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PALEOCLIMATIC AND MATERIAL CULTURAL PERSPECTIVE ON THE FORMATIVE PERIOD OF NORTHERN CHILE

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The recent development of a macrophysical paleoclimatic modeling methodology allows the reconstruction of site-specific models of Holocene precipitation and temperatures with a temporal resolution of 200 years intervals back to 14,000 B.P. Where suitable modern analogue data are available, rain intensity and evapotranspiration may also be modeled. Models of this type suggest that the hyperarid conditions found today in the Arica region of Chile have likely persisted over the last 10,000 years. Early agriculturalists must have been dependent on runoff from higher elevation precipitation and snow-melt rather than on local rainfall, as is the case today. Models of paleoclimatic change at a site near the headwaters of the Azapa Valley are considered with respect to their probable impact on water availability near the coast. Insights regarding Formative Period material culture resulting from a recent reanalysis of the burial collections from inland site AZ-71 are then considered in light of the paleoenvironmental reconstruction.

Key Words: Paleoclimatic modeling, Formative period, Chile.

El desarrollo reciente de una metodología de modelos paleoclimáticos macrofísicos permiten la construcción de modelos sitios específicos de precipitación y temperaturas del Holoceno con una resolución temporal de 200 años intervalos hasta 14.000 años AP. También se modela, cuando es apropiado y a la disponibilidad, datos análogos modernos de lluvias, intensidad, y evapotranspiración. Modelos de este tipo sugieren que las condiciones hiper áridas que se encuentran hoy en la área de Arica en Chile persistieron a través de los últimos 10.000 años. Los agricultores temprano debió depender de la precipitación del altiplano y del derretimiento de nieve en lugar de lluvia local, como hoy en día. Los modelos de cambio paleoclimatico en el sitio cerca a la cabecera de agua del valle Azapa es considerada en relación a su probable impacto a la disponibilidad de agua cerca de la costa. Visiones acerca de la cultura material del Periodo Formativo que resultaron de un re-análisis resiente de las colecciones mortuorios del sitio interior AZ-71 son entonces consideradas en luz de las reconstrucciones paleoambientales.

Palabras claves: *Modelos paleoclimáticos, periodo Formativo, Chile*.

Bounded by the Andes to the east and the rich waters of the Pacific to the west, the unique environment of the hyperarid coastal zone of northern Chile was apparently home to a single, equally unique culture from the early through the middle Holocene. As defined by Arriaza (1995:15), the Chinchorro culture consisted of "preceramic and premetallurgic (presmelting) fishing societies which inhabited the Atacama coast of southern Peru and northern Chile from at least 7,020 B.C. to 1,500 B.C., who buried their dead in an extended position, and practiced both natural and artificial mummification." Although they principally occupied the mouths of river drainages where both terrestrial and maritime resources where locally abundant, the Chinchorro relied so heavily on exploitation of the latter that marine foodstuffs comprised as much as 89% of their diet (Aufderheide et al. 1993). However, this lifeway changed sometime around 3600 B.P., artificial mummification all but disappeared from Chinchorro burials, and, by 3400-3200 B.P., "mortuary practices had become markedly different" (Arriaza 1995:156).

Owing largely to the effects of the cold Humboldt current, the domination of the Andean cordillera, and the steady, dry southerly airflow that occurs throughout the year, the Atacama is perhaps the driest of the Earth's deserts (Lettau and Lettau 1978). In this area where precipitation is at best rare and even coastal fog is infrequent (Miller 1976), cultivation of any type can only be executed through irrigation. By approximately 3500 years ago, however, people in the Arica area had begun to combine a minor amount of horticulture with maritime resource procurement. Soon after ca. 3200 B.P. subsistence practices, including fishing, changed and diversified (Arriaza 1995), interior portions of the Azapa Valley were occupied, and incipient agriculture and increased cultural complexity developed apace. It has generally been suggested that these cultural changes were the result of in situ cultural development shaped by high Altiplanic interaction (e.g., Núñez and Dillehay 1979; Muñoz 1980, 1986; Muñoz et al. 1991; Santoro 1980).

