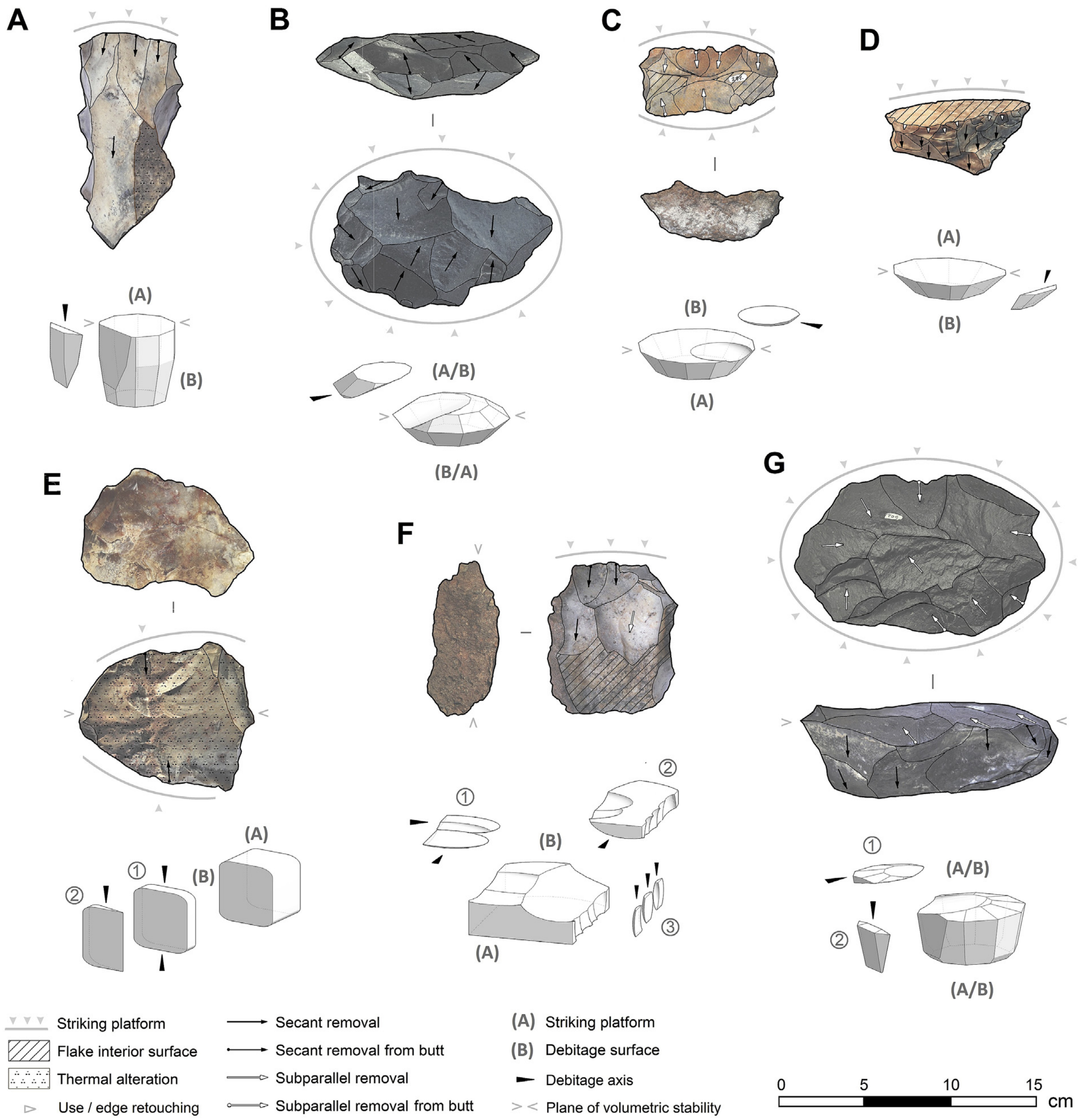

Fig. 6. Core reduction methods: (A) Peripheral secant, (B) Centripetal bisecant, (C) Facial subparallel on flake, (D) Unipolar secant on flake, (E) Facial on slice, (F) Subparallel slices, (G) Centripetal mixed (subparallel/secant).

also observed. A referential scheme of core reduction systems and blank production is shown in Fig. 7.

If we consider the width and thickness of complete tools (n = 737) by the core reduction system used to produce them, we can identify some trends in blank production. Cortical blanks have been excluded intentionally. Taking this into account, one group of blanks presents a wide range of dimensions, in which thick sections predominate. This is true of angular flakes 1 related to peripheral secant cores (n = 253), angular flakes 2 obtained from bisecant cores (n = 156), asymmetrical flakes (n = 160) and angular flakes 3, linked to centripetal mixed cores (n = 64). Slices (n = 46) form a second group that present less variation in their dimensions (Fig. 8), greater thickness (Table 7), and relatively thin sections (width/thickness >4). A third group consists of plane flakes (n = 58) that present smaller width/thickness dimensions and thinner sections.

4.4. *Bifacial knapping*

We recovered 69 bifaces, 16 projectile points and an indeterminate bifacial fragment. Tool blanks on bifacial flakes are very scarce (n = 47) and bifacial knapping flakes even more so (n = 20) (Fig. 4). It is true that these flakes are hard to distinguish, especially in their early stages; they may therefore be under-represented. Moreover, the processes of vertical selection affect smaller waste flakes. However, it is probable that bifacial tools were brought to the sites in a finished state.

