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Transitions in Social Organization: A Predictive Model from Southwestern Archaeology

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A number of studies from experimental psychology suggest the existence of information-processing constraints that place limits on the number of people with which an individual may simultaneously interact. The existence of such constraints means that increases in the size of a human group will push that population toward ''scalar thresholds,'' at which point a transformation of the social order must take place to reorganize patterns of group interaction. The model developed here incorporates ethnographic data into the scalar theory of social change in an attempt to refine the precision with which scalar thresholds may be predicted. This scalar model contributes to an understanding of social change in small- to midsized sedentary populations and provides insight into processes by which social differentiation can emerge in these societies.

Behavioral studies of interaction between members of human social groups have shown that limits on the capacity to process information can significantly affect the form and size of a group's decision-making structure (Meier 1972; Udy 1959; Miller 1956; Bass and Norten 1951; Gibb 1951). The possibility that this small-scale factor, stemming from essentially biological constraints on individual cognitive capabilities, could be a basic structuring force underlying the composition of larger social units such as clans and settlements raises exciting possibilities for its use as an explanatory tool in archaeology. If archaeological methods of identifying social responses to these cognitive constraints can be developed, they could provide new insights into why societies were organized in the way they were, why some grew while some collapsed, and why significant changes in social organization occurred when they did. However, to fully realize the explanatory power of information theory, applications must be developed that make use of the theory as a predictive model, not simply as a general explanation applied to observed patterns in a *post hoc* manner.

This study attempts to generate such an application of information theory, using ethnographic data to develop a model of social organization for small- to midsized sedentary groups that refines the predictive power of a model originally introduced into the discipline by Johnson over 15 years ago (1978, 1982). Johnson's primary contribution was to propose an explanation for the existence of regularities in the size and composition of human groups. Cross-cultural organizational regularities were argued to be grounded in cognitive constraints, shared by all humans, that limit the number of pieces or channels of information that can be simultaneously processed by the human brain. The identification of this constraint is highly significant, since it is at this type of information ''threshold'' that changes in the form of interaction between group members must occur for effective interaction to continue between them (in other words, group interaction must be reorganized so that the number of information channels within the group is reduced). Since this type of communications stress is argued to build up between group members in a regular and predictable man-

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ner, the phenomenon could be used to shed light on certain instances of change in the social organization of human groups.

What limits the explanatory power of this research, at least in nonsystematic (i.e., *post hoc*) applications, is the relatively high variability around the mean "threshold" level of communications stress, which can range from fewer than 6 up to 15 or more pieces of information (i.e., people). This variability is problematic when attempting to explain a single case, since the scalar threshold of any given case may or may not fall on the mean, even though larger numbers of cases will consistently tend to cluster around this value. This study proposes an attempt to calibrate the critical level of information-processing stress more precisely, reducing the variability in estimates of organizational regularities and thereby increasing the explanatory power of the predicted organizational thresholds (particularly for individual cases).

This attempt at calibration draws on the rich and detailed ethnographic record of the American Southwest, from which data on two important aspects of small- to midsized sedentary group organization can be collected with accuracy. First, ethnographic data provide counts of the number and size of interacting social units in a group based on observation of the actual social units, reducing the distortion inherent in archaeological estimates of these parameters. Second, the use of ethnographic data helps to avoid the teleological product of using expected archaeological correlates of high communication stress to identify an instance of such stress in the archaeological record. In other words, the ethnographic record provides behavioral data on disputes, factionalism, etc., indicating information processing strain that can be independently compared to data on the number and size of interacting social units at a settlement.

These benefits not withstanding, reliance on ethnographic data in this type of model can also be criticized for implied assumptions of continuity between prehistoric and historic groups—a long-standing source of controversy in Southwestern archaeology. Considerable impact on Native American society since European contact is acknowledged; a number of researchers have in fact suggested that it is precisely because the pueblos were able to change that they were able to survive European domination (Upham 1987:286; F. Plog 1978; Cordell and Plog 1979). However, ethnographic data need not be used as an interpretive template, and in the current study ethnographic data is used only as a source of possible interpretations of material remains. Regardless of whether the assumption of comparability of data is accepted or rejected by the reader, this study helps to demonstrate the potential impact of scalar thresholds on the structure of human social organization and should highlight the potential benefits to be gained by systematically incorporating this factor into models of social change.

The model developed here is based on ethnographic data from the fissioning of the Hopi village of Oraibi in 1906, which I interpret as a case study of a settlement that split as a result of conditions of "high scalar stress" (Johnson 1982) or a situation in which the social organization of a group could not accommodate the exchange of information necessary for its members to remain integrated as a single co-residential group. Working from ethnographic data on the number and size of Oraibi's primary decision-making units at the time of the fission (households, clans, phratries, and ceremonial societies), a model is constructed that predicts transition points in the social organization of settlements composed of these basic decision-making units but of varying population sizes. That is, the model allows the total maximum population size of a community to be predicted given knowledge of its largest decision-making unit; conversely, the size of the largest decision-making unit present in a settlement may be predicted, given knowledge of the settlement's population size. The predicted thresholds are then tested on archaeological data from the Anasazi region of the American Southwest to determine: (1) whether knowledge of total site size accurately predicts the size of decision-making groups at a site and (2) whether knowledge of the size of the largest decision-making group at a site enables the maximum size of that site to be predicted (in other words, a threshold, or transition point, in social organization).

Based on a positive correlation between observed and predicted thresholds of organization in the sites considered, I argue that future research into the behaviors through which decision-making status and identity are negotiated and communicated (e.g., stylistic communication, exchange, conflict) is best directed to these ‘‘hot spots’’ of social activity. These threshold points should be fruitful periods for research, since it is at these points that the impact of a cross-culturally universal process (scalar communications stress buildup) is negotiated on the ground by the individual members of a particular group. The ferment of differentially motivated actors within group during these periods may stimulate many of the behaviors that are of anthropological interest today. It is not unlikely that an aspiring individual, for example, might take advantage of one of these liminal social stages and attempt to advance his or her own position in the course of group reorganization (e.g., Aldenderfer 1993; Johnson 1982; Spencer 1993). The model thus provides a basis for systematically evaluating the effects of change in one component of human behavior (information processing stress) against other archaeologically observable dimensions of behavior. Though derived from the unique resource of Southwestern ethnographic data, the conclusions drawn here should contribute to a cross-culturally relevant understanding of processes of social change and the emergence of specialized decision-making in small- to midsized sedentary groups.

It should be emphasized that the organizational constraints identified in this paper pertain explicitly to co-residential groups. Within the boundaries of one site, some form of daily interaction, communication, and information exchange is guaranteed between its members. The site itself is a clear and undeniable expression of the community that its members form; a community whose interaction and interdependence necessitates the kind of group-level decision making that can generate information processing stress. However, interaction between spatially separate decision makers cannot be assumed and the demonstration of this interaction through archaeological data can be problematic. The mechanics of (re-)constructing *inter*-site decision-making systems (e.g., dispersed communities) do not necessarily follow the structure outlined below.

INFORMATION FLOW

Communication between individuals can be conceptualized as a flow of information. People exchange information on a number of different levels in daily interaction through language, gesture, clothing, and other material symbols. An individual operates as an information source, with the potential to broadcast information to and receive information from every person with whom they have contact. If every individual member of a group acts as both an information source and a decision maker, then information must be exchanged between all members of the group for a consensual group decision to be reached. However, a number of studies from social psychology and sociology have suggested that there are constraints on the human ability to process information (Meier 1972; Miller 1956; Udy 1959). The results of these studies suggest that in a situation where every member of a group functions as both an information source and a decision maker, the maximum information processing workload for an individual is exceeded at group sizes of greater than about six people. That is, for consensual group decisions, each person can maximally consider the views of about five other people, plus his own, to arrive at a choice. This information constraint should therefore affect both the ease and quality of decision making in groups with large numbers of decision makers. In fact, behavioral studies have noted that groups of greater than six people, in which all members are equal decision makers, are characterized by decreasing consensus, member satisfaction, and decision-making performance (Bass and Norten 1951; Gibb 1951).

The necessary level of information exchange in decision-making groups is therefore measured by the number of decision makers in the group. The number of one-to-one interactions that must take place for each decision maker to exchange information with every other decision maker in a group of n people may be expressed mathematically by the formula $(n^2 - n)/2$ and is termed the *scalar stress* value of the group (Johnson 1982:394). Groups that keep the number of decision makers below approximately six will experience an ‘‘acceptable’’ level of scalar stress. Conversely, groups with more than about six decision makers will experience a condition of ‘‘high’’ scalar stress associated with degraded group decision-making ability and performance, indicated by disputes, factionalism, and longer decision-making times.

The impact of these scalar constraints on group structure has been demonstrated to affect mean camp size (measured in the number of households) in a sample of 19 ethnographically recorded nomad aggregations (herding camps) by Johnson (1983). Despite varying environmental conditions (with groups from Nigeria to Afghanistan) and variable household sizes (ranging from 5–8.26 individuals), the average (mean of means) camp size was found to be 5.64 households. The fact that this mean is very close to the average scalar threshold of 6 observed in the small group studies discussed above provides compelling support for the hypothesis that scalar stress, as opposed to another factor (such as the environment), constrains the number of interacting social units in human groups.

As noted above, the actual level at which the detrimental effects of high scalar stress will be experienced by any particular co-residential group can vary around the mean of six. The factors that account for variation in the particular level at which the detrimental effects of scalar stress become critical for group cohesion may be subsumed under the heading ‘‘context of decision making.’’ The communication problems of small groups, for example, differ from those of large groups, whose large size produces problems such as the distortion of information as it passes through multiple tiers of decision makers (Williamson 1971) or difficulties in communicating with geographically disperse units of the group (Mileti et al. 1982) (see Bernardini 1996a for a more detailed consideration of these issues). The context of decision making in small groups may have more to do with the types of decisions being made by the group, including but not limited to decisions about group location, cooperative aspects of subsistence such as land tenure, social sanctioning of deviant individuals, and defense or external aggression (Boehm 1993). An acceptable level of scalar stress may also be in part a culturally mediated variable, so that different populations might experience the pressures of high scalar stress slightly above or below the noted mean level (Johnson 1978).