Models of climate change suggest one possible triggering mechanism for the shift from coastal fishermen to agriculturalists inhabiting inland river valley locations. Much like their modern counterparts, early horticulturalists in the Azapa Valley must have depended on runoff from higher elevations where precipitation and snow-melt are possible, rather than on local rainfall. Hence one must look outside of the region (i.e., near the headwaters of the Rio San José) to seek possible causes for changes in the hydraulic regime here. The apparent cultural discontinuity from the near total coastal adaptation of the Chinchorro to the horticulturalists of the Formative Period (post-3500 B.P.) can be further assessed in light of burial goods from an inland Azapa Valley site (AZ-71) recently reanalyzed at the Museo Arqueológico San Miguel de Azapa.

Modeling Northern Chile's Paleoclimate

The paleoclimatic models discussed here are based on the methodology which Bryson and Bryson (e.g., 1997, 1998) have called "Archaeoclimatology." This hierarchical approach works from the large scale down to the local in what they describe as a macrophysical view of climatic dynamics through time. In brief, these models consider three fundamental variables as the basis for calculating the past positions of major features of atmospheric circulation. These include: 1) cyclical shifts in the amount of incoming solar radiation due to changes in the Earth's orbital geometry about the Sun (i.e., the Milankovitch [1941] periodicities); 2) distinct changes in the transparency of the Earth's atmosphere due to volcanic activity (Goodman 1984), and; 3) alteration of the Earth's reflectivity (albedo) resulting from increases and decreases in the surface area of glacial ice (Bryson and Goodman 1986). Together these considerations make it possible to calculate hemispheric heat budgets for the radiocarbon period of record and from those, calculations of the past locations of major circulation features are possible. In general, if the latitude of the jetstreams and the locations of the subtropical highs can be calculated over time, then these and other major circulation features can be used to model local climatic elements, such as precipitation, temperatures, or potential evaporation, etc., over the same period (see, for instance, Bryson 1992). This is accomplished through the application of the techniques of synoptic (paleo-) climatology, by which the past behavior of each of these local elements is explained in terms of the interplay between large scale atmospheric circulation features and local topography based on modern analogues. This approach produces robust, site-specific estimates of the monthly mean values of precipitation, temperature or other variables, with a temporal resolution of 200 year intervals back to 14,000 B.P. The first requirement in this case is to understand the modern synoptic climatology of northern Chile.

Chile's climate is dominated by the effects of the Andean Cordillera and the Pacific Ocean. Together, these two geographic features effectively isolate the area to such an extent that the large scale circulation features prevailing over much of the rest of the South American continent have only a rather small effect on climates here (Miller 1976:113). During the winter months the southeast Pacific high moves northward, leaving the southern half of the country almost directly in the path of the Southern Hemisphere westerlies. As a consequence, the southern coast receives a great deal of precipitation from Pacific fronts during that season. The southeast Pacific high does not, however, move sufficiently far north during its seasonal cycle to allow the passage of these frontal systems farther north than about Copiapó at 27' S. North of that latitude, dry southerly flow along the eastern periphery of the Pacific anticyclone is stable, divergent, and essentially a continuous, year-round phenomenon. Because there are few passages lower than 4000 m through the high western range of the Andes, this range very effectively blocks the passage of easterly airflow which might bring moisture from the Amazon Basin, except at high elevations in Chile's extreme northeast (Miller 1976). The northern coast is extremely arid throughout the year as a result of these factors.

In contrast, summer precipitation is characteristic of the Altiplano. During the summer months, northeast winds caused by advection bring in very moist, high altitude air masses from the Amazon Basin which, due to strong convection from the Altiplano, create almost daily showers and thunderstorms. In some cases these storms may reach the western slopes of the Andes to elevations as low as 2500 m, but that is generally not the case (Schwertdfeger 1976). Although nearly 85% of the precipitation on the western edge of the Altiplano falls during the summer months of December to March, in any given year summer showers at a particular location can vary greatly in intensity and frequency (Miller 1976:120). During the winter, dry air masses from the southwest generally dominate circulation on the plateau. The only precipitation in this season accompanies troughs in the westerlies that once or twice each winter meet the western escarpment at sufficiently high elevations that they bring snow to the northern Chilean cordillera and the Bolivian Altiplano. In essence, the predominance of winter precipitation on the coast results primarily from the effects of Pacific air masses, while the summer precipitation of the Altiplano derives from moisture sources to the east.

