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RETICULATE IRRIGATION IN THE ATACAMA

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RESUMEN

El presente trabajo se refiere a Ramaditas, un sitio formativo de la Pampa del Tamarugal. Un motivo aparente para su ocupación fue el de tener acceso a depósitos de cobre, pero la aridez extrema debe haber sido un problema para el establecimiento humano. Ramaditas es posiblemente una derivación del complejo Wankarani de Bolivia, y localmente representa la fase Alto Ramírez del norte de Chile. En sucesivas temporadas de terreno en 1992 y 1993 se identificaron pozos artesianos fósiles que funcionaron como vertientes provenientes de un acuífero fósil. Un sistema reticular de irrigación, con segmentos escalerados, se ajusta a la topografía y ahorra agua. Trabajo de terreno desarrollado en 1995 reveló que Ramaditas puede haber sido parte del mismo sistema de drenaje que su vecino de Guatacondo-1 en los últimos siglos antes de Cristo.

ABSTRACT

Concerning Ramaditas, a formative site in the Pampa Tamarugal. An apparent motive for occupation was ready access to copper deposits, but the extreme aridity made human settlement problematic. A possible derivative of the Wankarani complex of Bolivia, Ramaditas was a representative of the Alto Ramirez phase local to Northern Chile. Work in 1992 and 1993 identified fossil artesian wells that functioned as springs driven by a fossil aquifer. A reticulated irrigation system, with trellis-like segments, fits the topography and conserves water. Work in 1995 has revealed that Ramaditas could have been part of the same drainage system as its neighbor Guatacondo-1 during the last centuries BC of the current calendar.

During recent field seasons, Beloit College personnel have excavated one compound of a multi-compound site called Ramaditas. Ramaditas is located at the mouth of the quebrada Guatacondo, as it leaves the western Andean slopes and opens into what is colloquially known as the Atacama Desert. The location is approximately 69 degrees 21 minutes West Longitude and 20 degrees 57 minutes South Latitude, and falls within the equatorial tropic zone. In current political geography it lies in the Chilean First Region, in the area known under the regional designation as Tarapaca. The location is well within the district famous for nitrate exploitation in the 19th and early 20th centuries. In fact, the name, Ramaditas, is apparently inherited from a station of the same name that was formerly located on the narrow gauge railroad used by the nitrate company.

In ecological terms, Ramaditas should be characterized as being just to the North of the area strictly called the "Atacama Desert", and falling within a zone called the Pampa Tamarugal. The Tamarugo tree (Prosopis tamarugo) is a member of the legume family, and it is the dominant vegetational form in the Chilean desert

North of San Pedro Atacama. The Tamarugo, which is somewhat like its North

American relative the Mesquite (Prosopis glandulosa), formerly covered large areas of the chilean desert north of the drainage of the Rio Loa. Severe deforestation occurred in the latter years of the nitrate industry (1900-1920), Tamarugo wood being used as fuel for the boiling of the nitrate solutions. Today parts of the Pampa Tamarugal serve as sites for the chilean reforestation project known as the Tamarugo National Park. It is of considerable importance to the interpretation of the site of Ramaditas to recognize that as late as 1850 much of the surrounding area had patches of tropical scrub forest. The deforestation of the late XIX and early XX Centuries has altered the landscape and water table so that the current Pampa Tamarugal has been reduced to an aridity even more like its southern neighbor the Atacama proper.

Any archaeological interpretation of the Ramaditas site must keep in mind the environmental parameters of the pre-nitrate period in the Pampa Tamarugal. Despite its aridity, for example, the Pampa Tamarugal may well have been attractive to various prehistoric immigrants, either to exploit the agricultural potential of nitrogen rich soils with local colonies, or to extractively exploit either copper or nitrates for use elsewhere. In the case of Ramaditas, irrigation should be seen not only as an adaptation to arid environment, but as an especially auspicious situation in which even very limited quantities of water may produce a vegetational florescence supported by the nitrogen rich environment.

