Doerr, Martin and Apostolis Sarris (eds) 2003. The Digital Heritage of Archaeology. CAA2002. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 30th CAA Conference, Heraklion, Crete, April 2002.

Geoglyphs and GIS: modeling transhumance in northern Chile

Dana E. Jensen
Stanford University, Department of Anthropological Sciences,
Building 360, Stanford, CA 94305-2117
djensen@stanford.edu

Abstract. The Guatacondo region of northern Chile is home to an amazing assemblage of geoglyphs which are highly visible on the desert slopes unlike the Nazca lines to the north which are found primarily on level ground. This fact has led scholars to interpret them as route markers which demarcate prehistoric trade routes. GIS is used to examine the road sign hypothesis through the incorporation of a cost-distance model. Using a modified form of Tobler's Hiking Function, the archaeological landscape of the *Guatacondo* region is quantified with respect to the energy expenditures involved in its traverse. It is suggested that while the least cost path method produces potentially compelling data in support of the road sign hypothesis, accurate assessment of prehistoric transhumance in the *Guatacondo* region must involve consideration of several variables which fall outside the scope of the mechanistic mathematical expressions often used to explain human behavior in GIS models.

Keywords. Geoglyph, GIS, *Guatacondo*, Tobler, transhumance

1 Introduction

The pattern recognition power of GIS is combined here with ethnographic data and social theory in order to draw specific inferences with respect to the geoglyphs of the Guatacondo Archaeological Zone.

In the process I hope to elucidate some of the weaknesses behind the traditional use of GIS and highlight the need for a new, more socially grounded approach. My intention is to show that GIS should be used as one in a complex of analytical devices, thus helping to ameliorate concerns that GIS on its own can be deterministic, coarse, and reductionist in nature (Hunt 1992, Gaffney et al 1995, Gaffney and van Leusen 1996).

Tying this methodology to a specific archaeological context necessitates the second goal, which is to develop a comprehensive conceptual scheme for analyzing transhumance in mountainous environments generally and in the southern Andes in particular, which will be accomplished through reference to the cross-cultural ethnographic and ethnohistoric literature on agropastoralism. This combination of social theory, ethnographic data and GIS will then allow for development of a series of new possible interpretations of the Guatacondo glyph complexes.

I agree with Llobera (1996), and Aldenderfer (1998) who believe that GIS as a technology is not inherently deterministic, but rather that the determinism comes from the models that are constructed for the GIS and, more importantly, the *interpretation* of the GIS output. It is the *assumptions* implicit in GIS model *construction* and *interpretation* that tend to undermine its utility as an explanatory device.

One common way to reconcile the use of GIS with the interpretation of human behavior and social interaction is essentially to compartmentalize the two steps. Llobera refers to using GIS as a "heuristic tool," (1996:612) while Gaffney and Leusen (1996) believe GIS is best suited to pattern recognition, but not necessarily to interpretation of those patterns.

Unfortunately, I have to agree that at this point GIS is best used for pattern recognition, and even the prime examples of GIS use for analysis of human cognition have not really moved beyond it. Whether is be applied to the linear ditches in Wessex (Llobera 1996), the settlement patterns on Hvar (Gaffney and Stančić 1991a,b, Gaffney et al 1995) or the Niagara frontier (Zubrow 1994) the GIS is used for pattern recognition, with ancillary data brought in to aid a discrete interpretive process. In most applications of GIS, patterns are sought in the distributions of viewsheds or different soil types, or in cost surfaces. My analysis is an example of the latter. Ideally, however, the social approach and the empirical approach (GIS) should somehow be integrated from the outset, abandoning this pattern recognition/interpretation compromise. I share a common goal with Llobera who wants to develop a methodology that "combines an interpretive (hermeneutic) approach with a more empirical study" (1996:612).