Our models of the past seasonal locations of the southeast Pacific high suggest that no significant changes took place during the Holocene. Figure 1 shows less than a 1 degree shift in the modeled January and July latitudes of this anticyclone's axis over this period. We consider this change to be insufficient for major Pacific storms to have come as far north as Arica during the winter months. It is thus not surprising that the model of Arica's mean January and July temperatures seen in Figure 2 also displays extremely little variance over the entire Holocene.

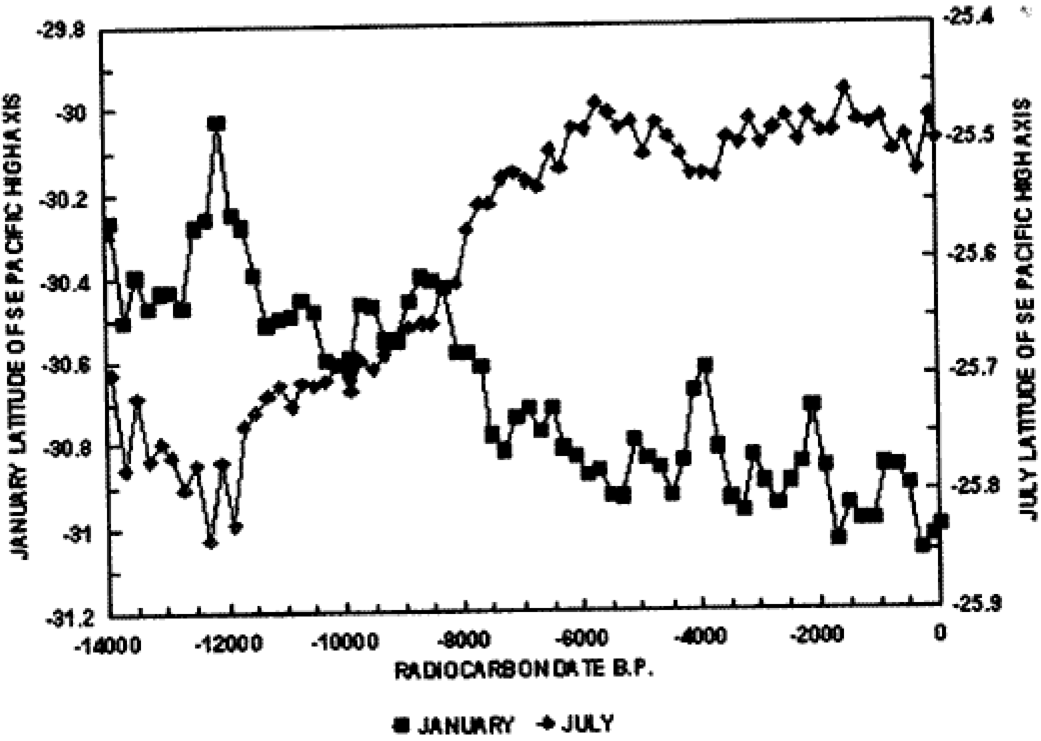

Figure 1. Modeled latitude of the SE Pacific high axis in January (left scale) and July (right scale)

