1983 Extending the Scope of Settlement Analysis

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Archaeological Hammers and Theories

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Central-place models and rank–size analysis are important tools for interpreting stratified society settlement patterns. Numerous reviews and compendia consider the use of central-place models in archaeology and anthropology (e.g., Blanton 1976a; Chang 1968, 1972; Clarke 1977; Earle and Ericson 1977; Hodder 1978; Hodder and Orton 1976; Johnson 1977; Renfrew and Cooke 1979; Skinner 1964, 1965a,b, 1977; B. D. Smith 1978; C. A. Smith 1976a). Rank–size analysis has achieved particular popularity as one bridging argument from central-place models to archaeological data (e.g., Blanton 1976b; Crumley 1976; Johnson 1977, 1980a,b; Kowalewski 1980; Paynter 1982). However, as is true with any model or analytical technique, there are limits to the usefulness of these ideas.

Recalling Flannery’s (1976:162) distinction between settlement systems and patterns provides a framework for investigating limits of central-place models and rank–size analysis. As Flannery points out, settlement systems are the explanatory models used to interpret empirical patterns; patterns, on the other hand, are drawn from the settlement data. In the
following, I consider three problems in using central-place systems to interpret archaeologically recovered settlement patterns.

First, due to uncontrollable biasing processes, some sites of a past system will have been eliminated. Thus, archaeologists are not likely to recover the entire pattern of the past system. Second, due to the spatial scale of past ways of life, any settlement pattern is not likely to be interpretable with one complete settlement system. Third, the institutional assumptions underlying conventional central-place systems are not likely to be relevant for interpreting past sociocultural systems. Obviously, interpreting incomplete patterns with models of entire systems, or using inappropriate behavioral assumptions leads to misleading results.

Whereas these points suggest that central-place systems cannot be simply applied to settlement patterns, they do not, as I argue subsequently, lead to the rejection of this approach. Rather, they stand as challenges to develop and refine available methods and theories. Thus, in more fully discussing these problems, I also make some suggestions for the circumvention of these problems. In this regard, rank-size analysis is particularly useful in illustrating alternative methodological strategies.

This chapter is organized into two sections. The first presents the role of central-place models and rank-size analysis in analyzing settlement patterns. The second section explores the three problems and suggests some concrete methodological strategies and theoretical directions to expand the usefulness of central-place models and rank-size analysis.

SETTLEMENT SYSTEMS AND THE RANK-SIZE RULE

The Analysis of Hierarchies with Central-Place Models

As in any field of scientific research, theory building in settlement studies follows two basic tendencies: (1) generalizing from patterns and (2) deductions about abstract systems. The generalizing approach is concerned with describing the range of settlement patterns encountered in the archaeological record. These include monographs and articles describing relatively egalitarian systems (e.g., Binford 1978, 1979a, b; Thomas 1973) and relatively stratified systems (e.g., Adams 1965, 1981; Adams and Nissen 1972; Blanton et al. 1979; Johnson 1973; MacNeish 1972; Parsons 1971; Sanders et al. 1979; Willey 1949, 1956). The payoffs of this approach include general temporal and spatial typologies of empirical settlement patterns (e.g., Chang 1972) and general correlations between settlement pattern types and other dimensions of culture (e.g., Beardsley et al. 1956). Thus, the generalizing approach provides intersubjective categories for describing specific settlement histories and provocative data concerning ethnoarchaeological theory (e.g., R. McC. Adams 1975; Johnson 1973; Sanders et al. 1979; Willey 1979; Wight and Johnson 1975).

A second broad approach elucidates the abstract relationship between settlement patterns and dimensions of a cultural system. A frequently studied relationship, inspired by general ecology (e.g., MacArthur 1972; Pielou 1969), is between the subsistence practices of a group and the resultant settlement location(s) (e.g., Binford 1964; Flannery 1968; Green 1980; Guumerman 1971; Jochim 1976; Keene 1981; Perlm 1976; Wilsen 1973; Zimmerman 1977). However, not all research has concentrated on human-environment interactions. For instance, demographic processes, particularly growth processes, have been linked to such settlement phenomena as waves of advance (Ammerman and Cavallo-Sforza 1979; Mosimann and Martin 1975), centralizing tendencies (e.g., Wobst 1974), and pattern evolution (e.g., Swedlund 1975). The frictional effects of space on interactions have been rigorously studied with distance decay models (e.g., Hodder and Orton 1976:98–154; Renfrew 1975). The effects of varying political economic institutions have been studied in prehistoric (e.g., Blanton et al. 1979; Johnson 1980b) and historical settings (e.g., Ceci 1977, 1980; Kramer 1979; Lewis 1977; Payntr 1982; C. A. Smith 1978). And, recent work considers how ideology (e.g., Marcus 1973), the ideology of legitimization (Kus 1981), and the nonuniform flow of information (Moore 1981) all constrain settlement patterns.

A key characteristic of stratified society landscapes, found in studies of patterns and systems, is that settlements are arranged in hierarchies (e.g., Flannery 1976) within a large number of small places and a small number of large places. Empirical studies have greatly refined the site typologies used to analyze hierarchies, as can be noted by comparing Willey’s (1949:7) pioneering site typology to the 15 types used by Sanders et al. (1979: 55–58) to study the Basin of Mexico. In theoretical studies, the major interpretive models are based on central place theory (e.g., Blanton 1976a; Crumley 1976; Evans 1980; Johnson 1972, 1975, 1977; Paynter 1982; Smith 1579; Steponaitis 1978).

Central-place theory includes approaches to a variety of problems concerning the variation in settlement size and location (e.g., Berry 1967; Christaller 1966; Lösch 1967). Reviews of these approaches are readily available in the anthropological and archaeological literature (e.g., Blanton 1976a; Crumley 1976; Johnson 1977; Smith 1976a; Skinner 1964, 1965a, b). Rather than cover this ground again, I briefly consider a few essential concepts used in studying settlement hierarchies.

Two key concepts used to model and interpret hierarchies are the economic functions of a place and the frictional effects of distance. Many
versions of central place theory conceptualize settlements as aggregates of economic functions. The economic functions often involve exchange, retail exchanges in Christaller’s models (1966) and wholesale exchanges in Vance’s (1970) approach. Hierarchies, in theory, result from different places supporting different numbers and kinds of economic functions.