2 The Guatacondo Archaeological Zone

The *Guatacondo* Archaeological Zone lies in the heart of the hyper-arid desert of the Atacama region of Northern Chile, much of which receives less than 2mm of rainfall annually, (Bowman 1938: 40). Among the many outstanding characteristics of the *Guatacondo* Zone is the amazing profusion of geoglyphs scattered throughout the region. Unlike the Nazca lines found to the north that lie primarily on level ground, the *Tamarugal* geoglyphs are usually situated on slopes. This fact has led many scholars to interpret them as "road signs" which lie along trade routes between highlands and coast. Núñez and Dillehay agree with this assessment, but add that "the relationship between a network of traffic and the geoglyphs appears to have a clear meaning, but without doubt there is a symbolic/religious aspect…"(1995:180 my translation). Unfortunately, little else is said regarding other possible interpretations. While the correspondence of the geoglyphs with proposed trade routes would seem to lend credence to the road sign hypothesis it seems to me unlikely that prehistoric peoples would dedicate such time and effort to geoglyph construction simply to mark a trail, especially considering the intricacy of the designs and their curious mixture of abstract and naturalistic motifs. Núñez and Dillehay (*ibid*) also posit that *apachetas*, stone cairns built at important places along Andean trails, are used as route markers. What is the reason for this

seeming redundancy? Ethnographic data seems to indicate that trade routes are well know to all parties involved (Flores-Ochoa 1968, Webster 1973) so why would demarcation of trails be so important? What are some other possible interpretations of the *Guatacondo* glyphs?

I have chosen to focus here on the glyphs of the *Guatacondo* Zone, but am operating under the assumption that the general pattern of geoglyph use is also in operation throughout the *Pampa del Tamarugal*, the vast, arid, intermontane basin which forms the broader physiographic backdrop for the north Chilean desert. Two major studies have been done concerning the geoglyphs of the *Pampa*. Fraile and Fernandez (1984) provide an exhaustive inventory of geoglyph motifs and their locations for the entire region, dividing them into a number of complexes that they believe are clustered around prehistoric trade routes. Núñez (1976) groups the glyphs into complexes and names them according to their location relative to geographic features or known archaeological sites, "*Guatacondo*" is one such complex. I will be drawing location data from both studies for the present analysis. The llama train and stepped rhombus motifs are the most popular geoglyphs in the region (Fraile and Fernandez 1984), and both probably originate in the highlands.

The glyphs themselves are thought to have been constructed during the Chilean Formative Period which spans about 1000-200BC. They share motifs with the nearby sites of Guatacondo-1 and Ramaditas, which are thought to have been occupied toward the end of this period.

3 *Alpwirtschaft* and Mixed Mountain Agriculture

Having provided a cursory introduction to the study area, I think it will be helpful to take a step back, and try to couch the discussion in broader comparative terms. Human cultural development in montane contexts has been a topic of considerable study by anthropologists for much of the latter half of the twentieth century (Bowman 1938, Mishkin 1946, Barth 1956, Berreman 1972, Rick 1980). Mountainous environments present a special set of challenges to human occupation which include marked variability in environmental and climatic attributes, low predictability, low primary productivity, and high instability, not to mention the profound effect of altitudinal hypoxia on human, animal and plant biology (Aldenderfer 1998). The majority of ethnographic work in mountain communities has been concentrated in the Alps of Switzerland and Austria, and also in the Himalayas of Nepal.

Netting (1972) studied the village of Törbel in the Swiss Alps and described human adaptation to montane environments. In Törbel, populations rely on a traditional system referred to locally as the *Acker-Alp Betreib* which consists of rye, wheat and barley farming combined with pastoral activities. Cows, goats and sheep were pastured in communally owned highland pastures on a seasonal basis. During winter months, herds were fed on reserves of hay set aside from the autumn harvest. Netting argues that given the limited growing seasons and subsistence strategies available in mountainous areas human populations would manage risk using techniques of expansion, intensification, and regulation. In Törbel, agricultural production was intensified by the construction of irrigation systems, some of which have been in use for 800 years or more. In addition, population growth was held in check by social regulation to ensure that demand for agricultural products did not outstrip the rather finite supply. Netting concludes that human populations in montane areas may be engaged in a feedback mechanism related to resource scarcity and minimization of risk. In this sense, cultural adaptation to mountain environments is reactive, and responds to the unique demands of its circumscribed zone of habitation, in this case one particular alpine valley system.