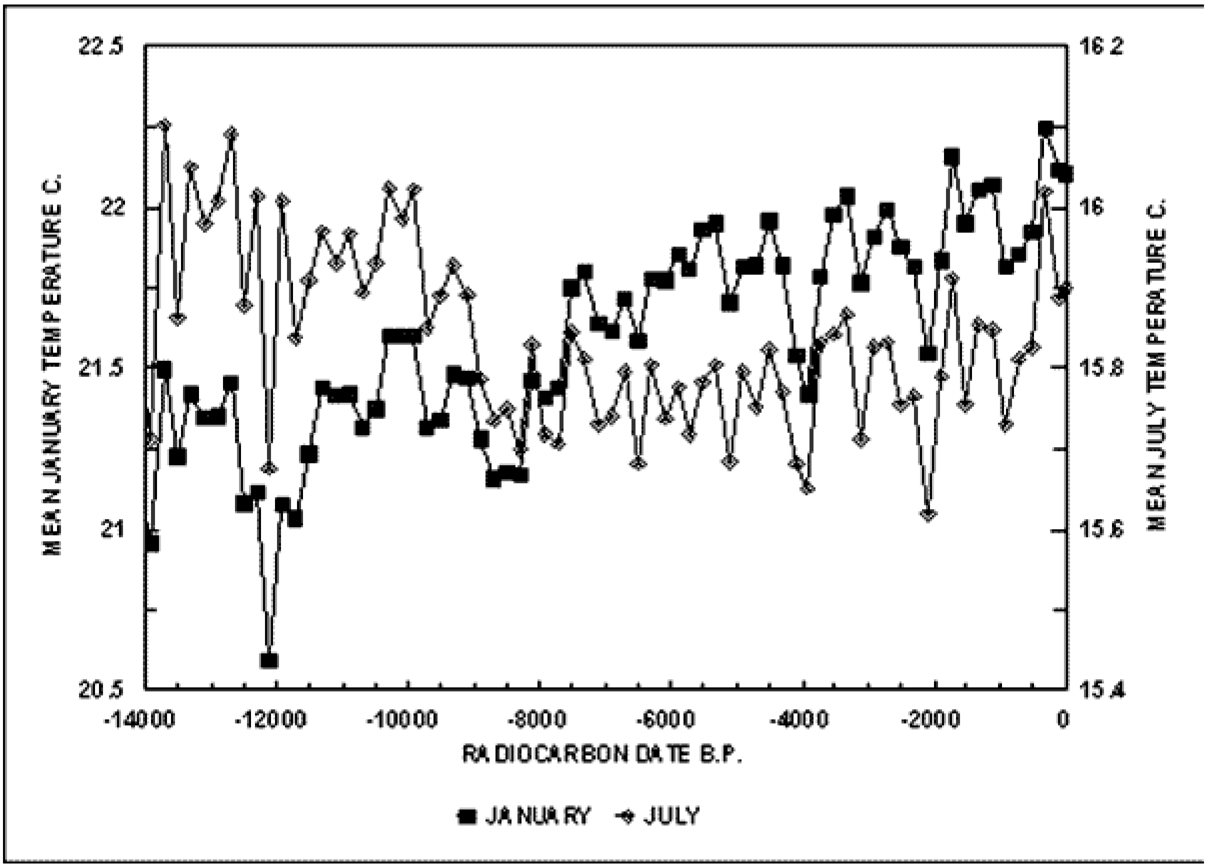

Figure 2. Modeled mean temperatures for January (left scale) and July (right scale) at Arica, Chile

Inhabitants of the Azapa Valley must have relied almost entirely on river discharge determined by high elevation precipitation following an Altiplano seasonal pattern. The graph in 3 displays modeled Holocene precipitation (left scale) at Charaña, Bolivia, located near the headwaters of the Rio San José at an elevation of just over 4000 m. This model suggests that precipitation here increased rather dramatically after about 7600 B.P. and, although it was highly variable, this condition persisted for roughly 4000 years.

It was also possible to model the number of days with precipitation based on modern records from the Charaña recording station. By dividing the modeled mean annual precipitation by the modeled number of "rain days" per year, one arrives at a measure of rainfall intensity, which appears on the right scale in Figure 3. Modeled rainfall intensity was consistently low during the mid-Holocene but increased markedly at the same time when precipitation, as modeled, decreased. That is, not only was there less rainfall in total, but also that which fell came in fewer, more intense episodes over a period of perhaps 600 years. We feel that this change would have a profound effect on the hydrological regime of the Azapa Valley, especially with respect to the availability and reliability of fresh water sources. A distinct increase in rainfall intensity would have increased runoff, probably hindered recharge of the aquifers feeding coastal springs, and generally reduced the reliability of fresh water sources. After about 3500 B.P., precipitation and rainfall intensity (as modeled) stabilized somewhat, such that slightly more favorable hydrological conditions persisted for nearly 1000 years thereafter. Grosjean et al. (1997) found a similar pattern of intermittent intense rainfall in their study of mid-Holocene hydrological conditions at Quebrada Puripica, however, their analyses suggest nearly the opposite outcome.

They conclude that intense rainfall heightened the local availability of water in ponds created by debris flows. That case does not appear likely in the Azapa Valley.