Using Scalar Stress to Predict Points of Transition in Social Organization

A group can alleviate increased communications stress by limiting the number of decision makers that it contains. As population growth (generated for whatever reason) exceeds a critical stress threshold, (i.e., increases the number of decision makers past about six), the number of decision makers

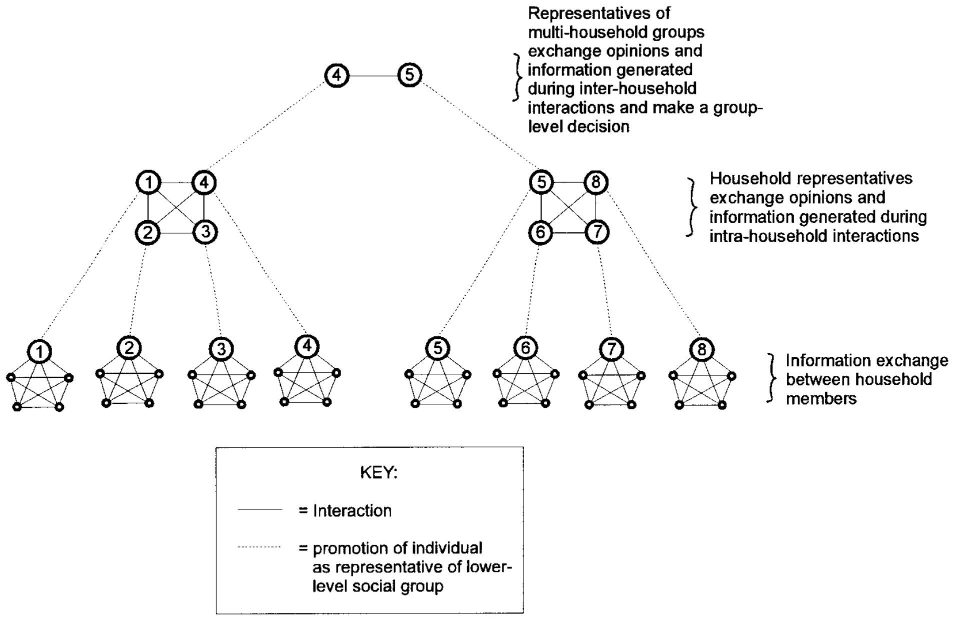

FIG. 1. Sequential decision-making hierarchy.

may be reduced by one of three basic means: (1) the development of a consensual, ''sequential'' decision-making hierarchy, (2) the development of a ''simultaneous'' decision-making hierarchy, or (3) fissioning of the group (Johnson 1978, 1982, 1983).

The development of a *sequential* decision-making hierarchy involves the formation of nested groups of decision makers, who pool information and opinions at one level before passing this decision to a more inclusive social group (Fig. 1). The heads of these larger social units, though they may operate as specialized decision-makers in particular contexts, generally do not transfer this status to other aspects of group life, and different specialized decision makers may emerge in different contexts.[1,*] This form of organization reduces the number of decision makers by expanding the size of the basal decision-making unit. The expansion of basal unit size (e.g., a switch from the nuclear to the extended family as the basic decision-making unit) reduces the number of decision makers by subsuming several smaller units (e.g., nuclear families) into fewer, larger units (e.g., extended families). In such a hypothetical situation, one individual from each extended family would then represent this social unit in group-level discussions, instead of one individual from each nuclear household. As delegates of the most inclusive social units, these individuals would convene to make decisions on behalf of the group as a whole. This process necessitates a reduction in the autonomy of smaller units at the expense of streamlined communication at a larger scale. The scalar stress value of a group with this type of decision making is calculated from the number of the largest, or most inclusive social units (those that interact in group-level decisions).

The development of a *simultaneous* decision-making hierarchy also produces a system in which each individual no longer has the responsibility of performing all duties relating to information processing and decision making. This hierarchical form of social

* See notes section at end of paper for all footnotes.

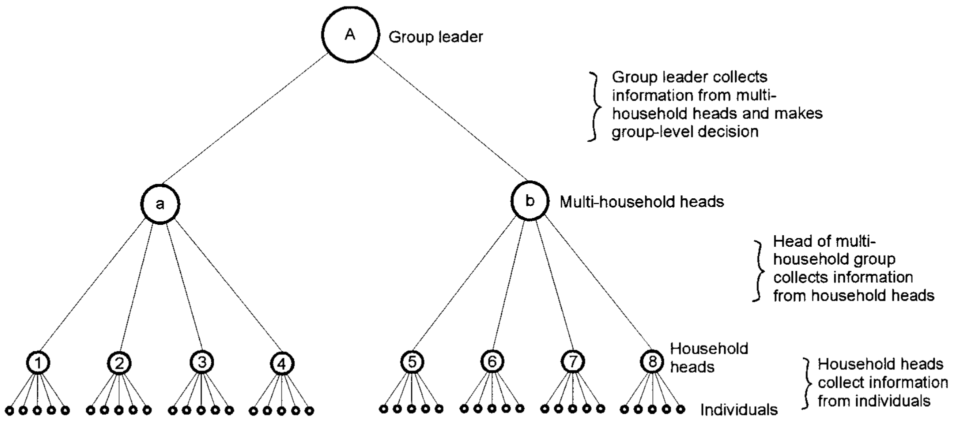

FIG. 2. Simultaneous decision-making hierarchy.

organization reduces scalar stress by designating specialized information processors who represent a number of related, recruited, coerced, and/or subordinated individuals in the decision-making arena (Fig. 2). The primary distinction between simultaneous and sequential hierarchies is that in simultaneous hierarchies, specialized decision makers generally apply their differential status to many aspects of group life, a situation which often translates into open social inequality (Johnson 1982). The scalar stress value of a group with this type of decision making is calculated from the number of second-tier decision makers controlled by the highest-level decision maker in the hierarchy (known as the "span of control"). As was the case in sequential hierarchies, as specialized decision makers represent increasing numbers of people, the autonomy of lower levels is reduced. Thus, in both simultaneous and sequential hierarchies, as group size increases there should be an increased emphasis on larger, or higher-level, decision-making units and a corresponding deemphasis on smaller, or lower-level, decision-making units. The increased emphasis on larger decision-making units at the expense of smaller ones should be expressed materially, for example in the presence or absence of architectural correlates for these social groups (see below).

The development of sequential or simultaneous hierarchies as alternate paths to reducing scalar stress are governed by the same cognitive constraints, so that *scale-based* transition points in the social organizations of both types of groups should occur with equal regularity. These alternate organizational strategies are schematically represented in Fig. 1 and 2. In both strategies, four households of six members each are organized into multiple-household groups. Though the organizational structure of the two strategies is parallel, the actual mechanics of decision making can be seen to differ greatly. One significant difference between the two strategies is that, although scale-based transition points may occur with equal regularity in the two types of organizations, the degree to which episodes of social reorganization correlate with scalar thresholds may vary with the degree to which social inequality is institutionalized in a society. That is, since nonhierarchical groups have been argued to be governed by a sophisticated web of egalitarian checking mechanisms (Boehm 1993), there may not be many social "cracks" available for aspiring leaders or aggrandizers (Clark and Blake 1994) to exploit. As a result, scalar thresholds, as times of *necessary* social change, provide important windows of opportunity for would-be leaders of nonhierarchical groups to manipulate times of social reorganization to improve their position in society (Bernardini 1996b; see also Aldenderfer's [1993] model of ritual change). Groups with more explicit or institutionalized hierarchy, in contrast, have already (by definition) broken the initial barrier to social inequality, so that subsequent changes in social organization may not be so dependent on the opportunities for social change provided by scalar thresholds. Once barriers to inequality begin to be explicitly broken down, subsequent episodes of organizational change in societies with institutionalized hierarchy may not correspond as closely to scalar thresholds.

In contrast to these first two strategies for reducing the number of decision makers in a group, the occurrence of a *fission* event signals that a group has reached an organizational stress threshold and is unable or unwilling to reorganize in order to maintain its social organization at a lower scalar stress level. At this point, the community can no longer function as a single political unit; instead, scalar stress is reduced by dividing the group into two or more smaller components, the size of each of which is more appropriate for the existing form of social organization.[2] The interpretation of a fission event as a response to a critical scalar stress threshold provides a unique opportunity to investigate the social organization of a group. The scalar stress that motivates a fission event is ultimately generated from the number of the largest, or most inclusive, decision-making unit present within the group (the units that must interact on a face-to-face basis to produce group-level decisions). Each of these units represent a number of nonspecialized group members in the decision-making arena. As the total population of a group increases, so must the number of these most inclusive decision-making units; without a corresponding increase in the number of these specialized decision making units, each group must grow larger. Continued growth of these groups will strain the interface between specialized and nonspecialized group decision makers, and nonspecialized group members may express their dissatisfaction with their representation in group affairs by ''voting with their feet.'' However, the number of specialized decision making units cannot be increased indefinitely, since the cognitive constraints of the individual specialized representatives of these groups make it increasingly difficult for them to interact with a growing number of colleagues (Williamson 1971; March and Simon 1958). It is at these threshold points at which scalar-motivated fissions occur.

It is clear that the social organization present at the time of a fission event represents the crystallization of a scalar threshold: at the point of fissioning, the number of the most inclusive decision-making units exceeds the level at which a necessary level of group communication can be maintained. Johnson (1982:396–404) has demonstrated the predictive power that can be generated from this type of situation using data on dispute frequencies in !Kung camps recorded by Lee (1979). Johnson interpreted the high frequency of disputes observed in !Kung extended family camps (where the extended family was the basic social unit) as evidence of degraded decision-making performance and thus as a proxy measure of high scalar stress. Given that the average frequency of 11 extended families per camp was high enough to generate scalar stress in those camps, Johnson then asked how large camps might be in the absence of extended family units (i.e., camps with only nuclear households). Assuming that interaction between nuclear households would generate scalar stress at the same rate as interaction between extended family households, Johnson predicted the maximum size of household camps in the following manner. The observed frequency of 11 extended families per camp required $(11^2 - 11)/2$, or 55, face-to-face interactions for each extended family unit to communicate with every other family. Interactions between as many as eleven nuclear families may be sustained without exceeding this scalar threshold of 55 interactions observed at the extended family camps. At an average size of 4 adults per nuclear family, the maximum size of nuclear family camps should therefore be about 40 adults. This predicted value was found to correspond closely with the population level at which nuclear family-level organization is replaced by extended family organization (about 35 adults)—a shift to a larger, more inclusive decision-making unit. Importantly, the frequencies of smaller social units present at the extended family camps, such as nuclear families or adults, were poorer estimates of maximum household-camp size, since they were only components of the operative, larger extended family decision-making units. This example demonstrates that organizational stress is best measured in terms of the number of largest, or most inclusive, decision-making units. As the highest tier of specialized decision makers, the representatives of these units ultimately bear the responsibility of making group-level decisions, and it is the face-to-face interaction between them that best measures scalar stress.