For this analysis it is important to draw a distinction between populations that choose to pursue an intense development of one technology in one ecological zone, and those that choose to move between zones exploiting multiple ecological niches on a seasonal of semi-seasonal basis. The former group, which I will refer to as "specialists" develop highly efficient and sophisticated exploitation techniques for their particular ecozone, and rely on outside trade or limited secondary resource procurement techniques, like house gardens or gathering activities, to supplement their subsistence. The latter group, or "generalists," are willing to sacrifice some efficiency in favor of direct control over small portions of each ecological zone, and move between these zones on a seasonal basis.

Rhoades and Thompson (1975) provide an excellent summary of the study of montane adaptations, and adopt a "generalist" vs. "specialist" continuum. They use cross-cultural information to examine montane adaptations common to populations of the Alps and the Himalayas ranges. They find cross-cultural similarities in economic and social organization both widely separated mountain ecosystems which leads them to conclude that "…successful subsistence agricultural adaptation to an alpine region requires rather specific institutions, regardless of the group's historical, cultural, or biological background," (1975:540).

Rhoades and Thompson's work touches on several points that are absolutely vital to successful analysis of human adaptation in the Andes. First, they see the need for cross-cultural analysis. Up to that point, most modern anthropological work had been performed in the Alps, a mountain system that, to a large degree, shares a common historical and environmental history. Thus, any similarities found in the Alps, even in dispersed locales, could be attributed to shared history and diffusion of adaptational strategies throughout the mountain range. This idea calls into question the cross-cultural validity of the work of Netting (1972) and Cole (1972). In an effort to extend their analysis, Rhodes and Thomson compare their findings with those of other Andean scholars.

4 Verticality

One of the most influential scholars in the study of Andean transhumance, John Murra, has been looking at prehistoric human populations along with ethnohistoric and ethnographic literature in an attempt to devise a generalized model of human adaptation to the extreme environments of the Andes. His prime contribution, called verticality (Murra 1972), has been a principal explanatory device for anthropologists dealing with human population movements in the Andes for almost thirty years. Verticality is basically an Andean version of the "generalist" or *alpwirschaft* strategy as outlined for Old World populations. Prehistoric (and extant) human communities have

developed complex systems of transhumance which allow them to exploit multiple ecological zones, which are generally arranged in an altitudinal (vertical) sequence. In the process, groups can mitigate the substantial risk associated with life in extreme and unpredictable mountain environments. The unpredictable nature of the Andean environment means that a population cannot rely on the resources of one ecozone, but must instead spread its risks over multiple zones to ensure survival.

Murra's work on the ethnohistoric literature of the Aymara kingdom of Lupaqa was instrumental in his formulation of verticality. Using documentation of the *visitas* of crown inspector Garci Diez de San Miguel to the region in 1567, Murra asserted that groups centered in the *puna* (in this case at Chucuito) knew that "control of far away ecological floors could be done through mutual concessions, through conquest and subordination or through colonists sent from the center," (Murra 1968:121). In the case of the Lupaqa, Murra was amazed by their ability to exploit very widely dispersed ecological zones, and called the control of particularly dispersed settlements the "archipelago" strategy (Murra 1968:123).