Copper

The enormous potential fertility of the surroundings of the Ramaditas site are emphasized first here because the attention focussed on another locally available resource often overshadows the discussion. The other locally available resource is copper. Ramaditas is located about 110 km.(less than 100 miles) to the North of the famous Chuquicamata copper deposit. "Chuqi" is one of the largest mines in the world, possibly the largest copper mine, and a major resource on the world metal markets. The area in the vicinity of Ramaditas also has copper mining potential, particularly in the Quebrada Guatacondo. Exposed ore veins in the Quebrada have invited exploitation from pre-Tiwanaku times right up to the present. Currently a joint Chilean/Canadian company is prospecting and mining in the area.

Copper slag has been found in a surface context at Ramaditas, and radiocarbon dated to a time slightly before the radiocarbon date of the first occupancy of the site itself (Graffam et.al. 1994:83). The authors explain this anomaly by assuming the use of "**old**" wood, that is wood found preserved in the desert from some earlier time, and exploited for use in the copper furnace. This hypothesis is consistent with the available evidence and with the availability of fossil wood, but must raise serious questions with respect to the radiocarbon dating of the site. In particular, the authors would have copper smelting continuing at the site after it was abandoned as a residence (Graffam et.al.1994:83), an hypothesis that must raise many additional questions if it is accepted.

Previous Work

Compared to the Atacama Desert proper, the Pampa Tamarugal has suffered from a relative archaeological inattention. In spite of this, or perhaps because of it, the immediate environs of Ramaditas have been investigated. Grete Mostny urged and encouraged investigation of the area and an important step was taken between 1965 and 1969 by the University of California, Los Angeles (UCLA), under the general direction of Clement W. Meighan (cf. Meighan and True 1980), and the Universidad de Chile, Santiago, under the direction of Grete Mostny (Mostny 1980), who also participated. Along with various subjects, such as C^{14} chronology, biface artifacts, fish remains, and prehistoric diet as revealed by coprolites, the zone of Guatacondo Quebrada (Mostny 1980), and a type site called Guatacondo-1 (Mostny 1980;Meighan 1980) were investigated. Meighan's Guatacondo-1 is about 10 km. distant from Ramaditas, and directly "up the quebrada" by the current road. Potentially belonging to the same ecology and time period as Ramaditas, Guatacondo-1 was a major stimulus for the archaeological exploration of Ramaditas. Mostny (1980:95,96) reports a number of early radiocarbon dates for Guatacondo (cf. Tartaglia 1980:20), but Meighan summarizes them with a cautionary dismissal; "The spread of time represented by the total set of C-14 dates is not to be taken literally,...(1980:111)." Meighan does suggest that the "overall evidence" places the occupation of Guatacondo at about "...the beginning of the Christian era,...(Ibid.:111)." The exact relationship between Ramaditas and Guatacondo is unclear, and yet to be worked out. However, it is now clear that the earliest C14 dates that troubled Meighan are likely to be correct, and should be considered to overlap with Ramaditas.

The following table should make the relationship between Ramaditas and Guatacondo-1 clear. IVIC dates are from Mostny 1980, UCLA dates from Tartaglia 1980, Ramaditas dates from Graffam et.al., and the approximate true calendar dates are from the decadal calibration of Stuiver and Becker 1993.

Table 1

lab number	radiocarbon date	material	approximate calibration
IVIC 168	775 +/- 160	charcoal	1279/1263 AD
IVIC 167	1175 +/- 90	Maize cobs	885 AD
UCLA 1698E	1830 +/- 60	charcoal	224/189 AD
UCLA 1698C	1865	Maize cobs	132 AD
IVIC 166	1890 +/- 100	wood	128 AD
UCLA 1698D	1900	human coprolites	126 AD
* TO 3573	2040 +/- 50	algarrobo seed	2/10/24/26/39 BC
* BETA 48822	2040	wood	2/10/24/26/39 BC
* BETA 50834	2320 +/- 60	charcoal	390 BC
UCLA 1698B	2370 +/- 60	reeds	399 BC
UCLA 1698A	2830 +/- 50	basketry	938/956/972/995 BC

* indicates dates from Ramaditas, all others are from Guatacondo-1

The multiple calibrations for several of the radiocarbon assays are included to show that the particular range of time involved has numerous "wiggles"(eg. in the bristlecone pine correlation table), and that single year equivalents would give an illusory precision that is unwarranted by the data. Nevertheless, if we ignore IVIC 168 and BETA 50834 on the advice of the respective authors that these represent stratigraphically anomalous situations (Mostny 1980:96; Graffam et.al. 1994:83), Guatacondo seems to have exploited materials dating from 1000 BC to 900 AD, with Ramaditas falling near 0 - 40 BC. Ramaditas thus appears to have been in operation at almost the exact half-way point of the occupation of Guatacondo-1.