Thus, from a ''high'' scalar stress situation it is possible to derive organizational thresholds at which similarly high levels of scalar stress would be reached by *different sizes* of decision-making units. In this manner, the size and organizational structure of a range of social groups can be predicted from social data from a single settlement.

THE ORAIBI SPLIT

The well-recorded fissioning of the Hopi village of Oraibi in 1906 will be used to conduct an investigation of social organization in the American Southwest parallel to that outlined by Johnson for the !Kung. Interpreting the split of the Pueblo of Oraibi to represent a critical scalar threshold that was resolved through group fission, ethnographic data on the size and number of social units present at the time of the split will be used as a baseline for predicting scalar thresholds in smaller pueblos (i.e., pueblos with smaller, or less inclusive, social units than Oraibi).

The two factions involved in the Oraibi split were the ''Friendlies'' (or ''Progressives''), and the ''Hostiles'' (or ''Conservatives''). The names, given by observers of the day, refer to the position of the factions on the issue of U.S. government involvement in Hopi affairs. The split occurred on September 6–7, 1906, when the Friendlies expelled the Hostiles, who made up roughly half of the population of Oraibi, from the village. The Hostiles settled in a number of splinter villages near Oraibi, and in the years following the split the population remaining at Oraibi dwindled. By 1911, what had been the largest Hopi village contained less than a quarter of the people that it did five years earlier (Rushforth and Upham 1992:129).

A number of factors have been advanced to account for the Oraibi split, which has been called ''the most celebrated example of village factionalism in the Southwest'' (Cameron 1991:106). Although the rhetoric of the factional dispute involved the issue of how the Hopi should respond to U.S. policies (Titiev 1944), evidence for political and power struggles in the village can be found before government issues arose (Levy 1992). Contemporary observers of the 1906 split posited the existence of underlying causes: ''It is believed by not a few persons who know these Indians well, that their division grew wholly out of the internal political dissentions of the tribe'' (Leupp 1907:118, cited in Whiteley 1988:265). Bradfield (1971) proposed that strain resulting from environmental degradation (arroyo cutting) motivated the development of factions competing for land, but later found that significant degradation did not occur until after the split. Whiteley (1988) has portrayed the Oraibi split as the fulfillment of an ancient prophecy, though failure to convincingly demonstrate existence of such a prophecy prior to the split and the third-hand nature of the information used (an account of his consultants' accounts of 1906 Oraibi leaders' accounts of their motivations in destroying the pueblo [Rushforth and Upham 1992:140]) weakens his argument. Levy has presented an argument that the Oraibi split was a ''revolt of the landless'' (1992:9) under conditions of population and resource stress. However, Whiteley (1988:150) notes that many of the families that left Oraibi as a result of the split (supposedly those dissatisfied with their economic conditions) ''continued to cultivate in the areas of the main Oraibi Valley and elsewhere which they had farmed prior to the split,'' making it unlikely that land was the sole or even primary motivating factor behind the split.

Although poor environmental conditions, land shortages, and interference by the U.S. government are all likely to have contributed to the strain on the economic and social base Oraibi at the turn of the century, none of these factors alone are satisfactory as causal explanations. Two nearby Hopi villages on First and Second Mesa experienced similar enculturative and environmental conditions at the turn of the century, yet neither fissioned as Oraibi did. In this light, it is possible that the large population size of the pueblo (almost 40% larger than any other contemporaneous Hopi village) could have played a factor in generating the type of scalar communications stress discussed above. There was an estimated 30% population increase at Oraibi between 1872 and 1900 (Levy 1992:113, Table 6.8), including the addition of 9 new clans into the existing clan–phratry structure (Titiev 1944:55), with no other evidence for reorganization of the existing social organization to better accommodate information flow within this larger group. An additional group of 30 migrants from nearby Second Mesa also settled in Oraibi in 1904 (Titiev 1944:83–84).

Given the evidence for population increase, it is significant that some or all of the factors listed above ultimately manifested themselves in the factional disagreement over the appropriate response to U.S. policies regarding the Hopi. While it is now clear that explanations of the Oraibi split must be multicausal, in light of this last point the failure of Oraibi's population to achieve a consensus in the decision-making process could be indicative of a situation of *high scalar stress* that was only resolved through fissioning.

Decision-Making Units at Oraibi

The initial stage of constructing a predictive model from the Oraibi fission involves determining the types and frequencies of decision-making units present at Oraibi at the time of the split and the scalar stress level of this social arrangement. The polarization of the population during the split should have forced the membership in social groups to be more clearly defined, with each social unit being confronted with the binary identity choice of ''us'' or ''them.'' Levy's (1992) analysis of the split does in fact indicate that a number of supposed ''integrating'' mechanisms, such as rules of exogamy, were violated to facilitate the polarization of social units along the lines of the split. In this sense, an examination of the lines along which the pueblo split should provide insight into the important social units that constituted Oraibi's decision-making hierarchy at the time of the fissioning. The most important task is to identify the most-inclusive decision-making unit operative at Oraibi during the time of the split. According to the information theory model developed above, scalar stress is generated and measured by the interaction of these decision-making units. Levy's (1992) detailed examination of the Oraibi split provides important insights into the relationships between these social units, and much of the following discussion is based on his study.

In his ethnography of Oraibi, Titiev described the Hopi as ''divided into a number of comparatively small unilateral exogamous groups which, in turn, are grouped into larger exogamic divisions'' (1944:44). Titiev recorded four primary types of these decision-making units above the adult at Oraibi at the time of the split, representing different levels of Oraibi's decision-making hierarchy: the household, lineage, clan, and phratry. In simplified form, each larger decision-making unit may be conceived of as being composed of smaller social units, so that a household is composed of a number of adults, a lineage is composed of a number of households, a clan is composed of a number of lineages, and a phratry is composed of a number of clans. However, the economic and ritual relationships between Hopi social groups must be considered in some detail for a complete understanding of Hopi social organization.

Levy (1992) identifies the clan and phratry as focal points around which important negotiation, for social position within Hopi pueblos occur. The importance of these two social groups stems from their function as the mechanisms through which inheritance of two critical resources, ceremonies and land, are reckoned. The distribution of ritual and economic resources within a village has important implications for the degree to which clan and phratry social units might act as cooperative decision-making bodies. Hopi mythology and practice suggest a differential ranking among clans along the lines of landholdings and control of ceremonies. According to Oraibi mythology, the social position of each clan in the village was determined by the order of its arrival and the ceremonial possessions it brought with it (Eggan 1966:125), so that the earliest arrivals received the best lands and contributed the best ceremonies. Although the members of such high-ranking clans are not visibly more wealthy than members of low-ranking clans, their differential status does translate into other types of social and economic power. For example, the well-watered fields of high-ranking clans may have, among other things, enabled them to produce cotton in addition to corn. Although cotton production was limited at the turn of the century, differential access to this ideologically charged resource in prehistory could have been highly significant (Riley 1987; Galle 1995). Brandt (1978, 1981, 1985) has also demonstrated the nontrivial, even oppressive, level of social control that can be exerted through control of ritual or knowledge-based power in modern pueblos. Levy (1992) created a system of clan ranks according to the variables of landholdings and ceremonial control and found that in fact there was considerable disparity in the ownership of both land and ceremonies among turn of the century Oraibi clans. Noting a strong positive correlation between these two variables, he combined them into a synthetic rank for each clan (see Levy 1992, Table 3.1, p. 41).

Oraibi clans are exogamous social units whose members are connected through fictive kinship. Clans can consist of only a single household, but are more often composed of a single matrilineage. A matrilineage may be broken down into two levels of subunits: lineages, which serve as the vehicle through which property and ceremonies are transmitted within the matrilineage; and households (components of lineages), which are the basic productive unit (Levy 1992). The matrilineage is headed by the clan mother (the head of the ''prime'' lineage), who controls the clan's land and ceremonial paraphernalia. One of the brothers of the clan mother usually serves as the priest of the ceremony controlled by that clan. The sisters of the clan mother head ''alternate'' lineages, and the daughters of these alternate lineage heads become members of a ''marginal'' lineage (Levy 1992).

There is some controversy over whether the lineage or the clan is the more important Hopi social unit. Eggan (1950) interprets the lineage as the primary corporate action group, but because Hopi lineages consist of non-coresidential kin they are often difficult to define in ethnographic contexts, prompting Titiev to call them "the vaguest of Hopi divisions" (1944:58). Whiteley (1988:49) seconds this interpretation, arguing that the lineage is "best regarded as an anthropological model rather than a full reflection of the empirical situation." In this analysis I follow Titiev and Whiteley in interpreting the lineage as an important mechanism of inheritance, but the *clan* as the primary cognized unit. Further, although the concept of "lineage" will be used to discuss the internal workings of a clan, the empirical focus will be on *households* as the productive subunits of a clan, rather than lineage segments (following Titiev (1944) but *contra* Levy (1992:47–53).[3]

The differential ranking of lineages within the matrilineage of a clan determines the inheritance of "rights, duties, land and ceremonial knowledge," with transmission generally following social proximity to the clan mother (Eggan 1950:109). Given this criterion, the importance of lineage position to clan members can be seen to vary both with the quality of the land and ceremonies owned by the clan (its rank) and with the status of a lineage within it. Lineage position is critical to the prime and alternate lineages of high- and middle-ranking clans, since these lineages stand to inherit considerable ceremonial and economic resources. These lineages have a vested interest in the survival of the clan, and this interest could be a basis for cooperative action between them. In contrast, lineage position is relatively unimportant to all lineages of low-ranking clans, since there are neither lands nor ceremonies to be inherited. This seems to accurately describe the situation that obtained in the Oraibi split, with the (land controlling) women of prime and alternate lineages tending to align themselves in opposition to the women of marginal lineages (Levy 1992). Since all but the highest-ranking clans contained a marginal component, clans therefore did not act as completely homogenous decision-making units during the split. Nevertheless, many clans still operated as relatively coherent social units—in 23 out of 28 cases (82%), at least two-thirds of a clan's members sided with a particular faction.