Two aspects of Murra's verticality model are particularly germane to the present discussion of transhumance in the *Guatacondo* region. First, Murra specifically ties Andean transhumance to the development of agriculture, that is, agriculturalists were moving between ecological zones to exploit multiple growing zones and pasture land for supplementary herds of Andean camelids (*llamas* and *alpacas*). Second, verticality was geared toward maintenance of group independence and did not necessarily promote trade or culture contact. While Murra acknowledges that "mutual concessions" may be involved, he sees verticality as a predominantly xenophobic institution. Orlove and Guillet astutely point out that according to Murra's scheme "…all groups sought to maintain self-sufficiency and reduce external trade by maintaining direct control over products obtained at different elevations," (Orlove and Guillet 1985:8). I submit that Murra's conclusions make sense with respect to the ethnohistoric literature, but that these documents describe a period of widespread upheaval in the Andes among a chiefdom or incipient State-level group. As such, extreme caution should be exercised when applying this pattern to prehistoric (archaeological) contexts.

Murra's concept of verticality has found widespread acceptance amongst Andean scholars, and rightly so. The model is lent extra credence by it general agreement with similar models of transhumance developed independently in Old World contexts. There are, however, important differences between Andean and Alpine/Himalayan ecologies which could have a dramatic effect on how Andean transhumance is practiced. The location of the Swiss Alps and Himalayas between 30 and 45 degrees north latitude means that climate and thus crop cycles are highly seasonal. This tie to seasonality is not nearly as pronounced in the Andes, where diurnal temperature variation is marked, but annual temperature variation is barely discernable (Aldenderfer 1998). Of course, as one moves south along the Andean chain seasonality gradually becomes more pronounced, but as a general rule the central and south-central Andes are not dramatically affected by seasonality (Rhoades and Thompson 1975). Consequently, models of transhumance developed for the Alps and Himalayas (Barth 1956, Netting 1971, Cole 1972) may not be quite as powerful when applied to the Andes.

One acknowledged aspect of agropastoral groups in the Andes is the fact that they are usually involved in some sort of trade network which supplements their lifestyle with food, raw materials, and crafts from lower elevations.

Flores-Ochoa (1968) discusses the fact that the pastoralists of Paratía engage in interregional trade and obtain maize, barley, figs, apples, potatoes and peaches from the residents of lower altitudes. This type of transhumance does not take place once a year as in *Alpwirschaft*, but instead is carried out every few months as new products become available in the lowlands or surpluses of their own products become available for trade. Agropastoral transhumance is seasonal in the sense that it is affected by the growing seasons at lower altitudes, but not in the traditional Old World sense whereby the migration happens only once or twice annually. Indeed, according to Flores-Ochoa (1968:92) the pastoralists of Paratía are engaged in intermittent interregional trade for at least nine months out of the year according to a schedule that is related to, but not dictated by seasonality. The point here is that transhumance in the Andes is probably much more frequent than commonly thought, and consequently trade routes will see more traffic than similar phenomena in Old World contexts.

5 Cost Surfaces

Before any theory regarding the *Guatacondo* geoglyphs can be evaluated, there needs to be some sense of the nature of prehistoric people's interaction with them. Who was likely to see these glyphs, and under what circumstances?

To help answer these questions, a GIS model was constructed using the least cost path approach. Least cost paths are based on the assertion that the amount of effort needed to traverse a landscape is mathematically related to the slope and aspect of the land surface with respect to the direction of movement. The mathematical function used here is known as Tobler's Hiking Function (equation 1).

$$WV = 6 * \exp [-3.5 * \text{abs} (\text{slope} + 0.05)] \quad (1)$$

Where WV is the output walking velocity which is primarily a product of the land slope. Other more complex equations which relate terrain slope and roughness to metabolic rate have also been developed, but their application to a GIS is problematic (Marble and Machovina 1996).

By feeding this equation and elevation data into a GIS it is possible to generate a cost surface which can in turn be used to determine the least costly path, in terms of caloric expenditure, between any two points on a given landscape. Cost surface analysis can provide a quantitative estimate of travel times and energy expenditure, as well as define possible routes of travel. Of course by now we are all aware of the considerable problems involved with cost surfaces. Human beings do not flow down valleys like water, and even grazing cattle have shown the ability to "outsmart" a least cost path approach with goal oriented behavior (Ganskopp et al 2000) While the assumption of resource scarcity seems justified, does this mean that prehistoric peoples were moving in lockstep with environmental constraints? Were environmental variables the

prime mover in human cultural development, with values and ideas as passive byproducts of an economic situation? This difficulty stems from the fact that distance is also a social construct, and perceived distance may in no way coincide with actual geographic distance. I rely on the assumption that in marginal environments like the atacama energy will be at a premium, forcing social concepts to more closely mirror the material constraints to travel. This assertion seems to be supported to some degree by some Andean ethnographic data (Flores-Ochoa 1968, Webster 1973).

