The Prehistory of Iberia:
Debating Early Social Stratification and the State

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Complex systems, social networks and the evolution of social complexity

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Introduction

Along with the origins of agriculture, the appearance of complex societies–often called 'chiefdoms' and 'states'–is one of the most widely discussed social processes in the archaeological literature. Explanations for the beginnings of complex societies commonly involve ideas of progressive social evolution that can be traced back to 18th century social philosophy of the Enlightenment. Initially propounded in the social sciences by Spencer (1857), Tylor (1865), and Morgan (1877), and employed by early Marxist social theory (Engels and Leacock 1972), similar progressivist concepts can be found in popular neoevolutionary models of Fried (1967) and Service (1962) as well as in the work of Childe (1936). In spite of the many, distinct theoretical perspectives that have been applied subsequently to the rise of social complexity (Damgaard Andersen, Horsnaes, et al. 1997; Nichols and Charlton 1997; Feinman and Marcus 1998; Kristiansen and Rowlands 1998; Cowgill 2004; Yoffee 2005; Johnson and Earle 2000; Lull and Micó 2007), they share with progressivist theory an underlying framework that societies inherently change with time, social universals can be observed in these changes, and social change is usually vectored from simple to complex (Rosenswig 2000, 4).

Complex systems and social complexity

An alternative approach for understanding the evolution of social complexity is based on concepts derived from the study of complex systems. As we illustrate below, complex systems give us new conceptual tools for studying the social processes that drove the evolution of small agricultural communities into political states.

At the outset, we need to be clear that there is no inherent equivalence between the archaeological concept of *complex societies* and the more general phenomena of c*omplex systems*; in fact the simplest human societies are complex systems. Rather, complex systems are a general class of open systems—i.e., requiring energy input to maintain structure and order—sharing a number of important characteristics (Simon 1962; Cowan, Pines, and Meltzer 1994; Henrickson and McKelvey 2002; Bentley and Maschner 2003; Mitchell 2009). Social systems are considered examples of complex systems (Bentley 2003a; Miller and Page 2007). Here, we briefly review the properties of complex systems and the processes by which they change that are particularly relevant to the origin and evolution of complex society.

Complex systems are composed of many interacting components organized into nested groups that can be represented as organizational hierarchies or hierarchically structured networks; the more complex the system, the deeper the nesting of the groups of components. In human terms, such nested groups could be nuclear families within forager bands, and bands within regional metapopulations. They also could be households within clans within chiefdoms, or individuals within craft guilds, within a city within a state.

As Simon (1962) shows, this organization of nested groups is a necessary result of the way in which complex systems evolve; low level components are joined into groups (or subsystems), and these groups are joined into higher level metagroups (or total system). Examples can be seen in the growth and development of multi-cellular organisms, from single cell to embryo to adult, and in the engineering of complex technologies. This evolutionary process helps explain why past societies seem to evolve toward levels of increasing complexity—especially when seen from an incomplete archaeological record. From a complex systems perspective, a multi-level social hierarchy cannot develop directly from autonomous households; a multi-level organizational hierarchy can only develop by combining social groups that already have simpler organizational hierarchies. That is, systems do not inherently progress from simple to complex, but systems that *do* become complex do so according to a characteristic set of evolutionary processes. Thus, from a complex systems perspective the apparent tendency for human societies to evolve in a progressivist way is a function of the way in which complex systems develop, the fact that today's world is dominated by complex societies, and the archaeological viewpoint of looking backward at the past from the present.

One implication of the process by which complex systems evolve is that the subsystems, or groups of components, that comprise complex systems are connected at the level of the subsystem rather than the components that make up the subsystems. For example, tributary states often are members of an empire through the allegiance of the heads of those states to the imperial government, not through the personal relationships of all individuals in each tributary state to the emperor. A further, related implication is that these subsystems potentially can continue to carry out their functions even if the linkages that connect them break and they become disassociated from other similar groups in a complex system. This property, called *near decomposability*, means that complex systems tend to decompose in reverse order to the way they evolve: the highest level groups become independent systems, disassociated from other groups. These groups can then further disaggregate into their respective subgroups. For example, human corneas, kidneys, and hearts can be removed from the system in which they developed, be transplanted into another human system, and continue to function. As complex systems, we should expect to see similar dynamics in the "collapse" of human societies. The western Roman Empire did not collapse into anarchy but decomposed into its administrative provinces, whose boundaries resemble those of modern European nations; recently, those same nations have again self-organized into the European Community.

It should be apparent by now that it is more the character of the *interactions* among components rather than their inherent characteristics that determines the behavior of complex systems. Complex *adaptive* systems (or CAS) are a kind of complex systems in which these interactions can change dynamically through endogamous processes and transmit information about the state of the system among components, allowing them to self-organize (i.e., grow "organically") and respond to their environments. Social systems are examples of CAS. When components of a CAS interact in multiple dynamic ways, the scale and direction of system-level change is not necessarily proportional to the scale and direction of phenomena that trigger it. As a result, a CAS sometimes can absorb a great deal of perturbation and remain relatively unaltered; in other cases, a comparatively minor disruption can initiate a cascade of changes that fundamentally alter a CAS—and can even cause high-level linkages among components to break, resulting in "collapse". This *nonlinear* causality can make system-level behaviour difficult to predict from component properties. However, it has been observed empirically, that the spread of such non-linear changes in a CAS sometimes can be represented by a statistical distribution called a *power law.* A power law is characterized by an equation of the form $N = C/rD$ where N is a property of interest, C is a constant, r is a measure of the scale of N, and D is an exponent (see Bentley 2003a). Power laws can describe changes cascading through a CAS in response to perturbations, relationships between scale and complexity, and the connections among interacting components—phenomena relevant to the evolution of human social systems.