Algorithms for allocating economic functions to places are usually based on the frictional effects of distance. All economic exchanges involve moving goods and/or people over space. Overcoming the friction of space (i.e., movement) involves someone’s expenditure of energy. Furthermore, central-place theory suggests that people will not travel equal distances to engage in all exchanges. Some exchanges attract people from great distances, whereas others only attract people from nearby. The maximum distance people move to enter an exchange is referred to as the range of the function (e.g., Smith 1976b:12). Thus, a settlement hierarchy has different-sized settlements supporting different numbers and kinds of exchanges that involve people from different-sized surrounding areas.

One of the major versions of central-place theory, Christaller’s (1966), develops hierarchies as follows. This approach assumes that if a place offers a large-ranged function, then it also offers all smaller-ranged functions. The allocation of ranges to places is based on various assumptions regarding the extent to which ranges of items from different places overlap. For instance, the marketing principle allocates large- and small-ranged functions so that any smaller place is equidistant from three larger places. This arrangement, known as \( k = 3 \) lattice, maximizes range overlap and minimizes the spatial costs of interaction between people of large and small places. The transport principle allocates economic functions so that any smaller place is equidistant to two larger places. This arrangement, known as \( k = 4 \) lattice, minimizes spatial costs for interaction between relatively large places. The administrative principle \( k = 7 \) lattice arranges economic functions to minimize range overlap, so that smaller places are closest to only one large place (e.g., Christaller 1966:71–80; Smith 1976b:18–23).

Central place models in general, and the Christaller approach in particular, have a number of useful characteristics for interpreting archaeologically derived settlement patterns. For instance, there is an intuitive connection between the number of economic functions supported at a place and the physical size of the place (a point subsequently given more attention). Thus, central-place models provide a behavioral correlate for archaeological data, namely that different-sized settlements supported different numbers of economic functions.

A second useful point involves the range of an economic function with the concept of the friction of distance. The Christaller assumption that large-ranged sites are also the sites supporting the greater number of functions. This matches the intuition that large places tend to influence large areas, whereas smaller places tend to influence smaller areas. This can be put to use in studying the degree of internal differentiation of a sociocultural system. For instance, the idea that some sites had more influence than others implies a differentiation regarding the exercise of power. Wright and Johnson (1975) suggest that settlement hierarchies reflect the degree of differentiation, and are especially useful for measuring the emergence of the control functions associated with the evolution of the state.

Finally, the variety in settlement hierarchies based on the different assumptions of range overlap and spatial-cost allocation suggest the operation of different kinds of sociocultural systems. Most well known is Skinner’s identification, in China, of transport principle hierarchies in mountainous areas (1964), market principle hierarchies on alluvial plains (1964), and the problems associated with some socialist strategies based on administrative hierarchies (1965b). In an archaeological application, these different settlement hierarchies have been used to argue for the operation of market economies versus administered economies in the Valley of Mexico (e.g., Smith 1979; Evans 1980).

The Christaller approach by no means exhausts the variety of hierarchy models. For instance, Lösch (1967) assumes a society of “rational men” and allocates economic functions to places based on the marginal utility associated with the specific location. Isard (1956), using similar behavioral assumptions, incorporates production along with exchange functions in developing model landscapes. And, in yet another approach, Vance (1970) uses a behavioral model dominated by wholesaling activities, rather than the retail activities associated with Christaller.

However, all these approaches share two characteristics. First, settlement hierarchies emerge from different numbers and kinds of economic functions occurring at different places. Second, the allocation of functions to places reflects the differential spatial costs associated with the functions. Even though the specific behavioral assumptions used to generate these models will subsequently be criticized, associating settlements with economic functions and allocating functions on the basis of the costs of overcoming the friction of distance, provide two useful assumptions underlying any settlement study.

**Rank-Size Analysis**

Substantial methodological problems beset interpretation of settlement patterns with central-place models. For instance, present methods of fitting
two-dimensional, central-place model landscapes have yet, in archaeology, to develop beyond eyeballing model and empirical maps (e.g., Johnson 1972; Paynter 1980:311–362; Smith 1979). The more rigorous procedures evaluate single dimension characteristics of the model, such as the nature of the regional hierarchy (e.g., Johnson 1975).

Hierarchy analysis, however, presents problems for most archaeological survey data. For instance, multivariate techniques are frequently used to identify settlement hierarchies with contemporary data (e.g., Berry 1967:26–40; Berry and Kasarda 1977:305–333). Archaeological survey data rarely include more variables per period than site location and site size. Thus, isolating discrete hierarchies to compare with Christaller's central-place models is a problem.

A solution lies in analyzing the entire distribution of settlement sizes without requiring the isolation of individual hierarchical levels. Rank-size analysis is one such analytic procedure (e.g., Blanton 1976a; Crumley 1976; Johnson 1977). It is easily conducted with archaeological data and can be logically linked to central-place models. For these reasons, rank-size analysis has attracted considerable attention (e.g., Blanton 1976b; Crumley 1976; Hodder 1979a; Johnson 1977, 1980a,b; Kowalewski 1980).

The rank-size relation is the relation between the size of the settlements in the region and their rank. This relation is specified by rank ordering the settlements from largest to smallest, giving the largest place the first rank. The relationship between a settlement's rank order and its size can be graphed as a bivariate plot, commonly with the rank on the horizontal axis and the size on the vertical axis.

One expectation used to interpret these empirical plots is encompassed by the rank-size rule. The rank-size rule predicts a rank-size relation for all the sites in a settlement pattern, under the assumption that they are equally well integrated in a single settlement system (e.g., Beckmann 1958; Beckmann and MacPherson 1970; Richardson 1973; Vapnarsky 1969). Its formal expression is

\[ S_i = S_i / R_i \]

where

- \( S_i \) = the size of the \( i \)th settlement in the area
- \( S_1 \) = the size of the largest settlement in the area
- \( R_i \) = the rank of the \( i \)th settlement.

