Transmission of Cultural Variants in the North American Paleolithic

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Abstract

North American fluted stone projectile points occur over a relatively short time span, ca. 13,300–11,900 calBP, referred to as the Early Paleoindian period. One long-standing topic in Paleoindian archaeology is whether variation in the points is the result of drift or adaptation to regional environments. Studies have returned apparently conflicting results, but closer inspection shows that the results are not in conflict. At one scale—the overall pattern of flake removal—there appears to have been an early continent-wide mode of point manufacture, but at another scale—projectile-point shape—there appears to have been regional adaptive differences. In terms of learning models, the Early Paleoindian period appears to have been characterized by a mix of indirect-bias learning at the continent-wide level and guided variation at the regional level, the latter a result of continued experimentation with hafting elements and other point characters to match the changing regional environments. Close examination of character-state changes allows a glimpse into how Paleoindian knappers negotiated the design landscape in terms of character-state optimality of their stone weaponry.

Keywords

Clovis • Cultural transmission • Fluted point • Guided variation • Paleolithic • Social learning

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9.1 Introduction

Cultural-transmission theory has as its purpose the identification, description, and explanation of mechanisms that humans use to acquire, modify, and retransmit cultural information in particular instances, whether it be rules concerning eligible marriage partners or instructions for how to produce fishing nets or any of a countless number of other cultural features (Eerkens et al. 2014). As Mesoudi (2013:131) put it, "this surely places cultural transmission at the heart of pretty much every social science discipline." This certainly is the case in American archaeology and anthropology, where interest in the process and mechanisms of cultural transmission runs deep (e.g., Boas 1904; Kroeber 1923; Mason 1895; Sapir 1916; Tylor 1871). Franz Boas, the oft-identified "father" of American anthropology, for example, pointed out that "the theory of transmission has

A. Mesoudi and K. Aoki (eds.) *Learning Strategies and Cultural Evolution during the Palaeolithic*, Replacement of Neanderthals by Modern Humans Series, DOI 10.1007/978-4-431-55363-2_9,

induced investigators to trace the distribution and history of [cultural traits] with care so as to ascertain empirically whether they are spontaneous creations or whether they are borrowed and adapted" (1904:522). He later noted that "we must investigate the innumerable cases of transmission that happen under our very eyes and try to understand how transmission is brought about and what are the conditions that favor the grouping of certain new elements of an older culture" (Boas 1911:809). The many discussions of cultural transmission that have appeared from the 1980s on rarely mention this earlier work, making it sound as if our forebears ignored the issue, when a more appropriate way of phrasing it would be to say that common sense substituted for rigorous models of transmission (Lyman 2008; Lyman and O'Brien 1997, 2003).

That lack of rigor began to be eclipsed in the 1970s with the mathematical-modeling work of Luca Cavalli-Sforza, a population geneticist, and Marcus Feldman, a theoretical biologist (e.g., Cavalli-Sforza and Feldman 1973, 1981; Feldman and Cavalli-Sforza 1976). The innovative aspect of their approach, which they labeled "gene–culture coevolutionary theory," was that they not only modeled the differential transmission of genes between generations but also incorporated cultural information into the analysis, which allowed the evolution of the two systems to be mutually dependent (Laland and Brown 2011). Cavalli-Sforza and Feldman's work was followed by that of Robert Boyd and Peter Richerson, whose 1985 book, *Culture and the Evolutionary Process*, laid the foundation for what they labeled as "dual-inheritance theory," which for purposes here we view as synonymous with Cavalli-Sforza and Feldman's "gene–culture coevolutionary theory." Boyd and Richerson's (1985) discussion of individual (asocial) versus social learning, especially their attention to transmission biases, would have a significant effect on anthropological and archaeological thought.

There now exist many applications of cultural-transmission theory, both in anthropology and archaeology, that attempt to define these mechanisms mathematically and to model their effects over time (e.g., Aoki 2013; Aoki et al. 2011; Atkisson et al. 2012; Bentley and O'Brien 2011; Bentley and Shennan 2003; Bentley et al. 2004; Bettinger and Eerkens 1997, 1999; Derex et al. 2013; Eerkens and Lipo 2005, 2007; Henrich 2001, 2004, 2006, 2010; Henrich and Boyd 1998; Hoppitt et al. 2010; Kameda and Nakanishi 2002, 2003; Kandler and Shennan 2013; Kandler and Steele 2010; Kempe and Mesoudi 2014; Kempe et al. 2012; Kendal et al. 2009; Kobayashi and Aoki 2012; Kohler et al. 2004; Kuhn 2013; Lipo et al. 1997; McElreath et al. 2005; Mesoudi 2008, 2011a; Mesoudi and Lycett 2009; Mesoudi and O'Brien 2008a, b, c; Nakahashi 2013; Neiman 1995; Powell et al. 2009; Premo 2012, 2014; Premo and Scholnick 2011; Rendell et al. 2011a, b; Rendell et al. 2010; Schillinger et al. 2014; Sharon 2009; Shennan 2000; Steele et al. 2010). Our goal here is not to summarize this extensive body of work (see Laland 2004; Laland and Brown 2011; Mesoudi 2011b; various chapters in this volume) but rather to extract a few points that would appear to be of considerable interest to archaeologists interested in how cultural information is acquired and transmitted. We use as a basis for discussion several studies that have examined variation in North American projectile points that date ca. 13,300–11,900 calendar years before present [calBP], a time span referred to as the Early Paleoindian period. To align our contribution with others in this volume, we can easily refer to that period as the American "Paleolithic."

9.2 Learning Models

Cultural transmission involves learning, which can be usefully subdivided into two categories, social learning and individual learning (Cavalli-Sforza and Feldman 1981; Laland 2004; Mesoudi 2011b). Although the division is analytically useful, it obscures the fact that humans are neither purely social nor purely individual learners. Rather, certain conditions, perceived or real, dictate which is used in any particular situation (Aoki et al. 2012; Bentley et al. 2014; Enquist et al. 2008; O'Brien and Bentley 2011). Humans use social learning for a variety of adaptive reasons (Bentley and O'Brien 2011; Boyd and Richerson 1996; Ehn and Laland 2012; Enquist et al. 2011; Henrich and Broesch 2011; Kameda and Nakanishi 2002; Laland 2004; Mesoudi 2011b; Reader and Laland 2002; Rendell et al. 2010; Richerson and Boyd 2005; Tomasello et al. 1993). They learn their language, morals, technology, how to behave socially, what foods to eat, and most ideas from other people. This process is the basis for human culture, organizations, and technology (Whiten et al. 2011); thus the first published definition of human culture by an anthropologist reads "that complex whole which includes knowledge, belief, art, morals, law custom, and any other capabilities and habits *acquired by man as a member of society*" (Tylor 1871:1, emphasis added). Humans continue to "learn things from others, improve those things, transmit them to the next generation, where they are improved again, and so on," and this process continues to lead to the "rapid *cultural* evolution of superbly designed adaptations to particular environments" (Boyd and Richerson 2005:4, emphasis in original).

Much of the time, social learning is an effort to replicate another's behavior accurately without embellishment. It is a powerful adaptive strategy that allows others to risk failure first (Henrich 2001; Laland 2004)—that is, to let others filter behaviors and to pass along those that have the highest payoff (Rendell et al. 2011a). Copying others is itself a set of competing strategies in that one might preferentially copy someone based on that individual's skill level (copy those who are better at something than you are, copy good social learners, copy those who are successful, and so on), whereas others might base their decisions on social criteria (copy the majority, copy kin or friends, copy older individuals). The various factors that can affect one's choice of whom or what to copy are often referred to as "biases," which in Boyd and Richerson's program are unique evolutionary forces for the selective retention of cultural variants (Marwick 2005). Hence, the term "biased learning" is commonly used as a synonym for certain social-learning strategies (Boyd and Richerson 1985; Laland 2004). Of importance is the difference in the effects of copying based on selection for knowledge or a skill level as opposed to copying based on random social interaction (that is, the term "bias" is used here in a statistical sense to indicate some deviation from random or "unbiased" copying; it is not used in any normative sense, such as "gender bias" or "racial bias"). Our view mirrors that of Rendell et al. (2011a): Copying confers an adaptive plasticity on populations, which allows them to draw on deep knowledge bases in order to respond to changing environments rapidly. High-fidelity copying leads to an exponential increase in the retention of cultural knowledge.

We should insert a few caveats here with respect to copying. First, the term "copying" carries a connotation that someone simply looks over someone else's shoulder, views a product, and then replicates it. This behavior might work on homework or a classroom exam, but it does not apply in many situations. One cannot, for example, watch a homebuilder and his crew construct a house and expect to replicate the behaviors and create a successful product. If the observer starts with moderate skills, he might learn some tricks of the trade, but he can never hope to go away and build a house that mirrors what he saw being constructed. Second, nonrandom copying can take several forms, including (1) "indirect bias," where learners use such criteria as success or prestige as a basis for selecting a model, and (2) frequency-dependent copying, where learners perhaps copy the most-frequent variant, which is often labeled as "conformity." Third, cultural models of model-based transmission often implicitly assume that individuals can find a master teacher from whom to learn. Likewise, models of conformist transmission often implicitly assume that individuals can sense how popular a behavior is in the population. These assumptions are fine for small groups but unrealistic for large populations, where individuals have only local, imperfect knowledge of what models, and hence what behaviors, are optimal (Bentley and O'Brien 2011; Mesoudi and Lycett 2009). Fourth, acquisition costs could affect the ability to copy faithfully (Mesoudi 2011c). This applies to all modes of social learning.

As opposed to learning socially, one can learn individually, or asocially. This is a slow process, wherein an individual modifies existing behaviors through trial and error to suit his or her own needs[1] Perhaps a learner obtains the basic behavior from a parent or master and then begins to tinker with it with no influence from other people. He or she then passes the behavior on to a few others. Boyd and Richerson (1985) refer to this as "guided variation." The guided-variation model shows that, in the absence of selection for a particular trait, a population will move toward whichever trait is favored by people's individual-learning biases. This occurs even when the strength of guided variation is weak (Mesoudi 2011b).

This form of learning is called "unbiased" (Boyd and Richerson 1985; Henrich 2001) because at the *population* level it approximately replicates the distribution of behaviors from the previous generation. After acquiring a behavior or tool, an individual can obtain environmental information about the relative payoffs of alternative skills or tools. If the difference in payoffs is clear, the individual adopts the behavior indicated by the environmental information. If not, the individual sticks with the behavior acquired through unbiased cultural transmission (Henrich 2001). Thus, Boyd and Richerson's (1985) "guided variation" has two equally important components: unbiased transmission and environmental (individual) learning. Henrich (2001) uses the term "environmental learning model" to include both the individual-level learning process, which may occur many times per generation, and its transgenerational counterpart, guided variation (unbiased transmission and individual learning).