Finally, CAS often exhibit novel behaviors at the system level that are very different from anything exhibited by any components, a phenomenon called *emergence*. An example of emergence can be seen in our bodies, which can carry out system-level behaviors that cannot be observed in any of its individual cells. No single individual posses the knowledge or skill to mine multiple metal ores, extract petroleum, grow appropriate fiber and cellulose-producing plants, and transform them into an automobile within his or her lifetime. But our industrial societies produce thousands of automobiles every day through the coordinated efforts of many thousands of individuals who each possess *part* of the needed knowledge and skills to do so.

Complex systems and society

How can a complex systems perspective help us to understand the evolution of complex societies? In reviewing theoretical considerations for the study of archaic states, Feinman (Feinman 1998, 113) notes that "social properties of human groups and groupings" are critical for understanding long term change in complex societies, and calls for a "reassessment of the size/complexity relationship", emphasizing nested organization of the components of complex societies and the social processes that link these components together. Our aim here is to illustrate the potential to investigate long-term social dynamics from the perspective of organizational and interactional phenomena that are central to both CAS and Feinman's view of social change. To do so, we trace the evolution of complex societies in eastern Iberia as a case study in which we measure variation in multiple facets of complexity across space and time. We focus especially on the dynamics of interactions among social groups as they scale up to increasingly more complex levels of organization.

Scale and complexity

Johnson (1982) examines the relationships between scale and complexity in human societies by focusing on a phenomenon he terms "scalar stress" that manifests itself as an increasing difficulty of consensus-based decision-making as the size of a social group increases. He attributes this decision-making stress to inherent limitations in human cognition and information processing. As the size of a decision-making body grows above approximately six individuals, the number of potential pairwise interactions among group members begins to exceed the ability of human minds to track and negotiate among all of the interactions. Johnson compiles an impressive array of empirical studies that show a clear tendency for a group leader to emerge (i.e., the abandonment of consensus decision-making) as groups grow above sizes that average about six. This process also occurs at the level of coordinating or cooperating groups; as the number of interacting groups increase much beyond an average of six, cooperation and the quality of group decision-making begins to degrade. The implication is that as social groups grow, they do not simply get larger, but rather self-organize and reorganize into hierarchical structures in order to process socially transmitted information and more effectively make decisions that affect constituting individuals and groups.

For small-scale societies in which consensus-based decision-making on a daily basis is feasible, decision-making hierarchies may only form occasionally when small groups come together for special activities, like communal hunts or ceremonies. In these circumstances, the hierarchical organizations are temporary, limited in decision-making scope, and decompose back into basal social units as soon as the need for large scale decision-making has passed; Johnson refers to these as "sequential hierarchies" (1982, 396).

In cases where large social groups exist on a long-term basis, ongoing information processing and decision-making needs encourage the emergence of what Johnson calls "simultaneous hierarchies" (1982, 407), hierarchies that become persistent and institutionalized. In many large societies, multiple, cross-cutting, hierarchically organized institutions emerge, each with leaders, representatives, or governing bodies. Johnson finds that across many societies with institutionalized hierarchies, organizational complexity is strongly related to the total population of the society on a log-log scale (1982, 21.5). Such a log-log scale relationship is also indicative of a power law relationship between the scale of a society and its complexity. As noted above, such power law relationships commonly describe the dynamics of CAS. Johnson suggests that the *scalar stress* of information management and decision-making is an important driver of organizational hierarchies as societies grow in size, and that the quantity, strength, and permanence of the linkages and interdependence among communities will be an important factor in the evolution of complex social structures.

Complexity and networks

The dynamic interactions among individuals and groups in human societies can be represented as networks in which the nodes are social agents and the connections between the nodes (*edges* in network terminology) are the interactions between agents. Hierarchical organization typical of CAS often exhibit particularly structured network topologies (i.e., organizational patterns of nodes and edges), especially when social or institutional components and subcomponents develop through a mechanism called *preferential attachment* (Barabasi 2009; Bentley 2003b). In such contexts, there is a preference for individuals to join groups that already have larger numbers of individuals than other groups, and for groups to join metagroups that include larger numbers of groups. For example, where wealth and social prestige are linked, wealthier individuals are likely to attract more social connections, which in turn generate more wealth, more prestige, and more social linkages; this is often called a 'rich-get-richer' process (Barabasi 2009; Bentley 2003b). CAS that evolve by preferential attachment have very many nodes with few local connections, while nodes that are major 'hubs', with very many connections that extend over entire system, are rare. Networks that evolve in this way are called scale-free networks, and the number of connections per node follows a power law distribution. In social terms, preferential attachment can occur in many settings where there is positive feedback between the number of people and organizational development. For example, if the number of followers of a chief is seen as a mark of his prestige, it can serve to attract more followers.

Similarly, the diversity of economic opportunities in a city can be draw for immigrants, which can increase the diversity and number of economic opportunities. Scale-free networks exemplify ways in which small differences amplify into large social asymmetries and inequalities. Of course, other processes than preferential attachment also can link together individuals and groups or even combine them into nested hierarchies of CAS. In such cases, the connections among network nodes are better represented by other statistical distributions than a power law, providing a way to differentiate between preferential attachment and other processes by which complex systems form.