The cost path analysis was performed with the *Salar de Laguna* in the highlands, and *Guanillos del Norte* on the Pacific coast as the endpoints. The archaeological sites near the *Salar de Laguna* and on the coast at *Guanillos del Norte* were occupied contemporaneously, and were thought to have been in regular contact during the Chilean Formative (Núñez 1976, Núñez and Dillehay 1995, Fraile and Fernandez 1984). The locations of the major glyph complexes in the region and the site of Guatacondo-1 were also plotted on a GIS layer. While not needed directly for the cost path analysis, their spatial relationship to the least costly path is of vital importance.

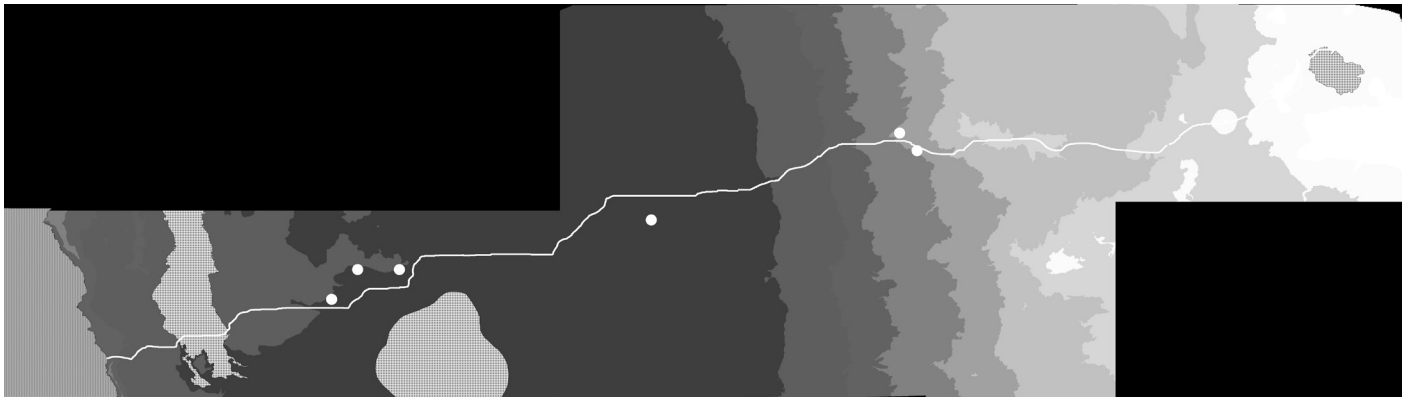

Figure 1. *The results of the cost path analysis, showing the least cost path from highlands to coast which passes within 3km of the Guatacondo glyph complexes.*

The result of the analysis (fig.1) was a path that passed through the Quebrada de Guatacondo, across the Pampa del Tamarugal and over the coast range to the Pacific Ocean. The path is 201.65 km in length and would take 129.45 hours to traverse, for an average rate of 1.557 km/hour, a rate similar to those observed ethnographically by Flores-Ochoa (1968). The GIS model predicts that the least costly path from highlands to coast passes within *3 km* of all but one of the prominent *Guatacondo* glyph complexes (black dots). The fact that all but one of the major Guatacondo glyph complexes falls within 3km of the least costly path through the region is striking given the vastness of the pampa. Now that the GIS has established a strong relationship between paths of travel and glyph placement it is important to recruit some ancillary evidence to help generate a rich, meaningful, and socially grounded interpretation of the situation.