In comparative terms, bifaces and projectile point account for less than 5% of the assemblages, except in SI-7 and SPN-19 where they are slightly over 10% (Fig. 4). Four bifacial operative chains were identified: lanceolate bifaces, stemmed and barbed projectile points, triangular non-stemmed projectile points, and fishtail

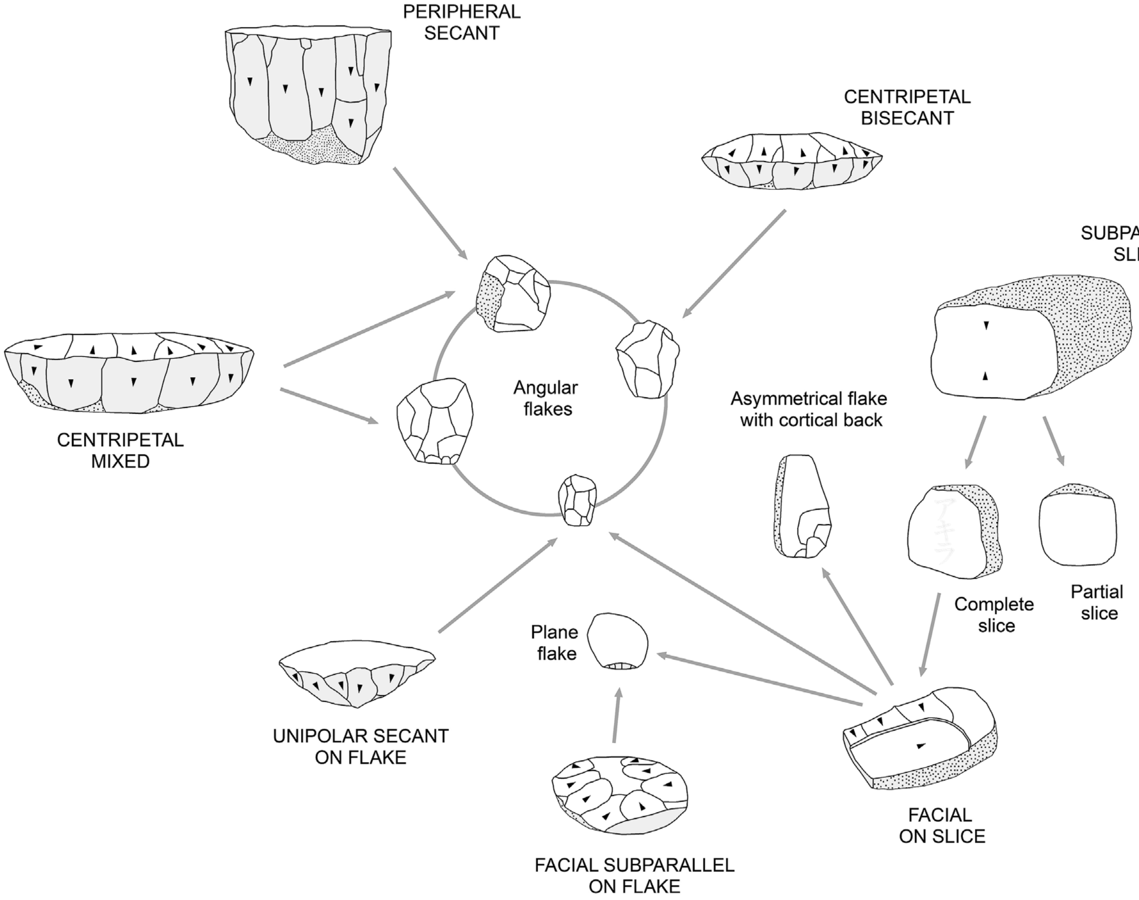

Fig. 7. Core reduction systems and blank production.

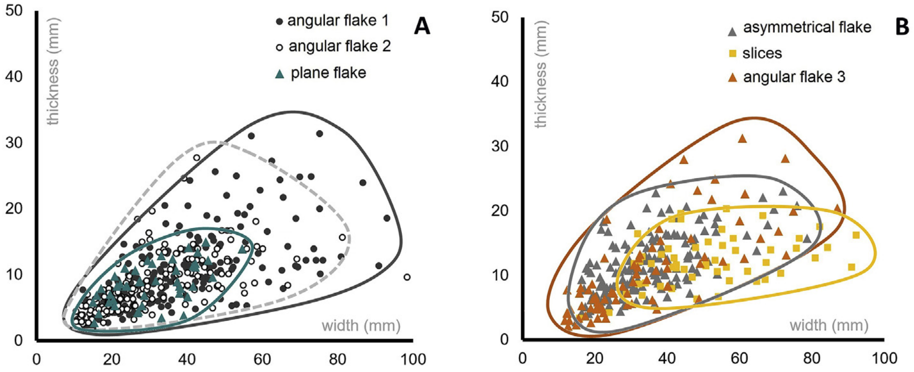

Fig. 8. Tool blank dimensions (width and thickness).

Table 7
Width and thickness by core reduction system.