Complexity in the archaeological record

From the perspective of CAS, social contexts can be characterized by structured ways in which individuals and groups are organized, distinctive evolutionary processes that create these structures as they bind individuals and groups into societies, and distinctive relationships between scale and complexity. To apply these concepts to prehistoric societies, it is necessary then to find expressions of these social dynamics in the static, material-dominated, archaeological record. We have attempted to reorganize existing data to serve as proxies for complex system dynamics, using the archaeological record of eastern Iberia as a case study. Over a span of more than five millennia, from the Neolithic through the pre-Roman Iron Age, we track long-term changes in:

- the structure of socio-spatial networks,
- the strength of coupling among social units, and
- relationships between scale and complexity.

While networks of interaction and communication pervade many aspects of human society, we currently lack consistent archaeological data to serve as proxies for monitoring many of them. However, sites represent communities of individuals whose regional-scale organization can serve as proxy to some kinds of spatially-explicit social networks and their structures. In such socio-spatial networks, settlement hierarchies can develop when one community comes to mediate interactions among other communities (ideologically, socially, or economically). Power law distributions of sites sizes can indicate scale-free socio-spatial networks and growth by positive feedback mechanisms like preferential attachment or wealth inequalities that behave according to 'rich get richer' processes.

Because CAS evolved as independent components become increasingly interrelated within nested hierarchies of functional, informational, and decision-making roles, monitoring the nature of couplings between communities and regions is important for tracking the evolution of societies as CAS. Communities can be largely or completely autonomous. They can be loosely coupled (i.e., near-decomposable) by ideological, kinship, or social ties for example. They can be tightly interdependent, relying on each other economically and politically. We track variation in measures of these kinds of inter-community couplings that can monitor the growth of regionalscale polities composed of increasingly specialized, interdependent segments of the population.

Johnson (1982) identifies power law relationships between social scale and complexity, as societies form increasingly permanent 'simultaneous' hierarchies in response to scalar stress in decision making; we look for such relationships in site distribution patterns. Finally, because complex systems can be characterized by phase changes or tipping points, and the emergence of new system-level phenomena, we seek to identify intervals of rapid societal reconfiguration and emergence.

Archaeological datasets

We draw on a wide range of published datasets from eastern Iberia, which we define as the region between the Rio Júcar (north) and Rio Segura (south). Agriculture appears here by 5,600 cal BC, with the expansion of Neolithic societies over the next two millennia. Copper metallurgy appears at the beginning of the 3rd millennium BC, and iron metallurgy in the 1st millennium BC.

During the first half of the 2nd millennium BC, the region seems divided socially into two zones, whose boundary lies between the Rio Segura and Rio Vinalopo. The southern zone is dominated by the well-known archaeological culture of El Argar Bronze Age; the different suite of archaeological assemblages to the north include the Valencian Bronze Age; Bell Beaker ceramics spread across the entire region at this time. The Late Bronze Age is poorly known in both zones. Most Late Bronze Age sites currently known are found in the geographically intermediate region between Argaric and Valencian Bronze Age. Archaeological data remain sparse after 1200 BC until the Iberic Iron Age communities of the 6th century BC. It was probably near the end of this 600 years that regular contact with the wider Mediterranean world began to have significant impacts, with the establishment of Phoenician and Greek colonies from at least the 8th century onwards.

Although much of the rich archaeological data published from eastern Iberia were not suitable for our analyses, we were able to sample the archaeological record from different parts of this region. Information about Neolithic through Bronze Age of the *central valleys* comes from upland Serpis, Albaida, and upper Vinalopó valleys, located between the cities of Valencia and Alicante (Jover Maestre, López Mira, and López Padilla 1995; Jover Maestre and López Padilla 2005; López Padilla 2009; Ribera and Pasqual Beneyto 1994; Ribera, Pascual Beneyto, et al. 2005). Data on the Argaric Bronze Age derive from the Segura valley, southern Alicante Province (López Padilla 2009). Due to its small sample size, we use the sample from the Vera Basin, Almeria province (Lull Santiago, Micó Pérez, et al. 2009) to complete the information. For the Iberic Iron Age we draw on data from the *northern valleys* in Utiel-Requena region of Valencia Province (Mata Parreño 1991; Moreno Martín 2011).

The chronology of the sub-regions used here is shown in Figure 1; the data, reorganized to monitor the evolution of societies as complex systems, are presented in Table 1 and Figure 2. For some of the analyses, we combined datasets to increase sample sizes, but only merged those that are chronologically equivalent or immediately sequential and that display strong similarities in the archaeological record. We combine: Neolithic IA and IB, Neolithic IIB an northern Bell Beaker, the Argaric Bronze Age of the Vera and Segura valleys, and Iberic Iron Age sites of the 5th through 3th centuries.

Measuring complexity

It is more difficult to identify power laws in real-world data sets than might be imagined from the literature, and further complicated by the incomplete nature of the archaeological record. A power law is often described as having a linear distribution when graphed on a log-log scale, but this is not always the case; while it may have a long, straight tail on a log-log plot the remainder of the distribution can be curved. Moreover, there are distributions that superficially resemble power laws but can have subtle but important differences (Bentley, Ormerod, and Batty 2009; Clauset, Shalizi, and Newman 2007; Maschner and Bentley 2003; Bentley 2003b; Vespignani 2009 ; see Figures 2A, B). Finally, structured networks in complex systems may not always follow a power law distribution (Xu, Liu, and Liang 2009). Hence, we followed robust procedures described by Clauset, Shalizi, and Newman (2007), and used their statistical routines for the open source R statistical package (R Development Core Team 2010), to identify power law distributions in the archaeological record.