Clans are also likely to contain a second economic motivate for integration, since their size corresponds closely to the "restricted sharing group" modeled by Hegmon 1991 as the optimal sharing strategy for agricultural groups in variable environments. Hegmon's simulation suggests that a form of restricted sharing between households increases the long-term chances of household survival over pooled sharing strategies. Household survival rates increase as the number of sharing households increases to about four, but little change occurs with further increases in the number of households (Hegmon 1991:319). Thus, there do seem to have been several bases for collective decision making by clans (at least within their upper strata), though a complete understanding of the decision-making position of clans at Oraibi requires a consideration of their position relative to two larger, more inclusive social units, the phratry and ceremonial society.

Hopi clans are grouped into phratries, averaging three clans per phratry at the turn of the century. Phratry members are clans that are believed to have become "partners" during their wanderings following their emergence from the underworld. Much like the lineages of a clan, Levy (1992:54) found that generally, one clan in each phratry was of preeminent rank (i.e., in control of valued ceremonial and land resources). The phratry is the largest exogamic unit at Oraibi, but is unnamed and was not thought by Hopi ethnographers to have any economic or political duties (Eggan 1950). The importance of the phratry lies in the transmission of the control of ceremonies, with "partner" clans assuming the ceremonial duties of shrinking or recently extinct clans. Often this transition is not a smooth one, with partner clans struggling for control of an available ceremony (Levy 1992:55). If the assumption of ceremonial duties from defunct clans by phratry partners is an important strategy of increasing a clan's ceremonial status, then the phratry may exhibit some cooperative aspects of decision making in much the same way as seen in the lineages of a clan. That is, phratry partners might act collectively to preserve the integrity and status of the phratry, if only to maintain access to the resources controlled by their fellow partners. Support for the suggestion that phratries acted as collective units or had collective interests which were an incentive for cooperative behavior comes from the fact that Titiev was able to determine phratry membership more clearly than clan membership in his census of Oraibi (1944:53).

Clans also figure prominently in the composition of ceremonial societies, which share with the phratry the position of being the largest, or most inclusive, social unit quantified by Titiev at the time of the split. Although the societies are controlled by a single clan (sometimes two), in theory the ceremonial societies are classic cross-cutting social groups that, because they draw membership from across the clan–phratry system, provide important horizontal integration to Hopi communities. In fact, however, the membership of ceremonial societies and phratries overlapped considerably, so that at Oraibi ''the majority of members in each society were drawn from its controlling clan or from related clans within the phratry'' (Levy 1992:9). Further, the development of factions at Oraibi caused men to withdraw from societies controlled by clans of opposing factions, so that ''*the ritual sodalities* [*ceremonial societies*] *themselves became factional nuclei*'' (Whiteley 1988:71, cited in Levy 1992:101, italics added). Although the existence of marginal lineages within most Hopi social units prevented these units from acting in complete unity during the split, in 6 out of 10 active ceremonial societies roughly two-thirds of the men sided with the same faction, and the plurality of members in 7 out of the 10 ceremonial societies was drawn from the phratry of the controlling clan. Thus, the sodalities seem to have functioned as important decision-making units during the split, serving as a vehicle though which factional alliance was consolidated.

A final decision-making component of Oraibi social organization consists of the members of the ''Chief's Talk.'' These members, led by the head of the ruling Bear clan and including the heads of the five or six most ceremonially prestigious clans, met annually to discuss village matters. However, the administrative power of all but two were limited primarily to their own clans (Titiev 1944:60), and the infrequent nature of their meetings does not suggest that the council was a strong governing force in the daily workings of the pueblo. Although several individual members of the Chief's Talk were important players in the factional dispute, the Chief's Talk group does not appear to have acted as a coherent decision-making force during the split.

This necessarily brief summary of the relationships of Oraibi social units has suggested that the ceremonial society and the phratry are most likely to have operated as the ''most inclusive decision-making units'' at the time of the split. The membership of these two groups seem to have overlapped considerably by the time of the split, and some combination of these two social units is thus the best approximation of the highest level of Oraibi's decision-making hierarchy. These two groups occurred with roughly equal frequency at Oraibi (9 phratries and 10 ceremonial societies), although the phratry is the larger of the two social units. Given the phratry's larger size, the motivation for at least some of the partner clans in phratries to cooperate with each other, the existence of a preeminent clan within most phratries, and the fact that this clan also controls the ceremonial society to which many phratry members belong (around which the fac-

Decision-Making Unit	Mean Size	Frequency
Phratry	63 adults	9
Clan	19 adults	30
Household	4 adults	147
Adult	1 adult	566

FIG. 3. Size and frequency of decision-making units at Oraibi in 1906.

tional nuclei developed), the phratry may best represent the largest potential decision-making unit at Oraibi. In simplified form, it was the interaction between representatives of these decision-making units that best measures the scalar stress of Oraibi at the time of the split.

Calculation of Scalar Stress for Oraibi at the Time of the Split

Figure 3 presents the mean size and frequency of decision-making units at Oraibi at the time of the split. Because most societies, including the modern Hopi, ascribe most of the power to make political decisions to adults, the size of decision-making units will be measured by the number of adult members.[4] The formula $(n^2 - n)/2$ mathematically expresses the number of one-to-one interactions that must take place for each decision maker to exchange information with every other decision maker in a group of n people; nine phratries were in existence at the time of the split, so the scalar stress value for Oraibi at the time of the split was $(9^2 - 9)/2 = 36$.

To predict transition points for sites with *smaller* most-inclusive social units (namely clans, households, or adults), a graph of population vs scalar stress at Oraibi (Fig. 4) was generated in which the scalar stress curves for adult-, household-, clan-, and phratry-level decision-making units have been plotted.[5] To generate this graph, the critical scalar stress value of 36 for Oraibi was first plotted (as a horizontal dashed line in Fig. 2). The rest of the graph was generated by using the size of average Oraibi households (4 adults), clans (19 adults), and phratries (63 adults) to calculate the frequency of these units in villages of variable sizes (e.g., a village of 10 adults, 25 adults, 50 adults, etc.). The increase in scalar stress for each unit was then calculated using the $(n^2 - n)/2$ formula and plotted against village size as measured by the number of adults in the population. The intersection of these individual curves with the horizontal line representing the critical scalar stress threshold identifies the points at which organizational transformations should occur. Organizational transformations can be seen to produce a marked reduction in the number of interactions between decision makers in a village. For example, a village of 40 adults, in which every person was an equal participant in the decision-making process, would require 780 interactions for all decision makers to interact with each other. However, if this same village of 40 adults were organized into households of four adults each, in which one person from each household interacted only with other household representatives to reach village-level decisions, only 45 interactions would be required for all decision makers to interact with each other. Note that the x-axis is plotted on a logarithmic scale, which has the effect of steepening the slopes of the larger social unit curves.

The methodology used to construct this graph requires the assumption that the interaction between different types of decision-making units (e.g., phratries, clans, households) generates scalar stress at the same rate, though Johnson's case study (1982, see above) suggests that this is not unreasonable. Further, it requires the assumption that during social reorganization, groups will use existing social units as building blocks to construct more complex forms. This assumption is consistent with the evolutionary principle known as "Romer's Rule," which proposes that "the initial effect of an evolutionary change is conservative in that it

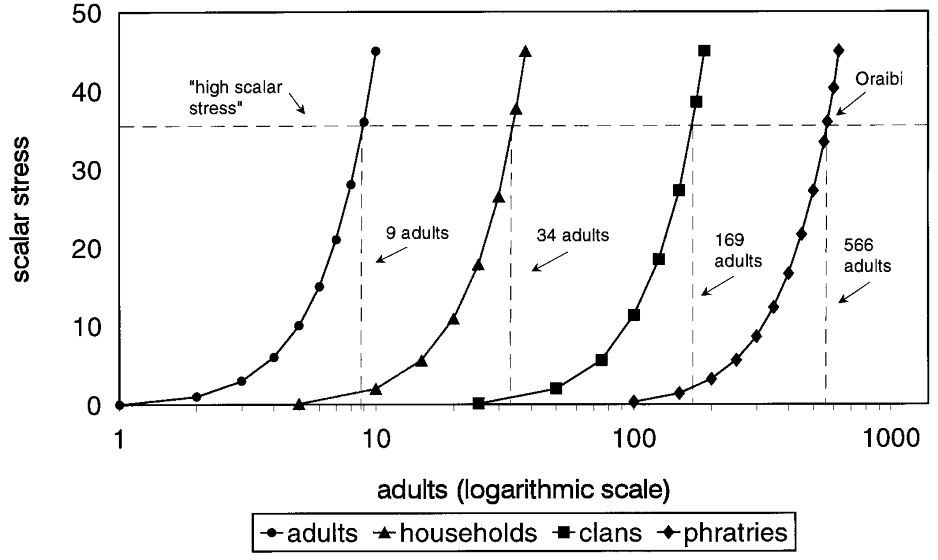

FIG. 4. Population vs scalar stress at Oraibi.

makes it possible for a previously existing way of life to persist in the face of changed conditions'' (Rappaport 1979:229–230).

The graph predicts four transition points for a decision-making hierarchy structured by adult-, household-, clan-, and phratry-level decision-making units at population sizes of roughly 9, 36, 170, and 570 adults. These values represent the maximum number of people capable of being organized by different levels of decision-making hierarchies, equivalent to the total population of nine of the most inclusive decision-making units present in the co-residential group:

- 9 adult decision-making units = total adult population of 9
- 9 household decision-making units of 4 adults each = total adult population of 36
- 9 clan decision-making units of 19 adults each = total adult population of 170
- 9 phratry decision-making units of 63 adults each = total adult population of 570

Given data on population size for a number of settlements whose social organizations are composed of these decision-making units, we should expect to find co-residential communities whose total adult populations fall between the boundaries of two critical thresholds. Specifically, settlements are expected to fall into the following ranges and feature the following decision-making units as the largest units of social organization within their decision-making hierarchies:

Adult-level sites: 1–9 adults without any higher level of decision-making unit than the *adult* (defined as any individual over 18 years of age, or 66% of the estimated population based on Hopi ethnographic data[1]).