Tool blank category	Width (mm)		Thickness (mm)		Width/Thickness	
	$\overline{X}$	σ	$\overline{X}$	σ	$\overline{X}$	σ
Angular flakes 1	32,86	16,35	13,30	5,13	3,90	1,56
Angular flakes 2	30,93	15,94	12,58	4,55	3,94	1,62
Slices	24,86	13,69	8,60	4,43	4,61	1,13
Angular flake 3	27,55	13,36	8,89	5,47	3,62	1,61
Asymmetrical flakes with cortical back	47,68	16,91	12,94	4,72	4,23	1,58
Plane flakes	36,06	13,63	13,19	7,37	3,10	1,13

points. Differential management of raw materials can be observed between them. While grey obsidian is used for fishtail projectile points, the rest are produced mostly in hydrothermal chalcedony.

In general, low technical investment is observed in bifacial operative chains, except in the case of stemmed and barbed points which present a larger number of stages and greater technical skills. In all cases and considering several models published (Callahan, 1979; Whittaker, 1994; Nami, 2010), bifacial knapping comprises four main stages: (1) blank selection and initial edging, (2) bifacial reduction and thinning, (3) final shaping, and (4) use and maintenance (Fig. 9).

4.4.1. *Lanceolate bifaces*

Three lanceolate bifaces present evidence of the use of slices as blanks (Fig. 9A). The lozenge-shaped cross-section of the slices allows the volume to be worked on directly, without preparing a dihedral edge. In all the other bifaces, the advanced stage of reduction makes it impossible to recognize the blank used. In

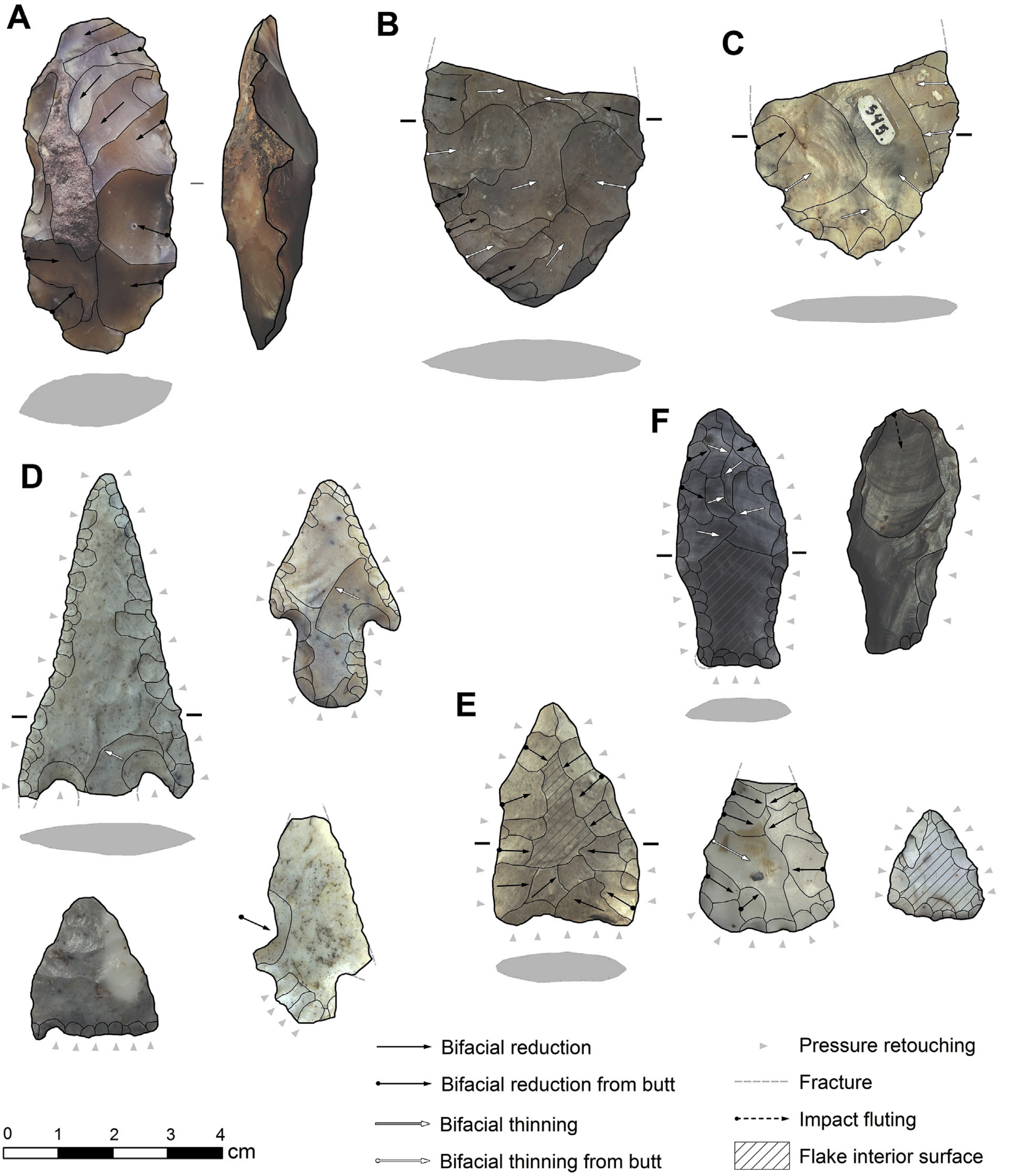

Fig. 9. Bifaces and projectile points: (A) Lanceolate biface with bifacial reduction, (B) Thinned lanceolate biface, (C) Preform of stemmed-barbed projectile point, (D) Stemmed-barbed projectile points, (E) Triangular, non-stemmed projectile points, (F) Fishtail projectile points.

general, lanceolate bifaces present initial edging by irregular removals (stage 1) along the edge or sometimes reaching the center of the piece (Fig. 10A). The object of these procedures is to eliminate irregularities and remove the cortex.