We evaluated a power law for site size distributions as a two-step procedure. First we evaluated how well a power law fit each group of sites, then we compared the power law fit to that of other statistical distributions (log normal and exponential, following Bentley (2003b)). To assess goodness of fit for a power law, we first calculated the equation of a power law distribution that best fit the archaeological site data. Then we used this equation to generate multiple test data sets that conform to a true power law distribution[1] (Figure 2A, B). Finally, we performed a Kolmorgorov-Smirnov (K-S) test between each of the power law test datasets and the archaeological site dataset, and averaged the p-values from the tests. These are reported in Table 1 (Table 1). Low mean p-values ($p < 0.1$) indicate that the empirical data differ from a true power law distribution; higher values suggest that the empirical data could come from a power law distribution. We then calculated the log likelihood for the fit of a power law, a log-normal, and an exponential distribution to the archaeological site data; we compared the log likelihood values for the three distributions with Vuong's statistic (see Clauset, Shalizi, and Newman 2007 for a complete description of this procedure).

Our analyses suggest that a power law may fit the distributions of the early Neolithic (Neolitithic IA and IB combined) and Chalcolithic (Neolithic IIB and Bell Beaker combined) sites from the central valleys, possibly the Argaric Bronze Age, and the merged 5th-3rd centuries sample for the Iberic Iron Age. Small sample sizes and negative log-likelihood analyses produced more questionable or inconclusive results for the Middle Neolithic (IC and IIA), Valencian Bronze Age, and Iron Age of the 6th and 2nd -1st centuries.

Measurements of linkages between social system components is shown in Table 1. We have attempted to identify published archaeological evidence for variation in the strength of coupling between components, scoring evidence for coupling on an ordinal scale (see legend of Table 1). Then we summed the coupling scores into an *Internal Coupling Index* (ICI). This provides a rough estimate of the degree of what is sometimes called system integration but which also characterizes the evolution of complex systems. We also calculated an *External Coupling Index* (ECI) in a similar manner, using evidence for interactions between regions and with systems beyond the Iberian peninsula. These indices represent an admittedly subjective, though systematic, transformation of qualitative data into quantitative form. However, the results we discuss below suggest the potential value of seeking more robust quantitative measures of intraand inter-system coupling in future work.

There is a long-term trend towards higher ICI and ECI values, suggesting increasingly tight social linkages at expanding regional scales from the Neolithic through the Iron Age. This represents a shift from autonomous communities to large polities, in which individuals and groups took on different but complementary ideological, social, and economic roles, and in which inhabitants were interdependent in many ways. However, as seen in Figure 2E, this did not increase continuously over time, but displays long periods of stability interspersed by intervals of rapid change.

To investigate relationships between social scale and complexity, we compared the number of sites (a rough proxy for the scale of the system) with the ratio of the areas of the largest and smallest site measured in each period. As the power law analysis made clear, site size distributions are skewed in different ways, and published sizes are binned for some regions

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[1] Clauset et al. (2007) recommend generating thousands of data sets. We were unable to do this, but generated 20 artificial data sets for each empirical one. Nevertheless, the averaged p-values from K-S comparisons of these 20 artificial data sets with the empirical one seem to do a good job of representing the central tendencies of the variability in the generated data points.

biasing variance and related statistics; size range also is strongly affected by the absolute size of sites. The ratio of largest/smallest is not affected by either distributional skew or absolute site area, providing the most consistent measure of site size complexity from the available data. However, even this simple measure was biased by the different ways in which site size was measured. For Neolithic through Chalcolithic sites, site area were calculated on the basis of the extent of visible artifactual material, while Bronze Age and Iron Age site areas were based on visible architecture. For this reason, we divided the analysis into earlier and later periods (Figure 2B, C). For both, scale and complexity are strongly related and covary in a power law relationship of the kind ascribed by Johnson (1982) to the creation and elaboration of permanent decision-making hierarchies. As with intergroup linkages, system-level growth is not continuous but displays equilibria punctuated by rapid change over the five millennia we examine (Figure 2F). Interestingly, those periods in which settlement sizes most closely resemble a power law distribution also mark periods of maximum growth and bracket intervals of rapid increase in the quantity and strength of intra- and inter-system linkages.

Discussion

Complex adaptive system concepts offer new insight into the evolutionary dynamics of social complexity over a period of more than 5,400 years in eastern Iberia. Measures derived from CAS properties and processes show that a number of features widely considered markers of complex societies have independent trajectories driven by different social/economic/ideological forces. Notably, the hierarchical organization appears and disappears independently of the dynamics of integration and interdependence. On the other hand, other features like scale and complexity do seem tightly linked. Moreover, temporal signatures of punctuated equilibria characterize the trajectories of social change.

Socio-spatial networks and system coherence

The analysis of power law distributions indicates that highly structured socio-spatial networks do not evolve gradually nor are they limited to the most 'complex' societies. The best evidence for hierarchically structured social networks generated through preferential attachment or similar positive feedback is for the early Neolithic, the Chalcolithic (possibly continuing into the Argaric Bronze Age), and the middle-late Iron Age. The demographic, economic, and ideological contexts differ significantly among these periods suggesting that this kind of social hierarchy can arise in multiple circumstances.

In the early Neolithic, population is dispersed within non-contiguous agricultural zones. Evidence for interregional or even inter-community connections seems to be at the level of individuals, and there is no evidence for significant wealth inequalities or ascribed status. Yet the marked differences in site sizes and evidence for a power law distribution suggests positive feedback mechanisms linking the size of a community and its potential for growth. One possibility is that founder communities with a head start in transforming woodland into farmland within each region made them more attractive to new settlers than communities established later. More new settlers clearing more land would increase the attractiveness of founder communities —the reverse of an ideal or despotic free distribution model for agricultural settlement (McClure, Jochim, and Barton 2006; McClure, Barton, and Jochim 2009). But we lack sufficient highresolution dating to verify this relationship between temporal preeminence and size at present.

