EXPERIMENTAL OBSERVATIONS ON SOME NON-OPTIMAL MATERIALS FROM SOUTHERN SOUTH AMERICA

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Historically, lithic analyses and studies were based on the attributes and characteristics of artifacts derived from flint and/or flint-like materials. However, during the last decades, emphasis has been put on another rocks used for manufacturing stones tools; among others, quartzite, quartz, and other rocks with diverse fractures.

Over the years, a number of experiments using varied flaking techniques and strategies were conducted in the Americas. In this endeavor, diverse non-flint-like materials were used to replicate varied core and bifacial reduction strategies. Among others, crystal quartz as well as varied acid and black volcanic rocks were flaked. The experimental observations allowed observing that several of these raw materials show subtle but different flaking qualities as well formal macroscopic attributes on the resulting products and by-products. Then, this paper presents and discusses some flaking qualities and attributes observed on some non-flint-like materials from South America.

KEYWORDS: *Experimental lithic technology, Raw materials, Flaking quality, South America*

The development and advances of lithic analysis in the southern cone of South America, mainly in Argentina, goes hand in hand with the progress that has occurred in other parts of the world. Historically, many of these studies were based on attributes and characteristics of artifacts made of flint, flint-like materials (F&FLMs, hereafter), or silex that, together with obsidian, and other excellent flakeable rocks, may be considered as "optimal materials" (OM). Traditionally and generally, from the macroscopic point of view, lithic studies use a number of attributes to analyze certain aspects of flaked products and by-products. They are employed with a strong typological bias that, despite theoretical and ideological approaches, mainly supports regional investigations about stone tools. However, over the years, lithic analysts have realized the difficulties of analyzing and understanding other rocks than OM. For that reason, during the last few decades, they have emphasized the study of stones that do not behave like them. These have diverse origins and composition, and for that reason, I will generically refer to them here as "non-flint-like materials" (NFLM) or "non-optimal materials" (NOM). As in the rest of the world, emphasis has been put on other stones used for manufacturing tools; among others, quartzite, quartz, and other rocks with diverse fractures.

Over the years, I have conducted a number of flaking experiments dealing with different technological issues from the Americas. In this endeavor, and in order to replicate varied core and bifacial reduction strategies, I used diverse local and worldwide NFLM. Among others, I flaked rhyolite, dacite, diverse black volcanic rocks (BVR), and quartz. The experimental activity allowed the observation of subtle but different flaking qualities, as well as diverse formal macroscopic attributes on the resulting products and by-products. Recent archaeological and experimental literature suggests that generically differences in raw material do not necessarily "determine" or "constrain" variation in lithic assemblages (e.g. Brantingham 2003; Eren et al. 2011, 2014). However, it is important to deeply know their particular behavior to better describe and understand specific stone tool studies. For that reason, as the "first step" toward more complex analysis later, in order to contribute to the exploration, differences, knowledge, and understanding of some of the above-mentioned rocks, I will discuss here the flaking qualities and attributes observed in a number of NFLM from South America (Figure 1). Hence, this

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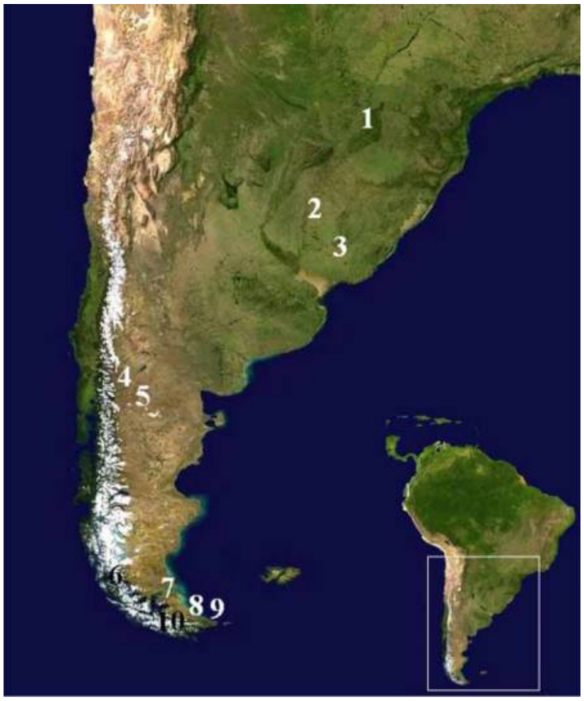

FIGURE 1. Map of the southern cone of South America showing the origin of the rocks discussed in this paper. (1) Puerto Esperanza, (2) Artigas, (3) Middle Negro river and Chamangá, (4) Pilcaniyeu formation, (5) Paso Limay, (6) Ultima Esperanza, (7) Gallegos-Chico river basin, (8) San Pablo bay, (9) Península Mitre, and (10) Península Ushuaia.

paper reports the observations made through many years of actualistic research by working and interacting with other contemporary flint-knappers and carrying out experiments with NOM. By this way, I will examine and discuss the utility of some of their attributes by describing and analyzing them.

EXPERIMENTAL STUDIES

GENERAL REMARKS

Since the end of the 1970s and the beginning of the 1980s, I have been working on flint-knapping from an actualistic perspective. Since then, considerable efforts have been made on a broad range of issues dealing with experimental lithic technology. Among various topics of research, they have addressed the entire lithic reduction process, from raw material procurement and selection to the manufacture and use of bifacial and unifacial stone tools. In this endeavor, and with comparative purposes, I have used diverse raw materials from South America, mainly Argentina, Uruguay, and Chile, as well as rocks from many places around the world.

Generally, in making stone tools, the first concern is choosing a rock with conchoidal fracture, adequate hardness, and quality of texture, which is governed by the fineness or coarseness of its microcrystalline structure. In this regard, the ideal stones for tool manufacture are F&FLM, or just "silex," a word that has the advantage of unifying a single group of isotropic materials (Crabtree 1967:8), other rocks with similar characteristics and, despite its brittleness, also obsidian. When these sorts of rocks are naturally available, they might be considered as OM for knapping. On many occasions, the rocks must be heat-treated to become OM; when this happens these raw materials, generally with glassy and aphanitic textures, acquire a waxy and/or lustrous aspect.

Flint is a sedimentary cryptocrystalline form of the mineral quartz that occurs chiefly as nodules and masses in sedimentary rocks, such as chalks and limestones. Inside the nodule, flint is usually dark gray, black, green, white, or brown in color, and it often has a glassy or waxy appearance. A thin layer on the outside of the nodules is usually different in color, typically white and rough in texture. Similar stones called "chert" show comparable characteristics.

On the other hand, obsidians are volcanic glasses formed during rapid cooling of certain types of lavas, generally with high silica content (>65%). Apart from minor impurities, most obsidians are homogeneous and isotropic in composition; as a natural resource, they were widely used by traditional technologies from the past and modern knappers also count them as one of their favorite rocks. There are many grades and types of obsidian in regard to their qualities, characteristics, or color, and like most raw materials, such variations can occur within the same sources or even nodules. The best ones generally have similar characteristics; however, some have subtle differences, which indicate that some are better than others. For example, the mahogany obsidian from Glass Butte (Oregon, USA) produces, due to its structure produces, directional changes in the transmission of force that causes problems in obtaining fine parallel edge-to-edge pressure (Callahan pers. comm. 2003).

In spite of being a hard rock with a value of 6 on the Mohs scale (Crabtree 1967), due to its brittleness, this natural glass presents less resistance to fracture, accidents being more likely to occur but, at the same time, being optimal for the making of stone tools since, for example, its characteristics facilitate the application of percussion and pressure flaking. The current differences between obsidian and other raw materials are well known, being especially evident for those American knappers who are well accustomed to their use. In this regard, since they require less force during the flake's detachment, other rocks, for example F&FLM, are considered to be "very hard" in comparison with obsidian (pers. obs.). Conversely, those knappers who are accustomed to F&FLM – more resistant and elastic than obsidian – state that the latter is very fragile and, therefore, not the best material for their purposes (Sollberger pers. comm. 1988). Interesting debates have been started on this aspect (i.e. Flenniken 1980). Because of their extreme fragility, it is one of the rocks that have a higher risk of fracture. However, obsidian facilitates the application of percussion and pressure flaking. Interestingly, some European knappers habituated to using silex, showed some difficulties when flaking dolerite from South Africa (de la Peña pers. comm. 2013).

In summary, obsidian is fragile and brittle, while F&FLMs are more resistant to fracture, meaning that they are "harder" than the natural volcanic glass. This difference was observed in practice by many academic, amateur, and commercial knappers. Nevertheless, throughout the history of lithic analysis, just a few authors have paid attention to such differences and their impact on the workability of raw materials. From this perspective, master flintknapper Errett Callahan pointed out the differences among the qualities of rocks. Thus, he constructed a subjective but very useful empirical grade scale ranging from 0.5 to 5.5 according to the degree of workability of lithic raw materials. On this scale, obsidian is placed at the lower level with 1.0 grade, while F&FLM has a rank of 3.5. In the latter case, its flaking quality improves with heat treatment. In this way, many rocks turn into more amenable materials rising of 0.5 and 1.0 grades and, under optimum conditions, even an increase to the 1.5 quality may be possible (Callahan 1979). Furthermore, Luedtke (1994) observed that the differences in lithic grades among cherts have some relation with their lithological structure.