Household-level sites: 10–36 adults without any higher level of decision-making unit than the *household* (defined as an interacting group of adults).

Clan-level sites: 37–170 adults without any higher level of decision-making unit than the *clan* (defined as an interacting group of households).

Phratry level-sites: 171–570 adults without any higher level of decision-making unit than the *phratry* (defined as an interacting group of clans).

I will use the labels ''adult-level, household-level, clan-level, and phratry-level'' to describe the organization of settlements in which this social unit (adult, household, etc.) is the most inclusive within the decision-making hierarchy (in other words, the next largest social unit below the site as a whole). Ethnographic terms for these social groups have been retained for consistency with the data from Oraibi, but these labels refer exclusively to the size and composition of social units rather than their function. Only the tendency for prehistoric and historic Southwestern groups to develop decision-making hierarchies with *numerically* similar social building blocks is being tested here; inferences about the nature of these social units are not logically produced from this model (though the conclusions of the model may be cited in support of specific interpretations about component social units).

Behavioral studies of small group interaction shed light on the specific distribution of sites within the ranges listed above. A study by Ziller (1957) noted that as group size increased from two to the critical threshold of six members (decision makers), the objective quality of the groups' decisions increased (cited in Cummings et al. 1974:461). The implication of this study is that up to the limit of nine units (the Oraibi threshold), the quality of decision making should increase with the number of decision makers. This, in turn, should be reflected in a higher group success rate for these groups than those containing less than two or greater than nine units. As a result, we should expect the frequency of sites to increase as the number of decision makers increases from two toward nine, followed by a decline in the frequency of sites containing greater than nine units as scalar stress rises and the critical threshold is crossed.

One final point should be emphasized. As noted by Johnson (1978:97, 98), "one of the most interesting aspects . . . of any maximization model is the implications of deviation from maximizing assumptions." In this sense, the potential insight to be gained by applying the Oraibi model comes as much from its ability to highlight exceptional cases (aspects of group organization that do not conform to scalar constraints) as its ability to identify and account for modal ones.

A Special Case: Dual Divisions

A dual division form of social organization provides an interesting alternative to the unilinear construction of a decision-making hierarchy discussed above. The creation of two parallel decision-making hierarchies within the same settlement effectively *doubles* the critical points of transition in social organization for the site as a whole. Although I did not collect the data necessary to evaluate this situation, both modern (e.g., Tanoan pueblos) and potential prehistoric (e.g., Miribal Site, Kluckholn Site, Archaeotekopa II, Pueblo Bonito) examples of dual division organization exist in the Southwest and could be utilized for such a comparison. Significantly, these potential prehistoric dual division sites are some of the largest in the Zuni and Chaco areas, perhaps reflecting the higher threshold points supported by a dual division type of organization.

APPLICATION OF THE ORAIBI MODEL TO THE PREHISTORIC AMERICAN SOUTHWEST

Ritual, Architecture, and the Use of Interactive Structures

The calculation of scalar stress levels in prehistoric populations requires knowledge of the number and size of social units in a population. Archaeologically, social organization is most readily inferred from architectural remains. An awareness of the unique characteristics of both ritual and architecture facilitates the identification of social units from architectural remains. By utilizing these characteristics, the number and types of residential and nonresidential structures may be used to postulate the size and nature of social units in a settlement.

Ritual possesses a number of characteristics that make it a unique form of communication among social groups. Rappaport (1979:174) has argued that "ritual is not simply an alternative way to express certain things, but . . . certain things can be expressed only in ritual." Religious rituals, because they include implicit or explicit references to the sacred (and therefore the unquestionable), impart a degree of sanctification to communication, increasing both the likelihood that messages will be considered truthful and that they will be acted upon in a predictable and orderly manner (Rappaport 1971:69). Further, the relative invariance of acts and utterances that characterize ritual "introduces significant redundancy into the information being exchanged," leaving less room for innovation and error in communication and facilitating more effective interaction within the social context (Adler 1989:41). Ritual thus provides a context in which the actions of participants are more predictable, and certain information and behavioral norms can be assumed to be shared knowledge. By reducing, simplifying, and standardizing the information that is exchanged among the participants of a ritual, ritual facilitates information exchange. Given the importance of maintaining effective information channels within even small groups of people, communication through ritual may therefore be interpreted as an important method of alleviating scalar stress.

Ritual architecture, in turn, provides a designated physical environment in which ritually facilitated communication activities may occur. Such structures enable and direct a number of people to formally indicate their acceptance of the canons encoded in ritual, facilitating information flow between the members of this shared experience. In an ethnographic survey of nonhierarchical communities, Adler (1990) noted the consistent presence of integrative architectural facilities, the size of which increases with the size of the use group (recall that Johnson [1982] demonstrated that basal unit size tends to increase with group size). In the context of a decision-making hierarchy in which efficient information flow between decision-making units is essential for group success, ritual "integrative structures" may therefore play an important role in the process of information exchange and decision making (Adler 1990:39; 1990). Below, following Ortman (in preparation), I will employ the term "interactive" in place of integrative in an attempt to avoid some of the functionalist baggage that has become associated with this term.

These unique characteristics of ritual and architecture "make the spatial arrangement of structures in a settlement a mnemonic, or *guide to expected social behaviors and social groupings*" (Hegmon 1989:8, emphasis added). In other words, if interactive structures are employed by the decision-making units of a hierarchy to facilitate information flow and decision making, then the architectural remains of these structures may be examined as potential correlates of the decision-making hierarchy of the group. Thus, although not all social units may have architectural correlates, all architecture can be expected to be meaningfully related to social units. In the following analysis of social organization in the American Southwest, "interactive ritual architecture" will be interpreted in this manner to infer different levels of decision-making units from architectural data.

The scale of social units can therefore be inferred by the simple method of comparing ratios of domestic:nondomestic architecture using the following basic assumptions (Lipe 1990:54): (1) the size of the structure has a more or less regular relationship to the size of the group that used it (a reasonable assumption given the results of Adler's [1990] study discussed above) and (2) that spatial propinquity can be used to infer use groups—in other words, that structures located adjacent to each other are more likely to have been used by the same group than are structures located far apart. The high surface visibility of architecture in the Anasazi region of the American Southwest has generated a rich history of research employing this methodology, notably including Prudden (1903), Steward (1937), Dean (1970), and Lipe (1989). The current research will focus on interpreting the social units that were related to the three primary classes of nondomestic, potentially ''ritually interactive'' architecture in the northern Southwest: small kivas, great kivas, and plazas.

There is general consensus that the three-to-four-meter-diameter circular, stone-lined, subterranean kivas that are common in many areas of the Southwest evolved from the round pithouse structures that served as the primary residence for a household in earlier periods. Recently, however, there has been considerable debate about the characteristics that define a kiva and the behaviors that are likely to have occurred in them (Lipe and Hegmon 1989; Lekson 1988; Adler 1993; Ortman, in preparation). The general perspective that has emerged from this discussion is that both ritual and domestic activities are likely to have occurred in small kivas during the period of interest here (the Pueblo III period, roughly A.D. 1150–1300). This mixture of activities is consistent with Adler's (1989) expectations for the generalized use of such ''low-level'' facilities (those that serve to integrate only a portion of a community). The consistent spatial relationship of small kivas with a cluster of 5–10 surface rooms during this period has led to a second generalization that small kivas were the locus of interaction for the members of a single, or small group of, co-residential households (Lipe 1989), though variability exists in the inferred size of the small-kiva use group within the period of interest (e.g., Dean 1970).

''Great kivas'' are much larger structures than these small kivas, averaging roughly 16 meters in diameter (Adler 1989:45), though the morphology of these facilities also clearly makes reference to ancestral pithouse dwellings. The larger size and more restricted range of behaviors attested to in these great kiva structures suggests that they served as ''higher-level'' interactive facilities (Adler 1989:45), facilitating interaction between the members of a use group several times the size of a small kiva. Finally, plazas are open spaces enclosed by domestic architecture, and their morphology is highly variable in terms of the size, formality, and boundedness of the open space. The size of plazas suggests that they served as the locus of interaction for a large-scale social group and, accordingly, tend to be found only in large, aggregated sites or in the midst of large, dispersed communities. Plazas and unroofed great kivas are notable in that they substantially increase the visibility of public ceremonies, a point that I will return to later.

The Data

A sequence of architectural change from three geographic areas will be evaluated with respect to the expectations of the Oraibi model, though individual areas will be used to consider a specific level of decision making: the Sand Canyon Locality of southwestern Colorado provides data on adult- and household-level sites, the Pot Creek area of northwestern New Mexico provides data on clan-level sites, and the Grasshopper area of east-central Arizona provides data on phratry-level sites. The sites from these three areas represent a nonrandom selection of case studies from each organizational tier; the architectural sequence of a single area is not presented because no single area offered a well-recorded example of each organizational level. The primary criterion for the selection of sites was exposure and accurate recording of all or most of the site's architecture. Although the sample of sites was largely determined by the availability of data, the sites can also be argued to share, at least broadly, similar ''contexts of decision making,'' in that they are all small-scale, sedentary, agricultural populations in similar environmental conditions.

Expectations for Adult- and Household-Level Sites

For adult-level sites, the Oraibi model predicts that up to nine adults can be integrated into a group under a form of social organization in which the adult is the most inclusive decision-making unit. Each adult may (theoretically) act as an independent decision maker, interacting with all other adult group members to reach group-level decisions. Though these individuals are likely to be grouped into a larger kin-based social unit such as a household, there should be no *scalar-motivated* groupings of adults within this unit. This does not preclude subdivisions for other reasons, but the Oraibi model would suggest that for decision-making purposes, up to nine adults may interact as equivalent decision makers without generating communications strain within the group. Accordingly, if the adults of this group utilize an *interactive structure* such as a kiva to facilitate information flow and decision making within a household or between households, only one such structure should be present.

