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Toward an unified Darwinian paradigm

Questions théorétiques et méthodologiques en archéologie évolutive

Vers un paradigme Darwinien unifié

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A SYNTHETIC DARWINIAN PARADIGM IN EVOLUTIONARY ARCHAEOLOGY IS POSSIBLE AND CONVENIENT

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Abstract*: A synthetic Darwinian framework, with the potential to link the short term microevolutionary mechanisms to the macroevolutionary patterns documented in the archaeological record, results after discarding a misconceived single-level selectionism. Promoting an expanded Darwinism, adaptationist and populational thinking is the best strategy to modelling the selective environments where humans, artifacts and behaviours evolve thanks to nested selective forces acting at the multiple focal levels of a genealogical hierarchy. After focusing on some of the elements of a multilevel Darwinian framework for evolutionary archaeology, I exemplify in this paper its utility by discussing the evolution of the earliest ceramics of Northwestern Argentina.*
Keywords*: synthetic Darwinian framework- selectionism- multilevel Darwinian*

Résumé*: Une approche Darwinienne synthétique, avec le potentiel de lier les mécanismes microévolutifs à court terme aux modèles macroévolutifs documentés par le registre archéologique, est possible après avoir rejeté une sélection à niveau simple mal comprise. Promouvant un Darwinisme étendu, penser en termes d'adaptation et de population est la meilleure stratégie pour modeler un environnement sélectif où les humains, les objets et les comportements s'élaborent grâce aux forces sélectives agissant à des niveaux multiples d'une hiérarchie généalogique. Après s'être focalisé sur quelques éléments d'une approche Darwinienne multiniveaux pour une archéologie évolutive, j'illustrerai dans cet article son utilité en discutant l'évolution des céramiques anciennes du Nord-Ouest Argentin.*
Mots clés*: approche Darwinienne synthétique – sélection – approche Darwinienne multiniveaux*

EVOLUTIONARY ARCHAEOLOGY NEEDS A SYNTHETIC DARWINIAN FRAMEWORK

Darwin´s theory of natural selection produced the unification and the success of the biological sciences. The "Modern Synthesis" fostered the proliferation of a diversity of disciplines to account for the many different evolutionary phenomena of the natural world. Of mayor importance was the realization that macro evolutionary patterns result from microevolutionary mechanisms (Foley 1992), and that Darwinian selection might also operates on several evolutionary entities (Gould 2002).

As Mesoudi *et al* (2006) convincingly argue given that culture exhibits key Darwinian evolutionary properties the structure of a science of cultural evolution should share fundamental features with the structure of biological evolution. Nevertheless, a unified Darwinism did not emerge in anthropology or archaeology. Since the application of the scientific theory of evolution in archaeology is a relatively recent enterprise, implicating different seleccionist frameworks and even national traditions, the discipline still lacks such a synthesizing framework. Hence, a broad spectrum Darwinian interpretation prevails under the label "Darwinian Archaeologies" (Maschner 1996).

Archaeology once was closer to converge to a unified theory of cultural evolution. Under the Culture History paradigm of the Americas, with its focus on artifacts change along space and time, archaeology developed a machinery of methods to document cultural homologous similarities (Lyman *et al* 1997). But the essentialist conception of the evolutionary processes, along with an ethnographic description of the archaeological record was the fatal mistakes of Culture History. Because of its lack of interest in scientific evolution –descent with modification- the New Archeology did not restore these mistakes, and many of the current Darwinian Archaeologies inherited these defective conceptions (*e.g.* Ames 1996).

Conceiving the archaeological record as a fossil record, here I hold that a synthetic paradigm in evolutionary archaeology is necessary and convenient. A synthesizing framework is required not in order to suppress theoretical diversity, but as a common ground where a variability of competing hypotheses and models may proliferate, fueling the natural selection of scientific ideas. This requires a logical theoretical framework capable of linking the properties of the archaeological record, a distributional phenomenon of the present (see Dunnell 1992), with the complexities of the Darwinian theory of evolution.

In this work I advocate for the adoption of and extended theory of Darwinian evolution, by which natural selection is a general process which might occur on biological objects at many levels of a genealogical hierarchy, with several units changing along histories of decent with modification (Gould 1994, 2002). Artifacts are one of such evolving units (Neff 2001).