When chipping excellent F&FLM, and other rocks with similar characteristics, obsidian and many heated rocks (i.e. novaculite, F&FLM), a number of attributes are visible both in the products and by-products, mainly in the flakes and flake-scars, as a result of the mechanical forces occurring during their working. As observed in Figure 2, these are: cone of force, bulb of force, eraillure scar, fissures, and compression waves. From a typological viewpoint, such attributes have been used for describing a broad range of stones, not only OM. It is significant to point out that, during the pre-experimental flint-knapping research that flourished in the northern hemisphere during the 1960s and 1970s, such attributes were usually registered without any kind of foundation for their description and analysis; they were just recorded in a descriptive way. This situation certainly happened in Argentina. However, further research showed the utility of some of them in the understanding and discussion of the techniques used for manufacturing stone tools. Nevertheless, many NOMs do not show several of these attributes, and therefore, I feel that it is convenient to discuss their utility when analyzing them. Being say that is important to point out that the following set of observations,

FIGURE 2. Examples of typical attributes observed on experimental pieces made by the author with OM from diverse parts of the world. (a) General view of a biface and close-up of a flake-scar made with Danish flint, (b) ventral and dorsal faces of a flake made with Chuska chert (Colorado, USA), (c) ventral face of chert from Kentucky (USA), (d) core of limestone from El Fresco (La Pampa, Argentina), and (e) ventral and dorsal faces of an obsidian flake from Laguna del Maule (Chile). Except when is clearly expressed, all the photographs and drawings are by the author.

like other experiments in lithic technology, are based on one individual; of course, more quantitative and controlled experimentation is necessary in the future to expand and deepening on the knowledge of raw materials diversity other than F&FLM.

MATERIALS, TECHNIQUES, AND FLAKING IMPLEMENTS

In the southern cone of South America, F&FLMs for manufacturing tools are available both in primary and secondary sources (sensu Luedke 1979). In certain regions, they are relatively easy to obtain, but not everywhere. For example, some of the former are located in the Piedra Parada area and the Deseado river basin, while the latter ones are placed in the northern Patagonian coast's beaches, the Sañicó creek in Neuquén province (western Patagonia) and in the shores of the Uruguay river (NE Argentina). Outcrops of obsidian are also present mostly along the western side of Argentina. On other occasions, as happens in the Buenos Aires province, quarries are highly localized, such as those of chalcedony or very good quality quartzitic rocks.

Of course, OMs were used in a number of regions in the southern cone (Nami 2013). However, despite being present in many areas, they are highly difficult to find; for example, south of the Santa Cruz river in southern Patagonia. Therefore, on many occasions, prehistoric people had to deal with the available regional rocks for tool manufacture, many of which in spite of their usefulness were NOM. The different petrographic characteristics of these rocks affect to their mechanical properties and these, in turn, deeply affect to their workability. Furthermore, such mechanical differences tend to produce specific attributes, which analysis is very useful for understanding lithic assemblages from a scientific perspective.

In order to discuss the formation of some of the aforementioned attributes on NOM, I will depict some of the rocks used in diverse replicative experiments from South America. Adapted to the regional stones, Table 1 briefly describes their general petrographic characteristics in terms of formation, origin, workability, and lithic grade. In this endeavor, I have employed the classification proposed by Crabtree (1967:10) and Callahan (1979), which I have adapted to the regional rocks. In the latter case, I personally discussed this with its author, I also cross-checked it by working the materials used for its construction, and I compared it with other ones from other places around the world. In addition, I used a scale ranging from "bad" to "excellent" according to the degree of workability of the rocks (Nami 1992; Nami et al. 2000) and their potential employment in different flaking strategies and techniques (Tixier et al. 1980).

It is worth mentioning that usually there is no agreement among petrologists and geologists when classifying a rock, a fact that is usually considered to be a normal professional situation. However, in some archaeological groups from the southern cone, differences in classification might be considered as a matter of "life and death" when being subjected to more useless debates (i.e. Charlín and Cardillo 2005; Franco 1998). It is significant to recall that serious and knowledgeable discussions about rocks should be made by scholars with a petrological background. For instance, it is known that rhyolite and dacite belong to the same petrological family, and just a few elements define their differences (Neveldorf et al. 2005; Tarbuck and Lutgens 2002). In this sense, there are outcrops with millions of pebbles with a high degree of petrological diversity in, for example, the Gallegos-Chico river basin (southern Patagonia), many of which have been used as raw material in the last 11 ky.

The determination of such diversity by the naked eye is not reliable in comparison with the results obtained from a few samples subjected to diverse analysis, whether chemical, thin sections, and/or others. In fact, during the last few decades in Argentina, to overcome the weaknesses of their categorizations, archaeologists have begun to consult geologists with different degrees of knowledge about determining rocks. In this endeavor, they sometimes do not agree on their classifications. This fact is compounded because many archaeologists consider these kinds of determinations as sacred, and which quickly becomes the "revealed truth." Hence, results that do not agree are inadequate or have to be dismissed (i.e. Charlín and Cardillo 2005; Franco 1998).

In order to work the listed rocks, I have employed diverse flaking techniques. I will point out here the observations made when using freehand, hand-held, and anvil percussion flaking. They were applied with different kinds of hammerstones, mainly with hard, semi-hard and soft rocks, antler, and wooden billets (Figure 3). I have also employed pressure flaking, mainly for finishing bifacial implements. The observations

TABLE 1. LIST OF NOM REPORTED IN THIS PAPER

Variety of lithic material	Rock	Origin	Lithic grade	Rank	Strategies and techniques	Figure
Crystalline varieties of silica	Crystal quartz	Puerto Esperanza, Misiones, Argentina	1.5	R	BR, PF, PrF	4(a, d–g), 5
	Crystal quartz	Colares, Tacuarembó, Uruguay	1.5	R	BR, PF, PrF	–
	Crystal quartz	La Bomba, Artigas, Uruguay	1.5	R-G	BR, PF, PrF	4(b–c)
Cryptocrystalline varieties of silica (Si 02)	Chalcedony	Middle Negro river, Tacuarembó and Durazno, Uruguay	4.0–4.5	B-R	PF, PrF	6(a–d)
	Chalcedony	Artigas, Uruguay	4.0–4.5	B-R	PF, PrF	6(e–g)
Igneous rocks	AVR*+	Güer Aike, Santa Cruz, Argentina	4.5–5.5	G-VG	BR, Bl, PF, PrF	7, 10(f)
	AVR+	Bahía San Pablo, Tierra del Fuego, Argentina	4.5–5.5	G-VG	BR, Bl, PF, PrF	–
	AVR*+	Península Mitre, Tierra del Fuego, Argentina	4.5–5.5	G-VG	BR, Bl, PF, PrF	8–9
	BVR	Güer Aike, Santa Cruz, Argentina	3.5–4.0	G-VG	BR, Bl, PF, PrF	10(a, i, k)
	Tuff	Ultima Esperanza, Magallanes, Chile	3.5–4.0	G-VG	BR, Bl, PF, PrF	10(j)
	BVR*	Paso Limay, Río Negro, Argentina	2.0–2.5	VG-E	BR, Bl, PF, PrF	10(b–d, h), 11
	Ignimbrite Pilcaniyeu	Pilcaniyeu, Neuquén province, Argentina	3.5–4.0	G-VG	BR, Bl, PF, PrF	12
Silicified sediments	Silcrete*+	Rincón del Bonete 1 and 2, *c.* Queguay creek, Uruguay	3.5–4.0	R-G-VG	BR, Bl, PF, PrF	13(a–e)
	Siliceous limestone*+	Chamangá, Flores department, Uruguay	3.5–4.0	R-G-VG	BR, Bl, PF, PrF	13(f)
Metamorphosed rock	Silicified slate ▲	Península Ushuaia, Tierra del Fuego, Argentina	3.5–4.0	R-G-VG	BR, PF, PrF	14

Abbreviations: B=bad, R=regular, G=good, VG=very good, Bl=blades, BR=bifacial reduction, PF=percussion flaking, PrF=pressure flaking. *There are excellent varieties, +: experiments showed that improves with heat treatment, ▲: it might improve with heat treatment.

only deal with unheated materials. However, many of them greatly improve their workability when heat treatment is applied (Nami et al. 2000).