Although the rank-size rule was initially an empirical generalization (Zipf 1949), it has been linked to theoretical models (e.g., Richardson 1973 for a review). One particularly interesting line of argument links the continuous rank-size rule to the discrete site-size distributions expectable under central-place theory. Developed by Beckmann (1958), he notes that if the sizes of settlements within a hierarchy level in a central-place system vary around the expected size for the specific hierarchy level, the overall effect is a continuous distribution of site sizes. Furthermore, if the variation in site size results from the multiplicative effects of a number of random variables, the resultant continuous distribution of site sizes approximates the log-normal distribution. The rank-size rule is a special case of the more general log-normal distribution (Beckmann 1958; Beckmann and MacPherson 1970; Parr 1969).

Linking the rank-size rule to central-place models in this manner is particularly useful for archaeological research. For one, cultural systems are frequently modeled with random effects and, these random effects are often considered to be multiplicative (e.g., Johnson 1980a; Renfrew 1972:25–44, 476–504). Thus, Beckmann's settlement system is not inconsistent with ethnological modeling on these grounds. Furthermore, the fact that the model generates a continuous distribution out of the hierarchical central place model is methodologically useful, as the rank-size rule can be used to evaluate empirically developed, continuous rank-size relations.
between the expected and observed distributions (e.g., Johnson 1980b; Paynter 1982). However, as the overall shape of the deviations in the following analyses proves informative, I will not base the following discussions on these measures.

Behavioral interpretations have also been developed for some of the patterns of deviation from the rank–size rule. Three have been used in the archaeological literature. The first is a concave pattern of deviations (e.g., Figure 11.3), in which the observed values fall below the expected rank–size rule line. Blanton (1976b:195–201) and Johnson (1977:496–499) suggest that concave deviations arise if an archaeological study area is much smaller

A word of caution is found in Richardson (1973). His review of rank–size relations points out that a number of different behavioral models give rise to the rank–size rule. Thus, as in any interpretive analysis, identifying the operation of central-place systems should be based on many independent lines of evidence, of which the rank–size relation is but one.

As mentioned earlier, conducting a rank–size analysis is quite straightforward. When plotted on regular graph paper, the rank–size rule—the expected distribution—appears as in Figure 11.1. Transforming the values for rank and size to their logarithms (base 10) and plotting these yields a distinctive straight line (Figure 11.2). Thus, when the empirical plot approximates the expected straight line, the interpretation that a study area contained a complete, well-integrated settlement system finds support. Various statistical procedures have been proposed to evaluate the accuracy of fit

**FIGURE 11.2** Rank–size rule: logarithm-rank–logarithm-size scales.

**FIGURE 11.3** Concave deviations.
than the area influenced by the past settlement system. In an archaeological application, Blanton (1976b:200) uses concave plots for the Valley of Mexico to support the Valley's central position in a larger political economy during the Middle Horizon and Middle Second Intermediate periods.

The second is a convex pattern of deviations (e.g., Figure 11.4), in which the observed plot falls above the expected plot. Two behavioral processes have been suggested to account for this pattern. One suggestion is that convex deviations arise when two or more complete, well-integrated systems are pooled in the analysis (e.g., Johnson 1977:499). The other suggests that areas located in the peripheries of larger political economies may also display convex deviations (Paynter 1982). Johnson (1980a) identifies an essential similarity in these situations, arguing that both peripheries and pooled study areas represent situations of poor system integration. More attention is paid to convex patterns of deviation in the following, particularly regarding discrimination between pooling and peripherality.

The third pattern of deviations is the primo-convex pattern (e.g., Figure 11.5). Johnson (1980b) identifies this pattern, interpreting it as resulting from a ‘‘settlement system composed of sub-systems (enclaves) which are articulated with a regionally dominant center but which are relatively independent of one another.’’ The Warka area during the Early Uruk period exemplifies these processes (Johnson 1980b).

In sum, rank–size analysis is an attractive interpretive tool. It enables one to analyze the rather poor data from archaeological surveys with rich central-place models. Furthermore, it is easy and inexpensive to conduct.

These are precisely the characteristics that also make it a tool that may be misapplied if attention is not paid to the limits of rank–size analysis, and the underlying central-place models. The next section considers some of these limits.
BIASING PROBLEMS, BOUNDARY PROBLEMS, AND STRATIFICATION

Although central-place models are useful tools for interpreting archaeologically recovered site hierarchies, there are limits to their applicability. The theory of conventional central-place models is too narrow to be facilely applied to the archaeological record. Furthermore, methodological problems arise because these models are designed to analyze the relatively rich, well-controlled data of the contemporary world. A number of recovery problems complicate their application to prehistoric settings.

In the following, I investigate three problems. The first results from biasing processes. The problem occurs because archaeologists do not control preservation processes; thus, it is unlikely that the full settlement pattern from a previous system will ever be recovered. This problem and means of compensation are illustrated with rank-size analysis.

A second problem also arises from the data. Archaeologists use rather arbitrary analytic units in collecting survey data. There is no assurance that the analytic system bounds an area containing a past cultural system. In fact, as I argue later, it is quite unlikely that survey units contain a settlement system. Again, rank-size analysis is used to illustrate this problem and suggest some procedural remedies.

A final problem in using central-place models for interpretation of past cultures concerns the relevancy of the behavioral assumptions found in these models. This is not a new criticism of central-place models. However, in the following I do not argue for the irrelevancy of these models; but, rather I suggest expansion of the relevancy of this approach by considering the allocation of the costs associated with overcoming distance in different political economic settings. I close with some suggestions about the role of spatial relations in maintaining the relations of inequality found in stratified political economies.

Biasing Problems

A basic problem in any archaeological research, and particularly in studying past settlement patterns, is the issue of bias. Even if we could decide what a site is (e.g., Chang 1972; Dinauze 1978; Hodder and Orton 1976:18–20), it seems highly unlikely that 100% would survive the variety of geomorphological processes and land uses impacting any area. Thus, it is unlikely that an archaeologist ever analyzes a complete settlement pattern.

However, most surveys fairly routinely reconstruct past patterns and evaluate the goodness of fit of various formal settlement models without giving much systematic thought to the effects of these biasing processes. Note that I am not considering issues in sampling strategy or design. These are certainly important issues and have received considerable attention in a number of reviews (e.g., Hole 1980; Mueller 1974, 1975; Plog 1976a; Plog et al. 1978). In the following, I presume sagacity in allocation of labor and money and I consider samples arising from incomplete preservation. I am concerned with the situation in which, after having conducted a 100% survey of an area, with appropriate intensity, an archaeologist suspects that some components of the past settlement pattern have been eliminated from the record. Obviously, this has to be taken into account, especially when using formal analyses, such as rank-size interpretations, which assume a total system. Since these preservation problems are different in each study area, the best strategy is unique to each setting.

