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Explaining the origin of fluting in North American Pleistocene weaponry

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A B S T R A C T

Clovis groups, the first widely successful colonizers of North America, had a distinctive technology, whereby manufacturers removed flakes to thin the bases of their stone projectile points, creating “flutes.” That process is challenging to learn and costly to implement, yet was used continent-wide. It has long been debated whether fluting conferred any adaptive benefit. We compared standardized models of fluted and unfluted points: analytically, by way of static, linear finite element modeling and discrete, deteriorating spring modeling; and experimentally, by way of displacement-controlled axial-compression tests. We found evidence that the fluted-point base acts as a “shock absorber,” increasing point robustness and ability to withstand physical stress via stress redistribution and damage relocation. This structural gain in point resilience would have provided a selective advantage to foragers on a largely unfamiliar landscape, who were ranging far from known stone sources and in need of longer-lasting, reliable, and maintainable weaponry.

1. Introduction

Although the timing varied, modern humans had dispersed around the globe (reaching all continents except Antarctica) well before historic times. As a result, the processes by which humans — hunter–gatherers for the most part — adapted to new landscapes, usually ones with diverse and unfamiliar resources and environments, and possibly undergoing geologically rapid climate changes, have never been recorded (Kelly and Todd, 1988; Meltzer, 2009). There are, of course, archaeological traces of the process, and these have shed important light on aspects of prehistoric colonization, particularly the speed and scale of movement across unknown lands, the newly arrived peoples' use of and impact on the native fauna, and the means by which colonizers learned their landscapes (Kelly and Todd, 1988; Meltzer, 2004a, 2009; O'Connell and Allen, 2012; Waters and Stafford, 2007).

Yet, less consideration has been given to the technology underpinning those processes. People new to a continent would have brought with them tools developed elsewhere that could have been used or modified, or they may have developed new tools to meet the challenges of the new landscape. Were the latter the case, it could potentially reveal elements of the technological strategies by which colonizers responded to novel challenges.

One example of a newly invented technology is the archaeologically sudden appearance of Clovis projectile points in Late Pleistocene North America (Eren and Buchanan, 2016). The oldest of these date to ~13,400 years ago and occur in the southcentral and southwestern portions of North America (Ferring, 2001; Meltzer,

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2009; Sanchez et al., 2014; Waters and Stafford, 2007). These bifacially flaked lanceolate spearpoints were often crafted on highly siliceous cryptocrystalline stone, principally chert, obsidian, or chalcedony and then carried, cached, traded, used, and eventually discarded, sometimes hundreds of kilometers from the stone's original geological source (Boulanger et al., 2015; Ellis, 2011; Eren et al., 2017; Hoard et al., 1992, 1993; Holen, 2010; Kilby, 2008; Meltzer, 2009; Speth et al., 2013). Edges of the proximal (basal) portion of the point, where it was attached (hafted) to a handle or shaft, are usually ground dull, presumably to prevent cutting of the lashings binding the point in place. Point tips often exhibit impact scars; microfracture analysis suggests this resulted from the weapons having been thrust or thrown (Hutching, 2015). Microwear evidence has supported the hypothesis that Clovis points were occasionally multifunctional tools, used as butchery knives in addition to hunting weaponry (Smallwood, 2013; Smallwood and Jennings, 2016).

Although Clovis points vary across space and many centuries, all share a singular technological attribute: a flake removal — the “flute” — that creates a shallow channel extending from the base of the point toward the tip (Fig. 1). Fluting is distinctive, widespread, and associated with the first widely successful colonizers of North America. Given its absence from the stone-tool repertoire of Pleistocene Northeast Asia, fluting appears to have been an American invention, likely the first (Meltzer, 2009; Waters and Stafford, 2007).

The purpose of fluting, however, is enigmatic. Early on it was hypothesized (Cook, 1928) that fluting enhanced bloodletting of a speared animal (akin to a grooved bayonet – at the time, World War 1 was still a recent memory). That hypothesis fails, as the fluting scars would have been largely filled in or covered by the shaft, mastic, and haft wrappings (Rondeau, 2015). Another early idea was that fluting enhanced hafting (Cook, 1928; Roberts, 1935). Yet, unfluted projectile points were mounted on spears for millennia without it, and it seems likely that if fluting did enhance hafting it would have presumably occurred prior to Clovis weaponry. The possibilities that fluting was done for stylistic or artistic purposes, was a form of costly signaling, or served in a pre-hunt ritual (Bradley, 1993; Frison and Bradley, 1999), are not unreasonable, but such notions are difficult to test, nor do they preclude the possibility that fluting also had a utilitarian function.