Upon these notions I argue that adaptationist and populational thinking, as in evolutionary biology, is the best avenue to modelling the selective environments where humans, artifacts and behaviours evolve by nested selective forces acting at multiple focal levels of a genealogical hierarchy. As natural selection produces populational level adaptations at particular focal levels, adaptationist and populational thinking are the common ground where evolutionary archaeology might converge in a synthetic paradigm. In this framework, by including some elements developed in the fields of evolutionary ecology and sociobiology, rewritten in proper archaeological terms, micro and macroevolutionary processes are not logically opposed. A unified Darwinism in evolutionary archaeology shall results from the more general extended theory of Darwinian evolution applied to the evolution of humans and other cultural animals. Hence, the unified Darwinian evolutionary archaeology paradigm will impact on the arguments of those scholars as Smith (2000) and Richerson and Boyd (2005) that by advocating for complementarities and for a synthetic theory of human behavior and evolution are reluctant to accept what evolutionary archaeology has demonstrated since its foundation: that natural selection directly acts on cultural variation as in genetic variation, without adopting a single-level reductionism and the artifices of a dual evolutionary model (*i.e.* Durham 1991).

EVOLUTIONARY ARCHAEOLOGY IS NOT A SINGLE-LEVEL REDUCTIONISTIC THEORY

Conceiving artifacts and behaviors as a part of the human phenotypes, evolutionary archaeology explains change in the archaeological record by the direct action of natural selection and other evolutionary processes on heritable variation (Dunnell 1980, 1989; Leonard and Jones 1987; Rindos, 1984, 1989; O'Brien and Holland 1990, 1992; O'Brien and Lyman 2000, 2002, 2003a, 2003b; Neff 2001; Neff and Larson 1997; Teltser 1995, O'Brien y Lyman 1998,).

Through a strong reliance on the phenotypic plasticity of modern humans, the whole research program of evolutionary archaeology has been questioned (see Boone and Smith 1998). Behind many of these critiques, it is a call to adopt the evolutionary ecology paradigm and the dual inheritance model of evolution (*e.g.* Ames 1996, Bettinger *et al* 1996, Bettinger and Richerson 1996, Boone and Smith 1998, Ortman 2001). These assertions are the logical derivations of following the reductionist uni-level selectionism characteristic of human behavioral ecology and sociobiology. The first advocates that individual organisms are the only valid units of selection (Smith and Winterhalder 1992), whereas for some versions of the later genes occupy this role (Dawkins 1976, 1982).

The issue about what actually evolves deserved the attention of the evolutionary paradigm since its foundation. By recognizing that artifacts and behaviours sometimes have differential inclusive fitness value, evolutionary archeologists often model evolutionary explanations taking the individuals as the unit of selection (O'Brien *et al* 1994). But as it is clear in the literature evolutionary archaeology is not reductionist on this matter. For instance, Dunnell (1978, 1995) has suggested that cultural transmission creates an opportunity for the level of selection to shift up from the individual to groups, a hypothesis discussed on empirical grounds by Kosse (1994) and Shennan (2002, 2003).

Because of this, the term "replicative success" was introduced by Leonard and Jones (1987), asserting that the replicative success of a particular cultural trait might or might not affect the reproductive success of the bearer of such trait (Leonard and Jones 1987:216). Here become critical the notions of *replicator* – "a unit that passes on its structure directly through replication" -and *interactor* "an entity that directly interacts as a cohesive whole with its environment in such a way that replication is differentia (Hull 1980:318). Selection operating on populations of interactors in turn modifies the population level frequencies of replicators (Hull 1980). For example, replicators may consist of the information comprised in the instructions or *recipes of action to* make and use some material forms -artifacts (O'Brien and Lyman 2003). Therefore, by conceiving that artifacts are interactors, evolutionary archaeologists explicitly have assumed that selection often directly act at the level of the artifact, structuring populations of interacting artifacts (Lyman and O'Brien 1998, Neff 2001, O'Brien and Lyman 2000). For natural selection to occur, fitness differences must exist between the interactors of an evolving population. Hence, whereas reproductive success is a critical component of fitness, a general definition of fitness is not attached to reproduction. Rather, fitness is defined and measured in terms of successful information transmission (Barton 2008). In this way, by considering multiple interactors, the epistemology of evolutionary archaeology avoided a uni-level reductionist framework. A similar multilevel perspective on selection guided many other biological disciplines to define evolutionary units suited to the properties of their own empirical domains, such as evolutionary genetics (Merlo *et al* 2007), metapopulation biology and evolution (Hanski and Gilpin, 1997, Olivieri and Gouyon 1997) and paleobiology (Eldredge 1989). Hence, the issue at hand is how this hierarchical multilevel framework would look in evolutionary archaeology. In the next paragraph I shall briefly face this topic.