Surveys often report on biasing processes (e.g., Johnson 1973:24–27; Parsons 1971:19–20; Price 1978:213; Sabloff and Rathje 1975:62–63). For example, Sanders et al. (1979:20–30, 60–65) present the range of activities that biased their sample of sites in the Basin of Mexico. These include geomorphological processes, such as erosion and alluviation, and contemporary land-use patterns, such as urbanization and heavy crop cover, hostile humans and hostile canines—problems and experiences quite familiar in any survey setting. So are the following observations:

We have never dealt systematically and rigorously with these potentially serious problems. However, we have always been aware of these difficulties and have tempered our observations in view of the more obvious limitations of our methods... While we are prepared to admit that problems of differential modern land use and seasonal variation have almost certainly produced some inconsistency and error in making inference about occupational density and site character, we believe that such errors and inconsistencies have not significantly affected our general conclusions [Sanders et al. 1979:64–65].

I leave the evaluation of the last conclusion to those more familiar with the area, and address the issue of introducing some rigor into considering the effects of biasing processes.

One method of coping with bias is to formally model the aggregate effect of all biasing processes. This involves using limit theorems, and thus assumes that past biasing processes were random and either numerous or frequent. For instance, Dacey describes one such theorem:

If artifacts deteriorate, are destroyed or are removed with constant probability, this theorem suggests that after a sufficiently long time the spatial distribution of the remaining artifacts will have a Poisson pattern [1974:3].
The strategy, in this case, is to compare the observed pattern against the Poisson under the suspicion of past biasing processes. A lack of fit to the Poisson would be encouraging, suggesting that some behavioral effects still remain. A similar strategy has been used by Hodder (1979a) in studying rank–size relations. He uses the normal distribution as the limit for a sampled hierarchy, acknowledging that this is not necessarily a well-founded assumption.

However, there are problems with studying aggregate effects that limit its practical utility, despite its mathematical elegance. Specifically, one seldom suspects that the biasing processes in the past were either many or random. In fact, one usually suspects that there was a distinct bias toward sites of certain characters or sites located in specific areas. Thus, the assumptions of limit theorems do not accurately model the past processes.

A more informative strategy is to test the strength of the relationship between archaeological data and the suspected biasing process(es). For instance, Hodder and Orton (1976:226) present Kolmogorov-Smirnov tests for evaluating the strength of the relationship between artifacts (Late Iron Age coins) and other landscape features, in this case Roman roads in central and southern England. Of course, Hodder and Orton's analysis proposes that old roads conditioned the deposit of old coins. However, this can be turned around to evaluate the proposition that contemporary roads positively bias the identification of artifacts or sites. This basic approach could easily be extended by identifying other landscape features likely to affect site recovery, such as erosion and alluviation surfaces, or zones of varying land-use intensity.

Simulating the Biasing Effects

A third approach to studying the effects of bias is simulation of the combined effects of the past behavioral and biasing processes. To do this, one needs to posit the past system, as well as the effects of hypothetical biasing processes. This strategy can be illustrated with rank–size analysis. The rank–size rule fulfills the first condition by providing an expectation for an unbiased settlement pattern. Let us consider what deviation patterns from the rank–size rule are likely under various biasing processes.

A few simple thought experiments using the rank–size rule suggest some of the effects. For instance, arbitrarily divide the sites in the rank–size bivariate plot into three groups: the larger places, the middle-sized places, and the smallest places. Eliminating the larger places leads to markedly convex deviations as this results in too few large places. If middle-sized places are lost, the pattern of deviations conforms to the rank–size rule for large places and becomes concave as there are too few smaller places (John-son 1977:496). Missing small places leads to overall conformity to the rank–size rule with a concave "tailing off" in the lower reaches. Thus, some very simple rules of thumb emerge. Convexity may be due to biases affecting large places, such as the development of contemporary urban places. Convexity may be due to effects in middle-sized places; and, concave "tailing off" may be due to elimination of small sites, such as through erosion and/or alluviation.

However, empirical situations are likely to be much more complex. First, some combination of large, middle-sized, and small places are likely to have been affected. Second, not all places at a given level are likely to have been affected. These more complex situations, especially when there is uncertainty about numbers of affected sites, can be studied with computer simulations.

The following is an example of one simulation. The simulation starts with the assumption of a complete, well-integrated settlement system in which the largest place was arbitrarily set at the size of 1000. The system is based on the transport principle, thus following a $k = 4$ lattice (Christaller 1966:74). The system has four tiers, thus exceeding one of Wright and Johnson's (1975:267, 270) characteristics of state settlement patterns. Each of these tiers was sampled randomly without replacement.

Different biasing situations were simulated. Table 11.1 specifies the number of places eliminated from each tier. The situations range from such qualitative judgements as, the survey recovered all but the small places (strategies a and b), to urban sprawl, erosion, vulcanism, agricultural land-use, pot hunters, and previous archaeologists got some of the larger sites as well as some of the smaller sites (strategies h and i).

The results are plotted in Figure 11.6. Three lines appear on each plot (most clearly seen in Figure 11.6g–i); a solid straight line for the underlying total system; a curved line with + for the observed sites after past processes sampled the total system; and, a straight line with + indicating the rank–

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sive problems. For instance, an empirical concave plot (e.g., Figure 11.6f) is generated by the biasing effects modeled as in Table 11.1, and, as presented previously, by boundary effects. An empirical convex plot (e.g., Figure 11.6g) is generated by severe biasing problems, by boundary effects and by low systemic integration. Given that different processes can produce similar deviation patterns, care should be taken to rule out alternative explanations when interpreting rank-size plots.

A further implication of these simulations is that other familiar analytic procedures may also be affected by biasing processes. For instance, nearest neighbor assessments (e.g., Earle 1976; Hodder and Orton 1976:38–51), analyses of intersite stylistic patterning (e.g., Plog 1976b, 1980; Voss 1980), or determinations of settlement hierarchy are also likely to be affected. Further research should be conducted to determine the kinds of biasing procedures most likely to create problems.