9.2.1 Learning Models in Archaeology

Archaeologists have taken advantage of these perspectives on learning to help explain certain patterns in the archaeological record (Mesoudi 2010). One example is Bettinger and Eerkens's (1997, 1999) study of Great Basin projectile points manufactured ca. 1,500–1,200 calBP, following the replacement of the atlatl (throwing stick) with the bow and arrow. Bettinger and Eerkens (1999) observed that specimens of two point types found in adjacent regions of the Great

[1]For an example of individual learning involving stone tools, see Eren et al. (2011a, b). In this example, it took the experimental knapper 18 months to master a Middle Paleolithic lithic technology called "Preferential Levallois," in which a stone nodule's upper surface is carefully shaped such that a large "predetermined" flake can be removed with specific, beneficial morphometric properties (Eren and Lycett 2012). Some researchers have cited this long learning time as evidence for the difficulty of learning the Levallois technique and the high skill necessary to master it (Bar-Yosef 2013; Bar-Yosef and van Peer 2009; Putt et al. 2014). While undoubtedly "Preferential Levallois" represents expert learning (Wynn and Coolidge 2010), it is reasonable to hypothesize that the 18-month-long Levallois learning period of the experimental knapper would have decreased significantly had the learning been social rather than predominantly individual.

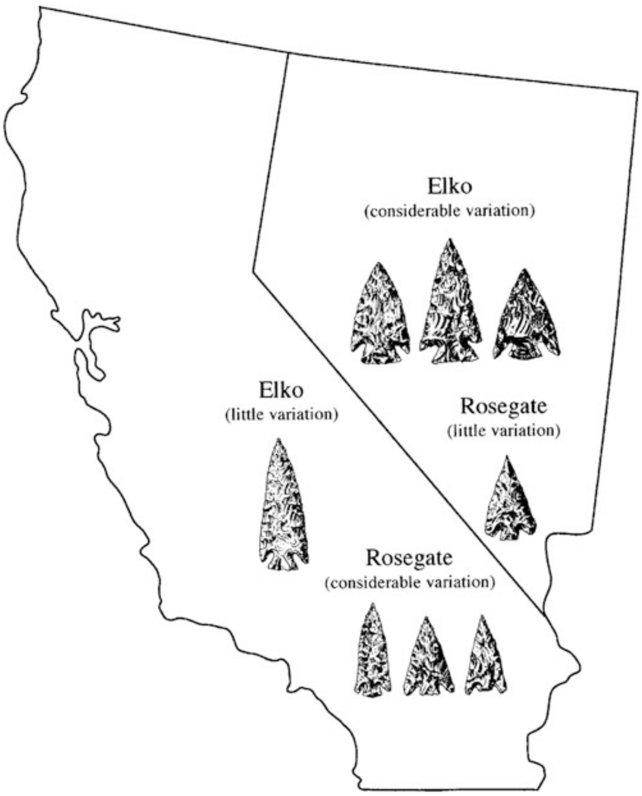

Fig. 9.1 Map of California and Nevada showing variation in the earlier Elko dart points and the later Rosegate arrow points from central Nevada and eastern California. Bettinger and Eerkens (1999) proposed that regional variation among Elko points from central Nevada was perhaps attributable to resharpening whereas those from eastern California were resharpened much less frequently. For Rosegate points, they attributed regional variation to different learning models—indirect bias in central Nevada and guided variation in eastern California

Basin—central Nevada and eastern California—differ in the degree to which attributes such as weight, width, and length correlate with each other (Fig. 9.1). The earlier, Elko points, which were used to tip darts, all have a similar base shape—the primary character used to place specimens in the type—but specimens from central Nevada vary considerably in weight and length, often being light and stubby, whereas those from eastern California are uniformly heavy and long relative to their width. Bettinger and Eerkens (1999) suggested that excessive resharpening drove the highly variable weight and length of Elko specimens from central Nevada. The lack of resharpening seen on specimens from eastern California is perhaps explained by the abundance of high-quality obsidian sources present. Elko points were simply discarded rather than resharpened.

Resharpening, however, cannot explain why the later, Rosegate points, which tipped arrows, are more variable in basal width in eastern California than in central Nevada. Bettinger and Eerkens (1999) attributed these differences to the manner in which prehistoric people of the two regions acquired and transmitted projectile-point technology. Specifically, the attributes of points found in eastern California were found to be poorly correlated with each other, which Bettinger and Eerkens argued was because point designs in that region originally spread as a result of guided variation. Hence, each attribute was subject to separate individual trial-and-error experimentation, causing them to vary independently. In contrast, projectile points of the same material and from around the same period found in central Nevada featured uniform designs with highly correlated attributes. Bettinger and Eerkens (1999) argued that points in that region originally spread as a result of indirect, or model-based, bias, with individuals copying wholesale the design of a single successful model. Hence, differences at the individual level (guided variation vs. indirect bias) can be argued to have generated differences at the population level (uncorrelated attributes vs. correlated attributes).

One inherent limitation in archaeology is that we have access only to population-level historical data. The details of cultural transmission at the level of the individual—who copies what from whom, and how—can only be inferred from these archaeological data, as Bettinger and Eerkens (1999) did, and not directly observed or measured. Mathematical simulations offer one means of addressing this problem, with the results of simple models of cultural transmission matched to archaeological data (e.g., Eerkens et al. 2006). Mathematical models, however, are only as good as their assumptions, in this case assumptions regarding people's propensities to learn socially rather than individually, to conform, to copy the most successful individual, and so on. What are needed are experimental data in order to verify the assumptions and findings of theoretical models.

Some experimental tasks, however, are unrealistically simple. By this we mean that, for example, agents are faced with only two choices, one of which yields a higher payoff. Similarly, it might be assumed that agents exhibit only two traits, one of which has a higher payoff in a particular environment. These scenarios tend to greatly oversimplify real life. For example, even the simplest of human technologies comprise multiple component traits, some of which might be continuous (e.g., projectile-point length) whereas others are discrete but with more than two states (e.g., the shape of a point base). Some traits might be functional (e.g., the thickness or length of points) whereas others are functionless (neutral) (e.g., designs incised on a ceramic vessel). The overall "cultural fitness" of an object is a combination of trait values, each of which interacts with one another as well as with the skill of the manufacturer and user and stochastic factors such as weather conditions (Mesoudi 2014).

Mesoudi and O'Brien (2008a) set out to design a task that was complex enough to yield insights about how people solve real-world technological problems yet simple enough so that the implications of theoretical models of cultural transmission could be tested. Specifically, they tested Bettinger and Eerkens's (1999) hypothesis that the different patterns of projectile-point variation observed in the Great Basin are the result of different cultural transmission processes—guided variation and indirect bias—by experimentally simulating those cultural-transmission processes in the laboratory. They had participants (university students) copy the design of a model after being given information regarding that model's prior success (permitting indirect bias) and then allowed participants to experiment with their point designs in novel selective environments (permitting guided variation). The results matched the patterns of attribute correlation found by Bettinger and Eerkens (1999), with the former points exhibiting highly correlated attributes and the latter points exhibiting less correlated attributes. Hence, more confidence could be placed in Bettinger and Eerkens's (1999) hypothesis that these different archaeological patterns were the result of differences in how projectile-point technology in the two regions was originally transmitted. The finding that cultural transmission was relatively more adaptive when there was a cost to modification suggested a possible explanation for the site differences: Perhaps the prehistoric Nevadan environment was harsher in some respect, imposing a cost on experimentation and necessitating a greater reliance on indirectly biased cultural transmission.

The Mesoudi and O'Brien (2008a) study was designed to also present a more general exploration of cultural transmission in a multimodal adaptive landscape, where point-design attributes are governed by bimodal fitness functions, thus giving multiple locally optimal designs of varying fitness. Mesoudi and O'Brien hypothesized that the divergence in point designs resulting from individual experimentation (the individual-learning component of guided variation) was driven in part by this multimodal adaptive landscape, with different individuals converging by chance on different locally optimal peaks. They argued that indirectly biased horizontal cultural transmission, where individuals search design space and copy the design of the most successful person, allows individuals to escape from local optima and jump to the globally optimal peak, or at least the highest peak found by people in that group (Fig. 9.2) (Lake and Venti 2009; Mesoudi 2008). Mesoudi and O'Brien's experimental results supported this argument, with participants in groups outperforming individual controls when the group participants were permitted to copy each other's point designs. Computer simulations confirmed that this social-learning strategy of "copy-the-successful" was more adaptive than a number of other social-learning strategies, especially in groups of more than 50 people, which have been typical throughout much of human evolution (Dunbar 1992), and showed that the multimodal-adaptive-landscape assumption was key to this advantage.

This latter finding is potentially important, as it demonstrates that the nature of the selective environment will significantly affect aspects of cultural transmission. To reiterate, whereas most previous experiments (e.g., Kameda and Nakanishi 2002, 2003; McElreath et al. 2005) used relatively simple learning tasks that required a participant to

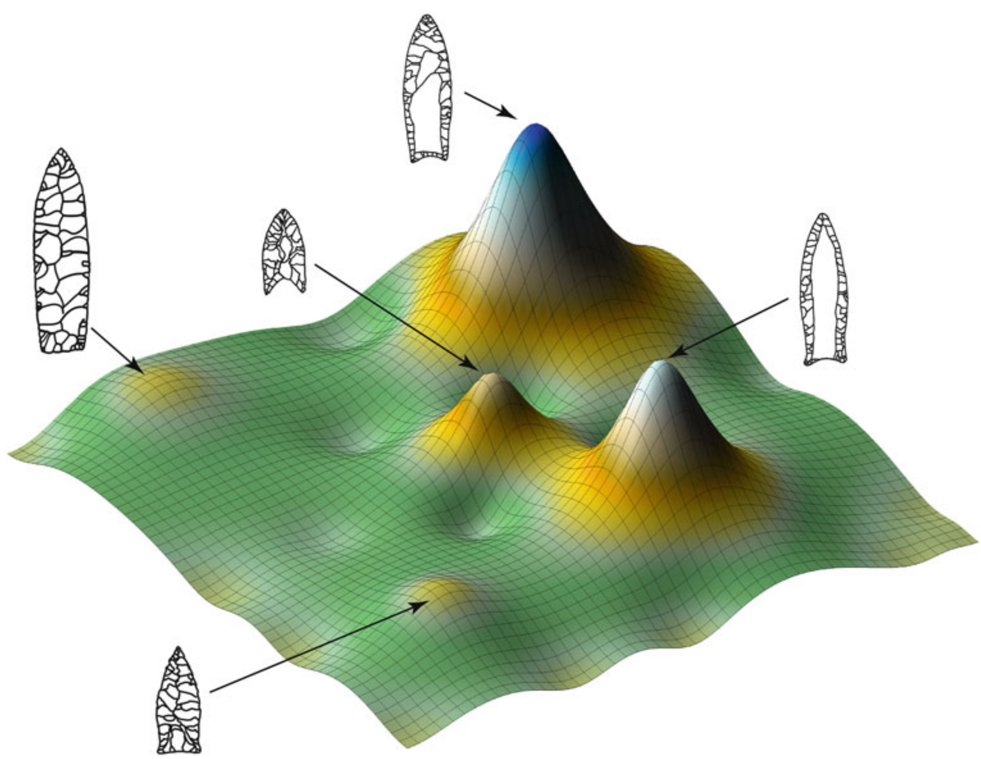

Fig. 9.2 A fictional, and highly simplified, multimodal adaptive landscape of point design. In this design universe, concave-base points have a higher fitness than those with straight bases, and fluted points have a higher fitness than those without flutes. Even among fluted points, however, there are differences. Here, Clovis points are shown as the highest peak—they are globally optimal relative to our design landscape—whereas Cumberland points, which are fluted from the base to the tip, occupy a lower peak—they are suboptimal. Importantly, suboptimality is a relative term. Cumberland points obviously did what they were intended to do in the environment(s) in which they were used