In groups with more than nine adults, the Oraibi model predicts that the adult may no longer function as the highest-level decision-making unit if an acceptable level of scalar stress is to be maintained; decision-making responsibility must be assigned to a larger social unit at the expense of the autonomy of lower-level units. In the face of communications stress generated by the interaction of too many individual decision makers, a logical step would be to convert the household, comprising a group of fewer than nine integrated adults, to the highest-level decision-making unit. Whereas in adult-level sites nine adults equaled nine decision makers, in household-level sites up to nine adults equal one decision-making unit. Individuals may still participate in the decision-making process *within* a household, but interaction *between* households would now be conducted by a specialized decision-making representative from each household (i.e., the ''head of household''). As in the case of adult-level sites, no more than about nine household-level decision-making units may be integrated at once, so that the number of households in a co-residential community should be limited to nine in the absence of a more inclusive decision-making unit. In terms of architectural correlates, if the adult members of each household continue to utilize a kiva as an interactive structure in the manner in which it was utilized in adult-level sites (to facilitate information flow within and between households),then no more than nine of these structures should be found at a single site.

A sample of sites from the Pueblo III period of the Sand Canyon Locality (Adler 1992), located in the Mesa Verde region of southwestern Colorado, provides data to evaluate these expectations. The Sand Canyon Locality is an area delimited by Crow Canyon Archaeological Center researchers designed to represent ''a spatial unit larger than a settlement and smaller than a region'' (Lipe 1992, following Willey and Phillips 1958). The Locality experienced a process of aggregation during the 12th and 13th centuries that culminated in the formation of two large, aggregated pueblos: Sand Canyon Pueblo and Goodman Point Ruin. The sample of sites employed in this analysis is drawn from the smaller sites in the Locality that date to this period of aggregation.[6]

Population estimates for these sites were calculated using a conversion of 1.5 persons per visible surface room (following Adler 1992) adjusted to include only adults (see discussion above and in Endnote 1). Room estimates were made from counts of walls when present or in the case of rubble mounds by estimating 10 m^2 of rubble per room. Following Hill (1970), it was assumed

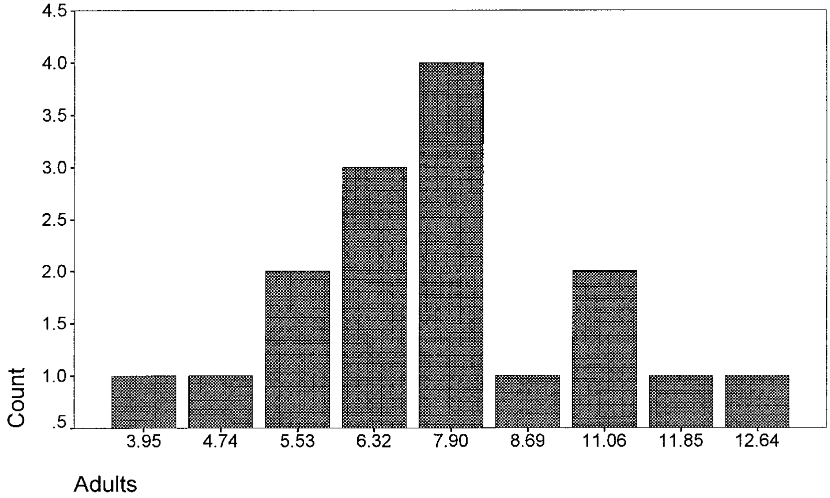

FIG. 5. Number of adults per single-kiva site in the Sand Canyon Locality.

that roughly 80% of the observed rooms were occupied contemporaneously.

As can be seen in Fig. 5, the distribution of the number of adults per *single-kiva* site forms a fairly normal bell-shaped curve centering around a mean of 8 adults, with a range of 4 to 13. This mean value and distribution closely match the expectations of the model for *adult-level* sites, which predicted an increase in the frequency of sites having up to 9 adults followed by a rapid decrease in frequency as scalar stress increased past the adult threshold. Importantly, all of these sites contain only one kiva; the presence of only one interactive structure per site suggests that the adult functioned as the highest-level decision-making unit.

Multiple-kiva nucleated aggregations of the Sand Canyon Locality (sites consisting of a cluster of kivas bounded by architecture; Fig. 6) exhibit patterning consistent with the *household-level* of decision making, although the relatively small sample size precludes robust patterning. All of these sites contain more than 9 adults, suggesting that the division of the population into multiple household units should have been necessary to maintain the organizational integrity of the village. Accordingly, all of the sites contain at least two and up to five kivas. No household-level sites contained more than 9 households (at which point the Oraibi model predicts an unacceptably high level of scalar stress), and no site contained more than 20 adults, a number which falls under the predicted household-level threshold of 34 adults (mean number of adults per site = 15). Notably, both of these values fall below the predicted thresholds for household-level sites, which suggests that factors outside of scalar stress such as land tenure or the nature of inter-village interaction were also affecting group size. Here, both the limitations

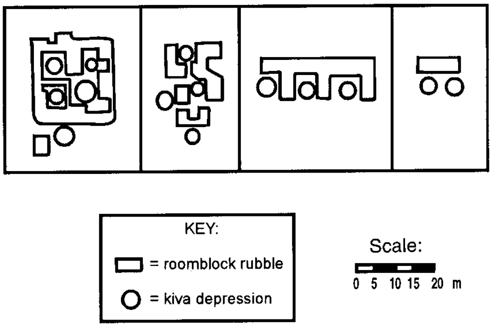

FIG. 6. Examples of multiple-kiva nucleated aggregations of the Sand Canyon Locality.

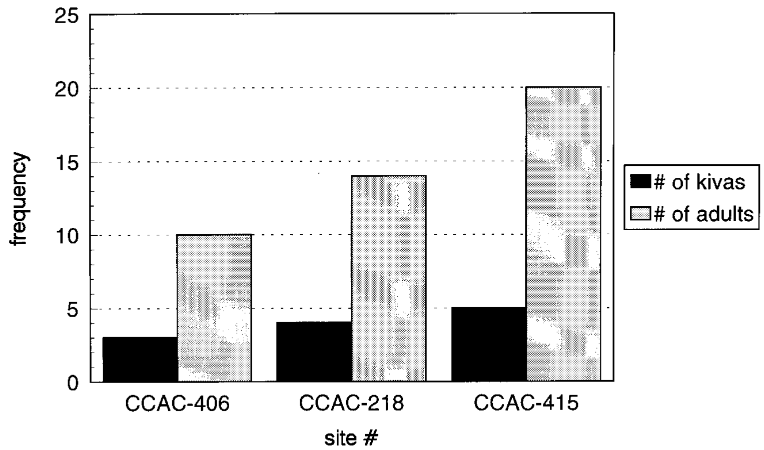

FIG. 7. Number of kivas and adults per site at multiple-kiva nucleated aggregations in the Sand Canyon Locality.

and the benefits of the Oraibi model are revealed—although scalar factors cannot explain all deviations from expectation, a scalar model can highlight the situations in which the operation of additional variables is likely. Other researchers working in the Southwest and Mesoamerica (Prudden 1903; F. Plog 1974:96; Marcus 1976:89, cited in S. Plog 1990:186) have also identified a restricted size range of household-level sites of not more than 10–12 households per site, suggesting a broader distribution of this pattern.

A strong positive correlation between the number of adults per site and the number of kivas per site is observed on the multi-kiva nucleated aggregations of the Sand Canyon Locality (r = .88, p = .045; see bar chart, Fig. 7), a pattern that contrasts sharply with that of the single-kiva sites in which the number of adults fluctuated around nine, but the number of kivas remained constant at one. I suggest that this reflects a fundamental change in social organization, one in which the household, not the adult, functioned as the primary decision-making unit. Importantly, the predictive model outlined above provides the grounds not only to recognize this reorganization but to understand why it happened and why it happened when it did.

In the mid-1200's A.D., the small adult- and household-level sites of the Sand Canyon Locality were largely abandoned, roughly contemporaneous with the construction of two large (ca. 400-room, 90-kiva) pueblos, Sand Canyon Pueblo and Goodman Point Ruin. Sand Canyon Pueblo has been intensively recorded and excavated, while less is known about Goodman Point Ruin. Sand Canyon Pueblo is relatively short lived, with few construction dates after A.D. 1270, and abandonment likely in the 1280's (Bradley 1992). Although two irregular plazas and a great kiva signal the potential existence of supra-household social units at the village, the plethora of small kivas dispersed among the domestic architecture of the site (of the variety observed on the adult- and household-level sites that precede it) indicate that the household persisted as an important, if not *the* most important, decision-making unit at Sand Canyon Pueblo. Despite the fact that the pueblo is more than 20 times larger than the largest household-level site, Bradley (1992) found a 1:5 ratio of rooms to kivas, a ratio very comparable to that of household-level sites in the locality.

According to the Oraibi model, sites the size of Sand Canyon Pueblo should have been structured by a form of decision making that privileged a much more inclusive (i.e., larger) social unit than the household (like clans or phratries) for effective internal communication to have occurred. The apparent reluctance of households to relinquish their decision-making autonomy in the face of scalar pressure is likely to have generated nontrivial communication problems within the pueblo, resulting in dissatisfaction among group members and poor-quality decisions that are likely to have contributed to the short life of the village (only about 25 years). Lightfoot and Kuckleman (1994) further note that the pueblo exhibits evidence of intermittent acts of violence throughout its occupation, also potentially indicative of poor internal integration.

Expectations for Clan-Level Sites

In aggregations of greater than about 36 adults, household-level decision making will begin to generate high levels of scalar stress, since more than 9 household units (of about 4 adults each) would be required to interact to reach group-level decisions. According to the Oraibi model, in such situations decision-making responsibility should be assigned to a larger social unit, namely the clan (defined as a group of integrated households). In this context, both individual adults within households and individual households within clans would retain some say in low levels of the decision-making process, but the primary decision-making responsibility for group-level decisions would (ideally) fall to a council of clan representatives (one drawn from each clan).

The Oraibi model predicts that up to about 170 adults (9 clans of about 19 adults each) may be integrated into a group under a form of social organization in which the clan is the most inclusive decision-making unit. If clans have architectural correlates (facilities in which information is exchanged within and between clans), the adult:interactive structure ratio of these facilities should be no more than about 19:1 (based on the average Oraibi clan size of 19 adults), and no more than 9 of these structures should be present.

Developmental period sites (ca. A.D. 750–1200) of the Taos District of northeastern New Mexico exhibit characteristics consistent with an interpretation of household-level decision making, with sites consisting of clusters of small pithouses, and few sites containing more than four such domestic structures (Adler 1993:336). In contrast to the sites of the Sand Canyon Locality, no separate interactive structures are found on these developmental period sites, implying that interaction within and between household units occurred in the pithouses (though Adler [1993:338] suggests evidence for interaction of between 4 and 12 household units). The earliest sites with both surface and subsurface (pithouse) architecture are quite small, with less than 2 pithouses and 18 surface rooms (e.g., the Llano site [Jeancon 1929]), also indicative of a household level of decision making.