In sum, it is safe to assume that a total settlement pattern will never be recovered. The landscape of a study area is best considered to be a continually evolving surface transformed by past cultural systems of interest, by intervening cultural systems, and by noncultural factors. Thus, models of patterns derived from central-place theory should differ from empirical patterns. Biasing, in particular, might be an important factor, if land-use practices have led to incomplete data on large settlements. However, rank-size analyses can be conducted by using hunches about missing data to construct sampling simulations as presented here. The resultant rank-size relations, rather than the rank-size rule, are the expectation for the incomplete, well-integrated central-place pattern.

**Boundary Problems**

A second problem in applying central-place models concerns bounding theoretical and analytic units. Theoretical central place models predict the landscapes of one spatially open system. The empirical situation departs from the model since a study area, for a specific period, may contain many small-scale systems, part of one larger-scale system, or part of two (or more) larger-scale systems. Rarely, however, will an empirical study area contain the pattern provided by just one system. This discrepancy between analytic and systemic boundaries has been referred to by Johnson (1977:489) as the boundary problem.

There are theoretical and methodological reasons why the boundaries of the analytic unit and the past system are not likely to coincide. Johnson (1977:498–499) identifies the arbitrary nature associated with archaeological boundary decisions as a methodological source of this problem. For
instance, Adams and Nissen (1972:5) point out the controlling effects of contemporary land-use and political subdivisions on their study area. Furthermore, recent research on the spatial scale of previous sociocultural systems suggests that archaeological study areas are not likely to coincide with past systems. Johnson (1975:294) notes that study areas of stratified societies tend to range between 2,000 and 10,000 km². Such areas would seem large enough to encompass earlier sociocultural systems under the received wisdom of cultural evolution. One of the major evolutionary trends is believed to be an increase in spatial scale with increasing sociocultural complexity (e.g., Beardsley et al. 1956; Mosely and Wallerstein 1978:261; Steward 1955:170–209). Study areas used in archaeological survey would certainly contain the interactions of households, as suggested for prestratified societies (e.g., Coe and Flannery 1964; Steward 1955:201–202), and even of stratified societies organized as Early State Modules of about 1,500 km² (Renfrew 1975:14).

However, there is good reason to suspect that the evolution from relatively egalitarian systems to stratified systems is not paralleled by a change from small areas to large areas in any simple fashion. It is abundantly clear that some band societies, either in the ethnographic present or in prehistory (Lee 1979; Wilsen 1980; Wobst 1976) operate in quite large areas. The isolated tribe model no longer seems viable in light of Fried’s (1975) critique and reports analyzing big-man exchange systems in New Guinea (e.g., Harding 1967; Malinowski 1961; Meggitt 1974; Paynter and Cole 1980). Furthermore, students of the early modern and contemporary stratified societies that emerged in northwestern Europe and North America find that it is not very useful to view nation-states as closed systems (e.g., Peet 1969, 1972; Schneider et al. 1972; Wallerstein 1974, 1980). The only remaining closed evolutionary type is the archaic civilization (e.g., Renfrew 1975). I would expect its closedness to fast go the way of the closed culture concept in these other areas, once attention is devoted to identifying its scale rather than assuming small spatial arenas (e.g., Johnson 1980b; Kohl 1978; Price 1977).

Obviously, if past social systems operated in arenas exceeding the size of survey units, it would be impossible to have analytic and theoretical boundaries coincide. The settlement patterns under analysis would be the product of part of larger settlement systems, or if situated at the border of a number of these past systems, might be parts drawn from more than one. Thus, it seems theoretically as well as methodologically unlikely that patterns under investigation represent one system. Using models of settlement systems that presuppose the operation of one system might be quite misleading.

In the same article in which he identifies the boundary problem, John-

son (1977:498) also offers spatial analysis based on the rank–size rule as a procedure for sorting out the fit between empirical study areas and theoretical units. Specifically, Johnson (1977:498) suggests that if two past systems are pooled within one study area, convex deviations from the rank–size rule should result. Alternatively, concave deviations are suggestive of the study area capturing only part of the relevant settlement pattern (see also Blanton 1976b:199–200; Vapnarsky 1969).

A problem for using deviations from the rank–size rule in identifying the boundary problem is that there are other interpretations for these patterns. For instance, as noted previously, deviations may also arise when biasing processes have eliminated some of the larger sites. And in yet another case, convexity is associated with drawing samples from the periphery of larger systems.

I became particularly interested in sorting out these different interpretations during my study of the settlements in the twentieth-century Connecticut River valley (Paynter 1980). Documentary sources indicate that the Connecticut River valley was an agricultural semiperiphery in the late eighteenth century and became more of a core-like industrial area by 1850 (e.g., Henretta 1973; Lemon 1980; Wallerstein 1974, 1980). Rank–size analyses were conducted using documentary data on three indices of town size. Being a sample of a larger system, the patterns should have been concave. This was not the case.

Figure 11.7 displays one of the convex rank–size relations for population density. For reasons of space, I do not include results of other analyses. They, as with Figure 11.7, are markedly convex.

Aside from the independent historical information indicating that this pattern of deviation is associated with peripherality, it was possible to rule out some of the competing hypotheses. First, biasing was not responsible since the documentary data covered the entire study area. Second, subdividing the area into the most likely smaller independent systems did not generally produce good fits to the rank–size rule—a predictable pattern if in fact the study area pools smaller independent systems. Both of these observations could be made with data from a prehistoric survey; thus, it is possible to distinguish convexity associated with pooling and convexity associated with peripherality.

In search of yet another diagnostic to distinguish peripheral and pooling convexity, simulations of pooling were conducted and the pattern of deviations studied and compared to the patterns from the Connecticut River valley. Four instances of pooling were considered. In the first (Figure 11.8a) two identical patterns were added in the same rank–size analysis. The patterns were derived from complete, well-integrated systems and therefore, followed the rank–size rule. The largest place in each was arbitrarily set at
each followed a $k = 4$ lattice, and each had four tiers. The other
analyses pooled patterns of different systems with this 1000, $k = 4$, four-
tiered system. The second analysis (Figure 11.8b) analyzes two systems with
the same largest place but different lattices and number of tiers (i.e., a
different structure). The third analysis (Figure 11.8c) pools two systems
with different-sized largest places, but identical structures. The fourth (Fig-
ure 11.8d) pools systems with different largest places and different struc-
tures. The system characteristics are found in Table 11.2.