OBSERVATIONS AND RESULTS

Actualistic experimental research by flaking diverse raw materials of different origins allowed the observation of the fact that most of them do not behave as OM. In the following section, I will describe their more notable characteristics regarding the workability and the aforementioned visual attributes formed in the products and by-products obtained during the knapping of the NOM reported in this paper. They are as follows:

Crystal quartz

It is important to mention here the distinction made by Rodríguez Rellán and Fábregas Valcarce (2015) between the "xenomorphic" and "automorphic" quartzes that respectively refer to the vein and crystal varieties. Unlike the former, the latter one is the purest variety of quartz, which is a euhedral mineral with the shape of a big hexagonal single crystal. Despite the fact that it was not

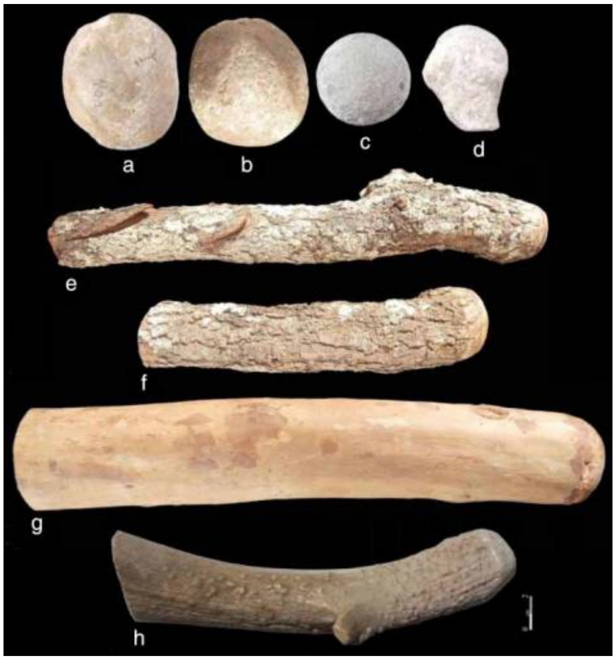

FIGURE 3. Flaking implements mostly used during the experiments. (a–d) Hammer-stones, (e–f) wood percussors, and (g) antler billet.

commonly used across the southern cone of South America, in general, xenomorphic quartz was utilized in a number of locales and periods. Their main use occurred in central Argentina, mainly in Córdoba and San Luis provinces. However, crystal quartz was employed to a lesser extent (González 1960:Lam. XXII: 3). In particular, it was widely used by hunter-gatherers during the Late Pleistocene in several parts of South America (Nami 2009).

The crystals experimentally used varied in purity, with differences in translucency, color, and texture such as the piece depicted in Figure 4 (a), showing different degrees of translucency and varying from violet to white tones. In general, in order to obtain flakes and the first steps of biface reduction, the most adequate flaking implement for percussion was the soft hammer-stone (Figures 3(d) and 5(b)), which was also useful for obtaining some uniform and regular quality flake-blanks for stone tools (Figures 4(e) and 5(a)). In the ventral faces, the flakes showed inner natural fissures, which caused the applied forces not to dissipate uniformly, and for that reason, step and hinge fractures were present (Figure 5(b)). In fact, due to its anisotropic nature, there was a remarkable variability of fracture. However, as discussed below, crystal quartz may sometimes behave as an isotropic material (Rodríguez Rellán and Fábregas Valcarce 2015).

In this rock, when force is applied, it does not spread uniformly and the detached flakes showed very irregular surfaces fractures, both in the flakes' ventral faces and in their flake-scars (Figure 4(e–h)). The waves of percussion were not uniform and smoothly continuous such as those observed in OM. The wooden billet depicted in Figure 3(e) was very effective in performing bifacial reduction. In this way, very thin reduction flakes were obtained, although they mostly broke into several pieces (Figure 4(g)). In some cases, flakes and their scars exhibit a saccharoidal texture or grainy surface (Figure 4(h)). In my opinion, wooden billets are highly useful for flaking crystal quartz when soft percussion is needed (Figure 4(c)). Also, antler billets were very useful, mainly for obtaining fairly uniform flakes that might be used as blanks for manufacturing small bifacial products by using percussion (Figure 4(i)) and pressure flaking. Usually, flakes show shattered platforms. When obtaining a flake, many small shattered pieces are produced as well. An example of a manufacturing sequence of a Paleoindian fishtail point made of crystal quartz is illustrated in Figure 5. Despite being an adequate size for making a small piece, the flake-blank shows many irregularities in the ventral face. However, it was possible to perform the initial edging and some bifacial reduction by percussion flaking using the soft stone hammer-stone. After that, it was finished by pressure flaking with an antler flaker.

Some crystal quartz has insufferable fissures that made their flaking almost impossible. This was the case in the samples from Arkansas (USA) that were flaked by D. Stanford, M. Frank and the author in 2006. In spite of raw material difficulties, Frank was able to make a well-finished Clovis point with that rock. Worth mentioning is the fact that there is some very good quality crystal quartz, which is homogeneous, non-resistant and, by its brittleness, might be comparable with natural and artificial glass. For that reason, this kind of variety might be considered as an OM. This may be particularly true with those homogenous variations, such as the Paleolithic piece exhibited by de Givenchy (1923:Planche II, lower line, right) and the samples from Cabana de Bergantiños (La Coruña), Sistema Central, north of Madrid, Spain, and Minas Gerais, Brazil, experimentally used by Rodríguez Rellán and Fábregas Valcarce (2015). Also, there is the excellent quality crystal

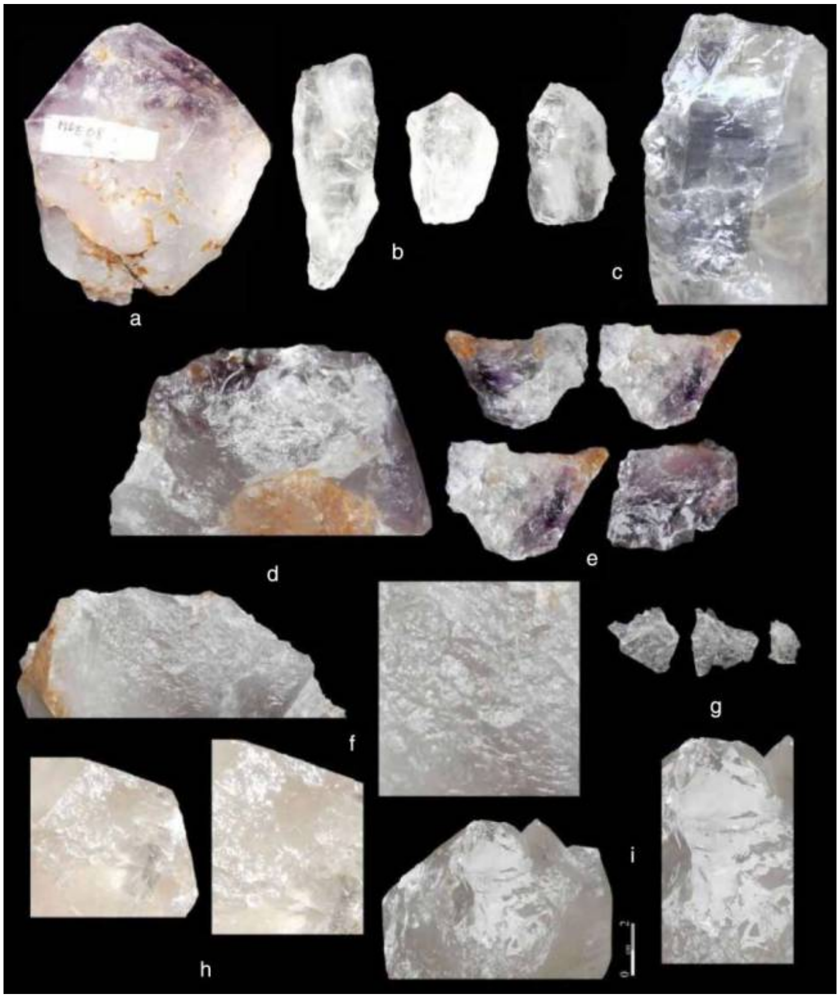

Figure 4. Examples of some crystal quartz nodules experimentally used and attributes observed on the flakes and their scars employing different flaking implements. (a–b) Crystal nodules from Puerto Experanza (a) and La Bomba (b), (c) flake-scar obtained with wood billet and its respective close-up, (d–e) hard hammer-stone flaking: (d) flake-scar (e) dorsal and ventral faces of two detached flakes, (f) flake-scar and close-up showing the saccharoidal texture obtained with a wood billet, (g) shattered bifacial reduction flakes chipped with a wooden billet, (h–i) scars and close-ups of flakes obtained by percussion using a soft hammer-stone (h) and an antler billet (i).

quartz from Brazil that was used by Woody Blackwell in his Clovis reproductions (Fogelman 1999; Jones 2012).