The bifacial reduction (stage 2a) starts with a regular marginal retouching to define a bilateral symmetry (Inizan et al., 1995) and a stable biconvex cross-section (Pelegrin, 1991; Stout et al., 2014). In this stage, parallel-alternate management (Pelegrin, 2005) is more frequent (Fig. 9A). The bifacial thinning (Aschero and Hocsman, 2004) reduces considerably the thickness of the piece (stage 2 b), working on a bifacial plane and defining symmetrical biconvex cross-sections (Fig. 9B). This is done by deep removals, which reach the center of the piece and occasionally reach or "overshot" the opposite edge (Stanford and Bradley, 2012). In this stage, an alternating management (Pelegrin, 2005) of the surfaces may be applied. The most common accidents are hinge removals or perverse and oblique fractures. Only one case shows final shaping by a pressure retouch (stage 3) and use (stage 4) but, none shows signs of maintenance.

4.4.2. Stemmed-barbed projectile points

Stemmed-barbed points were probably produced from thinned lanceolate bifaces as continuation of stage 2 b (Fig. 10B). None of the examples suggests direct use of flakes as blanks. A secondary thinning stage (stage 2c) was observed in projectile points of this kind, starting with preparation of the base by a bimarginal retouching. This creates two straight, convergent edges along which oblique thinning removals are carried out on both faces, intersecting in the center of the piece. This operation is probably critical: the three preforms with thinning of this kind all present perverse, transverse fractures (Fig. 9C). The object of these removals by oblique thinning is to create a depression which will subsequently allow access to the center of the piece in order to shape the stem and barb (stage 3) by alternate-bimarginal retouching, using pressure. In this way, a stem is created with slightly concave, expanded edges (Fig. 9D). The final shaping includes abrasion of the edges, to facilitate fixing. The barbs are straight and end in an oblique angle towards the stem. The base is convex and thinned by bimarginal retouching.

Subsequently the blade is regularized by pressure. Only one piece could be considered an "original design" (Aschero, 1988), which was discarded due to a fracture in the stem (Fig. 9D). It has an elongated, straight-sided, triangular blade and the arris regularized by alternating bimarginal retouching to produce an indented edge. The remaining points are therefore a "maintained design" (Martínez, 2003) in which the blade has been shortened by successive reactivations and reworking (stage 4). The repairs applied to fractured barbs, so that they end as rounded shoulders, are also