select one of two options (e.g., crops or rabbit locations), Mesoudi and O'Brien used a more complex learning task involving multiple continuous and discrete, functional and adaptively neutral attributes, some of which had bimodal fitness functions. The resulting multimodal adaptive landscape was instrumental in generating and maintaining diversity in the virtual-point designs. They also found in the model that the "copy-the-successful" strategy outperformed the "copy-the-majority" strategy. Indeed, the latter performed no better than individual learning because individuals are just as likely to converge on a local optimum as on a global optimum in the absence of information regarding the success of those individuals, unless individuals at the global optimum outcompete individuals at the local optima and become the majority.

How realistic is this assumption of a multimodal adaptive landscape? Boyd and Richerson (1992) have argued that multimodal adaptive landscapes are likely to be common in cultural evolution and may significantly affect the historical trajectories of artifact lineages, just as population-genetic models suggest that multimodal adaptive landscapes have been important in biological evolution by guiding historical trajectories of biological lineages (Arnold et al. 2001; Lande 1986; Simpson 1944). As we noted earlier, any problems and tasks faced by modern and prehistoric people would have had multiple solutions, some better than others, but all better than nothing. Further, solutions are likely to represent compromises between multiple functions and requirements. With respect to projectile points, for example, Cheshier and Kelly (2006) summarized experimental evidence for tradeoffs in point designs among such factors as accuracy, range, killing power, and durability, noting that "thin, narrow points have greater penetrating power, but wide, thick points create a larger wound that bleeds more easily" (p. 353). Such functional tradeoffs would potentially produce multiple locally optimal point designs, with, for example, one optimal design maximizing penetrating power and another maximizing bleeding.

9.3 The North American Paleolithic and Fluted Points

How might these learning models help us in understanding the cultural landscape of Paleolithic North America after its initial colonization? The exact timing of the colonization is open to question, as is the exact point of entry into the interior of the continent, but what is *not* in question is the point of origin of the early colonists. Despite a few claims to the contrary (e.g., Stanford and Bradley 2012), the overwhelming archaeological and archaeogenetic evidence indicates that humans entered North America by way of Beringia (Goebel et al. 2008; Kemp and Schurr 2010; Morrow 2014; O'Rourke and Raff 2010; Raff and Bolnick 2014; Raff et al. 2010; Rasmussen et al. 2014; Waters and Stafford 2007). Descendants of these migrants moved eastward and then south of the Cordilleran and Laurentide ice sheets, perhaps through an ice-free corridor that ran northwest to southeast through Canada (Catto and Mandryk 1990; Mandryk et al. 2001), and developed a technology known as Clovis (Goebel et al. 2008), which at 13,300–12,800 calBP represents the earliest well-documented archaeological evidence of human occupation of North America.[2]

Clovis is marked by the widespread occurrence of bifacially chipped projectile points that are lanceolate in form, have parallel to slightly convex sides and concave bases, and exhibit a series of flake-removal scars—"flutes"—on one or both faces that extend from the base to about a third of the way to the tip (Bradley 1993; Buchanan and Collard 2010; Buchanan et al. 2012, 2014; Morrow 1995; Sholts et al. 2012; Wormington 1957) (Fig. 9.3). These points were used to tip spears that were thrust and/or thrown. Clovis points were first documented in the American Southwest (Cotter 1937, 1938; Figgins 1927), where they were found alongside the remains of extinct mammals such as mammoth and large bison. They have since been found throughout North America, including Canada and northern Mexico (Anderson and Faught 1998, 2000; Anderson et al. 2010; Buchanan and Collard 2007, 2010; Buchanan et al. 2012; Goebel et al. 2008; Haynes 1964; Holliday 2000; Prasciunas 2011; Sanchez 2001; Sholts et al. 2012; Smallwood 2012; Waters and Stafford 2007).

It has long been suspected that Clovis points originated in the West—the earliest radiocarbon dates (not all of them are universally accepted [e.g., Waters and Stafford 2007]) are from the Aubrey site in northern Texas (ca. 13,450 calBP) and the Sheaman site in Wyoming (13,210 calBP)—but one credible date from the Southeast—Sloth Hole in Florida (Waters and Stafford 2007), at 12,900 calBP—falls inside the 13,300–12,800 calBP date range. With the exception of six radiocarbon dates on hawthorn (*Crataegus sp.*) seeds from Shawnee-Minisink in Pennsylvania (Dent 2007; Gingerich 2007, 2013), at ca. 12,865 calBP, the earliest dates from archaeological sites in the Northeast that have produced large numbers of fluted points—Bull Brook in Massachusetts (Byers 1954; Robinson et al. 2009), Vail in Maine (Gramly 1982), and Debert in Nova Scotia (MacDonald 1968)—consistently fall later than the earliest fluted-point dates in the West (Bradley et al. 2008; Curran 1996; Haynes et al. 1984; Levine 1990; Miller and Gingerich 2013a, b; Robinson et al. 2009).

In the western United States, especially the Plains and Southwest, Clovis points were followed by Folsom points,

[2] Waters and Stafford (2007) use a slightly more conservative span for Clovis, with a maximum span of 13,250–12,800 calBP and a minimum span of 13,125–12,925 calBP.

Fig. 9.3 Clovis points from various North American sites (Photo by Charlotte D. Pevny; courtesy M. R. Waters)

which tend to be smaller in size than Clovis and to have deeper and longer channel flakes (Ahler and Geib 2000; Buchanan and Collard 2010; Collard et al. 2010; Crabtree 1966; Wormington 1957) (Fig. 9.4). Folsom points date to ca. 12,800–11,900 calBP, with the earlier points found in the Northern Plains and the younger ones in the Southern Plains (Collard et al. 2010). In the East, Clovis points were followed by a host of fluted forms such as Gainey/Bull Brook and Crowfield in the Northeast and Great Lakes region; Dalton, Quad, and Cumberland over much of the South and Midsouth; and Simpson and Suwannee in the extreme Southeast (Anderson 1990, 2013; Anderson et al. 1996, 2010; Bradley 1997; Bradley et al. 2008; Brennan, 1982; Bullen 1968; Goodyear 1982; Lewis 1954; MacDonald 1968; Mason 1962; O'Brien et al. 2001; Robinson et al. 2009; Thulman 2007, 2012) (Fig. 9.4).

Not surprisingly, specimens in all these types exhibit variation in size and shape, some more than others. There is, for example, considerable variation among what archaeologists typically would label as Clovis points (Haynes 2013), whereas Folsom points appear to be more standardized in shape, possibly because the Folsom hafting technique had stricter requirements than the Clovis technique (Amick 1995; Buchanan 2006; Judge 1970; Tunnell and Johnson 1991). Focusing on Clovis points, what might account for the variation? Is it the result of drift—that is, is it random—or is there regional patterning that might suggest an adaptive reason? Buchanan et al. (2014) refer to the former as the *continent-wide adaptation hypothesis*. It holds that Clovis groups did not adjust the shape of their points in relation to local environmental conditions (Buchanan and Hamilton 2009; Byers 1954; Haynes 1964; Kelly and Todd 1988; Krieger 1954; Robinson et al. 2009; Sholts et al. 2012; Willey and Phillips 1958) and that variation in shape is the result of drift (Hamilton and Buchanan 2009; Morrow and Morrow 1999). The alternative—the *regional environmental adaptation hypothesis* (Buchanan et al. 2014)—posits that Clovis groups did adapt their hunting equipment to the characteristics of prey and local habitat, which resulted in regional differences in projectile-point shape (Anderson 1990; Meltzer 1988, 1993; Smallwood 2012; Storck and Spiess 1994; Witthoft 1952, 1954).