Another possible driver of site hierarchies relates to the creation of monumental earthworks. At the early Neolithic site of Mas d'Is, in the Penaguila valley of the Serpis River drainage, two very large ditches were built, at a cost of over 100,000 person hrs. (Bernabeu Aubán et al. 2006). Evidence that the ditches were dug rapidly and maintained open for a long time suggests that a large labor pool was assembled here, despite contemporaneous settlement being otherwise distributed in scattered farmsteads. The same large labor pools could conceivably have been mobilized to increase agricultural productivity in some way, but there is of yet no archaeological evidence for the construction of landesque capital at this time. The ability to mobilize large labor pools persisted (or returned periodically) to Mas d'Is and perhaps to some other localities with such earthworks, and so was attached to place in some way. It may have been driven by ideology, control of marriage networks, or other kinds of archaeological invisible social power, but it does not seem to have been associated with the accumulation of wealth and economic power. The subsequent disappearance of site distributions characterized by a power law could indicate that the structured socio-spatial networks of the early Neolithic fell apart or simply that we are lacking sufficient data to identify them. In this respect, there does seem to be significant social and economic reorganization at the end of the Neolithic that may result from the collapse of the early Neolithic subsistence system due to the interaction of land-use and climate change (McClure, Barton, and Jochim 2009).

The reappearance of highly structured socio-spatial networks in the Late Neolithic/Chalcolithic occurs in a very different socioeconomic context. The range of variation in site size (Max/Min ratio in Table 1) is greater than that of the early Neolithic by an order of magnitude, mainly due to the growth of sites like Les Jovades (at over 30 ha). There is no evidence for community projects like early Neolithic monumental earthworks, but considerable evidence for the accumulation and unequal distribution of wealth in various forms. Sites like Les Jovades have many large storage-pits clustered in small areas, and burials of a few individuals accompanied by goods that require considerable labor and expertise to produce (i.e., specialists) and sometimes materials from a great distance. Moreover, the appearance of the plow at this time indicates that the means of agricultural production come at higher cost (draft animals and more complex technologies) but allows an individual to produce more. Finally, there is evidence for competition and conflict in the form of defensive enclosures around sites like Niuet and Arenal de la Costa and La Vital (Bernabeu Aubán et al. 2006; Chapman 2008), and burials with daggers (Pérez Jordá et al. 2011).

Different and possibly co-evolving positive feedback mechanisms may account for the evolution of scale-free socio-spatial networks in the Chalcolithic. Increased agricultural costs can lead to debt relationships where a debtor owes labor to a patron, allowing the patron to accumulate more surplus and more means of production, and enter into more client-patron relationships. Centrally-controlled storage of agricultural surplus would attract households seeking to reduce inter-annual uncertainty in harvests, who could contribute additional surplus to stores available for redistribution, attracting yet more households. Prestige competition and conflict between emerging elites also would encourage them to seek more followers (e.g., through feasting, gift giving, and other forms of redistribution) who would augment their prestige.

The Chalcolithic is a time of significant and rapid population growth. Johnson's scalecomplexity relationship may apply here, but it looks as though any decision-making hierarchies are of the temporary, 'sequential' form. In spite of evidence for increasing complexity in social interactions and in inequalities of wealth and power, there is little indication of the kinds of socio-economic specialization and interdependence that bring together multiple communities in complex social systems requiring permanent hierarchical information processing and decisionmaking. There is no evidence of mass production and items of special workmanship could be created by part-time specialists at the household level. Most goods requiring special skills seem to end up with a few individuals, again indicating elite prestige and possibly elite-mediated ideologies as forces behind socio-spatial network structures. Agricultural production remains at a subsistence level, with some surplus production to contribute to community stores possibly managed by elites; although monoculture may begin to appear in a few locales, there is no evidence for market crops. Evidence for interregional and extra-regional trade increases (ECI in Table 1 and Figure 2E)–with some items coming from distant places like Africa (e.g., ivory, Schuhmacher, Cardoso, and Banerjee 2009; Chapman 2008)–but this makes up an insignificant part of the economy overall. If communities begin to operate in some kind of coordinated way at a regional level, they seem to be linked only very loosely. While Bell-Beaker ceramics exhibit common form and design attributes throughout the region, they were made locally. Craft products may move among elite, but seem to link them with weak ties over broad geographic areas (Chapman 2008; Bernabeu Aubán et al. 2006; Thomas 2009).

The trends in socio-economic organization that appear in the Chalcolithic, may continue to develop further in the Argaric Bronze Age, with more differentiation among sites—small agricultural communities and larger, fortified hilltop sites—and greater specialization in metallurgy (possibly with some regional scale standards represented by copper ingots). Argaric necropolises also indicate greater social differentiation than earlier. Elite burials display greater accumulations of wealth, especially in the form of weaponry, and even suggest the appearance of ascribed status (although there is no evidence for this in the Valencian Bronze Age). On the other hand, craft good seem to be moving among elites over much more limited distances than in the Chalcolithic (Chapman 2008). Moreover, the evidence for scale-free socio-spatial networks is more equivocal than earlier. This may be because of the nature of the available settlement data, however. There are few sites for which areas are reported, there are inconsistencies in the way areas are measured, and published sources group site size into classes rather than report them by site.