ARTIFACTS ARE EVOLVING UNITS IN A HIERARCHY OF EVOLVING INTERACTORS

Artifacts have five important properties by which they achieve evolutionary individuality (*sensu* Gould 2002): ***First***: artifacts have descendents by external replication, leading to genealogical processes. ***Second***: artifacts have discreet existence intervals, which mean that they began to exist and perish along time, having ontogeny. ***Third***: artifacts vary with respect to the traits they posses. ***Four***: the traits may impart different probabilities of survival and reproduction to the bearers, and differential replica-

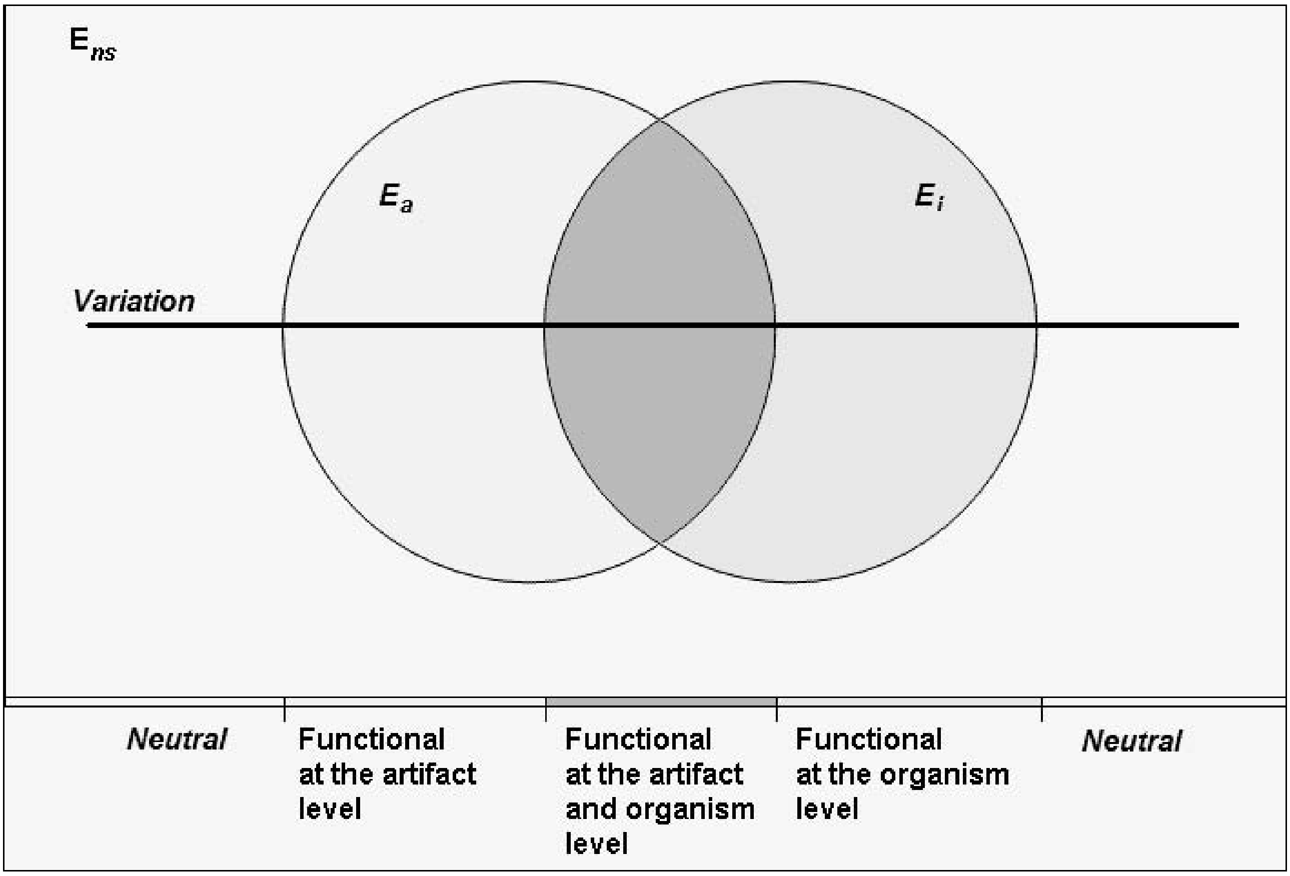

Fig. 10.1. Evolutionary environments and artifactual variation. Circle E_a represents the selective environment at the artifact scale; circle E_i represents the selective environment at the scale of the individual organisms, and E_{ns} is a non selective surface. Horizontal line represents artifactual variation. The labels show the status of the variation as a result of its interception with each environment (see text)

tive success to the artifacts into an artifactual linage or a cultural pool. ***Five***; there is heritability between artifact forms, with great correlation between the traits of antecedent and descendant classes of artifacts resulted by transmission. Thereby, artifacts satisfy Lewontin´s (1970), and Gould (2002) criteria to define evolving individuals –interactors- by Darwinian selection.

As genuine selective units, artifacts are competing interactors in selective environments defined at their own scale. But when the interactors are more inclusive entities, as the individuals or groups bearing them, their selective evolution will result from the impact of the artifactual variation in the fitness of these entities. The logical conclusion of the above statements is that the functional status of the cultural variation comprised in artifacts is dependent on the focal level of the evolutionary process. This brings us the opportunity to build Darwinian adaptive explanations in a multilevel framework with different empirical expectations by modeling the different dimensions of the environments in which the variation is expected to be functional.

Figure 10.1 is a graphical representation of the expected status of the variation as a result of its expression along different evolutionary environments. Functional variation at the artifact level results when the variation is correlated with some dimension of the environment that only affects the replication and use of artifacts –the interception of the line with the E_a environment. Broadly, artifacts and technologies have *performances* to accomplish some tasks controlled by their designs (Schiffer and Skibo 1997). Accordingly, the evolutionary environments at the focal level of the artifact are shaped by forces acting on the base of the properties of the artifacts to be more or less attractive to potential users for performing certain tasks (Neff 2001). As artifact use and replication have associated costs in terms of time, energy, and knowledge, every one of these dimensions will impact over the differential probabilities of alternative artifactual variation of being successfully transmitted and replicated, producing selection.