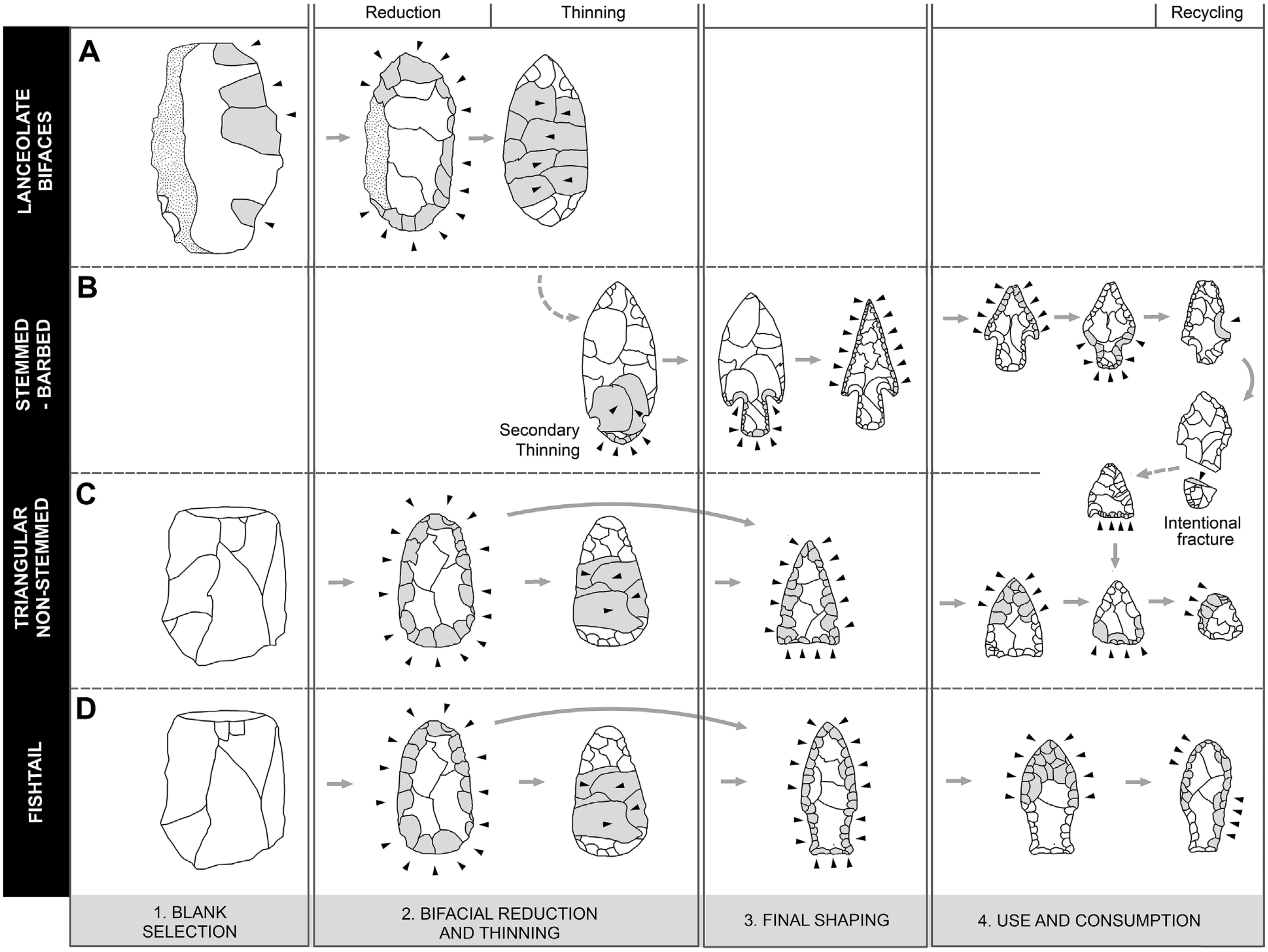

Fig. 10. Bifacial operative chains: (A) Lanceolate bifaces, (B) Stemmed-barbed projectile points, (C) Triangular, non-stemmed projectile points, (D) Fishtail projectile points.

remarkable. The same occurs with the base of the stem which shift from convex to straight. Other specimens have been recycled as notches or knives (Fig. 9D). It is probable that some stemmed points have been recycled as triangular points, by intentional fractures of the stem followed by marginal retouching. At least, two cases present these operations.

4.4.3. *Triangular, non-stemmed points*

The early stages (1 and 2) of triangular, non-stemmed points are very scarcely represented, as they are made directly from flakes (Fig. 10C). There are also greater variations in volume management. Some present thinning on one face and reduction on the other (stage 2) through alternate parallel management. In other cases, there is no reduction or thinning and the flake is shaped directly by marginal or bimarginal retouching, using pressure or direct percussion (stage 3). As Fig. 9D shows, the base is originally concave, the blade triangular and elongated, with slightly convex edges. Some specimens present bilateral notches, probably for a better fixing to the shaft. As fractures occur in the tip and wings, reworking shortens the blade and the base becomes straight and finally convex (stage 4). Besides, some specimens have been recycled as notches or knives.

4.4.4. *Fishtail points*

Only two complete fishtail projectile points were recovered (Fig. 9F), which were produced from flakes. In both cases the thickness of the blank is less than 7 mm, suggesting the use of bisecant angular flakes (stage 1). However, the intensive reduction makes it impossible to recognize the initial stages. In fact, other works have proposed that the initial reduction of this kind of projectiles points is done close to the quarry (Flegenheimer and Cattáneo, 2013). However, two biface fragments, also produced on flakes of Vc-5 could correspond to early reduction stages. This raw material is quite infrequent and almost always used for fishtail projectile points. These specimens and the two points were thinned on one face only (Fig. 10D), and reduced through a parallel-alternate management (stage 2). However, final shaping implies bimarginal retouching on both faces using pressure and the abrasion of the edge of the stem (stage 3). The two points show intensive reduction sequences. In the first case, a successive maintenance of the blade and reconfiguration as a knife was observed. In the second, the base of the stem is fractured and an impact fluting (Weitzel et al., 2014b) on the tip led to its recycling as a notch and scraper (stage 4).

4.5. *Blank consumption and use*

There is a wide variability of flake tools. From a technological perspective, they can be grouped into seven modalities of blank management, based on the organization, extension and position of retouching with respect to the technological axis. Unmodified flakes (Fig. 11A) are the most common modality but lateral (Fig. 11B) and frontal (Fig. 11C) management make up the bulk of the retouched tools (Table 8). Lateral tools are mostly sidescrapers, knives and denticulate edges. Frontal tools on the other hand consist mostly of scrapers and to a lesser extent rabots, raclettes, chisels, etc. It is arguable that this aspect presents differential raw material management: while lateral tools are mainly produced from basic rocks such as basalt and tuffs, the frontal method is mostly used for acid rocks such as rhyolites and chalcedonies.

Lateral and frontal modalities also show a relatively greater technical investment in the establishment of the active-edge morphology and the suitable thickness of the tool's cross-section. The other management modalities, apart from their low technical investment, present no significant modification of the blank shape but make use of potential sectors. In fact, most of them are included within lateral and frontal tools as complementary or recycled edges (Fig. 11C and 2). One exception is the ultramarginal modality on asymmetrical backed flakes and plane flakes. In these cases alone, functional criteria are obtained by the core reduction method. Thus modification of the blanks is not required. This could also apply to edge morphology, the tool being used first as an unmodified edge, and then retouched once exhausted. On this basis a direct relation between core reduction systems and blank management can be argued. Core reduction systems producing more predictable blank shapes require less retouching during the blank management stage.