Chalcedony from central Uruguay

It is known that chalcedony may become a very good raw material for manufacturing tools. However, some varieties do not behave as OM. In fact, in the central Negro river basin in central Uruguay, in the basalts from the Arapey formation, there exist clear chalcedony nodules of about 3–10 cm (Figure 6(a)) that were used for making unifacial tools during the Middle and Late Holocene (Nami 2013). Usually, they exhibit white, gray, pale brown, and yellowish tonalities, showing natural layers composed of very fine intergrowths of the silica minerals that make up the chalcedony. In spite of its fineness, it is not homogenous, and the experiments showed that it is NOM. Its structure with the above-mentioned layers of silica forms cleavage planes that impede the normal propagation of forces, and it certainly has an influence on the flaking quality. It also does not allow obtaining deep flake-scars, and therefore to perform bifacial reduction. Probably, due to this reason, this raw material was mostly used for manufacturing unifacial tools, usually employing the natural plane surfaces of the tabular nodules as flaking platforms. As depicted in Figure 6(b–d), the flakes and their scars resulting from the experimental activities respectively show ventral faces with bad development in the ripples and ubiquitous diminutive chips. The aforementioned characteristics also

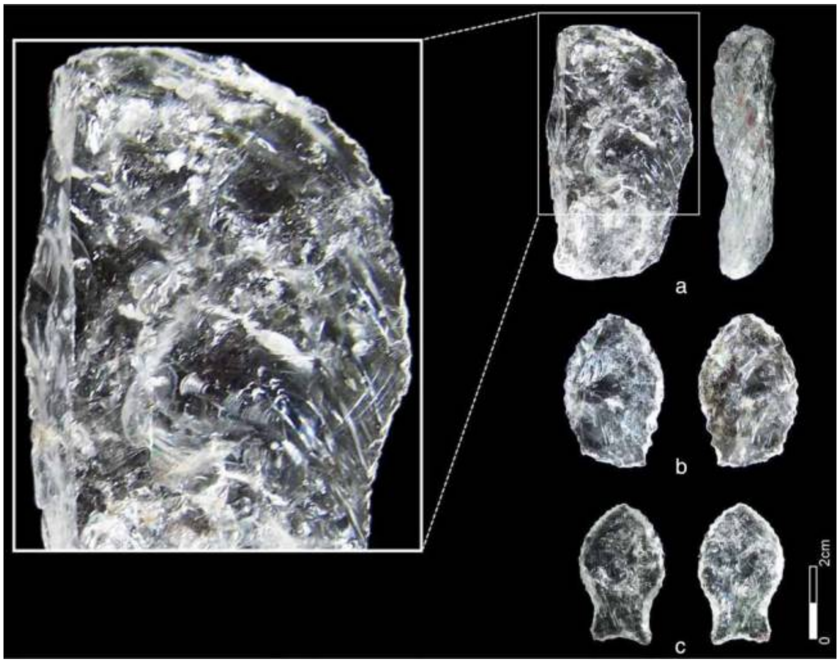

FIGURE 5. Different stages of manufacture without bifacial thinning of a fishtail projectile point made on a crystal quartz flake from Puerto Esperanza. The close-up exhibits the ventral face of the flake with multiple waves of percussion and striae.

occurred with chalcedony from Artigas, northwestern Uruguay. Despite the fact that it has a good conchoidal fracture (Figure 6(e)), it is not an OM for manufacturing tools. Figure 6(f–g) depicts a few flakes obtained by percussion flaking that show similar characteristics to the ones from the central Negro river (Figure 6a–d).

ACID VOLCANIC ROCKS FROM SOUTHERN PATAGONIA

In particular, I will report here the observations made on the rocks from the southern tip of continental Patagonia (Güer Aike department, Santa Cruz province) and the southeast of the Tierra del Fuego archipelago, the southern-most province of Argentina. In this country, south of the Colorado River, in the Patagonian region, there are ubiquitous outcrops of pebbles of varied lithology called "Rodados Tehuelches" o "Patagónicos" and "Gravas Tehuelches" (i.e. Auer 1956; Fidalgo and Riggi 1965). Also, millions of boulders and pebbles with a diversity of rocks are available depending on the area. I will first describe raw materials from southern continental Patagonia, where I have been working for about 25 years, searching for the stones' sources, mainly in the volcanic Pali Aike field in the Gallegos-Chico river basins, where a number of published and unpublished sources and rocks were discovered, registered, and employed in several experiments (i.e. Nami 1986a, 1997, 2003, 2010b, among others). It is worth mentioning that in this region, there is a remarkable local diversity of OM (F&FLM, BVR, and fine grain acid volcanic rocks (AVR)) and NOM. The former, in comparison with the latter ones, is scarce. In fact, in the gravel of the Chico River, after long stays and surveys, I recovered isolated small nodules of petrified wood, excellent quality translucent amber, and white chalcedony. I also found isolated pieces of tabular nodules of chalcedony in deflated sediments in the locality.

The whole range of volcanic rocks is regionally present. At this point, it is important to recall that the content of almost all igneous rocks composed of silicate and silica were traditionally classified as basic and acid in relation to the amount of silica present. In this way, they are acid (>66%), intermediate (55–66%,), basic (45–52%), and ultra-basic (<45%). At one end of the acid rocks are granite and rhyolite, while among the basic ones are the gabbro and basalt. The diorites and andesites are intermediate type. This classification deserves attention because in the Gallegos-Chico river basin there occur extensive secondary deposits of pebbles of varied lithology with abundant green, gray, and other tones of volcanic stones, which were formerly classified as "quartzite" by several scholars (i.e. Bird 1969; Emperaire et al. 1963; Nami 1984). However, for the purpose of making more precise

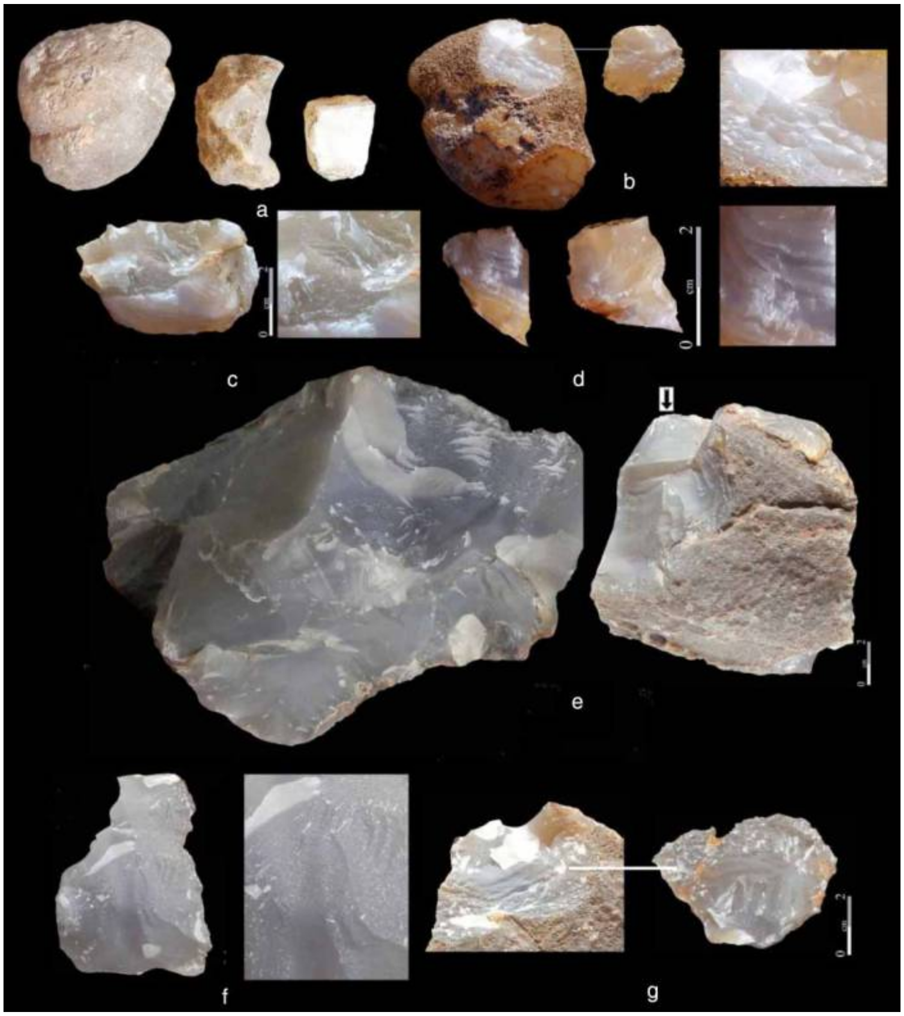

FIGURE 6. Chalcedony nodules from middle Negro river (a) and Artigas with and arrow pointing the cone of a naturally applied force (e), (b–d, f–g) different views and close-ups of the flake-scars and flake's ventral faces showing their characteristics after percussion flaking. (a–b, d–f) Same scale.

determinations, through the years I have sent numerous samples to several national and international specialists (i.e. A. Casé, B. Luedtke, among others). They determined that such rocks are rhyolite, dacite, and porphyritic rhyolite and other varieties of AVR (Nami 1986a), which were narrowed down to dacite by some authors (i.e. Charlín and Cardillo 2005; Franco 1998; Franco and Carballo Marina 1993). Because of this variability and the difficulties of performing a reliable classification by the naked eye of the enormous quantity of natural nodules and archaeological lithic remains made with them, in this paper, I use the generic name of AVR for those raw materials that encompass the variety of acid and leucocratic rocks mostly of gray and green tonalities. Different from F&FLM and BVR, they were mostly used for manufacturing large unifacial tools, such as knives and side-scrapers.