Hence, when the selective evolution of cultural variation takes place only at the focal level of the artifact, the individuals manufacturing and using artifacts are agents of Darwinian selection. The selective forces at this scale emerge from the population level effects of what has been called “biased cultural transmission” (Boyd and Richerson 1985) plus other decision making mechanisms. As in other forms of selection, the empirical pattern of these processes is an *S* shaped representation of the variation along time, an slow-fast-slow frequency distribution (Bettinger 2008), with a temporal scale imposed by the replicative rate and life span of the artifacts and qualitative shorter than what is expected from selection acting upon organisms (Bettinger 2008).

When the artifactual variation is consistently correlated with the properties of the environment that affect the differential reproduction of the individual organisms it became functional at this evolutionary level -the interception of the solid line with E_i. The empirical signature of this process should be a slower evolutionary rate of the variation under selection imposed by reproductive rate and life span, with rates of evolution of archaeological resolution (see Laland and Brown 2006). Also, variation might be functional at more than one level, a situation represented in figure 10.1 by the line crossing the area of superposition of E_a and E_i. Shortly, artifacts and traits fixed by selection directly upon the artifact pool and having also positive biologically fitness effects became adaptations built by a non conflictive multilevel process. In addition to the short temporal scale sigmoidal distribution of the favored variant, the expected empirical expression of these processes is a demographical success correlated with the reproductive improvements of the individuals (see Edwards and O'Connell 1995). But when selection at infraorganismal level fixes variation that is deleterious for the individual organisms or groups, Darwinian selection at these upper levels will remove this variation (see Durham 1991).

The same logic is transferable to neutral variation (style). As figure 10.2 shows neutrality comprises archaeological variation not correlated with selective forces of *any* focal level. Because of this neutral variation has no detectable selective value (Dunnell 1978). The behavior along time of this variation results by drift and chance alone, according with the neutral model. Neutral evolutionary environments are governed by probabilistic events at several focal levels. For instance, at the level of the organisms, demographic stochasticity, migration and founder effect might fix neutral cultural variation in a population. Similar chance processes are expected at the level of the artifacts as results of the vagaries of transmission, sampling error, and recombination only taken place into a given cultural pool (Muscio 2004).