A brief aside helps interpret the graphs. Four lines occur on each plot,
most clearly seen on Figure 11.8c and d. Two straight lines with + are the
plots of the independent patterns (in Figure 11.8a and b, these are superim-
posed). Two solid lines are the expected rank–size rule and the observed
rank–size relation resulting from pooling the two independent systems. In
these experiments, the pooled expected plot (the straight solid line) will
always be superimposed on the plot of the independent system with the
largest first rank place.

There are a number of interesting characteristics of these deviation
patterns. First, the expected convexity appears in all four types of pooling.
Second, compounding systems with different-sized largest places leads to
TABLE 11.2
System Characteristics in Compounding Experiments

<table>
<thead>
<tr>
<th></th>
<th>(a) Identical patterns</th>
<th>(b) Same size, different structure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>System 1</td>
<td>System 2</td>
</tr>
<tr>
<td>Largest place</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>$k$</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Number of tiers</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

(c) Different size, same structure

(d) Different size, different structure

<table>
<thead>
<tr>
<th></th>
<th>System 1</th>
<th>System 2</th>
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<tbody>
<tr>
<td>Largest place</td>
<td>1000</td>
<td>500</td>
</tr>
<tr>
<td>$k$</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Number of tiers</td>
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conformity between observed and expected in the lower ranks (larger places). Third, when the systems differ in either structure or size of the largest place, the observed line has a slight “tailing-off” in the higher ranks (smaller places). Finally, the convex deviations are roughly parallel to the rank—size expected line.

The characteristic most useful in distinguishing pooling from peripheral convexity is the roughly parallel character of the observed and expected lines. This contrasts with the patterns from the peripheral Connecticut River valley, which though convex, are strikingly nonparallel (Figure 11.7).

Obviously, these cases do not cover all possible instances of pooling. Thus, as suggested previously in the biasing process discussion, an investigator suspecting pooling might produce expected rank—size deviations based on hypothetical systems and use this to evaluate the observed rank—size relation. An example from Oaxaca illustrates this. Kowalewski (1980) argues that: during Monte Albán V, several independent polities occupied the valley. His rank—size analysis discloses the convex pattern. Consistent with the simulation of two, roughly equivalent systems (Figure 11.8a), the empirical pattern discloses a roughly parallel pattern (Figure 11.9).

Interestingly, Kowalewski’s case of pooling in the Valley of Oaxaca might be consistent with the revisions in evolutionary scale that began this discussion. It may be that pooling of independent systems within an archaeological study area is most likely in periods of state system collapse. Prior to the emergence of the state, political economic institutions lacked the ability to establish impermeable boundaries (e.g., Hodder 1979b). With the
emergence of the monopolization of force, the political apparatus of the state is available to regulate and enforce exchanges to the (heretofore unknown) extent of closing down exchanges.

Regardless of the eventual outcome of models for state cyclicity, the issues of scale and boundaries are clearly problematic. Rank–size analysis should prove useful in identifying boundary mismatches, if other interpretations can be excluded. A key may be parallel versus nonparallel convex deviation patterns. However, truly coming to grips with the boundary problem means carefully investigating the scale of precapitalist systems. Present evidence suggests that many systems operate at surprisingly large scales—exceeding the traditional scale of archaeological survey units. Since analytic and systemic boundaries are not likely to coincide, studying these units with inappropriately large central-place models distorts the understanding of these past systems. A strategy for coping with the boundary problem is to sample and pool central-place systems, using the resultant patterns as guides for interpreting empirical patterns.

**FIGURE 11.9** Compound rank size relation from the Valley of Oaxaca, Monte Albán V (from Kowalewski 1980).

Behavioral Models and Patterns

A third limit in using central-place models in archaeology concerns issues of theory. How useful are central-place models for interpreting past cultural systems and for developing interesting ethnohistorical theory? Even if the observational problems and the methodological problems discussed previously were overcome, would archaeologists, as social scientists, find settlement models based on central-place theory useful?

Flannery (1976:169–170) points out that criticisms of central-place models are often misdirected toward the assumption of uniform plains. The more important issue for the development of social theory concerns the societies and agents underlying these models. Two of the more important deficiencies of conventional central-place models involve the assumptions about social systems, and the effects of these social systems on the material world. Specifically, most models assume the action of rational men, an assumption that limits the ethnological interest of these models. Second, the models predict economic exchange activities rather than physical settlements. From the archaeologist's perspective, the models dangle above the ground. Keeping these aspects of conventional central-place models obscures the past, leads to irrelevant debates, and contributes to the misuse of settlement models. Considering these issues, however, points to ways to expand the scope of settlement models.

First, consider how central-place models are usually grounded. As noted previously, central-place models predict the location of economic activities—usually exchange. The link between exchange and the archaeological data is primarily based on correlations between the number of economic functions and population size, on one hand, and population size and the site area on the other (Johnson 1977:495). Obviously, correlations are not behavioral theory. People do not precipitate sites; rather, sites are built, abandoned, and destroyed within specifiable social relations.

Recent developments suggest that settlement size is strongly related to settlement age and to social factors, such as wealth distribution (Kramer 1979, 1980). What is called for are models following up on these relations of class, demography, and longevity, specifying what conditions surround site construction, abandonment, and destruction. Most generally, this involves a different approach to economic functions. Rather than being concerned with exchange, consider economic functions of production. From the point of view of production, sites are made up of factors of production (e.g., buildings, warehouses, factories, craftshops, domiciles). Site size and location represents how the past system built, destroyed, and abandoned large
fixed means of production that contributed to the reproduction of stratified social relations. Developing a production approach rather than an exchange approach to economic functions would minimally involve linking site construction with such social conditions as the mode of surplus extraction, processes of administration, and ideologies of legitimacy.