Otherwise, Table 9 shows the mean angle of reduction of the edge, obtained by the difference between the initial angle (first removals along the edge) and the final angle (last removals along the edge). It can be seen that this measurement is considerably higher in the lateral and frontal modalities, suggesting greater retouch intensity.

Recycling is one of the most recurrent behaviors in unifacial tools, especially in SPN-1 (18.33%), SPN-6 (4.55%) and SI-13 (5.28%) (Fig. 4). Three main recycling modalities may be distinguished: (1) intentional fracture, (2) direct retouching, and (3) inverse retouching.

Recycling by intentional fracture is carried out principally in tools with lateral management and is responsible for most undetermined flake tool fragments (Table 10). It involves causing a snap fracture in the dorsal face, creating a new edge (Fig. 11D) which can be used in one of two ways: (1a) unmodified, as a natural edge, or (1 b) as an ultramarginal retouched edge. On the other hand, recycling by direct retouching is applied to both the lateral and frontal management modalities (Table 10). This refers to the reconfiguration of an edge using the same technique of direct retouching but generally to produce another kind of cutting edge, notches and/or unipolar secant cores. Finally, recycling by inverse retouching is also carried out in both lateral and frontal modalities (Table 10) but reconfigures them as sub-parallel facial cores (Fig. 11E) to obtain plane flakes used as unmodified or ultramarginal retouched edges (Fig. 11F); the negatives may be re-used as notches but not exclusively. It is important to note that reconfiguration is not applied exclusively to exhausted tools do not always. Nearly half of them are far from the end of their useful lives.

5. Discussion and conclusions

According to our taphonomic study, vertical selection processes exist based on the size and shape of the artefact particles. This can be seen repeatedly in assemblages deposited in environments with wind-blown sediments at the edge of paleo-wetlands. Trampling is an important process both for macro-fractures and for the vertical and horizontal migration of artefacts. Although the assemblages come mostly from surface environments, temporal variability and synchronic/diachronic links should be studied carefully.

Bearing this in mind, certain general trends may be discussed. Firstly, procurement strategies included a wide range of local lithic raw materials. In a context of high mobility, local procurement without a suitable technological structure would be risky. The implementation of core reduction systems with low technical investment and high productivity was a key factor. The centripetal bisecant and the peripheral secant system provide a large quantity of blanks in a short time. The products are angular flakes with great morpho-dimensional variability. Since the shape of the flake does not coincide with the desired tool, the blanks will tolerate intense retouching, increasing their useful life and potential for ramification (Bourguignon et al., 2006; Meignen et al., 2009).

The advantage of producing “undifferentiated blanks” is that the products can be transformed into tools almost of any kind, with