For selection to occur variation must be blind (*i.e.* innovation should be independent of selection). The extent to which variation in culture is blind is an empirical issue (Bettinger 2008, Mesoudi *et al* 2006). Nevertheless, at proper archaeological time scales what is expected is the dominance of blind variation and selection (Rindos 1984, 1989). Actually, our skills as selective agents of undirected variation occur all time in our every day life. For example, in shopping centers we are surrounded by an amazing amount of cultural variability, explicitly designed with the intention to bring some part of this variability home. Artifact's designers, and brainstorm organizers, appeal to a multiplicity of devices to attract our attention, creating new artifact forms by the engineered recombination of existing variation, imitation, and innovation. But in a second step a crucial test happens: Darwinian selection. This is when variation confronts the nonlinear dynamics of the complex system emerging from collective individual behaviors (Barkley Rosser 2006). Confronting competition some artifacts have success and proliferate while others go directly to extinction (sometimes carrying also the firms to extinction). That intentional designers are incapable of predicting these nonlinear trajectories means that the variation they create is random with respect to natural selection, not only at the level of the artifacts, but at several focal levels in the hierarchy of interactors.

SEEKING COMMON ELEMENTS FOR A UNIFIED DARWINISM IN ARCHAEOLOGY

Behavioral ecology is a microevolutionary approach to phenotypic change along behavioral time (Smith 2000), whereas evolutionary archaeology is a macroevolutionary framework devoted to explain cultural change and the evolution of human populations along evolutionary times (Lyman and O'Brien 1998, 2001, Shennan 2003). Other microevolutionary approaches to cultural evolution are evolutionary memetics (Blackmore 1999), and the Cultural Transmission Theory (Cavalli Sforza and Feldman 1981, Boyd y Richerson 1985). Evolutionary archaeologists were always very aware that evolutionary ecology, sociobiology, and cultural transmission theory do not possess, *per se* any archaeological content.

Evolutionary archaeology and evolutionary ecology have little in common in terms of analytical goals, having different *explananda* (objects of explanation). But since the Darwinian research, in which both paradigms rely, demands populational and adaptive thinking (Dennett 1995), they have much in common in epistemological and methodological grounds. Not accidentally each paradigm decomposes complex phenomena in elementary pieces to explain. Behavioral ecology calls this strategy the *piecemeal approach* (Smith 2000), a way of explanatory reductionism (Winterhalder and Smith 1992). Evolutionary archaeology and paleobiology do the same under the label of *reverse engineering* (O'Brien *et al* 1994), where adaptive-selectionist thinking is the cornerstone to build arguments about function (Maxwell 2001).

Evolutionary archaeology has come to the conclusion that some of the ideas and methods built under the Culture History paradigm have critical explanatory value rewritten in Darwinian terms (Lyman *et al* 1997). Additionally, as Borrero (1993) suggested, explicitly materialistic Darwinian paradigms such as human behavioral ecology, might also have valuable elements, if rewritten in archaeological terms. Winterhalder and Goland (1996) Shennan (2003), Mesoudi (2008), among others, showed the utility of this approach to explain the emergence of large scale evolutionary changes through microescale evolutionary mechanisms.

More broadly, the unifying elements between human behavioral ecology, sociobiology, and evolutionary archaeology are the models predicting how people by adjusting their behavior to their current environments, in behavioral time, become selective agents of cultural variation, including artifacts and behaviors, remaining subject to natural selection at proper evolutionary times.

Predator-prey evolutionary dynamics exemplifies the issue at hand. At a populational level a predator –human or other animal- is a selective agent of its preys. Specialist predators obeying to their evolved design may modify the genetic composition of their preys, or by overexploitation or unstable local dynamics they may drive the local population of preys to extinction (Nee *et al.* 1997). In the last case predators may also go to extinction or to the evolution of new predator phenotypes by selection. Importantly, that predators may become extinct shows the limits of their evolved design into a new selective environment and over an evolutionary time scale. The same logic prevails when humans use resources and artifacts.