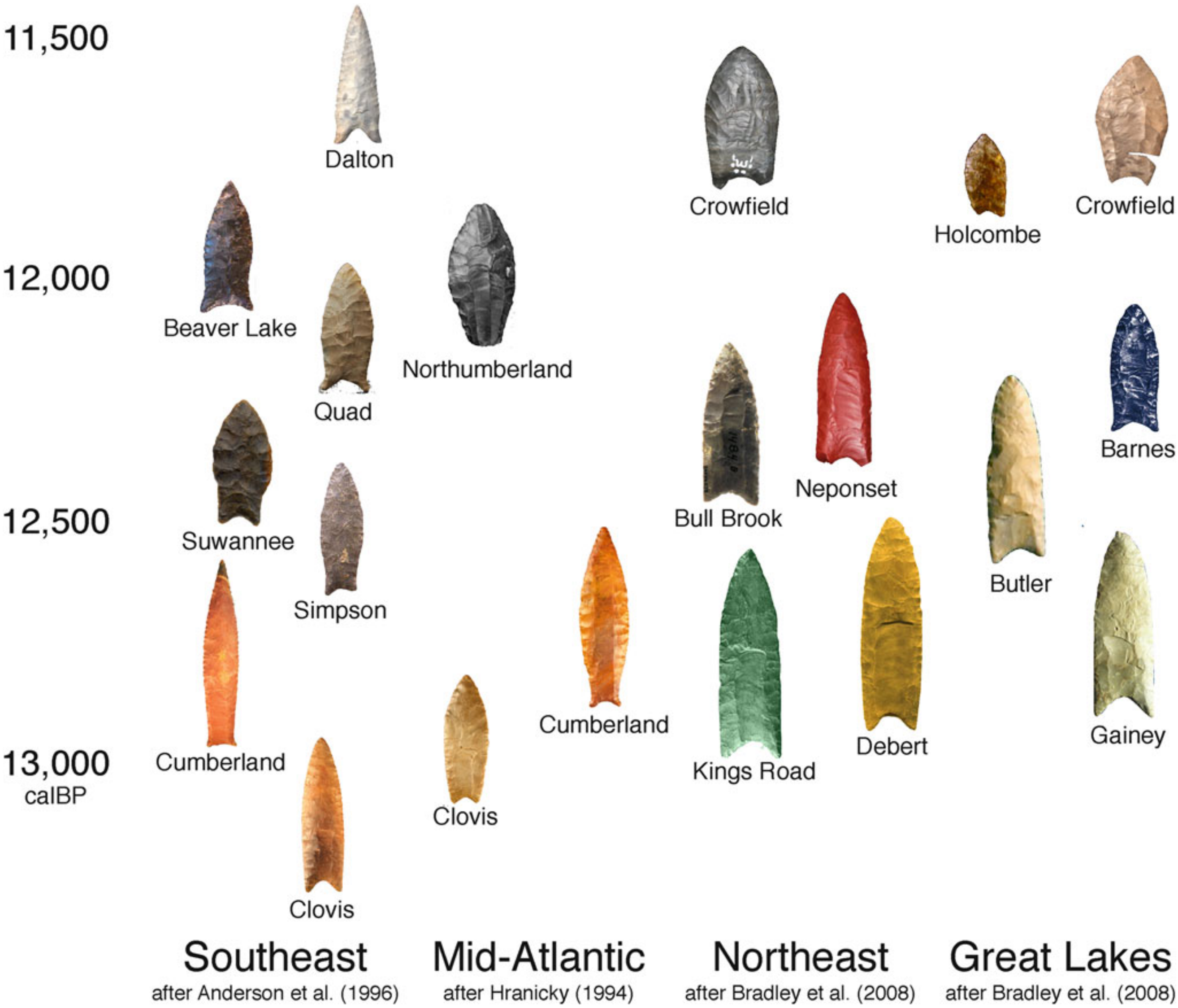

Fig. 9.4 Tentative chronology of Paleoindian fluted-point types from eastern North America

Buchanan and Hamilton (2009) expanded on the distinction between the competing hypotheses. With respect to projectile points, they defined drift as a measurable change in point form because of neutral stochastic processes caused by sampling effects that occur as the result of cultural transmission in finite, naturally fluctuating populations (Neiman 1995; Shennan and Wilkinson 2001). As a consequence of sampling, drift is amplified in smaller populations, where the number of people from whom to copy, and the number of objects or traits to copy, are limited (Bentley and O'Brien 2011). This process is heightened when populations bud off and become isolated from a parent population (Shennan 2000, 2001). This is known as the "founder effect"—smaller populations retain only a limited set of the cultural variation exhibited among the original population, which is then subject to drift. As Atkinson (2011) points out, the founder effect has been used to explain numerous patterns of variation in cultural replicators, including human material culture (e.g., Diamond 1978; Henrich 2004; Lycett and von Cramon-Taubadel 2008; Rogers et al. 2009).

In contrast to drift, adaptive modifications can be made to improve the functional performance of projectile points in specific environments. Buchanan and Hamilton (2009) proposed that functional innovations made to projectile points are expected to be the result of guided variation, a combination of unbiased cultural transmission and individual learning within specific environmental constraints. For example, in open environments it might be beneficial to have improved aerodynamic capabilities of weapons launched through the air (Lipo et al. 2012), or when hunting prey with comparatively thick hides it might pay to reduce impact-related fractures through the alteration of point shape or hafting arrangements (Cheshier and Kelly 2006; Frison 1989; Hutchings 1997; Musil 1988).

With respect to projectile-point types, how do we explain what appears to be considerably greater regional point diversity in the later portion of the Early Paleoindian period in the East (Fig. 9.4) than what occurred on the Plains (Fig. 9.4), where Folsom was the dominant form for 800–900 years? Was it a continuation of regional adaptation, as Buchanan et al. (2014) proposed for Clovis variation? In terms of learning models, could it reflect continued guided variation? Anderson and Faught (2000; see also Anderson et al. 2011) point out that disruptions in climate and food resources associated with the Younger Dryas (12,890–11,680 calBP), coupled with the disappearance of megafauna (Boulanger and Lyman 2014; Grayson 2007; Meltzer and Mead 1983), could have led to changes in logistic patterns (Boulanger et al. 2015). Large-distance movements may have given way to more-localized movements geared toward a wider range of small animals and plants. Anderson and Faught (2000) propose that the distribution of several projectile-point types—Suwannee and Simpson (Fig. 9.4), for example—within circumscribed ranges in the Southeast might reflect the beginning of that trend.

9.3.1 Studies of Variation in Clovis Points

To place these hypotheses in perspective, we briefly discuss five studies that have attempted to quantify and account for variation in Clovis points. The first four found no direct evidence of regional adaptation whereas the fifth did. The studies are important for what they tell us not only about the Clovis cultural landscape but also about potential limitations of some of the methods used to capture variation in projectile points.

9.3.1.1 Morrow and Morrow (1999)

Using four ratios derived from linear measurements of 449 fluted points from North America, 31 points from Central America, and 61 points from South America, Morrow and Morrow (1999) showed that changes in the form of Early Paleoindian points were positively correlated with latitude, with points becoming more stemmed and shouldered the farther south the sample, culminating in the "Fishtail" points of South America. They considered two possible mechanisms to explain the patterns: (1) point variation was the result of adaptive responses to local environmental conditions across the continents; or (2) variation was a result of drift, which Morrow and Morrow 1999:227) defined as "a process inherent in the ongoing translation of cultural practices from one generation to another under specific geographic and historical circumstances." They discounted adaptation as an explanation for the change in points because they did not detect any correlation between point form and environment. As Buchanan and Hamilton (2009) noted, however, Morrow and Morrow did not specify the environmental parameters that would be necessary to assess the relationship. Although they proposed stylistic drift as the likely mechanism for the change in points, a formal test of their hypothesis was not presented but clearly is warranted before either hypothesis can be rejected.

9.3.1.2 Buchanan and Hamilton (2009)

To test Morrow and Morrow's (1999) hypothesis, Buchanan and Hamilton (2009) generated shape data by measuring 12 interlandmark characters on a sample of 232 points from 26 North American assemblages. They also collected from the literature data on several measures of late Pleistocene regional environmental variation—net primary production, prey availability, prey selection, and prey body size—from eight subregions defined on the basis of physiographic association (Cannon 2004). They then used simple and partial Mantel tests to assess the significance of the correlation between matrices representing point shape and regional measures of environmental variation. They also tested the correlation between point shape and the possible confounding factors of geographic distances among sites, assemblage size, and site type (e.g., kill site versus residential site). Buchanan and Hamilton (2009) found no significant correlations between projectile-point shape and region-specific environmental factors, indicating that variation in shape was not the result of technological adaptive responses to local environmental conditions and therefore was more parsimoniously attributable to drift. They did find evidence of spatial autocorrelation, where regional variation in point shape correlated significantly and positively with geographic distances among sites, as would be expected in situations where populations close in proximity share either cultural phylogenetic histories or extensive horizontal transmission. This is compatible with a scenario of demic splits, which result in regional populations budding off from source populations while maintaining connections through social networks.

9.3.1.3 Hamilton and Buchanan (2009)

Hamilton and Buchanan (2009) used the same 232-point sample as used in the Buchanan and Hamilton (2009) study to examine spatiotemporal gradients in projectile-point size across North America. An earlier study (Hamilton and Buchanan 2007) showed that spatial gradients in Clovis-age radiocarbon dates indicate that the most likely origin of the Clovis colonization of North America was the ice-free corridor. Their analysis demonstrated that the date of the earliest Clovis occupation across the continent decreased linearly with distance from Edmonton, Alberta, traditionally taken to represent the approximate location of the southern exit of the ice-free corridor (Martin 1967; Mosimann and Martin 1975). Thus spatial gradients in Clovis occupations across the continent also reflect temporal gradients.

Hamilton and Buchanan (2009) found that projectile-point size mapped onto the gradient, with size decreasing as sample geographic origin occurred farther away from Edmonton. They also found that the variance in point size was statistically constant over time, which is consistent with biased social-learning practices. They noted that

> It is easily understandable why biased learning strategies would have played an important role in Clovis technologies. Clovis projectile point technology is complex and would have required a significant amount of investment both in terms of time and energy to learn effectively. Under these conditions it is likely that there was a significant amount of variation among the skill-level of flintknappers, such that recognized master flintknappers likely would have held considerable prestige. (Hamilton and Buchanan 2009:67)

Hamilton and Buchanan (2009) further proposed that in a fast-moving and fast-growing population subject to the widespread late Pleistocene environmental changes, conformist bias—copy the majority—would also have been a highly effective strategy for learning, alongside prestige bias—copy the most-skilled point maker. This was their rationale:

> Under circumstances where ecological conditions change on a generational level, the mean trait value is often optimal, leading to frequency-dependent bias, or conformism (Henrich and Boyd 1998). If ecological conditions change much faster than this, social learning will favor trial-and-error learning leading to increased variance. Although the Clovis time period would have seen widespread ecological change over time and space, the rate of this change may not have been experienced within a lifetime (Alroy 2001). As such, Clovis social learning likely involved a combination of both prestige bias and conformism, which had the effect of limiting variance over time.

9.3.1.4 Sholts et al. (2012)

Sholts et al. (2012; see also Gingerich et al. 2014) used laser scanning and Fourier analysis to examine flake-scar patterns on a sample of 34 Clovis points from 7 sites in the Southwest, Southern Plains, and Northern Plains, 5 specimens from the Meekins Neck site in Dorchester County, Maryland (Lowery and Phillips 1994), and 11 modern replicates made by an expert flintknapper. Their analyses suggested that flaking patterns were similar across regions (but not with respect to the replicates), and they concluded that there was a continent-wide standardization of Clovis technology. They tied this to direct transmission from craftsman to craftsman:

> Low flake scar variability among the ancient Clovis points suggests that when the Clovis style swept across the continent, it did not spread via Clovis artisans simply copying finished projectile points or independently developing techniques through trial-and-error. Instead, the similar flake scar patterns suggest that the ancient Clovis points were all created with a very consistent technology. . . . [T]he relative uniformity of flake scar patterns among the geographically diverse Clovis assemblages most likely reflects the Clovis artisans sharing their technical knowledge through direct transmission, i.e. by one knapper showing another the "proper" way to fashion a Clovis-style projectile point.

Sholts et al. (2012) suggested that their scenario was supported by results from modern experimental archaeology. Ferguson (2003), for example, found comparable ranges of variation between points he made and those made by novice knappers whom he had directly assisted as part of an intensive learning process. Conversely, Whittaker (1984) reported that when modern knappers have attempted to copy template points using strategies they acquired on their own or through training, a number of differences between the replicate points and the template points were observed.