Ramaditas resembles Guatacondo-1 in other ways. Excavation at Ramaditas has recovered numerous examples of vertebrae of relatively large salt water species of fish, and some bones of Andean camelids. Ramaditas is roughly 75 km.(50 miles approx.) from the nearest point on the Pacific, and less than 50 km (eg. 30 miles) from Altiplano zones that are camelid pasture and would have had the same potential in pre-columbian times. Ramaditas could have had access to seafood on a regular basis, and could participate indirectly in Andean pastorilism, but it is too far from its catchment areas to believe that complete dietary support was possible by movement of basic commodities on foot. The dietary evidence from Ramaditas is duplicated in Guatacondo (Meighan 1980; Mostny 1980), about 10 km. away, so it cannot be considered an anomalous isolate. In addition to fish and camelid meat, Ramaditas must have had some reliable local food source growing within less than 10 km. of the site.

Irrigation system

The surface of the desert near Ramaditas displays features that appear to be systems of canals and fields. Not only are the overall systematic linkages of lines and rectangles indicative of irrigated canals and fields, but intersections of canals have configurations of stones typical of the sluice gates of irrigation systems currently in use in the area.

The entire system is clearly visible to the naked eye, and unmistakable, but its vertical dimension is limited and does not photograph well. Following apparent irrigation ditches across the Pampa, one encounters occasional intersecting features, such as old road cuts. On these points of intersection, the cross section of the ditch is directly visible in some cases, and clearly if indirectly indicated in others. In no case is a ditch very deep, and for the most part they seem to have been about 30-40 cm. (eg. 1-1.25 ft.) maximum depth.

Ditches running in pairs are the key to its operation(see Figure 2 below). Water was taken from some source East of the site, and run downhill toward the West. Starting at a point where the ditch splits into two, it is possible to follow the system to where the ditches are wide enough apart to run on either side of the potential fields. Local swails and undulations cause first one ditch and then the other to be slightly higher than its pair. Thus for a time one ditch is the upper, "supply", ditch, and the other is the lower, "scavenger", ditch, but further downhill to the West they may reverse this relation. Water at any point can be transferred from one ditch to the other by cross ditches, or the main or cross-over ditches can feed water to a field. Segments of the system, if viewed from above, look like a ladder with the fields located in the rectangles formed by the ladder's "rungs". When one attempts to overview larger sections of the irrigation pattern, these ladders seen together form a sort of net or reticulated pattern. The net conforms to the local surface, fitting the undulations of the ground, and undergoing trapezoidal distortions where that is a convenient way to follow the contour. The 2.03% overall grade (eg. about 1° 10') guarantees a continuous flow, but is probably not drastic enough to cause severe erosion of the ditches.

The whole system is both opportunistic in the way it fits the minor relief in the local topography, and highly efficient in economy of distances through which water must flow. In addition, any water not absorbed by the soil or evapotranspired ends up in the scavenger ditch to feed fields further downhill.

Artesian Water Supply

The field excavations examined two locations which apparently were irrigation ditch "heads". These were located within 200m of the site of Ramaditas Compound-1.

Excavation revealed a fossil artesian well structure. Water had at some time in the past exited through a clay layer to the surface. The crack in the clay layer was visible, as well as clay and sand deposits indicative of water flow and water deposition. Evidence of biological activity was abundant in the form of roots, reeds, cat-tail parts, and black organic "muck" in the sand. Cultural evidences also occurred, including modified sticks, ceramics, netting, rock alignments, and one projectile point tip.

Work during the 1995 season not only exposed an additional well similar in type, but also revealed a more complex variant. Excavation of a structure west of compound 2 was attempted in order to satisfy our curiosity about an unusual wall feature that seemed to go nowhere. Excavation revealed what had been a shallow seepage structure that was channeled together to supply water to ditch running downhill to the West. What had initially appeared as a very unusual wall was in fact a sort of check dam used as part of a funnel for collecting water into a single canal.