It is important to mention that there are a great deal of lithological variations with gradations from very fine to coarse grain among AVRs from the Gallegos-Chico river basin and southeast Tierra del Fuego. The observations reported here involve medium to coarse grain materials, a topic that also concerns other stones discussed. Actually, there are some AVRs with texture and flaking behavior similar to silex, which show many OM attributes when chipped in natural form (Nami et al. 2000:Figure 4(a)). In most primary and secondary sources that I have studied, this sort of stone is very scarce. However, many of the above-mentioned AVRs need to be heat-treated in order to develop the well-marked force application waves and luster observed in heated materials (Nami 2010a; Nami et al. 2000).

I employed these AVRs in knapping experiments related to diverse bifacial reductions and prepared

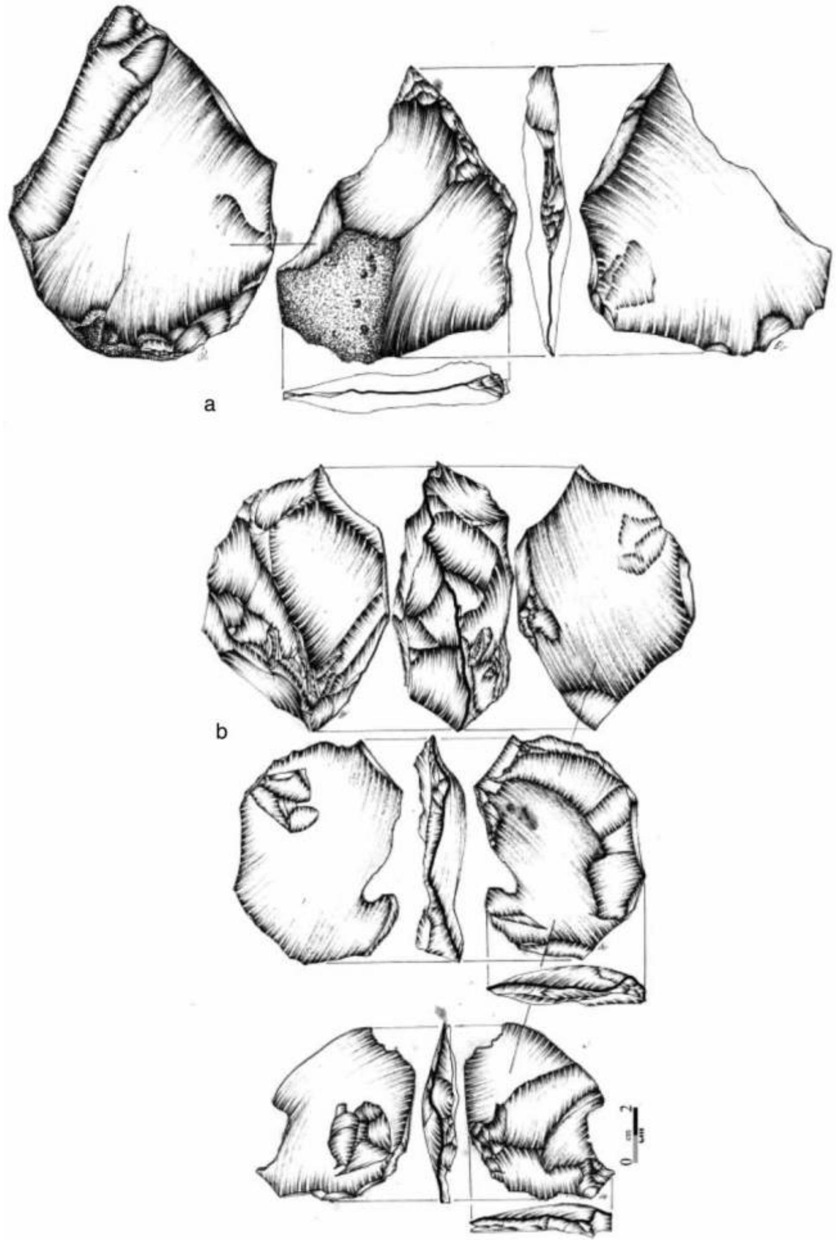

FIGURE 7. (a–b) Experimental prepared cores and flakes detached on AVR from the Gallegos-Chico river. Both cores were totally prepared by hard hammer-stone percussion flaking and the flakes were obtained with a 400 g hammer-stone with previous isolated striking platforms. Drawing by C. López.

core strategies. When detaching flakes from non-prepared and prepared cores with hard hammer-stone percussion, they sometimes did not form striae and percussion waves (Figure 8). At this point, it is significant to point out that, during my experiments, I used antler billets for bifacial reduction, which proved to be very useful. However, for flaking rhyolites from the eastern USA, the accomplished knapper Jack Cresson uses a wide collection of wooden hammers, which are highly adequate for flaking AVR, especially for large biface manufacture (pers. obs. 2006).

Concerning the south of the biggest island of Tierra del Fuego, I have performed diverse activities, mostly related to the search for sources of raw materials. For that reason, I spent a considerable time working in San Pablo bay, the northern Mitre Peninsula and the Beagle channel, where I found and recorded several quarries (Nami 1986b, 1987). Interestingly, for the purpose of this chapter, there are some rocks that deserve

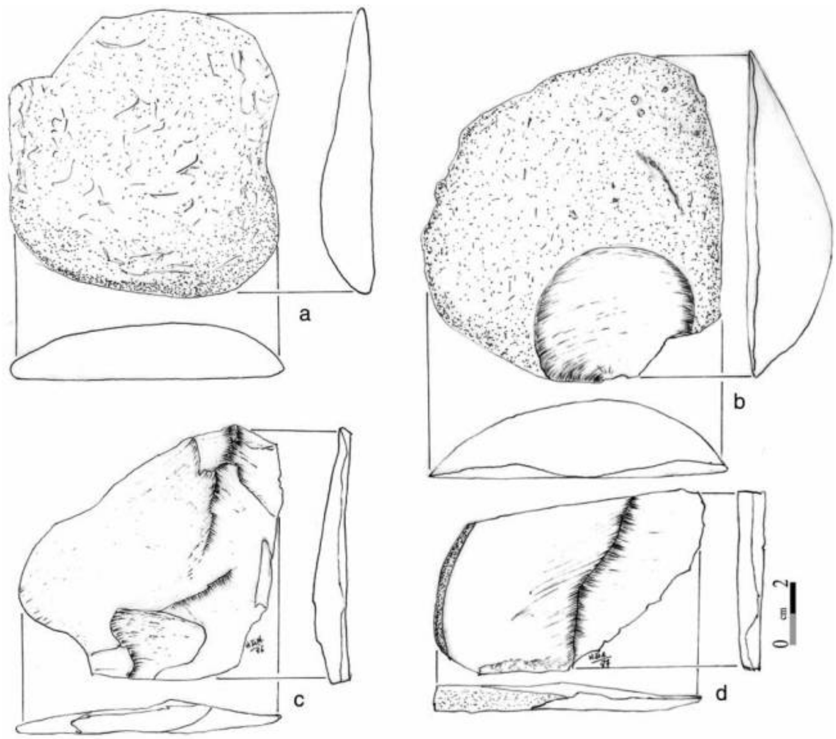

FIGURE 8. Flakes obtained with hammer-stone direct percussion flaking using AVR from Península Mitre. Note the flatness of the bulbs of percussion and the lack of curvature.

attention both in the Mitre Penninsula and in San Pablo bay. In fact, secondary sources with pebbles and boulders of diverse lithology are exposed in specific places along the beaches (Nami 1987: Photo 1–2). A number of volcanic rocks were identified, among them, dacite, rhyolite, porphyritic rhyolite, and basalt (Casé 1987). One of the more significant sources that I have found was located north of Duquesa beach, conformed by rhyolites and porphyritic rhyolite of diverse quality (Figure 9). Different from the AVRs from the Gallegos-Chico River, they were employed to produce a broad range of bifacial and unifacial tools by using diverse flaking strategies. Remarkably, they were centered in the manufacture of very thin pieces, some of which might be considered "ultrathin" bifaces and also Levallois-like prepare core strategies.