Humans, as agents of selection expressing their evolved nature, have the potential to modify the genetic and memetic information of their inherited environment, as *niche construction* predicts (Odling-Smee *et al.* 2003). Ecological inheritance is an important concept here, referring to the selective environment that new generations of individuals inherit from their ancestors, along evolutionary times (Odling-Smee *et al.* 2003). When humans, in behavioral times, introduce novel variation or act as agent of selection of preexisting variation they modify the selective environment for the next generations. The consequences of ecological inheritance can be archaeologically studied (Martínez 2002, Riede 2008).

As evolution may be conceived as an economic process in nature (Eldredge 1989), the models based on optimality have profound analytical value. Since energy and nutrients acquisition is critical for the survival of an organism during its whole ontogeny and reproduction, it is necessary to appeal to natural selection to explain the archaeological record of food consumption, including artifacts linked to food acquisition and consumption (Gremillion 2002).

Foraging behavior is a central issue for the application of adaptive models (Bettinger 1991). As humans socially learn many of their adaptive behaviors, including foraging strategies, what is expected is that cultural transmission, especially vertical transmission, takes the control of these behaviors (Guglielmino *et al.* 1995). Optimal diet models predict that humans will prefer higher return rate recourses; for example selecting big size animals instead of small game in particular environments, since the firsts lead to higher return rates. Then, assuming cultural transmission, and taking the hunting practice as a phenotypic trait subject to lower level selection pressures, the individual adaptive bias of preferring big game will begin the selective retention, at the scale of the population, of the *big game hunting practice* - a cultural trait. Since evolution runs on non-behavioral times, natural selection will ship-up to the level of the individuals. Since the cultural variation, retained for selection at the scale of the behavior, is adaptive on the focal level of the individuals, a no conflicting nested multilevel selective process will retain the big game hunting practice against small game hunting, leading to the selective evolution of an *economic tradition*. This example illustrates the logic by which it is possible to link important behavioral models to complex evolutionary processes of large temporal scales. Therefore, if we are going to apply some selectionist ecological models, we must be aware that they will be useful not by assuming "optimal designs" expressed on behavioral-ethnographical times to use as interpretative devices; but for their capacity to predict in a probabilistic way (see Dunnel 1999) the kind of phenotypic variation that natural selection will retain over evolutionary time frameworks, and regarding specific socio-environmental variables. The critical point to remark is that because we are interested in evolution these models allow us to build hypotheses concerning some directional macroevolutionary patterns produced by humans acting as agents of selection over many populations of evolving interactors, but still subjected to natural selection.

AN EXAMPLE

Optimality models are useful tools to apply in reverse engineering analyses, generating hypotheses about the context-dependent functional dimension of the variation under some optimal criteria. For instance, the puna region of Northwestern Argentina is a high altitude desert located at 3.000 meters above the sea level. Resource availability to use as fuel is scarce. In addition, hypoxia (a low concentration of atmospheric oxygen because of a higher altitude) increases the requirements of fuel for cooking. Ethnographical and experimental research conducted among farmers of the puna shows that cooked resources return rates are highly conditioned by fuel availability and cooking technologies, particularly corn return rates (Muscio 2004). Likewise, ceramic production costs are highly impacted by fuel availability (Camino 2006). From this knowledge about the selective environment of small scale pottery production and use in the puna, it was proposed that natural selection would fix, in a ceramic linage, any trait with the potential to diminish the costs of cooking and the costs of vessels replacement, enhancing the return rate of cooked resources (Muscio 2004). In the puna of Argentina the first ceramic record is dated around 3.000 Bp, associated with herding and hunting economies. Later, around 2.500 Bp, ceramics appear associated with agricultural and