The vertical walls of the quebrada give away the basic stratigraphic structure of the local talus fan that underlies Ramaditas(see below, Figure 1). The lowest several meters of deposit are a mixtures of sand, gravel, and clay, very unordered, and with evidence of water washing and multiple sources of material. About 1.5-2 m. below the surface is a well developed layer of clay 10-15 cm. in thickness. The clay is fine grained, shows evidence of sorting by hydraulic means, and is cracked in polygonal blocks in a fashion that is predictable of puddled clay when it dries. This clay layer is topped by about a meter of mixed sand, gravel, and clay similar to the lowest deposit, although in "eyeball" appearance somewhat finer grained than the lower deposit. Above this is another clay layer, similar to the first in thickness, and having the same general physical characteristics. On top of the second clay layer is a surface alluvium of varying thickness, but seldom more than 50 cm. in depth. This upper alluvium is the surface soil, and is primarily sand and clay by bulk, but with some gravel and smaller sized stones, and occasional water rounded cobbles or boulders. There is no real "topsoil" in any usual sense of the term. The desert pattern of wind erosion removes fine grained soils, leaving only rocks of various sizes. Since this primary material is lacking, the development of any mixture of organic and inorganic materials that might lead to soil development is out of the question. This stratigraphic structure as I have described is can be traced up and down the quebrada (eg. East and West along the quebrada), and is consistent for kilometers in either direction.

The origin of the clay layers does not require extensive research, a few minutes walk up or down the quebrada channel will encounter at least one such clay deposit on the channel floor. This sort of feature is produced by water sorting of clay from the general matrix of material, and the subsequent redeposition of the clay in spots where stream flow or flash flooding has encountered a location of relative calm. Such clay deposits are a predictable feature of the situation, and are plentiful near this location. Once formed, of course, these deposits dry in the sun as soon as the flash flood is terminated. Drying in the sun causes hardening and cracking along hexagonal, or approximately hexagonal, lines and patterns.

This stratigraphic situation, a layer of mixed deposit sealed between two clay layers, with the upper clay layer just a short distance below the surface, extends East and West from Ramaditas, and some distance to the North. This means that there is a potential aquifer, the mixed deposit sealed between two clay layers. The clay layers would be relatively impermeable to water passage once saturated. This potential aquifer is sloped downhill West toward the internal drainage basin of the Pampa Tamarugal, and could be expected to have some hydraulic pressure anywhere below (eg. West of) its head.

Summary Description

Overall the talus cone surface in the area around Ramaditas slopes downhill to the West, with about a 1° 10' degree gross slope, or about 2.03% grade. There are local swails and undulations with greater or lesser slopes, but repeated sightings with various instruments indicate that this is the picture in the larger view. Breakage of the upper clay layer, either by human intentional intrusions or by internal pressure of the aquifer, would at some time in the past produce an artesian well.

Auxiliary Wells

In addition to a clear cut beginning point of a supply ditch, excavation was also carried out on what appears to be an auxilliary well. This appeared on the surface as a rectangular stone outline. In early surveys it had been ignored as a small structure of little consequence, or assigned the presumptive category of "house". However, it was located right next to an irrigation supply ditch, and only a few yards from the main compound. Excavation demonstrated that it was another well, of essentially the same description as the well at the ditch origin, with the exception that it had been surrounded by a rectangle of stone. Perhaps the stone wall was to prevent windblown sand from entering the well exposure. Because of its proximity to the compound, it is also easy to hypothesize that the low wall served to reinforce the soil because that well would logically have been used for daily water supply for the residents of the compound.

In any case, it is apparent, that the artesian aquifer principle allowed for the exploitation of small wells at spaced intervals. Once the overall ditch channel was in operation, any location at which water could be obtained could become a tributary to the existing flow. Since such small wells could be almost randomly placed within the area, potentially they could be placed at the convenience of the residents, and could extend the reticulate system of ditches into any direction that was convenient. The single restriction on the development of a supposed system of irrigation is the obvious one that downhill to the west aggregates water sources and contributes to overall flow in a gravity system, any other direction is problematic. The uppermost clay layer described is only a little below the surface at any given point, and would not allow for the percolation downward of water from the system, a potential source of water loss in many irrigation systems. Lack of percolation loss means that this can be carried on downhill for quite a ways. Should there be other artesian sources further downhill they can produce their own systems, or be fed in as tributaries to enhance the flow in an existing system coming down from above.