I have used this stone to carry out a number of flaking experiments related to bifacial reduction and core strategies for which I mostly utilized hard hammer-stones for direct percussion in the initial stages; and also antler billets in the advanced stages of bifacial thinning. Without exception, they were very resistant to fracture and, hence, difficult to flake. Interestingly, as depicted in Figure 9, when flakes were obtained by direct hammer-stone percussion, this rock formed diffused very flat bulbs, different to those resulting from OM. Also, very flat flakes can be detached with little or no curvature (Figure 8). In my opinion, despite their toughness, these qualities help to perform nice bifacial reduction for manufacturing diverse lithic heads (Figure 10(e, g)). The formation of diffuse bulbs of percussion with both hard and soft percussion is surprising. Even lips are formed in some flakes obtained with hard hammer-stones (Figure 9(f)). In addition, flakes made up of this sort of rock usually show neither force application waves and/or striate (Figure 9). Some of the observations described above might be applicable to similar materials that I have observed at Cerro Benitez (Ultima Esperanza, Chile), the Beagle Channel in southern-most Tierra del Fuego, and some rocks from Mendoza province, in western Argentina (Pérez Winter 2008, several pers. obs.).

As a final comment, it can be said that controlled heat treatment experiments indicated that AVR samples subjected to temperatures from 350 to 450°C, improve their flaking qualities to very good and excellent (Nami et al. 2000). It is likely that this pyrotechnological method was used in the past, mainly for bifacial reduction.

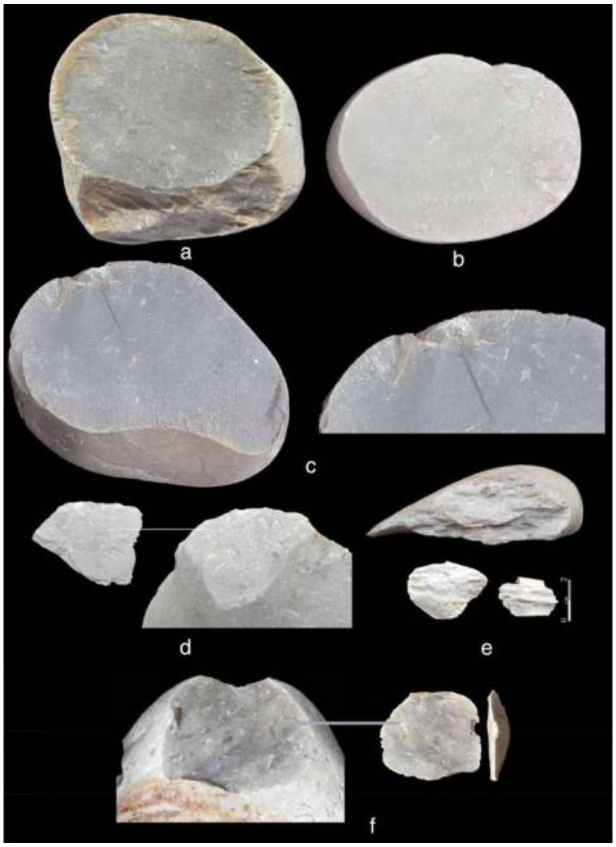

FIGURE 9. (a–d) Flake-scars of direct hammer-stone percussion and flakes detached from AVR from Península Mitre. They are very flat and also show flat bulbs of percussion exhibited with a close-up in (c), (e) Laminar cleavage planes observed in some AVR nodules and ventral faces of the flakes obtained, (f) flake-scar and flake obtained with a 400 g hammer-stone showing flat bulb of percussion and lip.

Black volcanic rocks from Patagonia

The Gallegos-Chico river basin is situated on a large volcanic region called the Pali Aike volcanic field (Corbella 2002). There, large extensions of diverse basalts dominate the landscape. Among them, there are very good examples, useful for manufacturing tools; therefore, they were used from the Late Pleistocene by employing bifacial, blade, and flake reduction strategies (Bird 1969; Emperaire et al. 1963; Nami 1984). Generally, their tones are black or very dark gray, and they were originally classified as "basalts" (i.e. Bird 1969; Emperaire et al. 1963; Nami 1984; Sanguinetti de Bórmida and Borrero 1977). However, diverse petrological studies using different methods classified them as andesites and basalts and, for that reason, when identifying archaeological samples with the naked eye, I have proposed to use BVR as a general descriptive term for describing the variability existing in this sort of melanocratic rock (Nami 2000). On the Pali Aike volcanic field, they appear in small pyroclastic nodules of diverse size (~4–10 cm), which are found in localized and non-localized sources (Nami 1994, 2000). For instance, the former are located in the Monte Carlo and Pali Aike lagoons and, among the latter ones, it is possible to find isolated pyroclastic nodules in the hills formed by old volcanoes, such as those located in El Volcán 1 cave and Estancia Markatch Aike. Also, despite being extremely scarce, I found a few nodules of this rock among the pebbles transported by the Chico River showing the characteristic fluvial action cortex. As for the usual direct percussion and pressure techniques, bipolar flaking was utilized at least during the last ~3.5 kya (Nami 2000). Extensive experiments show that, among these BVRs, there are variations in quality that enclose OM and NOM and, many of them showed very good flaking qualities (Nami 1986a, 1997, among others). When behaving like OM, they form similar attributes, mainly strong concentric waves, when bipolar flaking is used (Nami 2000). However, similar AVR sometimes does not form the described features, mainly in the force application waves formation (Figure 10(a, i, k)).

Another BVR that I flaked from southwestern Patagonia is a tuff from Ultima Esperanza (Magallanes province, Chile). There, in the Cerro Benitez area, there are a number of cave sites that show an unusually rich paleontological and archaeological record. Surrounding the Benitez hill, there are extensive glacial deposits that contain pebbles and boulders with varied lithology. Some of them were employed for manufacturing diverse bifacial and unifacial tools from the Paleoindian (Nami and Casé 1988). I have employed this rock to reproduce a number of mainly fishtail points (Figure 10(j)). Like other BVR, this tuff generally shows no waves of the applied forces, whether percussion or pressure.

Finally, in northwestern Patagonia, in the Río Negro province, there is a large workshop-quarry site in Paso Flores. It is a large site, several kilometers long, with an exposure of large boulders of the so-called Paso Limay "basalt" (Nami and Rapalini 1996) or "dacite" (Sanguinetti de Bórmida 2005). This rock is homogeneous, brittle and, like the "Wagner basalt" (Callahan 1979, pers. obs. 1995), there are variations from lustrous (Figure 10(b)) to dull surfaces: the latter one is majority in the outcrop (Figures 10(c–d, h) and 11). It has very good and excellent flaking

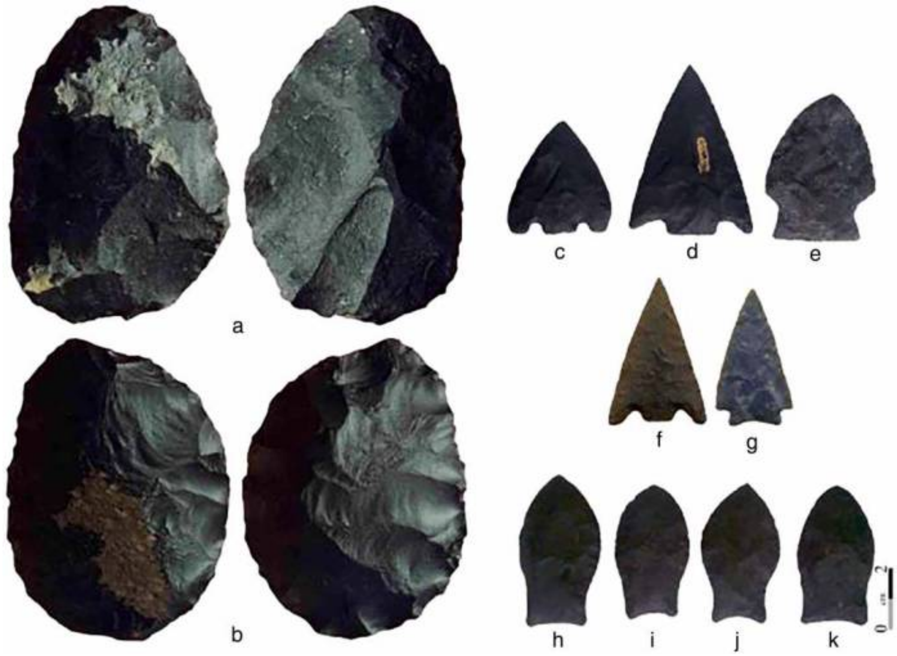

Figure 10. Experimental early biface stages of manufacture of fishtail projectile points from Southern Patagonia made on BVR. (a) Pali Aike, flaked with a hard hammer-stone, (b) Paso Limay, flaked with a 330 g antler billet. This is the finest dacite found in Paso Limay and behaves as OM, (c–g) Lithic heads' reproductions of the Late Holocene occupation from Peninsula Mitre. (c–d) Paso Limay dacite, (e, g) AVR from Península Mitre, (f) AVR from Güer Aike, (h–k) Fishtail projectile point reproductions made with BVR: (h) Paso Limay, (i and k) Pali Aike volcanic field, and (j) Tuff from Ultima Esperanza.

qualities, and in the former case, one may be considered as OM (Figure 10(b)). An interesting aspect of this rock relies upon the fact that its variety of dull textures sometimes have fractures with not very concave surfaces, producing flakes with little curvature and flat scars, probably because of the laminar cleavage planes that this rock generally has (Figure 11(d)). Additionally, as shown in Figure 10(c–d, h, 1), the lack of waves from the applied force is observable both in percussion and pressure flaking (see also Nami 1997:Figures 21 (a–b, d) and 24(a)).