The contemporaneous Valencian Bronze Age of the central valleys, on the other hand, does not show evidence of the kind of structured networks found in the Chalcolithic. And although there is considerable *relative* variation in site sizes (max/min ratio in Table 1), the largest sites known are much smaller than earlier Chalcolithic or contemporaneous Argaric ones. Moreover, there is a decline in extra-regional linkages for the Valencian Bronze Age that is not seen for the Argaric (ECI in Table 1), underscoring the more local character and smaller scale of social interactions in this part of eastern Iberia.

The archaeological record for the late Bronze Age (1,200-800 BC) is very sparse and not well known throughout eastern Iberia; the sample we use here comes from a much smaller geographic region than either the Argaric or Valencian Bronze Age samples. Some researchers have interpreted the limited available evidence as suggesting continued growth of inequalities in wealth and power, along with increased competition and conflict. This is accompanied by continued expansion in extra-regional exchange and craft specialization (especially metallurgy) (Chapman 2008; Perea Caveda 2001; Ruiz-Gálvez Priego 2001). Some of these trends also are reflected in our analyses (Table 1). However, the power law analysis indicates that socio-spatial networks are not highly structured, suggesting semi-autonomous communities and more 'egalitarian' inter-community relationships. Given the nature of the archaeological record, these results should be taken as suggestive at best.

The Iberic Iron Age displays for the first time a convergence in the trajectories of sociospatial network growth, wealth inequalities of the 'rich get richer' form, economic specialization, and interdependence. Moreno (2010) presents a detailed picture of the evolution of the northern valley regional system as communities join into local clusters, aggregate into larger ones, and eventually form a single regional polity centered on the primate center of Kelin. This suggests that the scale-free networks indicated by the power law analyses represent institutionalized information-processing and decision-making hierarchies that Johnson ascribes to scalar stress. Coeval with this are the presence of specialist-produced goods at the household level, polyculture for market and exchange, unified systems of weights and measures, and a writing system. These underscore the importance of specialized information processing in addition to specialized production. These are all indicative of the extent to which communities are interacting to create an emergent socio-political entity that exchanges with, competes with, wars with, and is eventually destroyed in the II century by other emergent polities in the Mediterranean sphere.

Growth, complexity, and organizational dynamics

Site numbers and sizes are only a rough approximation of population, but monitoring change in CAS phenomena shows that growth in Iberian social systems is neither consistent or gradual over the more than five millennia we track; both amount and rate of growth are episodic (Figure 2E, F, Table 1). Of especial interest to the evolution of complex societies, highly structured interaction networks seem to dominate during times of high system growth rates. This may be one common feature of the otherwise very diverse drivers of these kinds of networks. Moreover, system scale also seems closely tied to complexity, as Johnson (1982) predicts, regardless of time period (Figure 2B, C). In other words, increased complexity seems inevitable when systems grow, either due to demographic increase or due to autonomous communities organizing into the emergent meta-societies we call polities or states. Johnson offers a convincing argument that information-processing limitations at the level of individual agents are in part responsible for this emergent system-level behavior. However, the increased opportunities for accumulation of wealth and social power by a few individuals—and the related ability of wealth to generate wealth—also can initiate positive feedbacks that increase organizational complexity as systems scale up (Bentley 2003b; Maschner and Bentley 2003).

The CAS perspective on social dynamics we employ here suggests that there are multiple ways to achieve what appears as a settlement hierarchy in the archaeological record, and that the accumulation of wealth and power that mark elites can appear in a variety of contexts. However, these do not necessarily go hand in hand with multiple levels of socio-economic interdependence and socio-political hierarchies of decision-making, information processing, and control. The latter are found only in limited contexts. Following Johnson (1982), there is probably a threshold of system scale that makes these both possible and necessary. At several times in the *longue durée* of social evolution we follow here, some kinds of hierarchical interaction networks arose, only to decompose subsequently.

In fact, most of this time span is characterized by very loose couplings between communities and other social groupings. This allowed individuals, households, and communities to socially coalesce and disperse flexibly in response to a shifting social and ecological landscape. The convergence of previously distinct trajectories of social dynamics in the Iron Age created a larger and more productive system, but at the cost of social flexibility.

We do not use the term 'collapse' here because from the perspective CAS and long-term social dynamics we adopt here, there is no evidence for social collapse as it is commonly portrayed. While some aspects of society may become less complex, others become more so at the same time. Perhaps collapse as it is traditionally conceived cannot occur until the distinct features of complexity we discuss here converge and begin to operate synchronously, as they seem to do in the 5th -3rd centuries. Only with such convergence, can a social system decompose simultaneously in multiple ways.

Concluding thoughts

At the beginning of this essay we noted that much of the literature concerned with the rise of complex society implicitly or explicitly frames this topic within the concept that societies are organized into stages of complexity, whether they are called tribes, chiefdoms, and states or small-scale societies, middle range societies, and state-level polities. Change is seen as transformation from tribe to chiefdom or chiefdom to state. This implies that: 1) there are a suite of fundamental social phenomena that co-occur in human societies regardless of time or place that make them chiefdoms or states; and 2) a society stays in a kind of social equilibrium within one of these stages until the jump (or 'collapse') to another stage occurs as a transformation in which a society rapidly reorganizes to take on the suite of characteristics common to the new stage. When social change becomes transformation from one state to another, its causes become very difficult to discern archaeologically, in spite of numerous ideas about what those causes might be.