Supply Ditch Structure

Field excavations also cross sectioned what appeared to be a supply ditch directly below Ramaditas and somewhat downhill from the artesian water source. Cross section excavation produced more of the organic remains such as roots, plant parts, and organic blackening of soil. Additionally, and critical to this exposition, the cross section revealed the clay lining of the irrigation ditch. This clay liner did not appear be a "manufactured" artifact in its origin, but rather an emergent "evolutionary" aspect of the ditch having been used over several seasons at a minimum. The clay seal was fine grained, and apparently water laid, a product of constant siltation in ditches in use.

Implications

In Ramaditas it is possible that a unique adaptation to a very narrowly defined ecological and topographic niche has been achieved. However there is reason to believe that Ramaditas was part of a larger group of sites having the same characteristics Rivera n.d.b). That is, sites on the Eastern slope of the desert, ascending the lower hills of the Andes, and located near the mouths of quebradas that descend from the Andes. Such sites mark both the interface of the quebrada environment with the open desert, and the intersection of a quebrada route with a route going North and South along the desert edge. Given the presence of sites similar to Ramaditas like Tarapaca 18 (True and Gildersleeve 1980), and to other sites similar to Guatacondo such as Caserones (True 1980), it appears that a regular pattern of invading the desert North had developed by 300 BC, if not earlier. The invasion by the cultural complex called Alto Ramirez was a massive and well organized intrusion into the area (Rivera n.d.a; Rivera n.d.c). If Ramaditas' reticulate irrigation is unique, it nevertheless stands as a creative local adaptation used to advance that intrusion. It is highly probable that Ramaditas is not unique, and that the opportunistic adaptation will be duplicated several times in other locations in the Desert North of Chile.

Ramaditas and Guatacondo-1[2]

During the fieldwork of June and July 1995, the author began to survey the relationship between Ramaditas and Guatacondo-1 with an electronically enhanced transit of a type known as a "total station". A major advantage of this equipment is its ability to take numerous field readings rapidly, and immediately and directly store the resulting data in an electronic form. The 10 kms distance between Guatacondo-1 and Ramaditas had seemed too large a project to undertake in earlier field seasons.

The most important results appeared within 2 kms of Guatacondo-1 (hereinafter G1). West G1, toward Ramaditas and downhill, the fossil quebrada on which G1 is located crosses the modern quebrada in a narrow constriction. At the level of G1, the modern quebrada is almost 300 meters north of G1, and its bottom is about 6 meters lower in elevation than the bottom of the fossil quebrada next to G1 (see Meighan 1980:100, Map 1 for the relationship between G1 and the fossil quebrada; other data Shea n.d.). Although both quebradas drop in the next .75 (approx.) kilometer, the new route consistently remains lower than the old one. At the point of intersection, the new quebrada is almost 4 meters below the old quebrada route. Just west of (and below) the quebrada intersection the narrowest constriction of the valley occurs. Through that narrow constriction, which is about half a kilometer (eg. 486 meters) long, there is about an 8 meter downgrade (or about 1.01 degrees downslope)to the level at which the old quebrada route passes north into the area above Ramaditas. The new (eg. current) quebrada route, which is already 4 meters lower, drops even more, and exits the narrows more than 10 meters below the older route (all data Shea n.d.).

The author does not consider himself well enough versed in either Geology or Palaeo-Climatology to explain the change in routing of the main channel of the Guatacondo quebrada. The older route passed into the area where it would fill the aquifer above Ramaditas, and account for the fossil well system described above. The current route is north of G1 and south of Ramaditas, and six or more meters below both sites. Regardless of the exact cause, it is clear that the current route of the quebrada channel undercuts the older route, and has captured its drainage. The development of the current drainage system has literally left both Ramaditas and G1 "high and dry".