9.3.1.5 Buchanan et al. (2014)

Buchanan et al. (2014) re-examined the continent-wide-adaptation versus regional-adaptation hypotheses using the same sample of 241 points employed by both Buchanan and Hamilton (2009) and Hamilton and Buchanan (2009) but expanding it by nine points from four additional assemblages. As opposed to using interlandmark differences to determine shape, as Buchanan and Hamilton (2009) had done, Buchanan et al. (2014) used geometric morphometrics, which creates relative warps, or the principal components of the shape variables. The principal components reflect the major patterns of shape variation within a group of specimens. Figure 9.5 (top) shows the consensus configuration of landmarks, which represents the average shape of all points in the sample. The average point represented in the consensus configuration has a lanceolate-shaped blade and a concave base. The two basal landmarks (landmarks 2 and 3) are the most variable; variation associated with individual landmarks decreases toward the tip (Fig. 9.5 [bottom]).

Figure 9.6 plots the first two relative warps by region. The first relative warp, representing 85 % of the overall variation, is plotted on the X-axis; the second relative warp, representing 4.3 % of the overall variation, is plotted on the Y-axis. Overlap among the regions is evident, but points from the East are more variable than those from the West, particularly along the second relative warp. The wireframes in Fig. 9.6 show deformation from the consensus configuration at the positive and negative ends of each axis to illustrate Clovis shape space. That space is defined along the first relative warp by elliptical blades with deeply concave bases to the left (negative end)—represented by a point from Shoop (Pennsylvania)—and by more linear blades with shallow, rounded concave bases to the right (positive end)—represented by a point from Simon (Idaho). Along the second relative warp, Clovis shape space is defined by lanceolate blades with straight bases at the upper (positive) end—

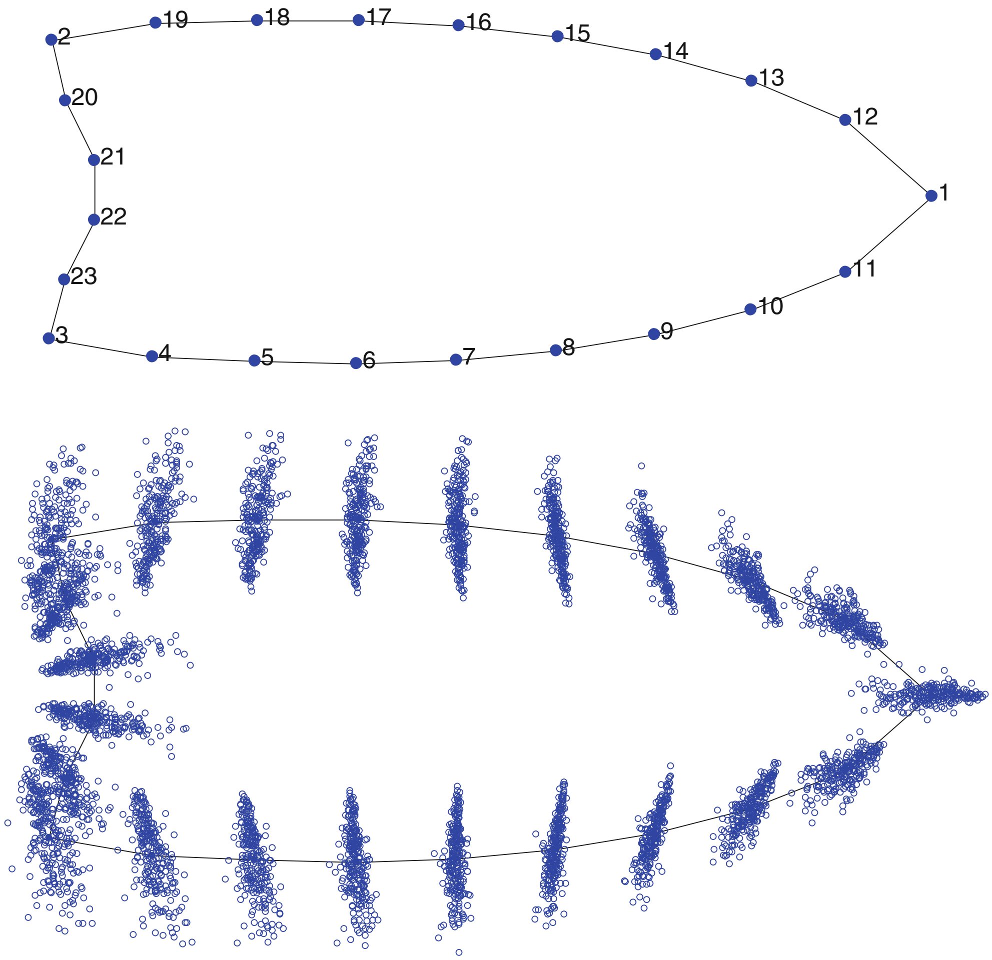

Fig. 9.5 Results of a geometric morphometric shape analysis of 241 Clovis points landmark: *top*, consensus configuration of all landmark configurations; *bottom*, variation in landmark configurations after being translated, scaled, and rotated (From Buchanan et al. 2014)

represented by a point from Murray Springs (Arizona)—and more deltoid blades with deep, concave bases at the lower (negative) end—represented by a point from Vail (Maine). These shape spaces have been casually identified previously (see summary in Gingerich et al. 2014) but not with the precision of the Buchanan et al. (2014) study.

Significance tests showed that among the four subregions in the East, points from the Northeast were significantly different from those from the Midatlantic, Great Lakes, and Midcontinent. In the West, points from the Northwest were significantly different from those from the Southern Plains and Southwest, and Northern Plains points were different from Southern Plains points.

9.3.1.6 Explaining the Interstudy Differences

Why the difference in findings relative to Clovis points? There are at least two reasons, neither of which has to do with the fact that in some studies different samples were used. Buchanan et al. (2014), for example, used virtually the same sample used by Buchanan and Hamilton (2009) and Hamilton and Buchanan (2009), yet came to different conclusions. One reason for the difference probably relates to the different methods used to characterize projectile-point shape. Buchanan and Hamilton (2009) used interlandmark distances to capture point shape, whereas Buchanan et al. (2014) employed geometric morphometrics. The latter approach is known to detect shape similarities and differences better than the former approach (O'Higgins 2000; Slice 2007), and it is likely that the Buchanan et al. (2014) study picked up subtle variation that was undetected by the technique used by Buchanan and Hamilton (2009).

With respect to the Buchanan et al. (2014) study and the Sholts et al. (2012) study, we think there is another reason for the difference: The former examined shape and the latter flake-scar patterning (O'Brien et al. 2014). One clever, and highly significant, aspect of the Sholts et al. (2012; see also Gingerich et al. 2014) study that tells us quite a bit about Clovis-period learning was their inclusion of 11 replicate Clovis points made by Woody Blackwell, who was well known in the knapping world of the 1990s for his ability

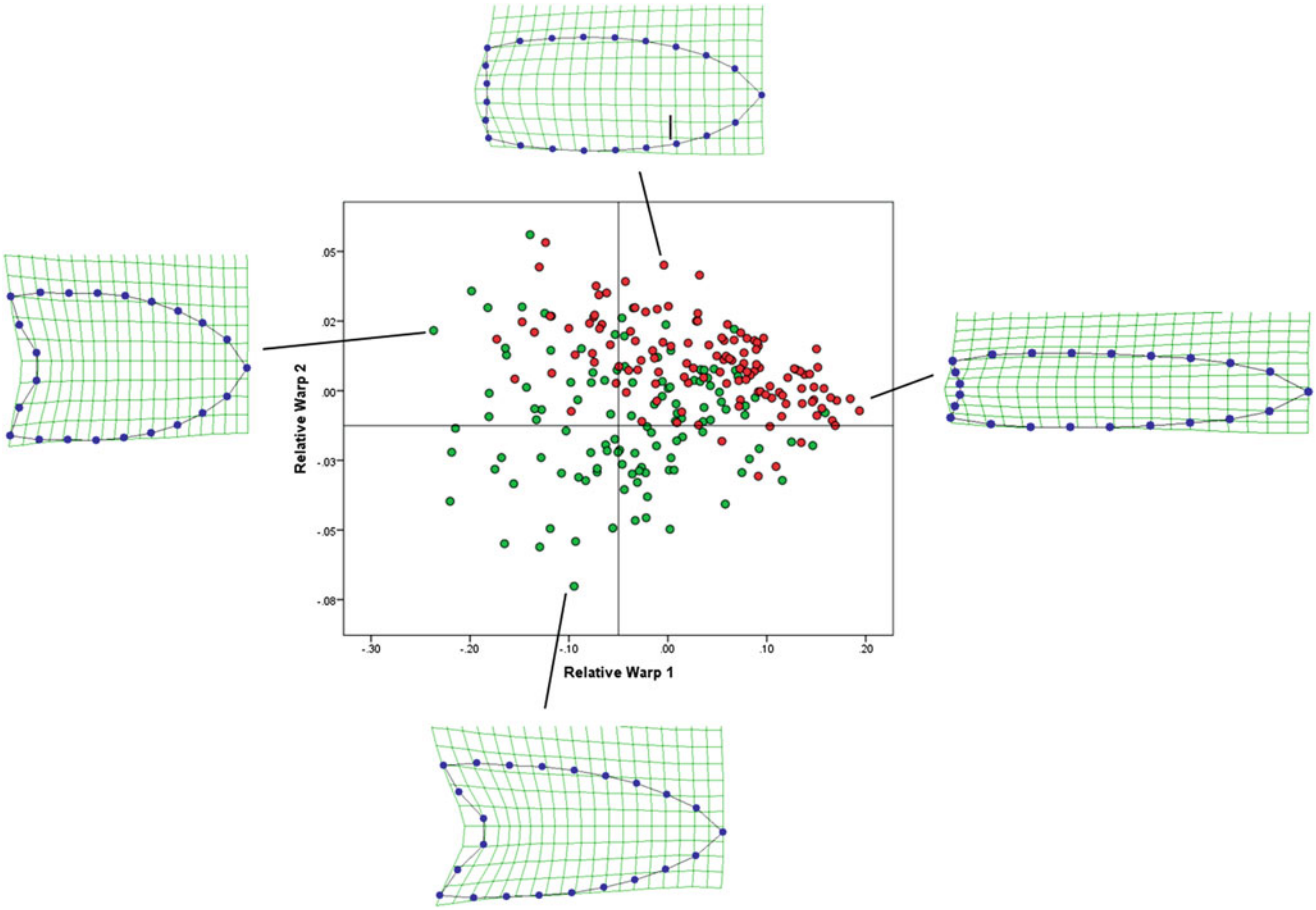

Fig. 9.6 Bivariate plot of relative warp 1 (85 %) against relative warp 2 (4.3 %) for 241 Clovis points (from Buchanan et al. 2014). *Red circles* indicate points from the West and *green circles* indicate points from the East. The four images are deformations from the consensus configurations and display the shape space defined by the first two relative warps. The *upper point* is from Murray Springs (Arizona), the point at the *right* is from Simon (Idaho), the *lower point* is from Vail (Maine), and the point at the *left* is from Shoop (Pennsylvania) (From Buchanan et al. 2014)

to make "superb Clovis points" and "large pieces as thin as anyone could make them" (Whittaker 2004:258). Blackwell copied points from the Drake Clovis cache in Colorado and not only passed them off to a highly knowledgeable collector as authentic but fooled any number of professional archaeologists familiar with Clovis artifacts.