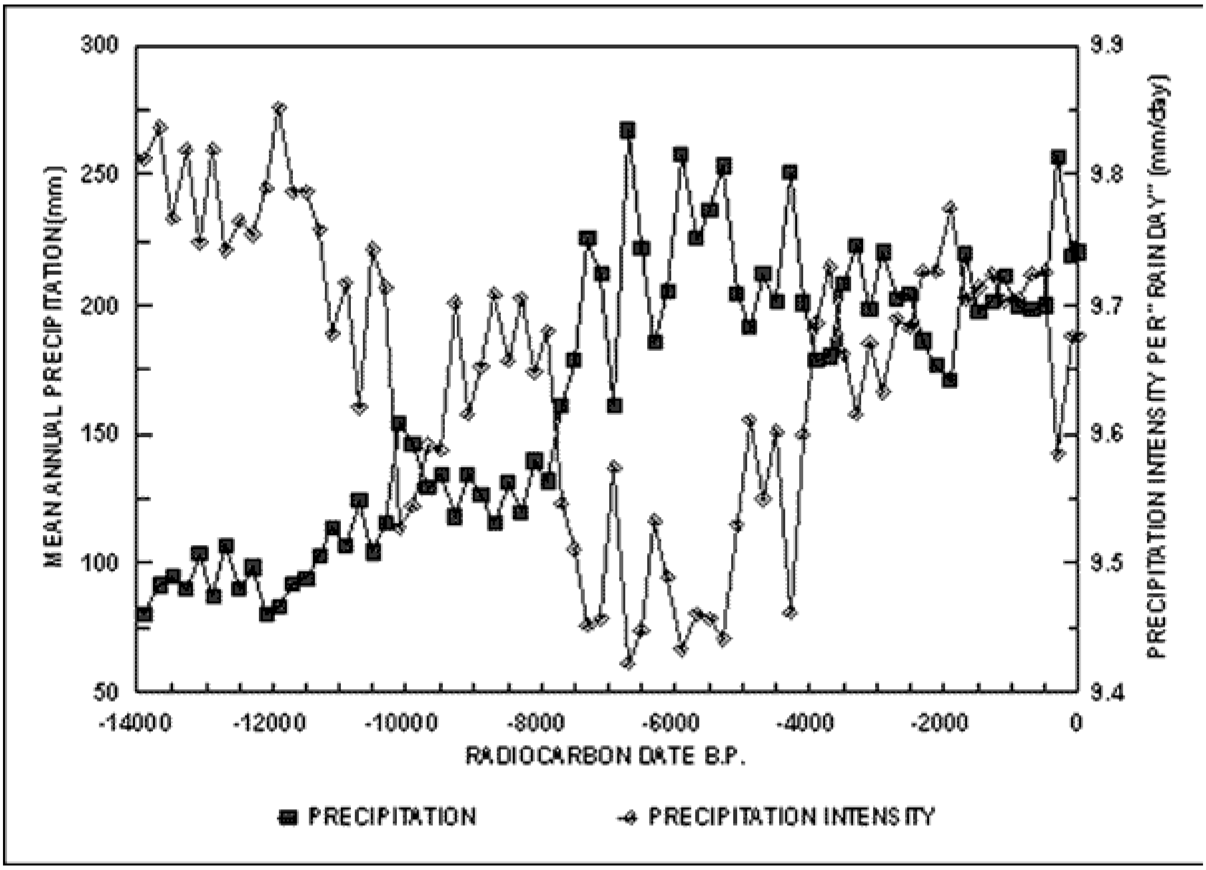

Figure 3. Modeled mean annual precipitation (left scale) compared with precipitation intensity (right scale) near the headwaters of the river San José in Charaña, Bolivia

The Cultural Shift from Chinchorro to the Formative

That Chinchorro peoples successfully manipulated their environment is evidenced by the fact that the culture persisted for at least 5500 years. As noted above, the region around Arica has likely remained extremely arid for at least the last 10,000 years. Nevertheless, Arriaza (1995:33) notes that there was once a rich littoral environment, fresh water was likely available from coastal springs, and lush riparian zones could be found at the mouth of the Azapa Valley. Stable temperatures (Figure 2) and rich maritime resources also provided ideal conditions for Chinchorro sedentism. Indeed this is what the preponderance of the archaeological evidence indicates. Given this situation, the question arises as to why the maritime Chinchorro lifeway, including its unique burial traditions, had blended into the incipient agricultural background by 3400-3300 B.P., and was replaced entirely by Quiani phase traditions shortly thereafter (Arriaza 1995:156). Following Darwinian tenets, Binford (1983:203) might suggest that this could result because: ...the system of adaptation may enjoy relatively stable periods of varying duration, representing times when it is able to cope successfully with the perturbations of the environment. Selection for change occurs when the system is unable to continue previously successful tactics in the face of changed conditions in its environment.