5 A Social Approach to the Problem

My interpretation of the Guatacondo glyphs will borrow two concepts from social theory, namely the idea of presencing as expressed in the works of Heidegger (Krell 1977 [1927]), and the concept of a dominant locale as outlined by Giddens (1984, 1985).

The Guatacondo glyphs could have been constructed as a means of presencing absent groups in the social discourse of the region. The Andes are a region characterized by transhumance, movement of groups between highlands and coast on a seasonal or semi-seasonal basis. This pattern of verticality (Murra 1972) can be seen cross culturally in most mountain environments and is believed to be tied to risk management and exploitation of multiple ecological zones (Barth 1956, Berreman 1972, Cole 1972, Netting 1972). Ethnographic evidence from the Andes points to the possibility that highland groups may have kin ties (fictive or otherwise) to lowland groups, and may only visit them several times per year (Browman 1974, Flores-Ochoa 1968). It is also noteworthy that camelids (llamas and alpacas) were used throughout the Andean highlands for millennia to facilitate this movement as pack animals (Carevic 1995).

This being the case, groups which are absent for a major portion of the year would want to reinforce their relationship with their lowland collaborators, and possibly attempt to exclude competing groups from establishing similar relationships. Absent groups wish to remain present in the minds of lowland peoples and tacitly reinforce their social bonds. This, then, goes to the issue on geoglyph placement. If presencing can be thought of as the "why" behind geoglyph construction, then the answer to "where" and "how" can be found in the idea of a dominant locale.

Transhumance is highly dependent on timing, scheduling, and routines. Migratory paths are followed year after year (and hence are well known) without fail, which means that certain locales are bound to be passed with regularity for generations. According to Giddens (1984) dominant locales are "power containers" where authoritative resources are stored, in effect binding time (past, present, and future) and space at that point. Thomas points out that dominant locales are often found in a "place to which subjects repeatedly return (1993:77), seasonal trade routes are an example of this type of location. Incorporation of these spaces into traditional cycles of activity and time-space routines causes dominant locales, and people who pass through them to help underwrite social reproduction.

In my mind, prehistoric Andean trade routes are excellent candidates for the location of dominant locales. They are passed through on a routine basis and they existed at a time when some groups were physically absent for much of the year but wished to maintain a continual presence in the minds of the permanent inhabitants. In this way, they would help to underwrite existing power relations and sanction traditional practices. Transhumance and its attendant regime of power relations and social network were underwritten by the presences found at dominant locales, in this case several major geoglyphs in the Guatacondo region. To my mind this interpretation of the Guatacondo glyphs does more to account for their form and placement than previous efforts, including an explanation of their highly complex symbolic content which would be unnecessary if route marking were the sole reason for their construction.

6 Conclusions

My aim here has been to explain the Guatacondo geoglyphs in light of a synergistic combination of empirical data derived from GIS and social data derived from ethnography and the broader literature of social theory. GIS can be thought of as an essentially empirical approach to finding patterns in spatial datasets. It should be noted, however, that GIS is not seen as necessarily objective but "rather it is a tool to create spatial relationships according to values we regard as important" (Gaffney et al 1995:44). I agree with Llobera (1996), and Aldenderfer (1998) who believe that GIS as a technology is not inherently deterministic, but rather that the determinism comes from the models which are constructed for the GIS and, more importantly, the *interpretation* of the GIS output. It is the *assumptions* implicit in GIS model *construction* and *interpretation* that undermine its utility as an explanatory device! The patterns found by the GIS can then be explained in light of the archaeology and social approaches to its interpretation. Ideally, this approach utilized the most robust aspects of both approaches, the spatial data analysis of the GIS combined with the power of cognitive approaches to humanize and flesh out questions with an eye toward understand the situation as it was perceived by actual human actors. There is a comforting complementarity in these two techniques that has not gone unnoticed (Aldenderfer 1998, Gaffney et al 1995, Llobera 1996, Reeler 1996, Zubrow 1994).