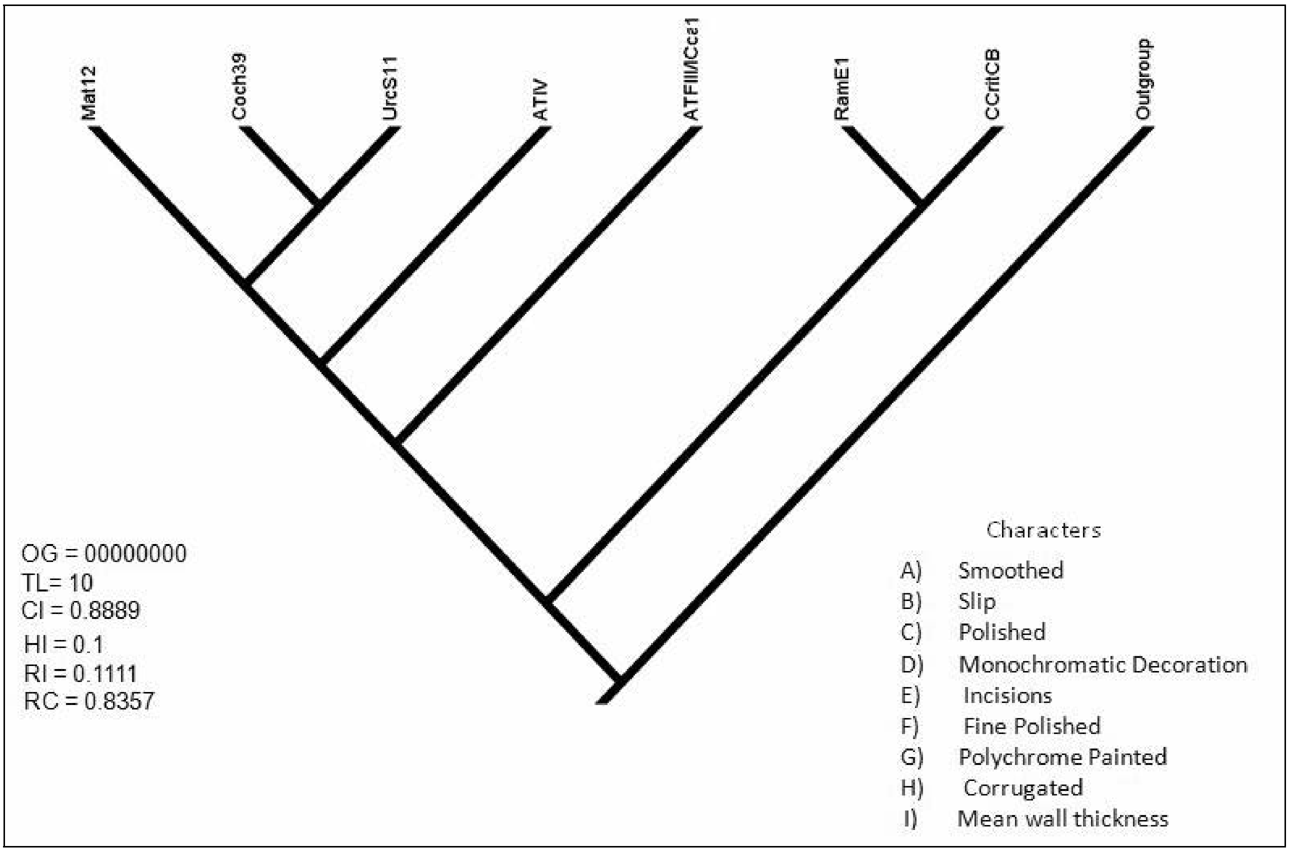

Fig. 10.2. Cladogram of the earliest ceramics of Northwestern Argentina. Each terminal taxa is a single assemblage. Mat12: Matancillas 1 and 2; Coch39: Cochinoca 39; UrcS11: Urcuro Sondeo 11; ATFIII: Alero Tomayoc Fase III; ATIV: Alero Tomayoc Fase IV; Ica1: Inca cueva Alero1; CcritCB: Cueva Cristobal Capa B; RE1: Ramadas Estructura. The information was obtained from the published bibliography (see Muscio 2004). Character states are binary, except for mean wall thickness

herding economies. The genealogical side of the hypothesis was investigated with cladistics and occurrence seriation analyses (O'Brien and Lyman 2001). Selection was assessed investigating the behavior along time of a single continues character: mean wall thickness, which in cooking vessels is positively correlated with thermal conductivity and thermal stress resistance (O'Brien *et al* 1994). Figure 10.2 shows the rooted cladogram of the earliest ceramic aggregates of the region. Only one cladogram was retained from an exhaustive search using PAUP 4.1 (Swofford 2002) from a matrix of eight binary characters, including mean wall thickness (see details in Muscio 2004). The phylogenetic signal is strong and significant (CI=0.8889, RI=0.8357, TL=10), documenting branching evolution. Figure 10.3 shows a robust pattern of declination along time of mean wall thickness, with a fast rate of –0.001 mm/year, which is consistent with a directional optimizing selection processes. This rate of change can be interpreted as the strong selective control of decision making and biased transmission forces over the wall thickness of the vessels. In a context of spatial aggregation and mobility reduction associated with food production, thin wall vessels, by enhancing the return rates of cooked resources should have enhanced the reproductive success of pottery users. Hence, independent evidence is needed to test the demographical implications of this hypothesis.