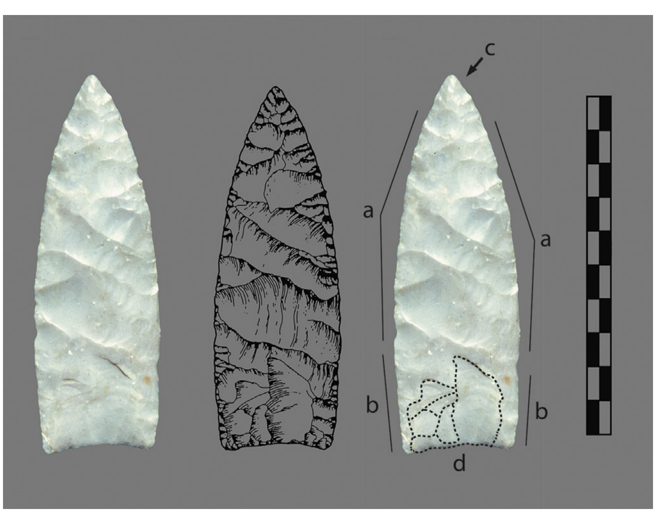

Fig. 1. Photograph (left) and line drawing (middle) of a Clovis fluted projectile point from the Clovis type site, Backwater Draw #1, New Mexico. Prominent features of a Clovis point (right) include the sharp distal lateral blade edges (a); the proximal lateral edges ground dull, presumably for hafting purposes (b); the tip (c); and the flute scars that thinned the base and basal edge of the specimen (d). (Source: modified from Meltzer 2004b, Fig. 3; originally drawn by F. Sellet and assembled by J. Cooper)

It seems reasonable to conclude that if fluting were simply a technological idiosyncrasy, it would not have been so widespread over space and time. Whether it spread by diffusion across an extant population or was carried by dispersing populations, it was associated with what appears in some instances to be the first groups to enter a region. Moreover, fluting was a challenging technology to master, occurring after a point was already thinned to ~7.5 mm. As modern stone-tool replication experiments suggest, further thinning by fluting is challenging, and examples of fluting failures in the Clovis archaeological record are common (Bradley et al., 2010; Morrow, 1995, 2015; Smallwood, 2012; Waters et al., 2011). Quantitative estimates indicate that 10.5–22.2% of points broke during fluting (Ellis and Payne, 1995). Considering that the time required for an expert knapper to produce a single point is at least 30 min, these persistent failures would have been costly to forager time and energy budgets (Schillinger et al., 2014), especially when stone supplies were scarce or sources unknown. There must have been a real or perceived functional advantage to fluting projectile points for Clovis groups to have adopted such a risky and costly technique and then maintained it for multiple generations. As such, understanding the purpose of fluting has the potential to provide insight into the challenge of colonizing a new and unknown landscape.

2. A hypothesis for Clovis fluting

One consequence of Clovis fluting on which researchers agree is that, when successful, fluting thins the proximal end of a point, especially its base (Bradley et al., 2010; Meltzer, 2009). In principle, a thinner stone-tool edge is weaker and more brittle than a relatively thicker one. Yet, given the many centuries fluting was applied to Paleoindian points, it raises the question of whether that weakness could potentially have been an asset.

Here we explore the possibility that fluting served as a “shock absorber,” a feature designed to crumple (rather than fracture) on impact, thereby increasing a point's overall resilience and extending its lifespan. Put in more formal terms, material specimens under load, such as a Clovis point upon impact, experience stress. Once a specimen's stress limit is reached at a given location, that portion of the specimen will break, or experience crunching or crumpling, and the stress will be redistributed. If the redistributed stress is below the overall failure stress level, then the specimen remains intact and may continue to support load; if not, the specimen fails, sometimes catastrophically. However, depending on the geometry of the specimen under stress, damage may relocate from one position on the specimen to another, including from the tip to the base.

Here we test the hypothesis that fluted points will withstand higher energies and last longer than unfluted points because stress will relocate from the tip to the thinner, brittle basal edge that results from fluting. We conducted two sets of analyses, one analytical and the other experimental. First, we examined whether the geometry of Clovis-style fluted points increased point robustness relative to unfluted points via stress redistribution and damage relocation. Two types of analytical modeling were performed: static, linear finite element modeling and discrete, deteriorating spring modeling. Second, we used displacement-controlled axial-compression tests to experimentally assess under controlled conditions the relative mechanical responses of fluted and unfluted specimens. We discuss each analysis in turn.