The same reconstruction makes it clear that the Ramaditas drainage and the G1 drainage were continuous at some point in the past. The alteration of the quebrada route in the narrows of the valley may have lowered the water table below the constriction first, and thus caused Ramaditas to expire for lack of water before G1. Alternatively, some event causing the overall lowering of the water table may have caused a change that affected both sites over the same time segment. The existing radiocarbon assays can be plausibly fitted to either scenario.

Figure 1. Stratigraphy of the Huataconao quebrada in the region near Ramaditas.

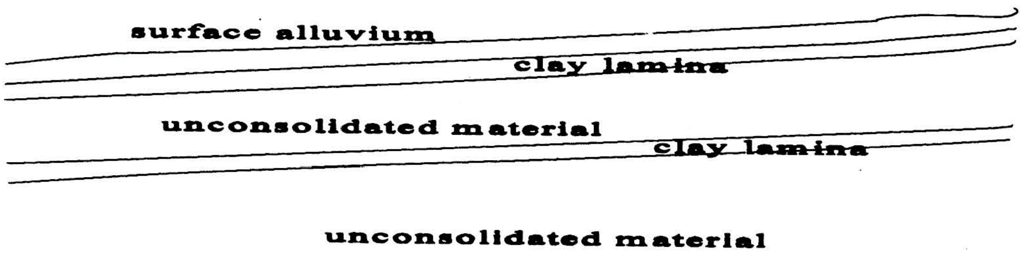
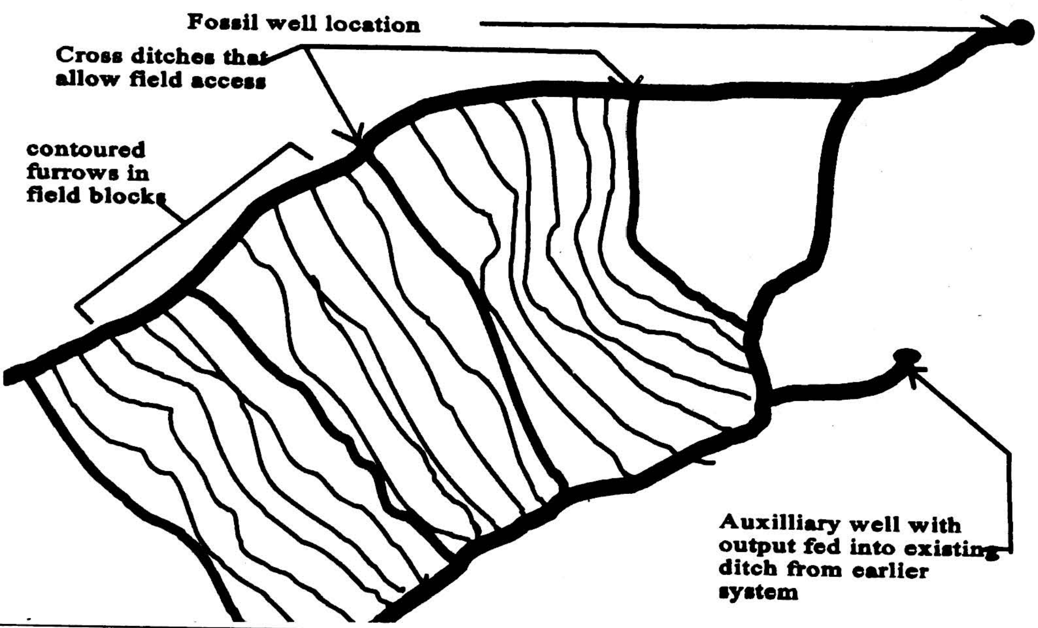


Figure 2. An example of the irrigation system of Ramaditas.



END NOTES

1. The principle text herein was developed for the 60th annual meeting of the Society for American Archaeology, Minneapolis, Minnesota, USA, May 3-7, 1995. The original version was part of a symposium entitled Northern Chilean Prehistory and the Atacama Desert, A Symposium Honoring Percy Dauelsberg H.. Some data have been added, and interpretations modified in accordance with fieldwork at Ramaditas June-July 1995.

2. This entire section has been added as a result of 1995 field work. The raw data in the form of distance and elevation numbers are derived from the authors' field notes.

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