PHYSICAL AND CHEMICAL STUDY OF THE FORMATIVE RITUAL SITE AZ-67 (*TÚMULO* Nº 1 AND Nº 2) FROM AZAPA VALLEY, NORTHERN CHILE

Nelson Lara Henríquez, Claudia Ogalde Herrera, Libertad Carrasco-Rios, Juan Chacama Rodríguez and Juan Pablo Ogalde Herrera

SUMMARY

*The soil of the ritual mounds (*Túmulo *Nº 1 and Nº 2) at the archaeological site Az-67 in the Azapa Valley, northern Chile, were studied. These monticules (*túmulos*) are formed by successive layers of vegetables and soil; they were built during the Formative period (1,500 BC- 500AC) in the area. The archaeological samples of soil were compared to a reference column without evidence of anthropogenic activity. The soluble and silicate fractions of the soil were analyzed with scanning electronic microscopy, inductively coupled plasma with optic emission spectroscopy, and granulometry. The silicate fraction data show that the soil layers of these* túmulos *are homogeneous and belong to this area, while the soluble fraction suggests a mixture of soils from areas richer in salts with soils poor in salt.*

Introduction

The so-called '*Túmulos*' are artificial mounds that were constructed with successive layers of vegetables and soil, always of a considerable size. The *túmulos* are an iconic cultural indicator of the Formative period (1500 BC-500 AC) in south-central Andes. In this macro-area *túmulos* have been studied from Moquegua, Peru, to Cobija in Chile (Focacci and Erices, 1972; Muñoz, 1980; Santoro 1980, 1981; Thomas *et al*., 1988; Romero *et al*., 2004; Muñoz and Chacama, 2014; Muñoz and Fernandez, 2014; Muñoz *et al*., 2014a). The emergence of the *túmulos* in the Azapa valley, northern of Chile (Figure 1), coincides historically with the first significant Altiplano influence in these occidental valleys, many of which flow into the Pacific Ocean. This influence includes a consolidation of agriculture and the arrival of rituality associated with trophy heads, among others (Santoro 1980, 1981; Chacama, 2004; Romero *et al*., 2004; Chacama *et al*. 2014; Muñoz and Fernandez, 2014).

At least 11 archaeological sites with *túmulos* have been located in the Azapa valley (Romero *et al*., 2004; Muñoz and Zalaquett, 2011;Muñoz and Fernandez, 2014; Muñoz and Gutierrez, 2014; and others). The dates of the *túmulos* on sites Az-12, Az-17, Az-24, Az-67, Az-80 and Az-148 show a range of construction from 790-380 BC in the earliest mounds to ca. 414-172 BC in the latest (Muñoz, 2014). Thus, the construction of *túmulos* in the Azapa valley of northern Chile probably took place before 100 AC, somewhat earlier than those built in Cobija and 'Caleta Huelén' (Costa Árida) and Moquegua (Santoro 1980, 1981; Romero *et al*., 2004; Muñoz and Fernandez, 2014; Muñoz *et al*., 2014b). The site of Az-70 (12km from the coast) has more than 40 monticules in an area of 3ha. The excavation of 30 graves in these *túmulos* related their function to funerary rituals. However, the small number of corpses found discards the funeral function *per se* and suggests that these mounds were made as part of a complex ceremonial system related, among others, to the ancestors and the freshwater hydrological resource (Focacci and Erices, 1972; Muñoz, 1980, 2005, 2007, 2012; Soto-Heim, 1987; Romero *et al*., 2004; Muñoz and Chacama, 2014; Muñoz and Gutierrez, 2014; Muñoz and Zalaquett, 2011; Silva 2014).

Túmulos Nº 1 and Nº 2 of Az-67

The *túmulos* associated with archaeological site Az-67 are

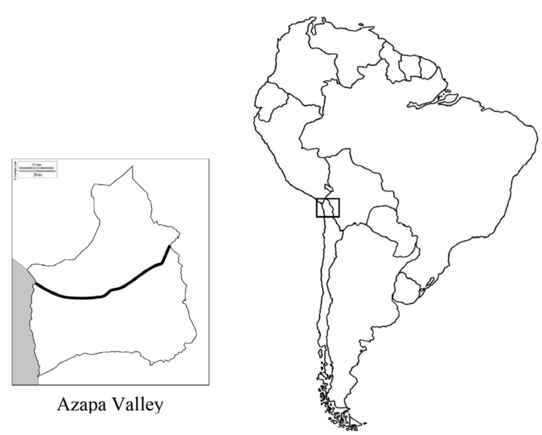

Figure 1. Location of the Azapa valley in northern Chile, South America.