In other words, only when the stable environment changed from that which had provided reliable resources for millennia were the Chinchorro or their antecedents forced to move to supplementary production. This argument is based on the concept that local productivity itself motivates sedentism except when the environment changes appreciably for the worse, in which case the maintenance of a sedentary lifestyle requires further intensification (i.e., agriculture; see, for instance, Binford 1983:202].

Following this line of reasoning, it would seem logical that some sort of environmental event took place which altered the stability of the coastal environment to such an extent that cultures at the mouth of the Azapa Valley were forced to alter their lifeways. That some changes were taking place as early as 3600 B.P. is suggested by the abandonment of artificial mummification by the Chinchorro and the adoption of some limited forms of horticulture by other coastal groups at this time (Arriaza 1995:157). If water became scarce or at least a less reliable commodity as our models suggest, a rather profound process was set in motion which resulted in the movement of coastal peoples to inland riparian areas where water sources were likely more reliable and productive intensification more viable. Even when the models suggest that hydrological conditions stabilized somewhat after about 3500 B.P., coastal cultures in the Arica area never returned to strictly maritime resource procurement strategies. The evidence from sites such as Quiani 7 and Faldas del Morro, dating to about 3500-3300 B.P. (Dauelsberg 1974; 1985), from Camarones 15 at ca. 2890 B.P. (Muñoz et al. 1991), and Playa Miller at about 2350 B.P. (Focacci 1974), indicates that horticulture was supplemented by an increasingly smaller percentage of marine resources. Once horticultural practices were adopted, possibly in response to the sort of environmental stress seen in these models as well as steadily increasing contact with Altiplanic peoples, this predisposed the following generations to supplement wild food sources with cultivation.

The site of AZ-71 is located 12 km inland adjacent to the present day village of San Miguel de Azapa. It consists of a series of temporally superimposed burials representing the Azapa, Alto Ramirez, Cabuza, Tiwanaku, Maitas, Chiribaya, and Loreto Viejo phases in succession (see Santoro 1980). Of principal concern here are the Early and Late Formative groups, the Azapa, dating to about 3300 B.P., followed by the Alto Ramirez from ca. 2500 to 1700 B.P., which are represented at AZ-71 by 53 and 30 burials respectively. Santoro (1980) characterizes Azapa and Alto Ramirez habitations as small groups of people occupying sedentary villages and relying on the exploitation of maritime and valley resources combined with incipient agriculture. He suggests that the wooden post and totora reed structures in these villages were just large enough to accommodate sleeping areas and possibly the limited storage of food supplies, but other domestic activities must have been performed outside. Further, outdoor domestic activities seem to have been carried on as combined group efforts rather than being practiced by individual households. These conclusions are supported by the results of autopsies showing that Formative period mummies essentially lack carbon in their lungs and by the finding of fire hearths in common outdoor locations where abundant charcoal, fire-affected rocks, fish remains, and large ceramics were found in association. This pattern represents only a small departure from Chinchorro traditions but is very different from that seen in later habitations.

Our review of the Formative period burial goods from AZ-71 supports Santoro's (1980) conclusion that Azapa and Alto Ramirez material culture is suggestive of a combination of coastal and altiplanic influences. The continuity of coastal traditions is seen in the ongoing, albeit reduced, production of fishing nets and harpoons and in the continued utilization of sea bird bone in bracelets, sniff tubes, and other artifacts. Much like the Chinchorro, Azapa and Alto Ramirez phase peoples made heavy use of vegetable fibers in basketry, mats, bags, ropes, and a variety of smaller items such as brushes and combs. Influences from the Altiplano and/or central coastal Peru are evident in the application of distinctive motifs such as geometric designs, human heads, and depictions of frog figures and the sun (Santoro 1980; Muñoz 1980). These appear on a variety of camelid wool textiles, especially those dating to the Alto Ramirez period, including camisas, blankets, bags, belts, head bands, and taris. It is interesting that we also observed the use of human hair in fairly large quantities combined with camelid wool in many textiles from both periods.