In the case study presented here, we find that phenomena commonly considered to characterize stages of social complexity do not necessarily co-occur or co-evolve, although their trajectories can converge to varying degrees in some cases. Following these trajectories and attempting to explain them leads to view social change as a multivalent evolutionary dynamic rather than transformation from one stage to another. A universal stage like a "state" into which Uruk, the Cordovan Caliphate, the United States, and—for some in eastern Iberia—the Argaric Bronze Age are classified, masks much more variability than it reveals commonalities. If there are universals in the rise of complex societies, it is more likely that they will be found in the underlying processes or *algorithms* that drive the evolution of complexity. The approach we illustrate here emphasizes the evolutionary dynamics rather than the outcomes of social change. While we consider this only an initial attempt to apply a complex systems perspective to the rise of social complexity, it offers a potential for new insights that warrants further exploration and elaboration.

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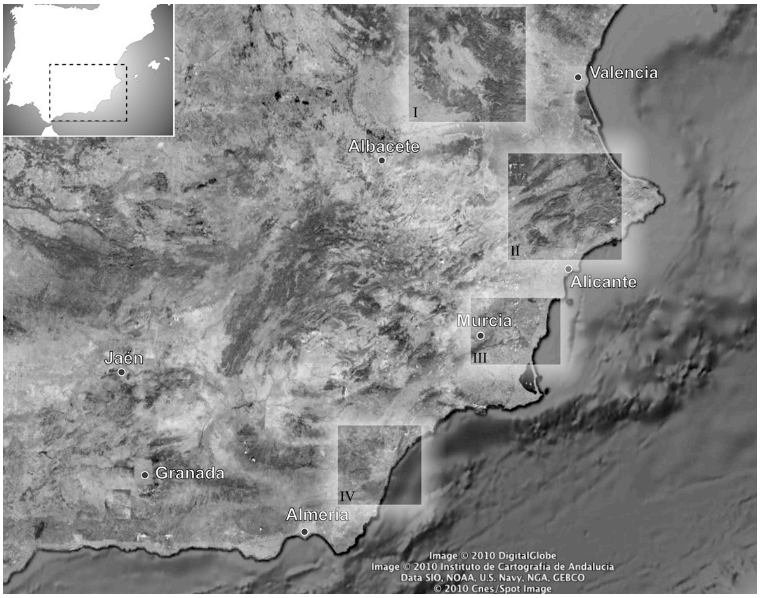

Dates B.C.	Cultural Period	PHASES	NORTHERN VALLEYS	CENTRAL VALLEYS	SOUTHERN VALLEYS
5600 5100	**NEOLITHIC**	Early Neolithic	*scarce and scattered evidences*	*Neolithic IA* *open villages in valleys bottoms*	*scarce and scattered evidences*
4900				*Neolithic IB*	
4500 4000		Middle Neolithic		*Neolithic IC, IIA*	
3500 3000		Late Neolithic	*Neolithic IIB/Chalcolithic* *Villages with ditches in valleys bottoms*		
2500	**COPPER AGE**	Pre-Beaker Chalcolithic	*First Metalworking (copper)*		
2100		Beaker Chalcolithic	*Bell-Beaker (HCT)* *First terraced settlements on hilltops*		
1500	**BRONZE AGE**	Early/Middle Bronze Age	*Bronce Valenciano*		*Cultura del Argar* copper ingods
1200		Late (*Tardío*) Bronze Age	*development of bronze Metalworking*		
850		Final Bronze Age			
700	**IRON AGE**	Early Iron Age	8th cent.: 1st Phoenician settlements in South Ib. Peninsula		
			600 BC Emporion is founded by Greeks		
500		Late Iron Age: Iberian Culture	*Ancient Iberian* (575/550-475/450 BC)		
			Classical Iberian (450-250/225 BC)		
200			*Final Iberian* (225 BC- CE)		
0	**ROMAN CONQUEST**		219 BC II Punic War; 218 BC begining of Roman Conquest		

Figure 1. Regions of eastern Iberia discussed in text and regional chronologies.

	Early Neolithic		**Middle Neolithic**		**Chalcolithic**		**Bronze Age**			**Iron Age: Iberian Culture**		
	Neol. IA	Neol. IB	Neol. IC	Neol. IIA	Neol. IIB	Bell Beaker	Valencian EBA	Argaric EBA	Valencian LBA	VI cent.	V/III cent.	II/I cent.
Median Age BC	5300	5100	4700	4000	2800	2300	1800	1800	1400	500	250	100
System Integration												
Agrocultural Economy	1	1	1	1	2	2	2	2	2	3	3	3
Craft Production	1	1	1	1	4	4	4	4	6	7	8	8
Shared Institutions	1	1	1	1	2	2	2	3	3	3	4	4
Specialized Settlements	0	0	0	0	2	2	2	3	3	6	7	7
Internal Coupling Index	**3**	**3**	**3**	**3**	**10**	**10**	**10**	**12**	**14**	**19**	**22**	**22**
External Coupling Index	**1**	**1**	**1**	**1**	**3**	**3**	**2**	**3**	**4**	**6**	**6**	**6**
	Autonomous			←			***Loose Coupling***		→			***Tight Coupling***
Settlement Organization												
Northern Valleys N(n)										14(37)	32(181)	17(85)
Total Area (Growth Index)										28.4	43.5 (1.53)	38.6 (0.88;0.94)
Max/Min site area ratio										NA	172	100
PowerLaw K-S mean p										0.210	0.390	0.240
Central Valleys N(n)	13	24(29)	11	7	31(46)	7	127		22			
Total Area (Growth Index)	12.4	24.4 (1.96)	13.3 (0.55)	11.6 (0.87)	104.3 (8.99)	6.8 (0.06)	8.65		5.2			
Max/Min site area ratio	32	46	13	5	250	30	167		40			
PowerLaw K-S mean p	0.330		NA	NA	0.320		**0.001**		**0.002**			
Southeast N								29				
Total Area (Growth Index)								24.5				
Max/Min site area ratio								53				
PowerLaw K-S mean p								0.350				