What might these systems look like? One approach is to posit universally applicable assumptions that abstract human behavior to the point where formal mathematical systems can be used to model settlement patterns. The rank–size rule represents one such formalization; others include many probabilistic models, such as broken-stick models (Hodder 1979a), social physics models (Renfrew 1979:31–32), distance-decay and gravity models (Renfrew 1975), and varieties of settlement growth models based on stochastic growth processes (e.g., Hodder 1979a). This strategy, however, is a circuitous route to interesting ethnology. Johnson (1977:500–501) points out the problems with these rather bloodless models:

Yet enthusiasm for stochastic processes may go too far. . . . If the most probable state of a variable or system is equated with maximum entropy, the behavioral patterns reflected in spatial regularities are viewed as most-probable steady states resulting from purely random processes. . . . These approaches encourage taking regularity as given and shifting the emphasis of explanation to deviations. At least, in archaeology we may profitably continue to try to understand the factors producing the probability distributions that make most-probable states most probable.

Thus, when all the math is done, we are still left with the question of what ethnologically interesting behavior is modeled by these stochastic distributions.

A more common approach to central-place modeling populates a model landscape with rational men, independent, omniscient, and equally interested in maximizing profits or minimizing losses (e.g., Isard 1956:24–54; Lloyd and Dicken 1972:9–29; Lösch 1967:92–100). These rational actors compete within the familiar institutional matrix of free markets and modern nation-states. There are a number of reasons why direct behavioral analogies are not likely to be useful.

For one, it is important to keep in mind the data central-place models were initially directed toward, namely core areas of capitalist political economies (e.g., Christaller 1966). The behavioral institutions used to generate various models (such as the marketing, transporting, and administrative principles) are those of core capitalist political economies. Critiques of the universal applicability of core capitalist institutions caution that the separation of economy and politics paralleled in the central place literature by the differing interpretations given to \( k = 3 \), \( k = 4 \), and \( k = 7 \) lattices, is unlikely in preindustrial and peripheral social formations (e.g., Amin 1980; Godelier 1977:15–62; Hindess and Hirst 1975; Polanyi et al. 1957; Sahlins 1968, 1972; Service 1975). This ethnographic narrowness should make us wary of arguing from these patterns to these institutions when outside of capitalist cores. Thus, it seems beside the point to ask if politics or commerce was responsible for a given pattern (e.g., Evans 1980; Smith 1979). The more ethnologically interesting problem is to consider the range of combinations of politics and economics appropriate for noncapitalist settings, also leading to \( k = 3 \), \( k = 4 \), and \( k = 7 \) lattices. Helpful empirical data and models may be found in the realms of the geography of peripheral areas and contemporary socialist landscapes (e.g., French and Hamilton 1979).

There is yet another problem with formalist assumptions. These formulations fit Renfrew's (1979:31–32) notion of social physics models, in that all actors have similar characteristics. The crucial characteristic driving the settlement system is that all actors attempt to minimize the cost of overcoming the friction of distance (e.g., Lloyd and Dicken 1972:9). Although settlement systems can be imagined that generate hierarchies based on the aggregate interactions of individuals seeking to minimize transport costs, what do we learn of ethnological interest from doing this? Particularly, when studying stratified societies, in which individuals have unequal access to strategic resources, it might be the case that all parties are not interested (or able) to minimize transport costs. Or, in egalitarian societies, might it not be the case that the distribution of transport costs is one of the leveling mechanisms—a leveling achieved by unequally assigning higher transport costs to those who begin to develop unequal access to other strategic resources? The suggestion is that alternative ways of thinking about social and spatial relations start from more ethnologically provocative assumptions than those in the social physics of conventional central-place models. Minimally, the societies of these models should incorporate inequalities, and the models should consider how landscapes are created as a result of, and to maintain, these inequalities.

**Political Economy and Settlement Systems**

One alternative stresses the power relations implicit in settlement systems. Developing a political economic approach to settlements need not abandon all aspects of conventional central-place theory. Useful aspects include the importance of the effect of the friction of distance on social relations, and an expectation for the landscape of capitalist societies.

To briefly elaborate on these points, a key concept offered in geographic models is that space is not socially irrelevant. All too often anthropologists have missed this aspect of space by conceiving of it as a dimension of measurement (e.g., Spaulding 1960), while paying little or no attention to its role as a socially conditioned factor. Specifically, overcoming distance in-
volves a cost, and although this much is true of all societies, the distances overcome and the distribution of costs are socially determined.

The point is most clearly seen in the relationship between surplus production and settlement patterns. Any society produces and distributes a surplus (e.g., Hindess and Hirst 1975; Wolf 1966, 1981). This production involves bringing together people, tools, and natural resources. Accomplishing this production requires, in part, solving locational problems. For instance, are the people who will do the work moved to where the tools and the natural resources are located, or, are tools and natural resources moved to where the labor force is located? Alternatively, are all three moved to new locations for the performance of production? Movement also enters into the distribution side. For instance, are those who moved labor, tools, or natural resources compensated when the production is distributed? If so, at a rate less than, equal to, or greater than the energy they expended?

The production and distribution of surplus obviously involves spatial relations. And just as obviously, there will be physical results of these decisions, results that are recovered as settlement patterns. On the production side, for instance, labor reproduction implies domestic structures, production involves factories—shops—fields, raw materials are extracted in mines and quarries, and transportation uses roads, warehouses, and marketplaces. Relative locations of these fixed structures should be informative about the distribution of costs. For instance, is worker housing near or far from natural resources, or from locations of production? Are production locations easily accessible to many or few consumers? Do transport facilities (e.g., roads, depots, docks) equally link all the factors of production with the locations of production? All the locations of production with all potential locations of consumption?

To summarize, inherent in any production is overcoming the friction of distance. There is, however, no single way to locate fixed structures to overcome this friction. The nature of the solutions depend on the institutions within a society that allocate labor to tools and raw materials, and the institutions that then distribute the surpluses among the sectors of society. As these institutions vary, one would expect the organization of production and the costs of transportation to be differentially arranged. In other words, as modes of production vary, so should associated settlement patterns.

What is the range of variation in settlement patterns associated with varying modes of production? Answering this goes well beyond the scope of this paper. It does suggest a role for central-place theory. Conventional central-place theory assumes that people allocate resources and distribute production through the market. Thus, conventional central-place theory gives insights into the landscapes of capitalism (e.g., Harvey 1973). The challenge to anthropology is to discover the landscapes associated with alternative modes of production and distribution (e.g., Smith 1976c).