How was Blackwell able to get away with it, at least initially? The answer is, he was a master flintknapper and was able to reverse engineer certain aspects of the Drake points (Preston 1999). Until the study by Sholts et al. (2012), it was widely believed that Blackwell's replicas were all but perfectly executed, and that his mistake, which eventually revealed the points' inauthenticity, was his choice of Brazilian quartz as the raw material for some of the replicas. Sholts et al.'s analysis showed, though, that there was another giveaway: As skilled a knapper as Blackwell was, he could not faithfully copy a Clovis knapper's pattern of flake removal. As Blackwell later said (Preston 1999:85), "I just stopped and looked at this piece and said, 'That really looks like a Drake-style Clovis if I stop right there.' Until then, I had always kept going, cleaning up the edges, making the point smoother, getting the symmetry dead on, and really dressing the thing up. What I'd been losing was its immediacy, its simplicity."

Superimposed front and back flake-scar contours on four points used in Sholts et al.'s (2012) study—one each from the Colby site (Wyoming) and the Drake cache and two of Blackwell's replicates—are shown in Fig. 9.7. Note the difference between the replicates and the authentic points. Figure 9.8 shows the results of a principal components analysis that was carried out to identify shape deviations among the 100 flake-scar contours (front and back) on the sample of 50 points. Most flake-scar contours cluster in the center of the diagram, with the most extreme outlying contours being those of the replicates. In other words, Blackwell could sometimes replicate the flake-removal pattern of a Clovis knapper—note that in terms of the principle components analysis (Fig. 9.8) some of the replicates are indistinguishable from authentic Clovis points—but he was inconsistent in his ability to do so.

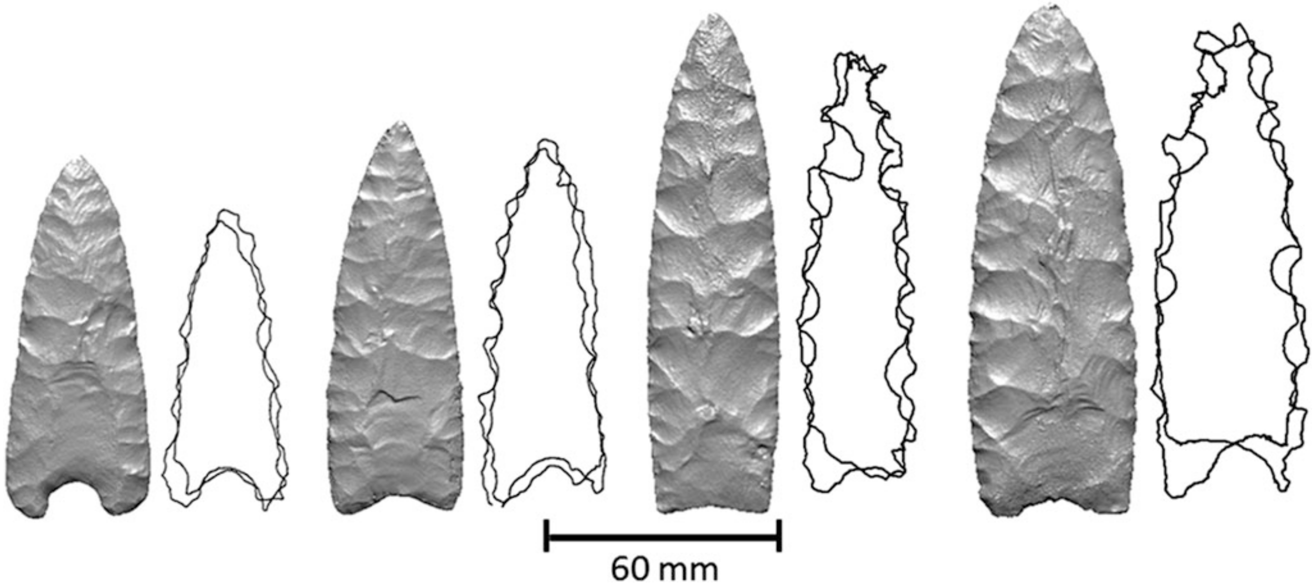

Fig. 9.7 Images of three-dimensional models and overlaid front and back flake-scar contours from prehistoric Clovis points from Colby (*left*) and Drake (*center left*) and two replicate Clovis points (*center right* and *right*) (From Sholts et al. 2012). Despite the markedly different bases on the Colby and Drake points, there is little difference in their flake-scar contours. For the two replicas, their flake-scar contours are more uneven relative to what is seen on prehistoric Clovis points. The replicas also display larger differences between overlaid front and back contours than what is seen on prehistoric specimens

Results of this study support Tankersley's (2004:54) point that biface-manufacture technology is "as much a signature of Clovis as is the morphology of its characteristic projectile point" (Tankersley 2004:54). As Sholts et al. (2012) note, this is especially true for points recovered from the Colby site (Frison and Todd 1986), which have distinctive "C"-shaped bases as opposed to the "typical" Clovis base shape. Despite the odd base shape, they are consistently referred to as Clovis points (Frison 1983). Note that the Colby flake-scar contours are similar to the flake-scar contours of Clovis points from the other assemblages Sholts et al. (2012) examined (Fig. 9.7). In particular, the Drake flake-scar contours show a closer resemblance to those of the Colby points than to the contours of Blackwell's replicates, which he made to mimic the Drake points. Consequently, it appears that the Colby points were manufactured using the same flake-removal process as the other Clovis specimens in the study; they just have a unique base shape. Sholts et al. (2012:3024) believe "this technological uniformity—without evidence for diversification, regional adaptation, or independent innovation—is consistent with Clovis being a short-lived phenomenon."

In summary, taken together the five studies suggest that Clovis learning appears to have been more complicated than any single study demonstrates. The Sholts et al. (2012) study, even with a small sample, indicates there was a standard Clovis lithic-reduction technology that occurred across North America. Whether this standardization was the result of "personal interaction and direct transmission of technological knowledge between Clovis age knappers," as Sholts et al. (2012:3025) propose, is perhaps unknowable, but in terms of learning models, it appears that a good case can be made for some form of biased transmission across the continent (Boulanger et al. 2015; O'Brien et al. 2014). It is understandable why biased learning strategies would have played a key role in fluted-point technologies (Hamilton 2008; Hamilton and Buchanan 2009). The manufacture of a Clovis or Folsom point is a complex procedure that would have required a significant amount of investment both in terms of time and energy to learn effectively (Bradley et al. 2010; Crabtree 1966; Whittaker 2004). Under these conditions, it is likely that there was significant variation among the level of skill exhibited by toolmakers (Bentley and O'Brien 2011; Henrich 2004, 2006)—one does not become a flintknapper, let alone an accomplished one, overnight (Olausson 2008; Pigeot 1990)—such that recognized craftsmen could have held considerable prestige (Hamilton 2008).

Prestige bias—learning from (not simply copying) certain individuals to whom others freely show deference or respect in order to increase the amount and accuracy of information available to the learner (Henrich and Gil-White 2001; Reyes-Garcia et al. 2008)—allows a learner in a novel environment to quickly choose from whom to learn (provided the population is not so large as to "swallow up" highly skilled individuals [Bentley and O'Brien 2011]), thus maximizing his or her chances of acquiring adaptive behavioral solutions to a specific task or enterprise without having to assess directly the adaptiveness of every potential model's behavior

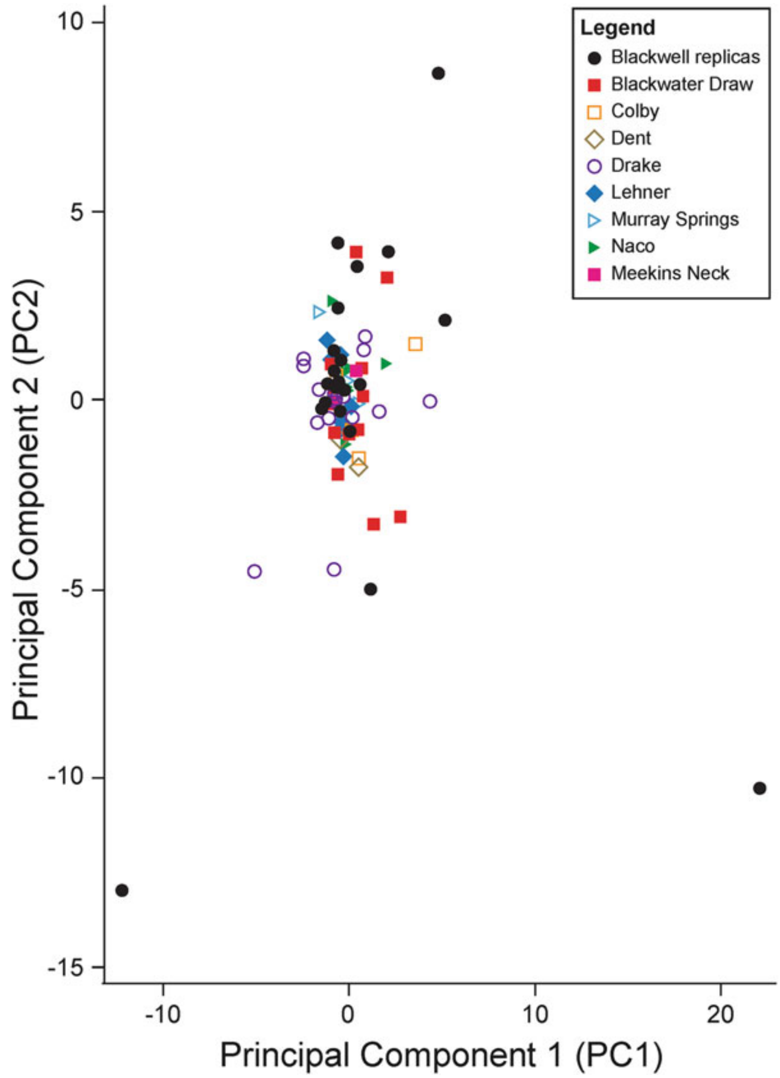

Fig. 9.8 Principal components analysis results for 100 analyzed flake-scar contours on 50 authentic and replicate Clovis points, showing the first principal component (PC 1) versus the second principal component (PC 2) for each contour (From Sholts et al. 2012). Note the outlying *black circles* representing modern replicas for which flake-scar contours deviate from the average shape. Also note that the hollow *orange squares* representing the Colby specimens appear in the center of the diagram, showing that their flake-scar patterns have shapes similar to the other Clovis points

(Atkisson et al. 2012). In a fast-moving and fast-growing population subject to the widespread environmental changes of, say, the North American late Pleistocene landscape, prestige bias would have been a highly effective strategy for social learning (Hamilton 2008) because under circumstances where ecological conditions change, say, on a generational scale, the mean trait value is often optimal, leading to frequency-dependent bias, or conformism (Henrich and Boyd 1998). However, if ecological conditions change faster, social learning may favor individual trial and error or even a combination of the two (Mesoudi 2008; Toelch et al. 2009).