Perhaps the most exciting development in GIS applications to archaeology in a decade is the use of an agent-based approach to modeling (Lake 2000). This type of analysis allows social phenomena to be directly incorporated into a GIS based model from its inception, not simply tacked on at the end as an interpretive device. It allows for ethnographic and ethnohistoric parameters to be used in the development of "agents" that interact with one another and the physical environment to arrive at collective "decisions" about various activities.

The task at hand has been an analysis of the Guatacondo geoglyphs, hoping to explain who constructed them, why they did so at these particular locations, and what they were intended to "say." The GIS least cost path model showed that projected trade routes seem to pass quite close to the geoglyphs, and it had already been asserted that the glyphs were "road signs" to mark these routes (Núñez and Dillehay 1995). By combining a social approach to this pattern I assert that the glyphs are probably not mere road signs, but instead are complex expressions of social relations between highland and coastal groups. Using the concepts of presencing (Krell 1977) and dominant locales (Giddens 1984) *I assert that the glyphs were not constructed to mark unknown routes, but rather were placed where they were precisely because the routes were so well known.* The glyphs were constructed as dominant locales to presence absent highland groups in the minds of their "kin" on the coast and at intermediate elevations. They help to legitimize and reproduce a set of unequal power relations stemming from the unequal distribution of camelid resources. They were meant to be viewed by everyone, reinforcing feelings of superiority among passing highland people while simultaneously intimidating coastal people and reinforcing the reproduction of this unequal social relationship.

While the glyphs of the Pampa del Tamarugal have been cataloged and photographed at various times during the past century, relatively little interpretation has been undertaken aside from the assertion that the glyphs may have been road signs that marked important trade routes. Instead, I have argued here that the geoglyphs played a much greater role in social reproduction, ethnic identity, and presencing of absent highland groups on the landscape.

References

ALDENDERFER, MARK, S., 1998. *Montane Foragers*. University of Iowa Press, Iowa City.

BARTH, FREDRIK, 1956. Ecologic Relationships of Ethnic Groups in Swat, North Pakistan. *American Anthropologist* 58: 1079-108.

BERREMAN, G. D., 1972. 1972: *Hindus of the Himalayas: Ethnography and Change*, 2nd edition. Berkeley: University of California Press.

BOWMAN, I., 1938. Desert Trails of Atacama. American Geographical Society, New York.

BROWMAN, D., 1974. Pastoralism nomadism in the andes. Current Anthropology, 15: 188-196.

CAREVIC, ALVARO R., 1995. Hombre andino y camelidos en el norte Chileno. Revista de Agricultura del Desierto 1:45-54. Universidad de Arturo Prat, Iquique, Chile.

COLE, JOHN, W., 1972. Cultural Adaptation in the Eastern Alps. *Anthropological Quarterly* 45:158-176.

FLORES-OCHOA, JORGE, 1968. *Los Pastores del Paratia*. Instituto Indigenista Interamericano, Serie Anthropologia Social 10, Mexico.

FRAILE, S.F., AND FERNANDEZ, P.C., 1984. *Prospeccion de Geoglifos de la Provinca de Iquique, Primera Region Tarapaca - Norte de Chile*. UNAP : Chile.

GAFFNEY, V. AND LEUSEN, M., 1996. Postscript – GIS, environmental determinism and archaeology: a parallel text. In *Anthropology, space, and geographic information systems*. Mark Aldenderfer, Herbert D.G. Maschner eds. New York : Oxford University Press.

GAFFNEY, V. AND STANČIĆ, Z., 1991a. *GIS approaches to regional analysis:a case study of the island of Hvar*, Yugoslavia, Ljubljana University. 1991b. Diodorus Siculus and the island of Hvar, Dalmatia: testing the text with GIS. In *Computer Applications and Quantitative Methods in Archaeology 1991* Oxford : Tempus Reparatum.

GAFFNEY, V. STANČIĆ, Z. AND WATSON, H., 1995. Moving from catchments to cognition: tentative steps towards a larger archae-

ological context for GIS. Scottish Archaeological Review, 9-10:41-64.