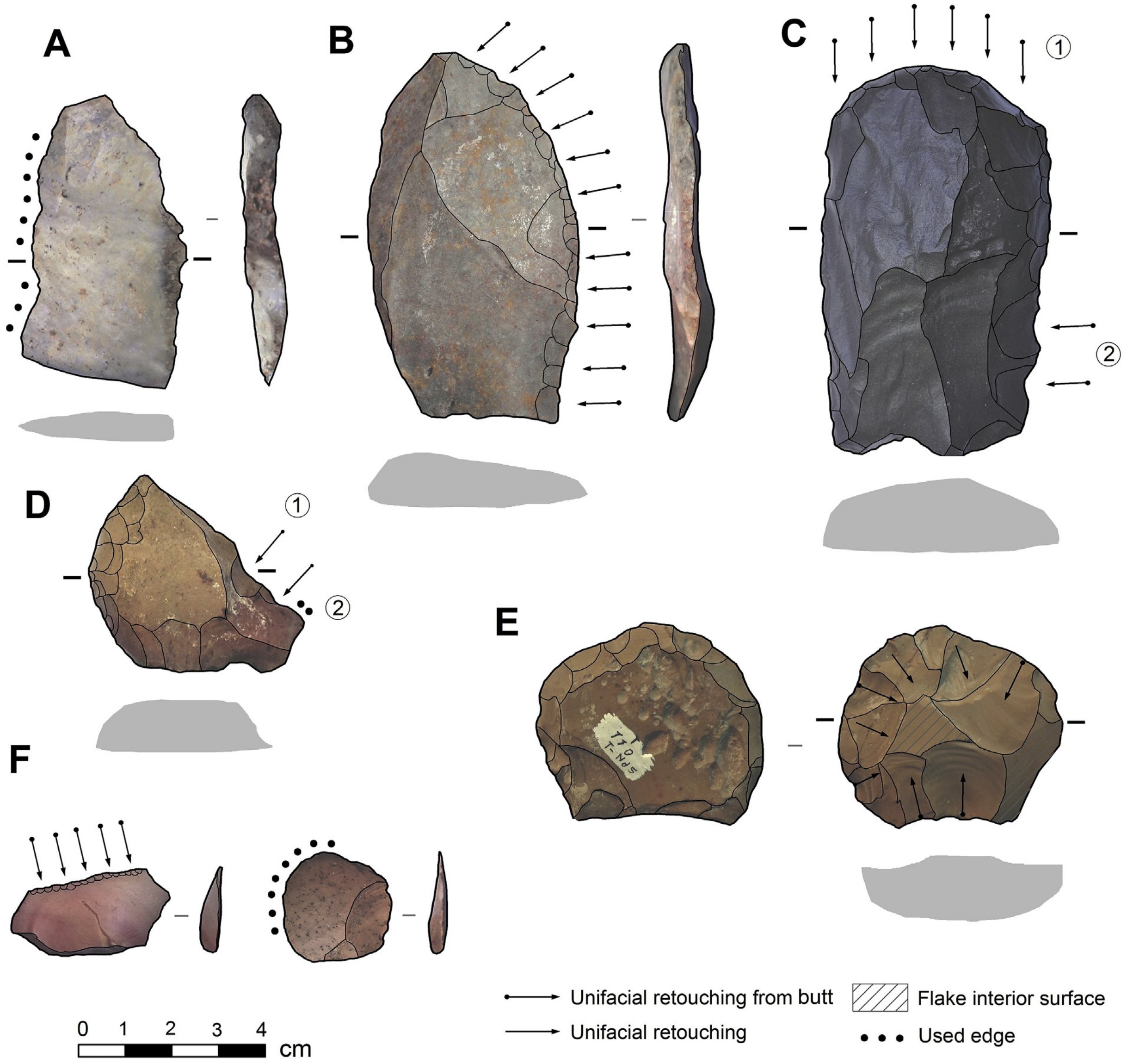

Fig. 11. Blank management modalities: (A) Lateral modality, (B) Non-modified modality, (C) Frontal modality with complementary restricted modality (two notches), (D) Inverse-retouching recycling modality (facial core), (E) Intentional fracture recycling modality (notch and burin), (F) Plane flakes with ultramarginal and unmodified management.

Table 8
Blank management modalities.

Blank management modality	SPN-1		SPN-6		SI-7		SI-13		SPN-19		SPN-20	
	n	%	n	%	n	%	n	%	n	%	n	%
Lateral	595	51,52%	8	40%	29	45,31%	92	16,85%	65	51,59%	40	29,63%
Frontal	174	15,06%		0%	22	34,38%	35	6,41%	30	23,81%	15	11,11%
Restricted	4	0,35%		0%		0%	6	1,10%		0%	3	2,22%
Ultramarginal	8	0,69%	1	5,00%		0%	85	15,57%		0%	3	2,22%
Burin	11	0,95%		0%		0%	9	1,65%	1	0,79%	8	5,93%
Notch strike	5	0,43%		0%	1	1,56%	25	4,58%	1	0,79%	3	2,22%
Unmodified used flake	114	9,87%	10	50%	9	14,06%	226	41,39%	16	12,70%	57	42,22%
Undetermined flake tool fragment	239	20,69%	1	5,00%	3	4,69%	67	12,27%	7	5,56%	4	2,96%
Other	5	0,43%		0%		0%	1	0,18%	6	4,76%	2	1,48%
Total	**1155**	**100%**	**20**	**100%**	**64**	**100%**	**546**	**100%**	**126**	**100%**	**135**	**100%**

rapid adaptation to technical-functional demands, using two main blank management modalities and other complementary ones. At the same time, the high morpho-dimensional variability of the blanks allows them to be chosen for specific functional criteria from a behavioural point of view. As a result, core reduction and blank production can be independent of the blank management stage.

Furthermore, reconfiguration is not only used to increase the efficiency of raw materials, but also allows the tool's technical-

Table 9
Mean reduction angle according blank management modality.

Blank management modality	Median decrease angle (°)	Standard deviation
Lateral	−21,96	12,20
Frontal	−18,98	10,33
Restricted	−8,15	8,33
Ultramarginal	−7,82	14,25
Burin	−5,31	9,45
Notch strike	−10,42	11,64
Flake tool fragment	−22,45	12,32

functional trajectories to change at the end of the operative chain through adaptation to new technical demands. At least, the fact that the reconfiguration occurs when tools are far from the end of its useful life supports this idea. The same is true of ramification. When flakes or exhausted tools are used as cores, transport is easier and the efficiency from the raw material is increased (Wallace and Shea, 2006). Second order production also occurs, providing blanks with new and specific morphologies (Dawson et al., 2012).

Regarding bifacial technologies, the potential coexistence of several operative chains with different degrees of technical investment is also important. On the one hand, stemmed-barbed points require thinning procedures to obtain thin, symmetrical, biconvex sections. This is made more difficult by the large size of the original designs and the time invested in final shaping. Some authors propose that systems with greater technical investment are to be expected in a context of unpredictability (Bousman, 1993), but stemmed-barbed points show a high degree of risk. The same operations which increase the technical investment make them more prone to fracture during either production or use. The emphasis on resistance raw materials and intense reworking were probably intended to compensate and handle the risk of damage. However, considering their greater mass, thin cross-section and risk of fracture, it may be that they were used on manual throwing weapons. In this case the hunter controls the angle and force of impact, reducing the likelihood of damage (Hughes, 1998).

Triangular, non-stemmed points on the other hand, require a very low technical investment. They are made directly from flakes; no thinning is applied and final shaping is simple. This could also be a suitable technique for recycling broken stemmed-barbed points. As they have no exposed sectors as barbs, stems and notches, they are more resistant to impact (Hughes, 1998). This may explain, for example, the use of more varied raw materials. As with fishtail points, the smaller mass, thicker sections and greater strength suggest they were used in throwing darts propelled with spear-throwers.