System Integration

Agrocultural Economy

Subsistence agriculture = 1; mixed agriculture & secondary products = 2; polyculture & market crops = 3

Craft Production

Household = 1

Part-time: basic metallurgy; specialized flint (long blades); textiles (1 each)

Specialized: advanced metallurgy, pottery, jewelry, art (1 each)

Shared Institutions

Basic-low: local/regional styles (e.g., ceramics, ground stone) or iimited interregional design elements = 1

Basic-medium: interregional styles (e.g., figurines, Bell Beaker ceramics) = 2

Advanced-low: standardized items (e.g., ingots) = 3

Advanced-high: standardized weights and measures; writing; currency = 4

Specialized Settlements

Primary production: agriculture/pastoralism; olive/wine = 1 each

Raw material extraction: stone (e.g., flint, green stone); metal ore = 1 each

Craft production: metallurgy; ceramics = 1 each

Social/political control: military; administrative (e.g., palaces) = 1 each

***Internal Coupling Index** (ICI) = sum of system integration scores*

Intersystem Linkages

Interregional Trade (between neighboring regions)

Low (a few raw materials only) = 1

Medium (common exchange of raw materials) = 2

High (finished craft items) = 3

Long Distance Trade (beyond Iberian peninsula)

Low = 1; Medium= 2; High= 3. (same categories as interregional)

***External Coupling Index** = Sum of intersystem linkages scores*

Settlement Organization & Socio-spatial Networks

N: sites with area calculations used in the power law analysis

(n): all known sites for each period

Total Area: total combined area (ha) of sites with area calculations for each period

Growth Index: Total Area of current period divided by Total Area of preceding period

Max/Min: area of largest site divided by area of smallest site for period

Power law K-S mean p: Repeated Kolmogorov-Smirnov test probability that the observed distribution differs from a power law distribution. White on black highlights cases where p > 0.1

Table 1. Archaeological data indicating degree of system integration (top) and site distribution data, including summary of power law analyses (bottom) for each time period discussed.

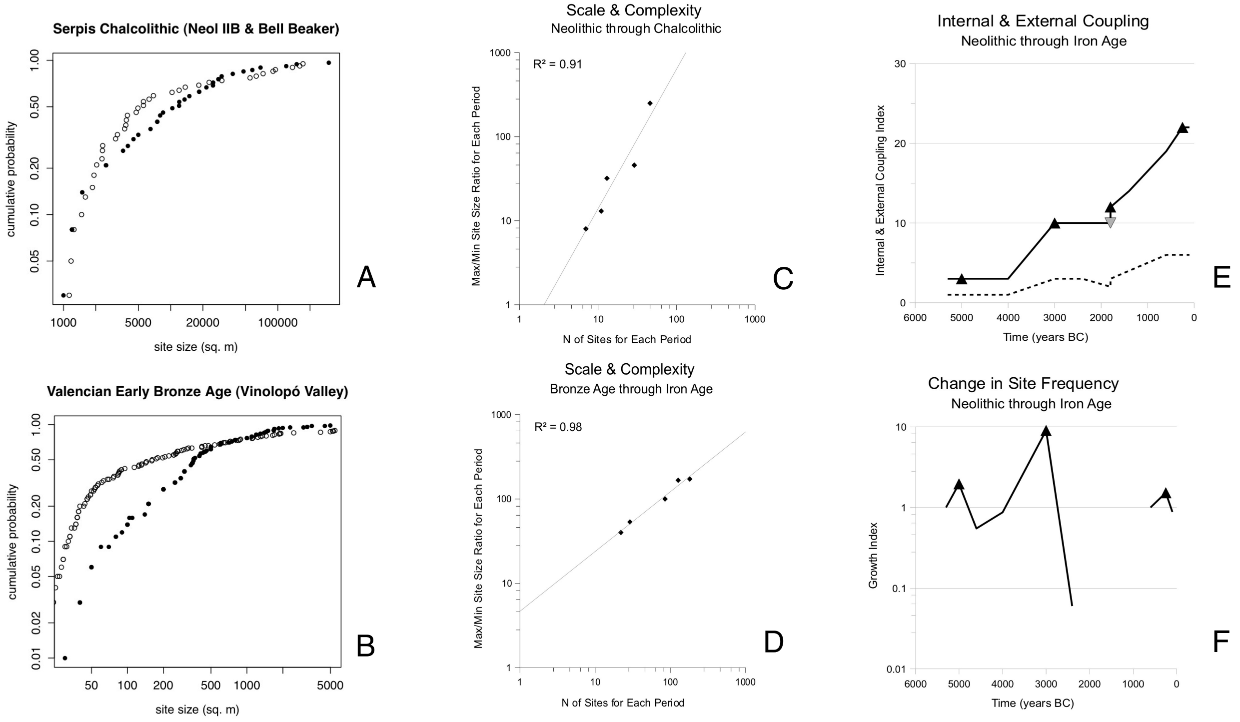

Figure 2. Results of analyses. A and B: site size distributions for Chalcolithic and Valencian Bronze Age (solid circles) and points generated from best fit power law (open circles). C and D: scale vs. complexity for sites with areas calculated from artifact distributions (C) and with areas calculated from extent of architecture (D); lines and R^2 indicate least square fit on log-log scale. E: Internal and External Coupling Indices plotted over the time interval discussed; vertical black triangles indicate periods with likely power law distributions for sites, reversed grey triangles indicate period when site distribution is not a power law. F: growth index plotted over time interval discussed; gap in line indicates missing data; power law site distributions indicated by triangles as in E.