CONCLUSION

Dennet (1996) suggested that evolutionary ecology and evolutionary archaeology are entirely compatible, arguing that adaptive-directed selection of cultural variation is a *variety* of natural selection. In agreement with this idea, here I proposed that this variety of selection is a consequence of the change in the level of the evolving interactors, from the individual organism to the artifacts and behaviors. In short, the links between micro-evolutionary mechanisms to macroevolutionary patterns come from the realization that cultural variants usually evolve in environments that include a particularly well-focused selective pressure consisting of human agents, and that these agents are not free from the action of selection .

Upon this basis a unified paradigm in evolutionary archaeology is possible and convenient. It is possible because natural selection as a mechanism is not confined to only one kind of interactor, and the archaeological

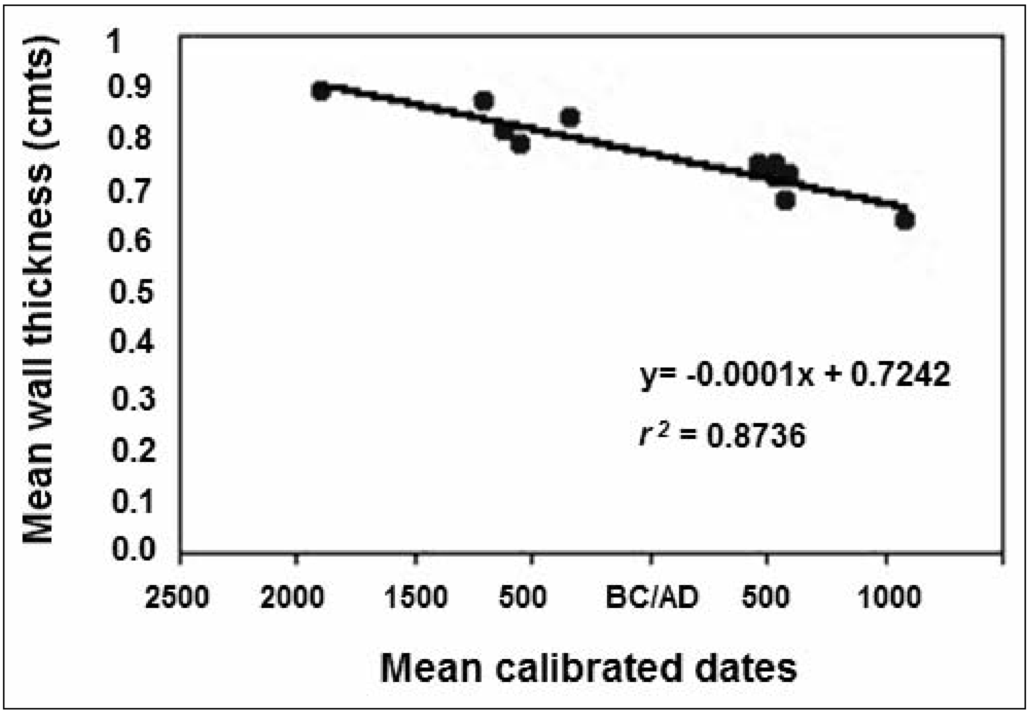

Fig. 10.3. Declination throughout time of the mean wall thickness of the earliest ceramics of Argentina

record documents the evolutionary history of many interactors. It is convenient because evolutionary archaeology needs to enhance the inclusiveness of phenomena to explain with better learning strategies to account for the past than those derived from a single level reductionist approach.

Science demands the existence of standards to assess the true content of competing hypotheses, in a process of selective retention of ideas. As in evolutionary biology, a synthetic paradigm in evolutionary archaeology will provide the theoretical basis for such standards. In this way, an expanded synthetic Darwinism in evolutionary archaeology increases the inclusiveness of the paradigm, leading to the integration of several lines of selectionist research on human behavior and evolution into a single logical framework rooted in evolutionary biology.

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