Results of the Buchanan et al. (2014) study—that there is some regional variation in point shape—is in no way at odds with the Sholts et al. (2012) findings of technological uniformity (O'Brien et al. 2014). We propose that patterns of flake removal are less sensitive to adaptive change driven by environmental conditions than is point shape because flaking is less strongly linked to performance than point shape is (Buchanan et al. 2014). In other words, Clovis flintknappers across North America used the same methods to produce points that were similar in flaking pattern yet, where needed, were adapted to different environmental conditions. At the regional level, this takes the appearance of guided variation, with one regional "group" varying its points one way and another regional "group" varying them in an alternative, and oftentimes subtle manner.[3] It is that subtle variation

[3]Recent analysis of Clovis points from one environmentally homogeneous region of the Upper American Midwest demonstrates that although production technique was the same across the sample, differences in shape occur and are highly correlated with the type of chert used to manufacture the points (Eren et al. 2015). These dichotomous results indicate that Clovis foragers engaged in two tiers of social learning. The lower, and more ancestral, tier relates to point flake-scar patterning and can be tied to conformist transmission of ancestral tool-making processes across the Clovis population. The upper, and more-derived, tier relates to point shape. In this case it can be tied to drift that resulted from increased forager interaction at different stone-outcrop hubs. Eren et al. (2015) suspect that we are viewing the very beginnings of a relaxation of social mechanisms that normally

that was just below the visibility threshold in the Buchanan and Hamilton (2009) study but that was picked up in the Buchanan et al. (2014) study. This “structural integrity,” wherein key components are more conservative and therefore less likely to change relative to other components, is also found in other aspects of culture (e.g., Mesoudi and Whiten 2004; Mesoudi et al. 2006; Washburn 2001).

The continent-wide method of point manufacture apparently began to shift immediately following Clovis. In a follow-up study to the one by Sholts et al. (2012), Gingerich et al. (2014) examined flake-removal patterns on specimens of several Early Paleoindian eastern fluted-point types that immediately postdate the height of classic Clovis-point manufacture—for example, Bull Brook (Byers 1954) and Debert/Vail (Gramly 1982; MacDonald 1968) (Fig. 9.4)—and found more variation and bifacial flake-scar asymmetry than what Sholts et al. (2012) found among Clovis points. Gingerich et al. (2014:117) hypothesize that the differences “may represent a time-transgressive shift, where Clovis interaction and the direct transmission of knowledge responsible for consistent reduction techniques is breaking down, causing biface symmetry to become more variable with greater flake scar variation.” They point out that their results may support morphometric studies (e.g., Buchanan and Hamilton 2009) that suggest changes in fluted-point shape resulted from drift and related to a colonization process or a shift in population dynamics. If we had to guess, we would take a shift in population dynamics—that the changes in point form had to do with shifts in the use of space (territories) by Paleoindian groups. Those shifts in turn had implications for how information about point technology and performance was transmitted (O’Brien et al. 2014).

To explore this issue, we undertook a series of phylogenetic analyses aimed at (1) clarifying evolutionary relationships among Paleoindian point forms (Buchanan and Collard 2007, 2010; Collard et al. 2010, 2011; Darwent and O’Brien 2006; O’Brien et al. 2012) and (2) highlighting some of the changes in traits, or characters, of various forms across North America. Several of those studies focused on fluted points from the East and Southeast (O’Brien and Lyman 2000, 2003; O’Brien et al. 2001, 2002, 2013, 2014). Common to those studies was the use of the same eight characters and character states to define projectile-point classes (Fig. 9.9). Because of the nonsystematic manner in which projectile-point types have been created (Anderson 2013; Lyman and O’Brien 2002; Miller and Gingerich 2013b; O’Brien and Lyman 2002; O’Brien et al. 2014), the classes often contain specimens that, in the literature where they were described, were placed in different types.

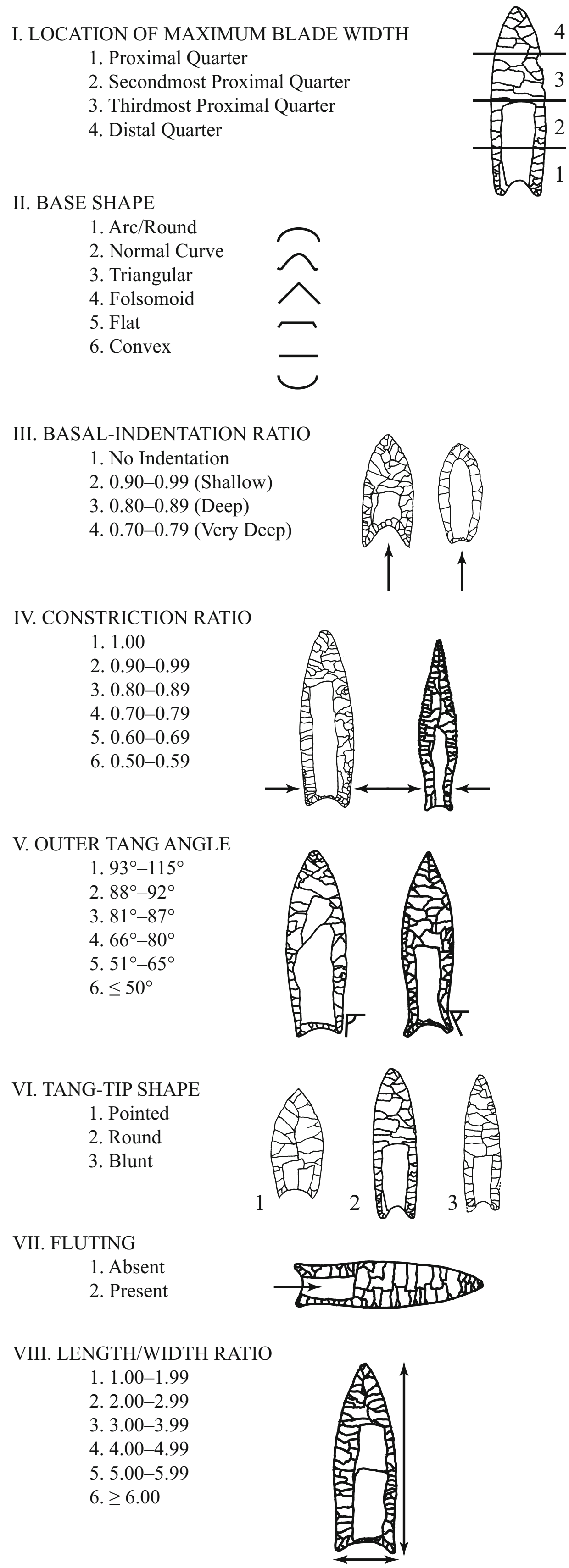

Fig. 9.9 Characters and character states used in the analysis

would act to reinforce ties and a concomitant gradual increase in the diversification of projectile-point shape that will accelerate in the post-Clovis period.

Focusing solely on the latest study (O'Brien et al. 2014), the phylogenetic tree shown in Fig. 9.10, which was built using 218 specimens in 41 classes, contains 48 character-state changes, represented by boxes.[4] Each box is labeled with a Roman numeral indicating the character that has changed; the subscript Arabic numeral indicates the evolved character state (Fig. 9.9). White boxes indicate phylogenetically informative changes—shifts that result from descent with modification as opposed to changes that result from either adaptive convergence (black boxes) or a reversal to ancestral character states (half-shaded boxes). The latter two types of change are not useful in tracing phylogeny, but they do provide information on the kinds of subtle variation present. The tree exhibits numerous clades, defined as two or more related taxa and their common ancestor, some of the larger of which are labeled I–VI.

Projecting the tree into geographic space allows us to observe the significance of the phylogeny in both time and space (Fig. 9.11). Classes in Clade I all contain specimens identified as Clovis points, and all are restricted to the Midwest. Classes in Clade II are skewed toward the Northeast and Middle Atlantic regions. Key constituents of the classes are projectile-point types described as having deep basal indentations—for example, Bull Brook, Debert, and Gainey (Simons et al. 1984) (Fig. 9.4). Several studies have shown that relative depth of the basal indentation varies widely across time and space, with the deepest indentations being in the Northeast and around the Great Lakes (Curran 1996; Ellis 2004; Ellis and Deller 1997; Miller and Gingerich 2013b). Classes in Clade III show a split distribution: One class is restricted to the northern portion of the study area, whereas all other classes in Clade III have distributions in the southern portion. This is not particularly surprising, given that a key constituent of the subclade is Gainey (Fig. 9.4), a point type that occurs primarily along the southern edge of the Great Lakes eastward, although it is found sporadically throughout eastern North America (Morrow and Morrow 2002). Classes in Clade IV occur in a northeast/southwest-trending band from the Tennessee River valley northward, generally following the Ohio River valley. This is also not surprising, given the large number of Cumberland points (Fig. 9.4), a key component of classes in Clade IV, that are found in the Tennessee and central Ohio River valleys (Anderson et al. 2010). Classes in Clade V occur, like those in Clade II, in the Middle Atlantic and Northeast. Classes in Clade VI cluster in the Midwest eastward to the Tennessee River valley. Constituent types include the long, narrow, heavily fluted Cumberland point. Interestingly, Clade VI shows minimal taxonomic diversity and diverges from the superclade comprising the other clades early in the phylogeny.

Of particular interest are the 11 unresolved classes—those that do not fall into one of the six clades—represented in black in Figs. 9.10 and 9.11. In their classic model of Clovis colonization of North America, Kelly and Todd (1988) suggest that the speed of colonization was driven by high rates of residential mobility because of the large foraging areas required of a primarily carnivorous diet. Hamilton and Buchanan (2007) note that Clovis colonists would have moved rapidly through large river systems such as the Missouri and Mississippi drainages, leading to an initially rapid rate of colonization through the midcontinent, which would have then slowed dramatically as diet breadths broadened with the increased biodiversity of the eastern forests (Steele et al. 1998) and as prey size, abundance, and availability changed (Meltzer 1988).