After A.D. 1250, the population of smaller sites apparently aggregated into much larger sites composed of roomblocks, such as Pot Creek Pueblo (Woosley 1986). This site provides an example of a settlement in which a more inclusive, possibly clan-level social organization would have been necessary. The primary and latest component of this pueblo was constructed beginning in the late 1260's and grew by accretion as a series of discrete roomblocks around a central activity area (Crown 1991:292). By the 1300's, 10 distinct roomblocks surrounded the plaza, each with 10–35 rooms, for a total peak occupation estimate of 207 contemporaneous rooms (Crown 1991:308), or 201 adults (Fig. 8).

At least three of the excavated roomblocks are associated with kivas and/or small courtyards. Applying the conversion of 1.5 persons per room (subtracting the 35% sub-

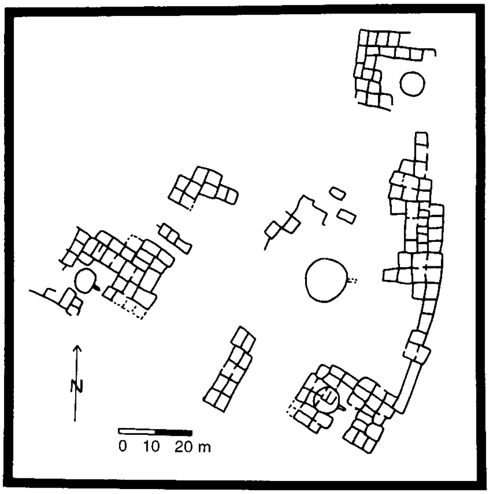

FIG. 8. Excavated units at Pot Creek Pueblo, New Mexico (redrawn after Crown, 1991).

adult population) to the roomblocks, at an average of 21 rooms per roomblock, each contained about 20 adults. This value produces an adult:kiva ratio of 20:1, a figure that closely approximates the clan size of 19 adults predicted by the Oraibi model. This correspondence suggests that these facilities served to integrate the household-level decision-making units of a roomblock into something approximating a clan-level decision-making unit. In contrast to the pattern at Sand Canyon Pueblo, Pot Creek Pueblo thus seems to have had a decision-making structure that was focused on a social unit whose scale was appropriate for the population size of the village. There is no evidence comparable to the plethora of small kivas found at Sand Canyon Pueblo to suggest that household-level social units retained decision-making autonomy at the expense of village-level integration.

However, other lines of evidence indicate alternative sources of communication strain at Pot Creek Pueblo. The 10 clan roomblocks enclose a central plaza that may be interpreted as the interactive structure that served to facilitate the flow of information between clan-level decision-making units. The 10 clans proposed at Pot Creek exceed the predicted maximum number of decision-making units (9) by one, so the scalar stress level of social organization may have been high. Interestingly, in the 1300's and 1310's, the central plaza area was more formally enclosed by the construction of the last roomblock, possibly reflecting the plaza's increasing integrative importance as scalar stress rose and integration of the clans became more tenuous. In addition, at around 1318 A.D. construction was begun on a large kiva in the center of the plaza. The kiva was apparently never finished, and the pueblo was abandoned shortly thereafter. The construction of the large kiva may represent the reaction of the pueblo's inhabitants to the high levels of scalar stress being generated by the 10 clan-level information sources in the decision-making system of the pueblo. The fact that the kiva was never completed and the site was abandoned soon afterwards suggests that this attempt was unsuccessful.

The appearance of plazas on clan-level sites suggests some interesting developments in the way in which integration may have been generated on these larger sites. Plazas differ from kivas, the interactive structures that characterized adult- and household-level sites, in two important ways. First, plazas generally provide larger spaces in which to gather a group of people than do kivas. The larger size of plazas is not unexpected given the larger size of the clan-level decision-making units that would have utilized them (Adler 1989). Second, and related, plazas are open, highly visible areas, as opposed to kivas, which are subterranean and restricted in nature. Rappaport (1979:195) has proposed that participation in ritual indicates acceptance of the tenets of its liturgical order, so that "it is the visible, explicit act of acceptance, and not the invisible, ambiguous, private sentiment that is socially and morally binding." The fact that plazas are often centrally located in a village means that a participant's acceptance was visible not only to his fellow participants (as was the case in a kiva), but to all other members of the village as well. This may suggest a greater emphasis placed on higher-level integration at larger population levels.

Expectations for Phratry-Level Sites

Aggregations of greater than approximately 170 adults exceed the maximum predicted integrative capacity of clan-level sites. In order for more than 170 adults to be integrated, more than 9 clans (at an average size of 19 adults) would have to exist in the decision-making system. This frequency of decision-making units would result in a situation of high scalar stress and a corresponding reduction in group decision-making quality and member satisfaction. Consequently, if aggregations of more than 170 adults are to occur successfully, another level of decision-making unit should be developed above the clan. Based on Oraibi data, a transition to *phratry*-level decision-making units is expected at this point (i.e., decision-making units composed of multiple integrated clans). The primary class of interactive structure expected for phratry-level sites is expected to correspond roughly to the size of a phratry, so that the adult:interactive structure should not exceed about 63:1, and there should be no more than 9 such structures present in a village. The focusing of the village's decision-making structure around the phratry should come at the expense of the autonomy of lower-level units, so that household-level units, for example, should be de-emphasized in large villages.

An example of a well-documented, potentially phratry-level site exists in Grasshopper Pueblo (Graves et al. 1982), located in east-central Arizona. Occupation of the Grasshopper region in the century before the primary occupation of Grasshopper Pueblo (1200–1300 A.D.) was characterized by small dispersed settlements (Graves and Holbrook 1982), with sites ranging from 1 to 20 rooms (mean = 19 rooms) (Reid and Riggs 1995). Though there do not appear to be clear ''interactive'' architectural correlates of households in the Grasshopper region analagous to the small kivas of the Sand Canyon Locality, Chodistas Pueblo, an 18-room site occupied during this period, does exhibit evidence for interactive architecture that may have corresponded to small social units. This village contained two ''ceremonial rooms'' and a large plaza (Reid and Riggs 1995), suggesting that the pueblo was occupied by several households which may have used ceremonial rooms for intra- and inter-household interaction and the plaza for inter-village interaction. Chodistas Pueblo was burned to the ground just prior to 1300 A.D., coincident with the establishment of a large block of rooms at Grasshopper Pueblo. The rapid growth of Grasshopper Pueblo between 1300–1330 (an increase from 35 to nearly 500 rooms), indicates that a combination of local and migrant populations settled at Grasshopper Pueblo in social units of different sizes (Graves and Holbrook 1982:196, 197). A number of lines of evidence suggest that, at least initially, the founding groups were distinct from each other, including differences in architecture, patterns of cranial deformation, and burial practices (e.g., Birkby 1982).

Grasshopper Pueblo, the largest site in the region by the early 1300s A.D., contained an estimated 500 rooms clustered into 12 roomblocks (Fig. 9). Three main roomblocks contain the vast majority of the site's rooms and surround a large, central plaza and a small roofed plaza (interpreted as a great kiva) and small plaza. Two other types of nonresidential architecture are present in these roomblocks: kivas and ceremonial rooms, which contain some of the ceremonial features associated with a kiva but which are also associated with storage and manufacturing activities. By 1325 A.D., the bulk of the 3 main roomblocks had been built and were occupied (Graves et al. 1982). The roomblocks contained an average of 95

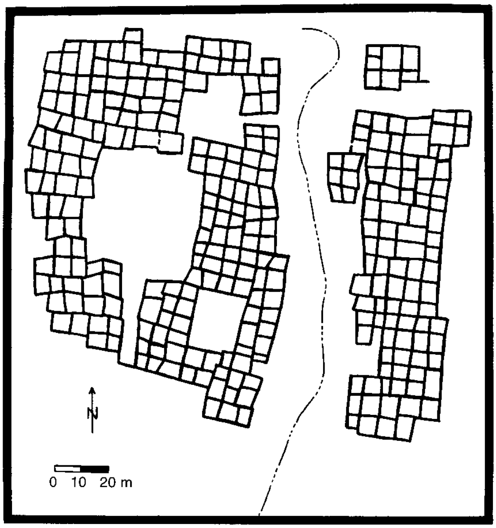

FIG. 9. Major roomblocks at Grasshopper Pueblo, Arizona (redrawn after Graves et al., 1982).

rooms each (93, 92, and 99), for a total room count of approximately 284. Roomblock 2 enclosed a roofed plaza interpreted as a great kiva, and Roomblock 3 enclosed a comparably sized open kiva. Together, the 2 roomblocks enclosed a large, central plaza. Each of the 3 roomblocks also contained a number of kivas and ceremonial rooms. Extrapolating from percentages of architectural types at Grasshopper (Reid and Whittlesey 1982:697, Table 2), each roomblock is estimated to have contained about 7 kivas, 11 ceremonial rooms, and 31 households.[7] Converting room counts to adults as in the manner described above, the total population of the 3 roomblocks was 414 adults, a population level that falls comfortably within the range of 170–566 adults predicted for phratry-level sites by the Oraibi model. Each roomblock contained approximately 138 adults.

As with Sand Canyon Pueblo, lower-level decision-making units appear to have retained some decision-making autonomy at Grasshopper Pueblo, potentially at the expense of village-level integration. Comparison of numbers of adults with the number of different architectural forms present at Grasshopper pueblo reveals four levels of social units above the household. First, each roomblock contained an average of 11 ceremonial rooms, for a ratio of about 13 adults per ceremonial room. Based on wall abutment data, Reid and Whittlesey (1982) independently arrived at the comparable estimate of three households, or 12 adults per ceremonial room. The social unit suggested by this ratio has no clear analog to any of the expected Oraibi units, though its size approximates that of an extended family or localized lineage. The frequency of this unit conforms closely to the predicted threshold of nine despite the fact that it is a much lower-level social unit than was predicted for a site of this size. The ceremonial room may have functioned in a quasi-ritual context as an interactive space for the component families of an extended family. The retention of some level of autonomy of the extended family indicated by these data is not predicted by the Oraibi model, which expects primary decision-making responsibility to be consolidated in the phratry. In a large sequential hierarchy, lower-level units are still likely to meet and make decisions before passing these on to a higher-level decision-making unit, but use of ritual architecture by this group could signify the retention of significant autonomy by lower-level units that may have come at the expense of higher-level unit integrity.