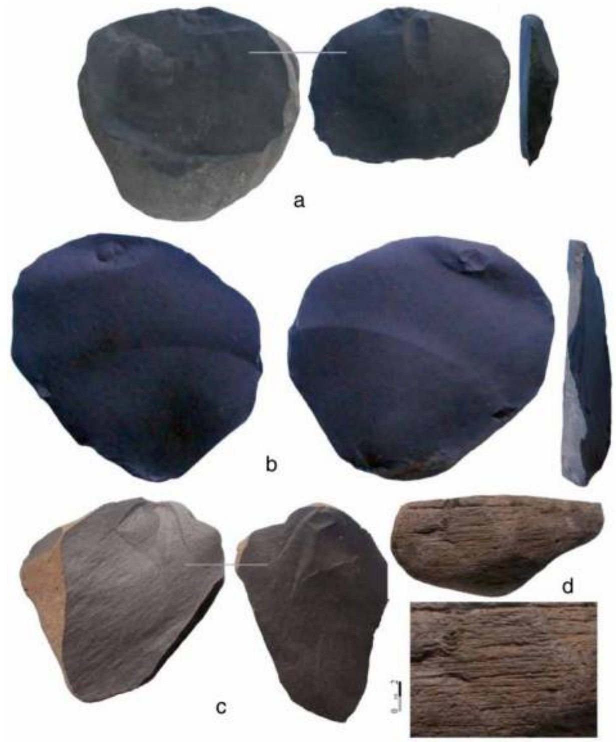

Figure 11. (a–c) Flakes obtained by direct percussion flaking on Paso Limay dacite showing their flatness and lack of curvature, (d) general view and close-up of the laminar cleavage planes clearly observed in the core illustrated in (c).

Pilcaniyeu ignimbrite

In northwestern Argentine Patagonia, in the Neuquén and western Río Negro provinces, there are outcrops of a flakeable stone called "Pilcaniyeu ignimbrite," which constitutes a member of the Middle Miocene "Collón Cura Formation" (Figure 12(a)). "Ignimbrite" or "ash-flow tuff" is used to differentiate this type from the normal tuff, "ash-fall tuff," or the pyroclastic volcanic rocks produced by ash flows. Ignimbrites have a generally acid to intermediate chemical composition, although in certain parts of the world more basic variations are known. The ignimbrite's welded portions are hard rocks with a

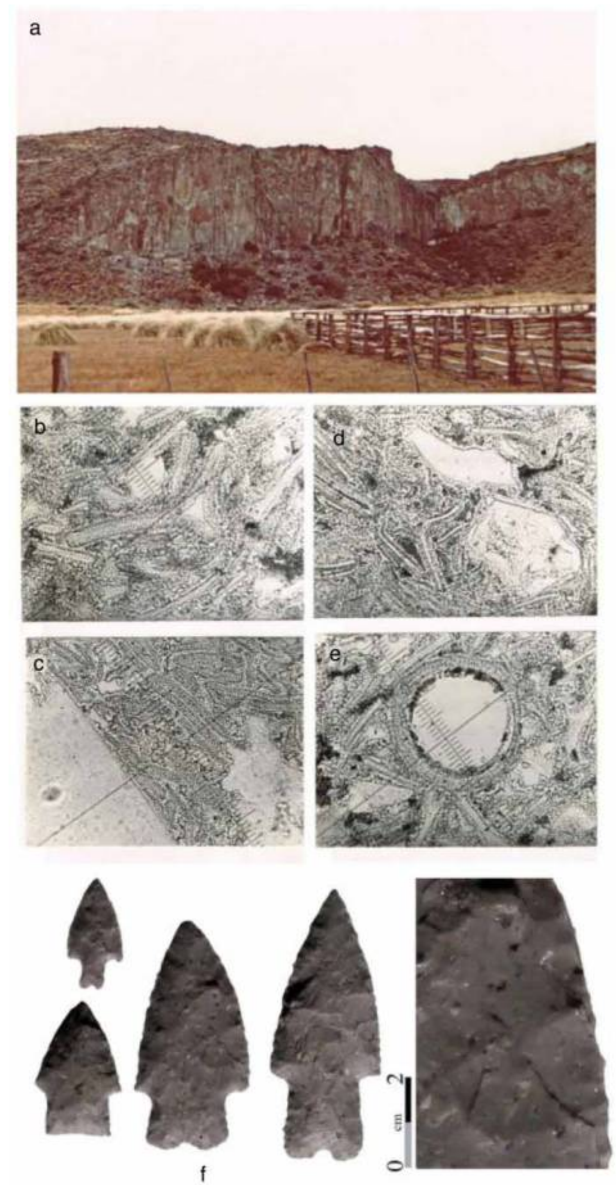

FIGURE 12. (a) Photograph of the Pilcaniyeu ignimbritic member at Paso Coquelén (Río Negro province, Argentina) showing the welded facies with columnar disjunction of rhyodacic ignimbrite, (b–e) photomicrographs of different mineralogical elements included in the vitroclastic matrix of the Pilcaniyeu ignimbrite, (f) different projectile points made by percussion and pressure flaking and close-up of pressure retouch. (a–e) Photographs courtesy J. Rabassa).

consolidated lavic aspect, phenocryst clasts characterized by quartz and/or feldspar, a glassy mass vitroclastic texture with a very thin weld bead between the siliceous shattered glasses (Figure 12(b–e)). Like all the vitreous rocks, they predominantly have a siliceous composition, usually have a glassy luster, a slight turbidity similar to opal, can be translucent but not transparent, and show conchoidal fractures and medium density (Figure 12(f), Nami and Rabassa 1988; Rabassa 1978).

During the flaking experiments, I used several blocks obtained along the Route 40 between La Rinconada and the bridge on the Collón Cura River in the province of Neuquén. They were moderately and very well welded ignimbrite obtained from an outcrop, with the remarkable columnar disjunction that the Pilcaniyeu ignimibrite formation has in its most intensely welded faces. The flaking experiments showed that it is useful for manufacturing both unifacial and bifacial tools. In the latter case, after flake-blank detachment using direct percussion flaking with a hammer-stone, I performed bifacial reduction using antler billets to perform the early and advance stages of manufacture (Nami and Rabassa 1988:Figure 1). Afterwards, during the final shaping, I employed pressure flaking (Figure 12(f)). Despite not being very homogeneous, this stone shows that it is flakeable, and has adequate flaking qualities. In general, the flakes and their scars do not show application force waves or striate.

It is significant to point out that Pilcaniyeu ignimbrite is different from the ignimbrite from the northwest USA, which may be considered as OM with a 1.0 lithic grade (Callahan 1979:16); a rock that was widely used by some American knappers, among them Crabtree (1967) and Bonnichsen (Callahan 1978:Figures 1(b, d) and 2(k)).

SILCIFIED LIMESTONE AND SILCRETE

In Argentina and Uruguay, there are primary and secondary sources of these rocks situated in different locations. Extensive limestone outcrops are located in the Entre Ríos province, in eastern Argentina, and in Uruguay. They have diverse origins, petrography, and colors (Flegenheimer et al. 2003; Loponte et al. 2010; Martinez et al. 1997) and show regular to excellent quality. Some of them behave like excellent silex and are comparable to the best F&FLM in the world, such as some limestone obtained from the Chamangá primary sources (Nami 2011).

Limestone from Uruguay has a different genesis. The ones with remains of microfossils and generally of a reddish tone were identified as silcrete (Flegenheimer et al. 2003). Experiments using this kind of rocks showed that they have good to excellent flaking qualities that, in some Uruguayan limestone, improve with heat treatment (Nami 2010a). However, many of them show differences from the OM and have also been used in the past (Nami 2013). Actually, by chipping a number of samples, it was observed that many of them, when using hard hammer-stones, do not show application force waves, fissures, or striae. Figure 13(c–f) depicts some examples of the flakes obtained by hard percussion flaking. It can be seen that they do not show pronounced bulbs of percussion, and in some cases, they are extremely flat or almost absent. A good quality example of silcrete, an NOM rock from Uruguay, is depicted in Figure 13(b). It is a flake obtained from a nodular flake (Figure 13(a)) that, due to its form, was used as a "naturally" prepared core. After platform preparation, the flake was detached with a heavy antler billet using direct percussion flaking (Nami 2006:Figure 2). The rock showed a similar fracture to flint, but much of the unheated chert in the ventral face does not show attributes most useful to describe OM. This fact also occurs in many unheated silcretes and limestones from Uruguay (Figure 13). It is significant to point out that, sometimes, the stone described in this section presents raw material flows, for instance, alveolus and changes of texture with influences on its workability and knapping behavior.