GANSKOPP, D., CRUZ, R., AND JOHNSON, D.E., 2000. Least-effort pathways?: a GIS analysis of livestock trails in rugged terrain. *Applied Animal Behavior Science*, 68:179-190.

GIDDENS, A., 1984. The Constitution of Society: Outline of the Theory of Structuration. Berkeley: University of California Press. 1985. Time, Space, and Regionalization. In *Social Relations and Spatial Structures*. Gregory, D. and Urry, J. eds. pp. 265-295. London: MacMillan.

HUNT, D.E., 1992. Up-grading site-catchment analyses with the use of GIS: investigating the settlement patterns of horticulturalists. *World Archaeology* 24 (2): 283-309.

KRELL, D.F., 1977. *Martin Heidegger – Basic Writings from Being and Time (1927) to The Task of Thinking (1964)*. San Francisco: Harper.

LAKE, MARK, 2000. MAGICAL Computer Simulation of Mesolithic Foraging on Islay, in S J Mithen (ed). Hunter-Gatherer Landscape Archaeology: The Southern Hebrides Mesolithic Project, 1988-1998. Cambridge: The McDonald Institute for Archaeological Research

LLOBERA, MARCOS, 1996. Exploring the topography of mind: GIS, social space and archaeology. *Antiquity* 70(269): 612-622.

MARBLE, D. AND MACHINOVA, B., 1996. A GIS-base approach to estimating the human effort involved in movement over natural terrain. Iskos 11, 117-126. [Keynote address given at the VII Nordic Conference on the Applications of Scientific Methods in Archaeology, Savonlinna, Finland, September 1996.]

MISHKIN, BERNARD, 1946. The Contemporary Quechua. *In* Handbook of South American Indians. Vol. 2. Bureau of American Ethnology, Bulletin 146. Julian H. Steward, (ed.), Washington: Smithsonian Institution, pp. 411-470.

MURRA, J., 1968. An Aymara Kingdom in 1567. *Ethnohistory*, 15:115-151. 1972. El "control vertical" de un maximo de pisos ecologicos en la economia de las sociedades.

NETTING, ROBERT, 1972. Of Men and Meadows: Strategies of Alpine Land Use. *Anthropological Quarterly* 45: 132-144.

NÚÑEZ, L., 1976. Geoglifos y trafico de caravanas en el desierto Chileno. In *Homenaje al Dr, Gustavo le Paige, SJ*. Universidad del Norte, Chile.

NÚÑEZ, L. AND DILLEHAY, T., 1995. *Movilidad giratoria, armonia social y desarollo en los Andes Meridionales: Patrones de Trafico e interaccion economia.* Universidad Catolica del Norte, Antofagasta, Chile.

ORLOVE, B. S., AND GUILLET, D. W., 1985. Theoretical and methodologicalconsiderations on the study of mountain peoples: reflections on the idea of subsistence type and the role of history in human ecology. *Mountain Research and Development* 5(1): 3-18.

REELER, CLAIRE, 1996. Beyond GIS: artificial intelligence in archaeology. *Archaeology in New Zealand* 39(3): 193-199.

RHOADES, R.E. AND THOMPSON, S.I., 1975. Adaptive strategies in alpine environments: Beyond ecological particularism. *American Ethnologist*, 2(3): 535-551.

RICK, J.W., 1980. Prehistoric Hunters of the High Andes. New York, Academic Press.

THOMAS, JULIAN, 1993. The Hermeneutics of Megalithic Space. In *Interpretive Archaeology*, Christopher Tilley ed. Providence: Berg.

WEBSTER, STEVEN, 1973. Native Pastoralism in the South Andes. *Ethnology* 12:115-133.

ZUBROW, EZRA, 1994. Knowledge representation and archaeology: a cognitive example using GIS. In *Ancient Mind: Elements of Cognitive Archaeology*. Cambridge: Cambridge University Press.