It would be at best difficult to conclusively determine whether the Azapa or Alto Ramirez phases represent the arrival of people from the Altiplano who occupied this portion of the Azapa valley, as Rivera (1977, 1980) has suggested, or that coastal groups displaced by a changing environment were simply influenced by Altiplanic customs, some of which they adopted. What can clearly be said is that during the Azapa and Alto Ramirez phases, a limited set of cultigens was added to coastal subsistence traditions which had persisted for thousands years, and that at least some exotic items, particularly textiles, were used. This however, only confirms some type of interaction among coastal and Altiplanic groups, and in no way directly suggests their replacement by them. It seems much more likely that peoples with established coastal traditions adopted several cultural traits as a result of contact with highland cultures, rather than the reverse.

Discussion

Perhaps a more important question that one might ask is, under what did the Chinchorro and other coastal peoples abandon their apparently successful strategy of maritime resource procurement in favor of first horticulture and eventually full-blown agriculture? Although there are myriad options available to cultures which face environmental perturbations, the choices which they make to deal with such changes are intimately related to the combined cultural experience of their members. Cultural knowledge determines a society's resilience in the face of environmental (or other) disturbances. It may be that there are identifiable thresholds beyond which the quantity, frequency or reliability of certain resources may trigger specific, culturally defined responses. To identify those thresholds it is first necessary to clearly understand the specifics of the environmental changes involved and it is toward this end that archaeoclimatic modeling was developed.

According to the results of the paleoclimatic modeling presented above, the hyperarid environment of the Arica region has likely remained more or less unchanged, with relatively stable temperatures and very little or no precipitation, for the last 10,000 years. This conclusion is based on models of the position of the southeast Pacific high which maintained a relatively stable average seasonal movement of about 5 degrees of latitude (see Figure 2), or essentially just what it does today. Therefore, the Chinchorro and later cultures of this area must have relied on runoff from higher elevations where precipitation and snow melt were possible. The models for Charaña, Bolivia (see Figure 3), which should be representative of the Rio San José's headwaters, indicate that between 7000 and 4000 B.P. annual precipitation was high while rainfall intensity was relatively low. As a result, the river flow would have been reasonably steady, the flood plain would have been relatively stable, and it is likely that a higher water table than present would have been maintained within the valley. This created a suitable environment for fresh water springs, swampy areas, and a lush ecosystem of plants and animals at the mouth of the Azapa Valley. However, toward the end of the mid-Holocene the region suffered from a drought at high elevations, which, if the models are correct, was exacerbated by a radical increase in precipitation intensity and changed the hydrologic regime of the Rio San José to nearly its present condition.

Both our paleoclimatic modeling and the archaeological record seem to support the conclusion that the stable coastal ecosystem of the early to mid-Holocene was sufficiently disrupted between roughly 4000 and 3500 B.P. that coastal cultures passed an as of yet unidentified cultural/environmental threshold which inevitably led to the replacement of their maritime life way with an agricultural subsistence base. The abandonment of artificial mummification by the Chinchorro and the adoption of some limited forms of horticulture by other coastal groups at about 3600 B.P. provide evidence of this sort.

By the time that the interior portions of the Azapa Valley were in agricultural production (i.e., after about 1700 B.P.), the models suggest that the variance in both annual precipitation and rainfall intensity had diminished from their late mid-Holocene values. Increased populations and their greater reliance on what was produced under the management of cultigens and domesticated animals, however, probably rendered the peoples of this period more susceptible to the effects of environmental change. Regardless of the specific causal factors involved, the pace of cultural changes during this later period matches the frequency of modeled climatic changes rather closely.

References Cited

Arriaza, B. T.
1995 *Beyond Death: The Chinchorro Mummies of Ancient Chile*. Smithsonian Institution Press, Washington, D.C.

Aufderheide, A., I. Muñoz and B. Arriaza
1993 Seven Chinchorro Mummies and the Prehistory of Northern Chile. *American Journal of Physical Anthropology* 91: 189-201.

Binford, L.R.
1983 *In Pursuit of the Past: Decoding the Archaeological Record*. Thames and Hudson, New York.