Although stimulating hints concerning an extended theory exist (e.g., Harvey 1973; Peet 1975), no complete alternative models are available. A guiding principle is that cultural landscapes are never neutral; rather they are constructed by members of specific political economies. Although the aims of the various actors may be to perpetuate or to change these relations, the actors are affected by the landscape in which they reside, and their actions regarding social production will in turn transform this landscape. A useful point for understanding how a stratified landscape is transformed is to study the manipulation of the friction of distance in the perpetuation of inequality.

For purposes of illustrating the intertwining of spatial relations and power relations, presume a simple stratified society. I have in mind Fried's (1967:185–242) notion of stratification, namely the creation of inequality of access to strategic resources and the perpetuation of such relations. In this model society, there are elites and nonelites, the former possessing access to strategic resources, such as energy and/or sanctity and/or force, that gives them power over the nonelite (R. N. Adams 1975). The elites are interested in maintaining and possibly increasing the access gap; the nonelite are minimally interested in changing these social relations. The following are a few possible ways in which the friction of distance might be related to these different strategies of reproduction and how they are crystallized as a given settlement pattern.

One way in which elites can reproduce their position is to locate fixed items of the infrastructure (e.g., roads, terminals, government buildings) or to arrange schedules of mobile infrastructure (e.g., subway and bus schedules) to minimize their costs without considering the effect of locational and scheduling decisions on the costs of nonelites. The twentieth-century United States settlement pattern provides evidence of this reproduction effect, in both the ideology of planning as well as the physical constructions. For example, Morrill and Symons (1977) point out how the models used in making locational decisions in some instances lead to poor people bearing society's transport costs. Specifically, they (1977:224) note that "contrary to the presumption of location theory, an efficient location pattern that maximizes system profits or minimizes system costs, including travel, may result in socially unacceptable inequality in access over space, usually owing to area variations in density and income."

For a specific example, consider a government trying to cut taxes. It might use arguments of spatial economy of scale to centrally locate public services, such as health care at large hospitals, without considering the
implicit spatial costs of accessing these facilities. Morrill and Symons (1977:222) note in this regard:

> In the past, it was considered “efficient” to concentrate care of the poor in one large county hospital, often beyond better, but intervening, hospitals that served paying patients; only recently has it been found more efficient, as well as far more equitable, to subsidize the care of the poor at nearby voluntary or private hospitals.

They note that the latter decentralized locational patterns cost more per unit service provided (and are less system efficient), but that the efficiency of centralization is achieved by shifting the burden of accessing these facilities from the society as a whole to the poor. Empirically, this shift toward equitable (rather than efficient) health-care locations can be seen in the proliferation of community health centers in the late 1960s and 1970s. If the tendency to consolidate health care, a trend developing in the 1980s, is realized in the spatial concentration of this care in major hospitals (Berkson 1980; Kleiman 1980), the result will likely be a shift back to a less equitable health-care landscape.

As a second case, elites may seek to maximize the distances among groups of nonelites as a way of increasing the difficulties for organized nonelite group action. An important trend in the United States settlement pattern has been the dispersion of production sites and residences outside of the eighteenth- and nineteenth-century urban centers. David Gordon (1978) points out one factor behind this trend. Conscious locational decisions were made in the late nineteenth century by factory owners to relocate outside of the city as a way to separate workers in different factories. It seems that every time one factory went on strike, the strikers would march down the street attempting to get other workers to go out on sympathy strikes. In the suburbs, factories were separated by enough distance to make sympathy strikes more difficult to organize.

The spatial political economy of capitalism (and other political economies) is not simply one of elites versus nonelites. Locational decisions of infrastructure location may also reflect the competition between elites. Thus, New Haven, Connecticut, and Northampton, Massachusetts, tried to bypass the entrepôt of Hartford in the nineteenth century through canal construction (Martin 1939). Similarly, Utica and Syracuse, New York, managed to bypass Rome, New York, with the Erie Canal (J. Antici, personal communication 1980). These reflect merchants and entrepreneurs competing from these different towns.

Finally, nonelites can use the friction of space to isolate themselves from more powerful forces. The Long March is only a recent example of the general principle noted by Wolf (1969) that successful peasant wars generally occur if the peasants effectively isolate themselves from continual harassment by the central state.

These observations on the use of space by factions within stratified society are only suggestive of what a fuller integration of political and spatial economy promises. One shortcoming is that they are all drawn from the modern world. They do, however, suggest a way to imaginatively integrate social and spatial surplus accumulation. Their challenge is to fruitfully incorporate the frictional effects of distance in models of premodern stratification. The resultant spatial systems would be far more relevant for evaluating past settlement patterns than the assumptions underlying conventional central-place models. And, using models incorporating spatial inequalities to evaluate past patterns is more likely to lead to interesting ethnological theories of stratified society.

CONCLUSIONS

The study of the settlement patterns of prehistoric and historical stratified societies has been an important theme in contemporary archaeology. Settlement systems, based on central-place theory, have enriched our understanding of culture process and culture history. However, these models and associated test implications, such as rank-size analysis, have seldom been applied in a critical manner. Problems of bias, boundaries, and behavioral assumptions all deserve closer attention.

A basic strategy for coping with all three problems is to develop alternative models. In the section on biasing processes, the major suggestion is that explicit models of potential biasing processes, as well as the settlement models, are needed if this problem is to be overcome. The section on modeling and peripherality pointed out that generating alternative models of rank-size deviations under varying conditions of pooling is a useful way to sort out the methodological problem of interpreting convexity. And, the last section pointed to the need to identify the landscapes implicit in noncapitalist modes of production to supplement the central-place landscapes associated with capitalism.

That the notion of alternatives emerges from this discussion of settlement studies is quite reasonable given the volume's concern with archaeological methods and theories. The solution is not to throw out frequently used methods, but to place them within the context of alternative approaches, methods, and theoretical insights. Individuals can then choose
definitions, methods, and models that most closely address questions they find interesting. In this richer context, behavioral problem-solving, and not technical virtuosity, can direct archaeological research.

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