The different operative chains are strongly interconnected, forming an integrated but non-centralized network; thus technical investment is distributed evenly over the different stages. This gives the technical system the capacity to respond rapidly to new technical-functional demands or unplanned situations without the need to transport cores. We propose that this structure was very efficient in a context of colonization and high mobility over large geographical scales. Certainly, orientation towards a generalized economy is not apparent in the production of a diverse tool-kit with specific functions. This would have conflicted with the group's mobility. The key lies rather in the capability of transforming components at any stage of the operative chain. This flexibility implied that different solutions might be generated to deal with the same problem, considerably increasing the variety and complexity of the assemblages in each context.

It can be argued that a greater variety of core reduction technologies developed over time. The secant systems (peripheral secant and centripetal bisecant) are dominant in SPN-1 and SPN-6 (12,600 to 10,200 cal BP). Sub-parallel systems such as facial on flake are present but limited mostly to recycling; they are more frequent in SI-7 and SI-13 (11,700 cal BP) in the form of facial on slice cores and later as centripetal mixed cores in SPN-19 and SPN-20 (11,000 cal BP). Unlike the former, subparallel systems of this kind require greater technical investment and provide more predictable blank shapes. Parallel slices production also becomes more frequent in SI Northwest and SPN South sites. In this context, the greater variety of core reduction technologies leads to production of more differentiated blanks. At the same time, recycling is reduced. These trends may be interpreted as the result of greater knowledge of the distribution of lithic resources, and more stable occupation.

5.1. Imilac-Punta Negra and its regional technological relations

Similar trends have been reported from other areas of the Atacama *puna*. For example, Yacobaccio et al. (2005) on the Argentinean slope relate the emphasis on local resources with the high availability of productive spaces, minimizing the transport of raw materials from place to place. Recent technological studies stress the predominance of centripetal, unidirectional platform cores (here called peripheral secant cores) and multidirectional cores (Hoguin, 2013; Hoguin and Oxman, 2015). They also mention that core reduction is independent of blank management phase. A relationship is also proposed between low technical investment, the flexibility of operative chains and high mobility.

Comparable cases exist in much more distant areas. Lourdeau (2012, 2015), based on study of the Itaparica complex in north-western Brazil, describes the use of centripetal and unidirectional cores with low technical investment for producing unifacial tools. He proposes that the flat convex section and the elongated size tolerate a greater intensity of retouching, increasing the useful life without drastically modifying the blank shape. Skarbun (2012),

Table 10
Recycling and blank management modalities.

Blank management modality	Recycling management modality							
	Intentional fracture		Direct retouch		Inverse retouch		Other	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Lateral	69	43,40%	13	33,33%	42	44,79%	6	40%
Frontal	10	6,29%	10	25,64%	30	33,33%	6	46,67%
Ultramarginal	2	1,26%		0%		0%		0%
Burin	2	1,89%		0%		0%		0%
Notch strike	2	1,26%	2	5,13%		0%		0%
Flake tool fragment	73	45,91%	14	35,90%	20	20,83%	2	13,33%
Other		0%		0%	1	1,04%		0%
Total	158	100%	39	100%	93	100%	14	100%

based on a study of early assemblages in Argentinean Patagonia, presents a model of technical organization supported by local procurement, and several interconnected reduction sequences. Also, she notes the production of unstandardized blanks through core reduction systems requiring low technical investment.

For bifacial technologies, Hocsman et al. (2012) consider that triangular, non-stemmed points are subjected to a high-use life through systematic reworking and reconfiguration (also see Herrera et al., 2015). They relate these tendencies directly with site functionality. They also note the use of flakes as blanks, and very varied knapping strategies. In the case of stemmed-barbed points, experimental studies with Paiján projectile points stress a relationship between high technical investment and increased potential for fracture damage (Pelegrin and Chauchat, 1993). These authors consider this relationship to be almost irrational, and a heavy social burden. Paiján projectile points may also suffer intense reduction and drastic techno-functional changes (Maggard, 2015). For example, analysis of the use marks on projectile point from “El Inga” site, show they were also used as cutting tools for processing animal and vegetable resources (Aceituno and Rojas-Mora, 2015). Intensive reduction models (Suárez, 2003; Castiñeira et al., 2012; Flegenheimer and Weitzel, 2017) and the use of flakes as blanks have also been proposed for fishtail points (Nami, 1997, 2001, 2003, 2010; Suárez, 2015; Flegenheimer and Weitzel, 2017).

In the assemblages studied, when the diversity of the operative chains and their relations are considered, certain strategies (generally treated in isolation) can be correlated in a common framework: strategies such as local procurement, relationship between unifacial-bifacial reduction, diversity of bifacial designs, and a generalized techno-economy and how they are related with human mobility. Despite the technological variability during the Pleistocene-Holocene transition in Punta Negra and Imilac basins, some interesting trends can be identified beyond specific lithic typologies. Without discounting local processes, the extra-local links indicated in this work, as in many others, open an interesting discussion on the complexity of technological systems and the social interaction networks of human groups. These need to be examined exhaustively, using comparable methodologies and taphonomic associations.

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