As a final comment, limestone and silcrete were not commonly used worldwide. However, there are some localities where they have been employed for stone tool manufacture, such Australia and South Africa, places where nicely flaked unifacial and bifacial tools were made (i.e. Mourre et al. 2010; Webb and Domanski 2008).

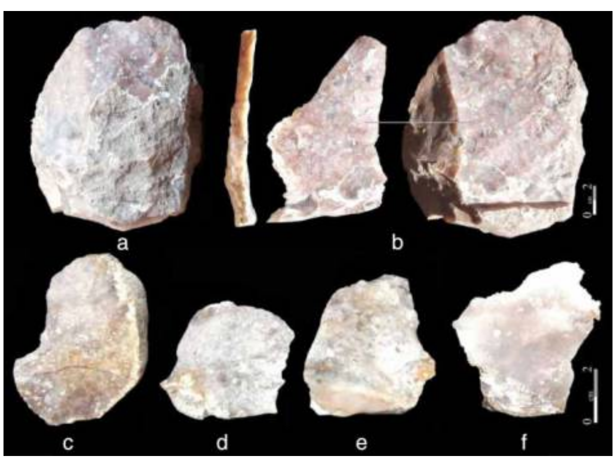

FIGURE 13. (a–b) Nodular flake of silcrete and a flake detached with an antler billet, (c–e) ventral faces of flakes made up with silcrete from Rincón del Bonete 2 source (b–d) and limestone from Chamangá (e).

SLATE

This rock is not commonly used for making tools in the southern cone. However, I was able to record its use in the ethno-historic patrimony curated at the *Museo Nacional de Historia Natural* – currently in the *Museo Nacional de Antropología* – in Montevideo, Uruguay. There, there are a number of harpoons heads made by the Yamana groups from Tierra del Fuego. Interestingly, they were made of wood with lithic points of ground slate (Nami 1989–90). Related to this material, in the southern part of this island, I found a primary source of a flakeable stone with conchoidal fracture. It showed abundant layers of diverse black and gray tones with white patches that have different degrees of silicification. Geologist R. Caminos identified this rock as slate limolite (Nami 1986b). In the outcrops, I have been able to acquire several blocks that, due to the conspicuous fissures and existing flaws, were not used for performing extensive flaking (Figure 14(a)). Nevertheless, in order to observe its workability, I carried out some direct percussion chipping with hard hammer-stones. The used block showed layers of silicified slate that, despite conchoidal fractures, were resistant to fracture. However, the same block had layers of highly siliceous and fine grain stone with very good fractures similar to chert (Figure 14(b)).

DISCUSSION AND CONCLUSION

As previously observed, many NOMs do not show percussion waves or striate when using hard and soft direct percussion flaking. This fact also occurs with most AVR from the Gallegos-Chico river basin and southeast Tierra del Fuego. In the latter case, direct hard hammer-stone percussion sometimes does not form cones of forces and bulbs, meaning that this sort of rock generates flat or absent bulbs from the applied force. On the other hand, by using hard hammer-stones for obtaining big-sized flakes, it does not leave any cones, or they just are very diffuse. In other words, bulbs in some AVR of medium grain are absent or are extremely diffuse, a fact that contradicts usual classifications based on OM. Also eraillure scars, fissures, and compression waves are generally non-existent. Flake-scars, in some cases being plane probably due to their natural cleavage, also produce flat flakes. Different from that of southeast Tierra del Fuego, AVR from Gallegos-Chico River shows well-formed bulbs of percussion, but usually not waves. Limestone,

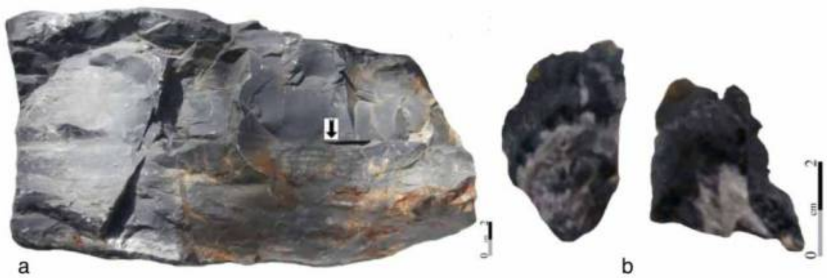

FIGURE 14. (a) Block of slate limolite from Península Ushuaia showing fissures and changes of texture. The lower part, pointed with an arrow, shows its more siliceous portion. (b) Flakes of very flakeable material detached from the more siliceous portion of the block exhibited in (a).

silcrete, tuff, and some BVR do not form force application waves on many occasions, phenomena formerly observed in some flints (Mewhinney 1957). When crystal quartz is used in the manufacture of flaked tools, it must be treated differently from other rocks. It shows dissimilar behavior according to the variety, but many of them share common natural fissures that produce numerous fractures during flaking. One important characteristic is the formation of crushed platforms and sometimes multiple waves of percussion obtained by soft percussion; they also produced shattered by-products during chipping.

Of course, there exist subtle variations among stones, and together with the raw materials described here, there are natural OMs. Actually, as reported above, it is possible to found nodules comparable with F&FLM among the AVR and BVR from the Gallegos-Chico river basin, F&FLM, which sometimes are exceptional cases (Nami et al. 2000:Figure 4(a)). A similar fact occurs in the Uruguayan limestone, which – in certain places – shows optimal qualities without heat treatment. Also, despite the fact that some crystal quartz shows regular to bad qualities for stone tool manufacturing, there may be found excellent varieties that produce the traits described in Figure 2. However, a number of them do not show similarities with the attributes used in the analysis of artifacts made up with OM.

The aforementioned observations on NOM showed that the features experimentally observed are not exceptional, but rather common, and should not be taken as an anomalous situation, but as more normal than previously thought, and – therefore – should be treated with the attention they deserve. Also, because they are not generally formed, it is not pertinent to try to record attributes derived from OM when analyzing NOM. Because they are not useful for describing this sort of rock, classificatory schemas based on generalizations about lithic artifacts are sometimes useless. In other words, lithic analysis related to NOM by using traditional typological schema is a nonsensical goal and a waste of time.

In spite of classifications being needed in lithic studies, the dominance of typology as a general archaeological approach has been used since several decades ago in North and South America. However, a strong emphasis among some lithic analysts is still in vogue and was recently reborn. Actually, in Argentina, there is a certain influence from a small group forcing the use of some typological confusing jargon and, sometimes fallacious, schemas and classifications, which this group reveals as being uniquely true. However, concepts and attributes are non-critically employed and are not directed to answer specific questions, but just descriptively recorded. It is also known that the epistemological background underlying typological thinking relies upon an idealistic philosophical perspective. For that reason, in this sort of approach underlies the use of the "ideal type," which is a group of objects of the same class as an idealized model of things or processes. They are made by using attributes to consider them as typical or remarkable and by rejecting other ones that are considered irrelevant, despite the fact that on closer inspection they may be significant.

However, in the real world, things are varied, diverse, and subjected to the influence of many processes and complexities. For that reason, classifications might take into account the variability occurring in the processes and the evolution affecting such phenomenon. Needless to say, not all the attributes proposed as an "ideal type" are present in the real facts, such as has been shown above. It is significant to bear in mind that, on occasions, lithic analysis should be performed from a polythetic viewpoint and using OM attributes when necessary. In the case treated in this paper, the "ideal" stones are OM; hence, because NOM does not behave like them they were usually considered as "bad" rocks influencing the poor quality of the flaked products. Nevertheless, despite the fact that they do not behave like OM, a closer examination shows that they are very good for chipping and adequate for tool manufacture.

In the particular case discussed here, the lack of waves in some rocks might be an obvious fact. However, many archaeologists tending toward lithic analysis using a normative typological background are continuously looking for attributes derived from OM. They assume that they should be present in all kind of suitable rocks for manufacturing tools. Therefore, it is my opinion that because they are barely formed, the search for such attributes in raw materials other than OM must go into decline. The practice of this assertion would imply the awareness that they might not exist and besides, save time and energy invested in their finding and recording.

In summary, the experimental studies, using diverse NOMs from South America, allow me to conclude that there are a lot of obvious differences among useful rocks for manufacturing stone tools. Most NOMs do not show similarities with the attributes used in the analysis of artifacts made with OMs. Thanks to the experimental observations, they are both susceptible of being observed in workability and in their visible attributes and can, therefore, be analyzed and described. Also, the symposium organized by Rodríguez Rellán was a significant event in exploring the differences from an analytical point of view, mainly for describing and analyzing their archaeological analogs. In this regard, and due to the variability existing among raw materials and the difficulties of forming generalizations, this paper is an attempt to start the exploration of NOM behavior and their understanding in stone tool analysis in South America.

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