Second, each roomblock contained an average of 7 kivas for a ratio of about 20 adults per kiva. Reid and Whittlesey (1982) identified construction units of approximately six households per kiva based on wall abutment data for a comparable estimate of 24 adults per kiva. The kiva use-group could therefore have consisted of up to six household units or two extended family units, or some combination of both. The frequency and size of kiva groups conform to the constraints of a clan-level site, which would predict nine units of 19 adults. Each kiva thus appears to be the interactive structure which facilitated information exchange and decision-making between the household/extended family units of a clan.

Third, Roomblocks 2 and 3 each enclose a small roofed or open plaza for a ratio of 138 adults per structure. The inward focus of these plazas (which are enclosed by several rows of rooms) suggests that these structures serviced the members of the roomblocks only, not the site as a whole. The fact that the number of adults associated with each plaza is very close to twice the predicted size of an Oraibi phratry suggests that each roomblock may have been organized into two phratry-sized units, which may have utilized the same plaza as an interactive structure in some sort of cyclical fashion. The absence of a phratry-level structure associated with Roomblock 1 is problematic, especially since the roomblock conforms to the social organization of Roomblocks 2 and 3 for less inclusive decision making units. The members of Roomblock 1 are likely to have utilized some form of integrative structure to facilitate the integration of clans into phratries, and the open space between Roomblocks 1 and 2 could potentially have served this function as a less formal plaza area. If each roomblock contained two phratries, then there were six phratries at Grasshopper—the largest social unit at the site, present in a frequency, consistent with the maximum of nine predicted by the Oraibi model. Finally, one large, centrally located plaza is present at the center of the site. This plaza is interpreted to have served as an interactive facility for the site as a whole, facilitating information flow between the six phratries.

Although Grasshopper Pueblo does exhibit evidence for phratry-like decision-making units of the size and frequency predicted by the Oraibi model, perhaps more enlightening are the hints at weak village-level integration provided by evidence for autonomous decision-making at lower levels of the decision-making hierarchy. After the phratry-level, the predictive potential for the Oraibi model has been exhausted and no predictions may be made concerning the social organization of sites with more than 566 adults (roughly 800–900 rooms), except that another transition in social organization should occur to achieve this level of aggregation. The decision-making hierarchy must be augmented again to reduce the number of decision-making units in the system.

DISCUSSION

Perhaps the most significant observation to emerge from the application of the Oraibi model to archaeological data is that in two out of the three large sites examined (Sand Canyon Pueblo and Grasshopper Pueblo), low-level social units appear to have retained considerable decision-making autonomy despite scalar considerations that would have encouraged the delegation of decision making to larger social units. This observation may have broader relevance to a repeated pattern of large-scale aggregation and rapid abandonment that characterizes many areas of the American Southwest in the Pueblo III period (ca. A.D. 1150–1300). This pattern of aggregation and abandonment came to a head in the late 1200's, when the entire northern Southwest was vacated, and tens of thousands of people redistributed themselves over the Eastern and Western pueblo regions in a series of large- and small-scale migrations (Adler 1996; see also papers in Spielmann, in preparation). The pueblos constructed in the subsequent Pueblo IV period are of a markedly different character than those of the Pueblo III period, indicative of a new and different organizational strategy that must have governed the workings of these villages. Notable differences include an increased scale of aggregation (an order of magnitude larger than many Pueblo III sites) and, perhaps most significantly, a radical restructuring of social units as indicated by ratios of interactive architecture to rooms. The ratio of kivas to rooms increases dramatically (from roughly 1:6 in the Pueblo III period to 1:40 or more after 1300 A.D. [Lipe 1989:56, Table 1]), suggesting that the use of kiva architecture became disassociated from the household level and was transferred to a much larger social unit. Ortman (in preparation) has suggested that this transformation may have involved a change in the ''conceptual metaphors'' with which people conceived of their community and their role within it. Similarly, Lipe (1989:65) has suggested that the Pueblo III/Pueblo IV transition may have involved transferring the concept of sacred space from one that moved with the household group to one that centered on the village.

The scalar perspective brought by the current study can thus be seen to both help focus attention on patterns of architectural change and provide an explanatory perspective within which to interpret them. Cognitive constraints on information processing limit the number of viable forms of social organization in human groups, but these constraints never generate automatic or necessary responses. The organizational tensions that can be inferred to have underlain many large Pueblo III sites must have been negotiated on the ground by individuals within these communities. The Oraibi model developed here helps us to identify architectural patterns that are likely to signal significant social phenomena, but at this point another round of postulation and testing must begin to understand why individuals chose the *particular* actions that they did under these conditions.

CONCLUSIONS

The model of scalar stress and decision-making hierarchies developed from the pueblo of Oraibi has enabled specific points of transition in the social organization of prehistoric Southwestern sites to be accurately predicted. The ability to predict when the social organization of these small- to midsized sedentary groups should change has the important function of freeing archaeologists from searching for archaeological signs of social reorganization and then attempting to explain their occurrence *post hoc.* Directed by these predicted points of transition, research may now be focused on the processes of change that accompany the periods before, during, and after successful or unsuccessful efforts to augment a decision-making hierarchy. It is during these ''hot spots'' of social activity that an unusually large amount of negotiating of social roles should occur. The amount of exchange, the rate and intensity of stylistic messaging, the level of conflict, the use of material goods to signal status, and other archaeologically observable correlates of social interaction and messaging may experience profound transformations during these transitional periods. Testable hypotheses regarding these behavioral responses to scalar stress can be derived from the model and evaluated against archaeological data.

The focus of research on social activity during these hot spots could, for example, help to resolve some of the debate over the nature of social complexity present in the prehistoric populations that occupied the American Southwest and in other areas populated by small- to midsized sedentary groups. Scalar thresholds, as points of increased pressure for social reorganization, may provide important ''cracks'' in the shell of the egalitarian checking behavior (Boehm 1993) that has been argued to characterize many small- to midrange societies (Aldenderfer 1993). As such, they may play out as periods in which social and political position is contested and negotiated by self-interested individuals (see Bernardini 1996b, for an interpretation of architectural change in the Pueblo IV period of the American Southwest in this light). Thus, it is during these scalar thresholds that we might expect forays in the direction of increasing social differentiation or concentration of authority to occur.

This study grew out of a theoretical perspective put forth by Trigger (1991) that encouraged archaeologists to identify and synthesize as many of the factors that constrain human behavior as possible. The work on the identification of external constraints imposed by information flow begun by Gregory Johnson and continued here advance archaeological theory along this path. Added to an existing body of knowledge about what limitations humans have on their range of behavioral options, this study furthers the archaeologist's ability to isolate and understand the meaning behind variability in material expressions of human behavior.

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NOTES

[1] The relatively egalitarian ideology of sequential hierarchies can also conceal considerable nonmaterial [i.e., knowledge-based] social inequality [e.g., Brandt 1978, 1981, 1985]).

[2] However, a fission event need not imply a lack of change in the resulting social organization. For example, if the leadership of the parent group is distributed unequally among its splinter groups, a fission event could actually produce a more hierarchical system than had previously existed.

[3] In his ethnography of Oraibi, Titiev described lineages as consisting of smaller lineage segments termed ''household'' units. Levy objects to this practice, arguing that it conflates a descent group with a residential group. Levy, following Eggan (1966:124, 125), therefore substitutes ''lineage'' for Titiev's ''household'' and ''maxilineage'' for Titiev's ''lineage.'' I have preserved Levy's terminology for consistency with his discussion of clan ranks, but will use Titiev's household term when discussing the Oraibi data since the analysis is based on data recorded by Titiev.

[4] Ethnographic data on the Hopi suggest a transition to adulthood at puberty (early teens), but the only cutoff point available for use in this study was at 18 years of age. Levy (1992:6) determined from U.S. census data that 566 of the 858 individuals alive in Oraibi around 1906 were 18 years of age or older, for a 66:34 ratio of adults:subadults. This ratio is fairly close to the ratio of adults:subadults of 60:40 suggested as appropriate for prehistoric American populations by Jaffe and Medina (1979, cited in Cordell et al. 1987) and the ratio of 61:31 derived from Palkovitch's corrected life table for Pecos Pueblo (1983). Therefore, to standardize the demographic data from Oraibi and prehistoric sites used in the analysis, the Oraibi ratio of adults to subadults of 66:34 will be used to modify all prehistoric population estimates.

[5] The household is the smallest decision making unit above the adult and is the primary residential, productive, and reproductive unit among the Hopi (Whiteley 1988:48). One hundred forty-seven households were identified among the 566 adults at Oraibi for an average size of 3.8 adults, or 5.8 total people, per household. However, the synchronic nature of ethnographic studies, in combination with the tendency of ethnographers to draw normative generalizations rather than examining variation, has combined to obscure the range of household units present at Oraibi. A number of different household forms, reflecting the domestic cycle of the household, were noted by Cameron (1992:139, 140) in a review of the 1900 census: nuclear family, matrifocal extended family, couple, and other. Thus, a count of ''households'' at Oraibi potentially includes considerable variation in what is actually being counted.

According to the 1900 census, of the 109 households that could be identified, half (49.5%) were nuclear households, less than 25% (n = 24) were extended families, 8% (n = 9) were couples, and 20% (n = 22) were other household types (Cameron 1990:140). The combination of these different household forms has resulted in a slightly higher household size estimate than is traditionally used in Southwestern archaeology. If, as a result, the estimate exceeds the average size of prehistoric households, both levels of scalar stress and the maximum number of household-sized units capable of being integrated in a population may be underestimated. On the other hand, the Oraibi estimate may account for some of the variation in nuclear family size as a result of natural growth, especially if some of the prehistoric sites being considered were not as tightly packed and thus did not discourage the development of localized extended families.

[6] In the study area, the transition from pithouses to kivas occurred sometime around 900–1000 A.D. (Adler 1990:223). To eliminate possible confusion stemming from kiva misidentification, only Pueblo III (1150–1300) sites were analyzed.

[7] This assumes that each room identified as specialized and generalized habitation corresponds to one household.