Bryson, R.A.
1992 A Macrophysical Model of the Holocene Intertropical Convergence and Jetstream Positions and Rainfall for the Saharan Region. *Meteorology and Atmospheric Physics* 47: 247-258.

Bryson, R.A. and R.U. Bryson
1997 Macrophysical Climatic Modeling of Africa's Late Quaternary Climate: Site-Specific, High-Resolution Applications for Archaeology. *African Archaeological Review* 14(3): 143-160.

Bryson, R.A. and B. M. Goodman
1986 Milankovitch and Global Ice Volume Simulation. *Theoretical and Applied Climatology* 37: 2228.

Bryson, R.U. and R.A. Bryson
1998 Application of a Global Volcanicity Time-Series on High-Resolution Paleoclimatic Modeling of the Eastern Mediterranean. In *Water, Environment and Society in Times of Climate Change*, edited by A. Issar and N. Brown, pp. 1-19. Kluwer Academic Publishers.

Dauelsberg, P.
1974 Excavaciones arqueológicas en Quiani, Provincia de Tarapacá, Depto. de Arica, Chile. *Chungara* 4: 7-38.
____1985 Faldas del Morro: Fase Cultural Agro-Alfarera Temprana. *Chungara* 14: 7-44. [Links]

Focacci, G.
1974 Excavaciones en el Cementerio Playa Miller-7, (Arica) Chile. *Chungara* 3: 23-74.

Goodman, B.M.
1984 *The Climatic Impact of Volcanic Activity*. Unpublished Ph.D. dissertation, Department of Meteorology, University of Wisconsin-Madison.

Grosjean, M., L. Núñez, I. Cartajena and B. Messerli
1997 Mid-Holocene Climate and Culture Change in the Atacama desert, Northern Chile. *Quaternary Research* 48: 239-246.

Lettau, H.H. and K. Lettau
1978 *Exploring the World's Driest Climate*. University of Wisconsin, Madison, WI USA.

Milankovitch, M.M.
1941 Kanon der Erbdestrahlung und seine Anwendung auf das Eiszeit-problem. *Königlich Serbische Akademie Edition Sp cializat* 133:1-633. Beograde, Yugoslavia.

Miller, A.
1976 The Climate of Chile. In *Climates of Central and South America*, edited by W. Schwerdtfeger, pp. 113-146. Elsevier Scientific Publishing Co., Amsterdam.

Muñoz, I.
1980 Investigaciones Arqueológicas en los Túmulos Funerarios de Valle Azapa. *Chungara* 6: 57-95.
_____1986 Aporte a la Reconstitución Histórica del Poblamiento Aldeano en el Valle de Azapa (Arica, Chile). *Chungara* 16-17: 307-322. [Links]

Muñoz, I., R. Urbina and S. Caceres
1991 Camarones 15: Asentamiento de Pescadores Correspondiente al Periodo Arcaico y Formativo en el Extremo Norte de Chile. *Actas XI Congreso Arqueología Chilena* Vol II: 1-32.

Núñez, L. and T.D. Dillehay
1979 *Movilidad Giratoria, Armonía Social y Desarrollo en los Andes Meridionales: Patrones de Tráfico e Interacción Económica*. Facultad de Ciencias Sociales, Universidad del Norte, Chile.

Rivera, M.A.
1977 *Prehistoric Chronology of Northern Chile*. Unpublished Ph.D. thesis. Department of Anthropology, University of Wisconsin, Madison.
_____1980 Arqueología Andina en el Panorama de las Investigaciones Arqueológicas en Chile. *Temas Antropológicos del Norte de Chile. Estudios Arqueológicos*, Número Especial, pp. 46-174. [Links]

Santoro, C.M.
1980 *Estudio de un Yacimiento Funerario Arqueológico del Extremo Norte de Chile, 1.300 A.C. - 1.300 D.C.* Proyecto para Optar al Título de Arqueólogo, Departamento de Arqueología, Universidad del Norte, Antofagasta, Chile.

Schwertdfeger, W.
1976 The Climates of Peru, Bolivia and Ecuador. In *Climates of Central and South America*, edited by W. Schwerdtfeger, pp. 147-218. Elsevier Scientific Publishing Co., Amsterdam.