Note the locations of the unresolved classes: They occur in the Upper Midwest near the junction of the Mississippi and Ohio rivers, northeastward along the Ohio River, and southeastward along the Cumberland River. All 11 classes, including the two outgroups, contain specimens identified in the original literature as Clovis points. In some cases, all specimens were identified as Clovis, and in others some were classified as Gainey, Cumberland, Redstone, Debert, and/or Dalton. A working hypothesis based on this distribution would be that the unresolved classes were the products of groups moving rapidly across the landscape—so rapid that there was not enough time for a strong phylogenetic signal to develop. There were technological changes, to be sure—they are what define the classes in the first place—but there were not enough changes to allow much resolution of phylogeny. This conclusion runs parallel to our reasoning for the lack of regional variation in the Buchanan and Hamilton (2009) study of Clovis point shape.

If, as we propose, the unresolved classes are associated primarily with Clovis groups, then a related proposal is that the more-resolved classes, those in clades II–IV, represent later Early Paleoindian points (O'Brien et al. 2014). Figure 9.10 shows the numerous character-state changes that produced those classes. Note that all but one change, the loss of fluting ($VII_2 \rightarrow VII_1$) in Clade III, are either instances of convergence, where knappers or groups of knappers landed on the same adaptive peaks through independent experimentation, or instances of reversal to an ancestral state. This apparent pattern of increased experimentation is what one would expect from the guided-variation model: in the absence of selection, a population will move toward whichever trait is favored by people's individual-learning biases (Mesoudi 2011b; O'Brien et al. 2014). Our proposal of a shift from biased social learning to guided variation accounts for the changes in flake-removal patterns identified by Gingerich et al. (2014) for eastern Paleoindian points compared with the findings of Sholts et al. (2012) for a continent-wide sample of Clovis points. Future work will be directed

[4]See O'Brien et al. (2001, 2013, 2014) for details on how trees were constructed.

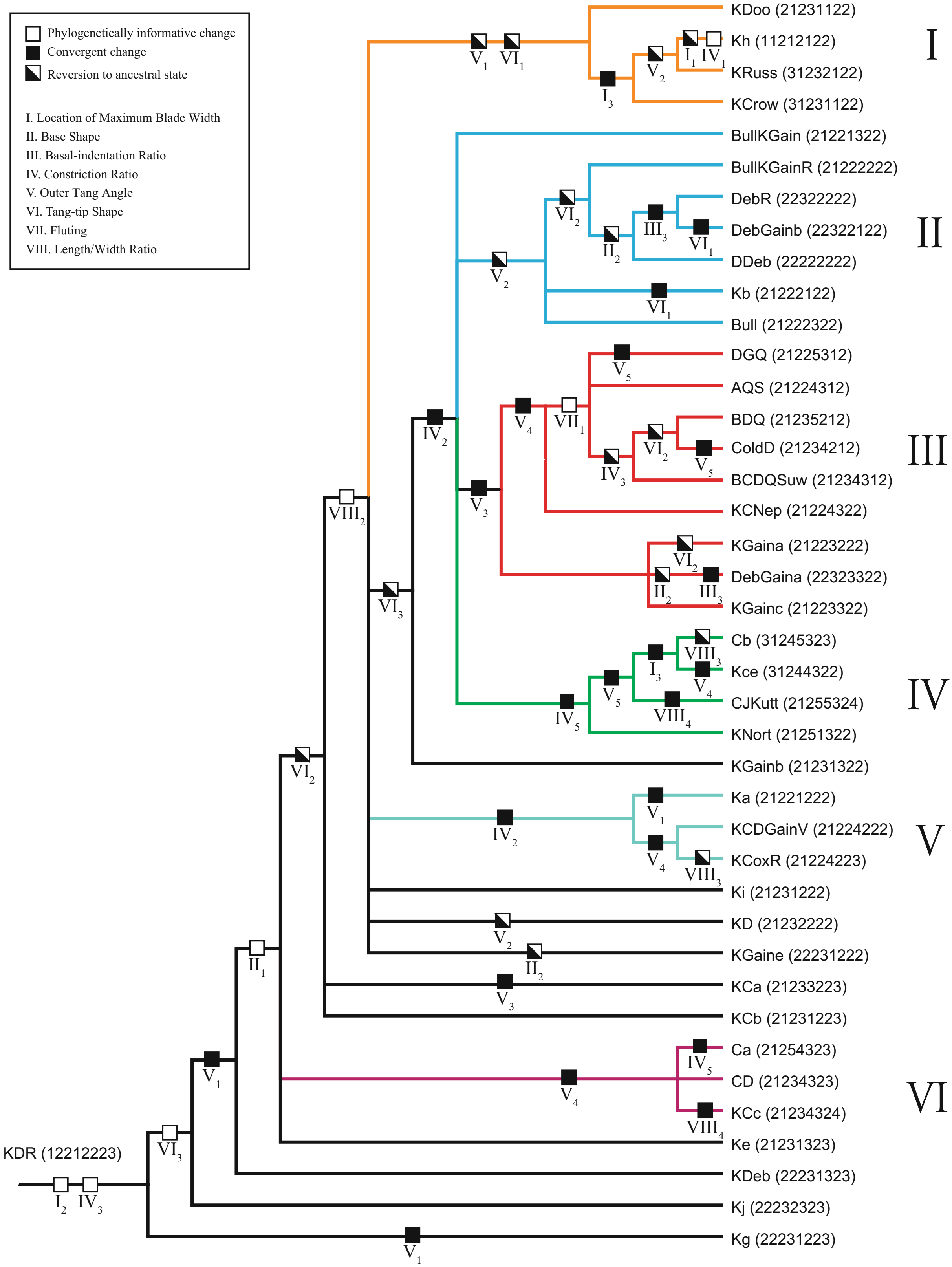

Fig. 9.10 Phylogenetic tree of the 41 classes, with clades shown in different colors (from O'Brien et al. 2014). *Roman numerals* denote characters, and *subscript numbers* denote character states. *Open boxes* indicate phylogenetically informative changes; *shaded boxes* indicate parallel or convergent changes (homoplasy); and *half-shaded boxes* indicate characters that reverted to an ancestral state (The tree is a fifty-percent majority-rule consensus tree based on 100 replicates.)

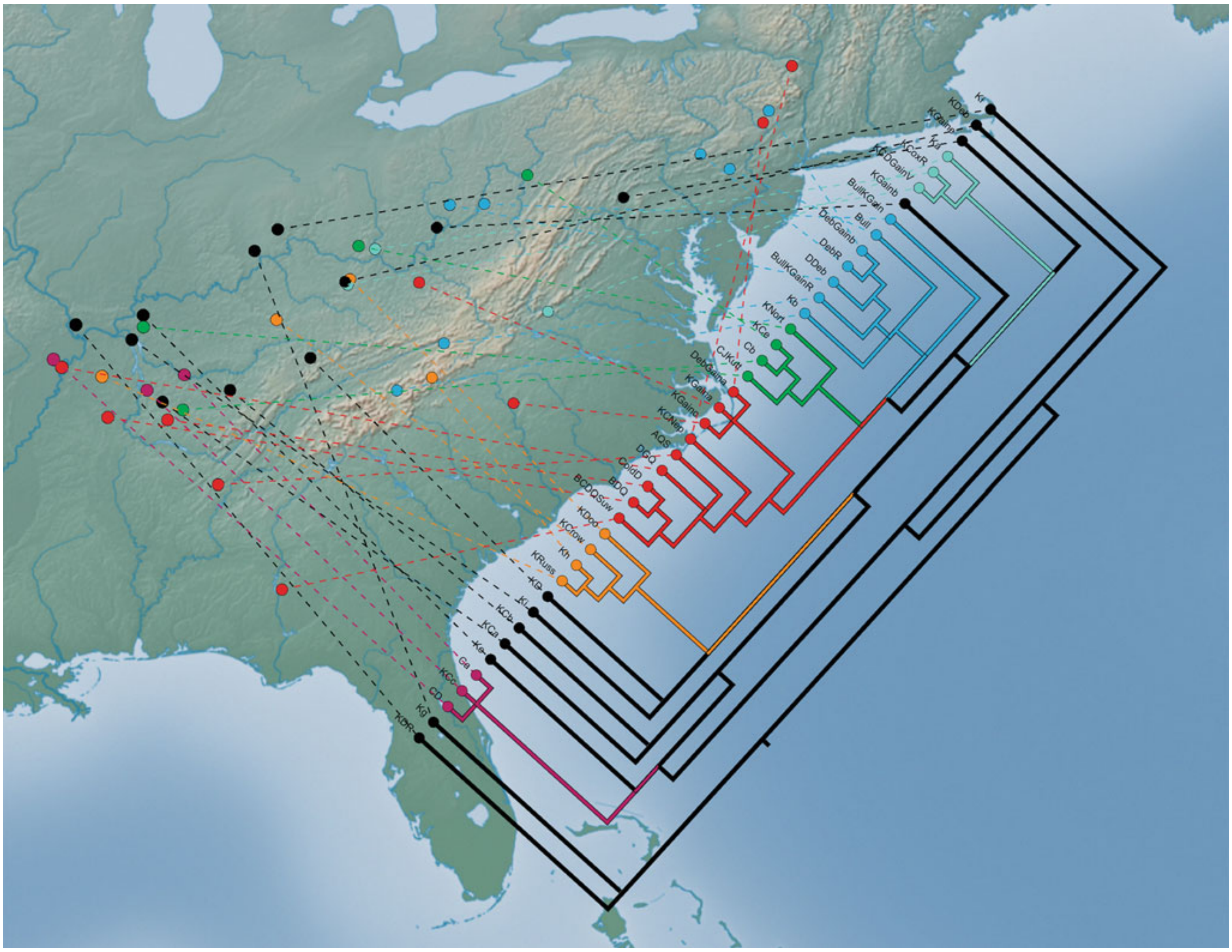

Fig. 9.11 Geographic distribution of clades shown in Fig. 9.10 (from O'Brien et al. 2014)

at developing a better understanding of the "fitness" of character states in terms of performance, which undoubtedly underlies the fact that groups from widely different regions during the late half of the Early Paleoindian period landed on the same fitness peaks in terms of character states—in other words, they found similar solutions to common adaptive problems.

9.4 Conclusion

If nothing else, our discussion should make it clear that in terms of point manufacture, the North American Paleolithic cultural landscape was anything but static. We did not need to conduct the studies reported here in order to reach that conclusion, but taken together, they offer glimpses into just how fluid the landscape was. The studies also underscore the fact that there were myriad subtleties to how information was acquired and transmitted during the Early Paleoindian period—subtleties that in some cases match expectations derived from models of learning. We return to a point made earlier that is difficult to overemphasize: Humans are neither purely social nor purely individual learners. Rather, certain conditions will dictate which kind of learning is used in any particular situation. The analytical tools discussed here, including geometric morphometrics and cladistics, offer a powerful means of moving forward.

Acknowledgments We thank an anonymous reviewer for extremely helpful suggestions for improving the manuscript.

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