KEYWORDS / Archaeological Soils / Archaeometry / Formative Period / Silicate Fraction / Soluble Fraction / *Túmulos* /

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Nelson Lara Henríquez. Ph.D. in Sciences, Universidad Complutense de Madrid, Spain. Professor, Universidad de Tarapacá, Chile.

Claudia Ogalde Herrera. Archaeologist, Universidad de Tarapacá, Chile. M. Sc. student in Anthopology, Universidad de Tarapacá, Chile.

Libertad Carrasco-Ríos. Ph.D. in Forestry and Veterinary Sciences, Universidad de Chile. Professor, Universidad de Tarapacá, Chile.

Juan Chacama Rodríguez. Anthropologist, Universidad de Tarapacá. Professor, Universidad de Tarapacá, Chile

Juan Pablo Ogalde Herrera (corresponding author). M.Sc. in Anthropology Universidad Católica del Norte, Chile. Ph.D. student, Universidad de Tarapacá. Adress: Avenida 18 de Septiembre Nº 2222, Arica, Chile. Email jpabloogalde@yahoo.es.

ESTUDIOS FÍSICO-QUÍMICOS DE LOS TÚMULOS Nº 1 Y Nº 2 DEL SITIO FORMATIVO AZ-67 DEL VALLE DE AZAPA, EXTREMO NORTE DE CHILE

Nelson Lara Henríquez, Claudia Ogalde Herrera, Libertad Carrasco-Rios, Juan Chacama Rodríguez y Juan Pablo Ogalde Herrera

RESUMEN

Se presentan los estudios físico-químicos realizados en los suelos del Túmulo Nº 1 y Nº 2 del sitio arqueológico Az-67 del valle de Azapa, extremo norte de Chile. Estos montículos están constituidos por capas sucesivas de vegetales y material estéril, siendo construidos durante el periodo Formativo (1,500 AC-500 DC). Las muestras de suelo arqueológico fueron comparadas con muestras de suelos de una columna de referencia, tomada en las cercanías del túmulo sin evidencia de actividad antrópica. En ambos casos se analizó la fracción soluble y silicatada del suelo con microscopía de barrido electrónico, espectroscopía de emisión óptica con plasma acoplado inductivamente y granulometría. Los resultados de la fracción silicatada muestran que las sucesivas capas de suelo de estos túmulos son homogéneas y tienen un origen local, mientras que el análisis de la fracción soluble sugiere que ha habido una mezcla de suelos de áreas ricas en sal con otros suelos pobres en sal.

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RESUMO

Apresentam-se os estudos físico-químicos realizados nos solos do Túmulo Nº 1 e Nº 2 do sitio arqueológico Az-67 do vale de Azapa, extremo norte do Chile. Estes montículos estão constituídos por camadas sucessivas de vegetais e material estéril, havendo sido construídos durante o período Formativo (1,500 AC-500 DC). As amostras de solo arqueológico foram comparadas com amostras de solos de uma coluna de referência, tomada nas proximidades do túmulo sem evidência de atividade antrópica. Em ambos os casos se analisou a fração solúvel e silicatada do solo com microscopia eletrônica de varredura, espectroscopia de emissão ótica com plasma acoplado indutivamente e granulometria. Os resultados da fração silicatada mostram que as sucessivas camadas de solo destes túmulos são homogêneas e têm origem local, enquanto que a análise da fração solúvel sugere que tem havido uma mistura de solos de áreas ricas em sal com outros solos pobres em sal.

located 14km from the coast on a fluvial terrace. The west side of the archaeological site coincides with the access to the Quebrada del Diablo, while the east is delimited by Cerro Moreno (a natural mound). This site has now six large mounds; however, satellite images show the existence of 14 burial mounds in a 9,000m^2 area of alteration, and many of them have disappeared (Muñoz and Fernandez, 2014; Muñoz and Gutierrez, 2014). Thus, this complex of *túmulos* could be a strategic logistic node in the circulation between the valley and the coast, and also related to the route to the Lluta valley through the Quebrada del Diablo (Muñoz and Zalaquett, 2011; Muñoz and Gutierrez, 2014).

Túmulos Nº 1 and Nº 2 of Az-67 were excavated in 2010 and two burials of female sex were found (in *túmulo* Nº 1); one of them is a woman of ~27 years old who died giving birth (Muñoz and Fernandez, 2014; Silva, 2014). As in other *túmulos*, mounds Nº 1 and Nº 2 of Az-67 are made of successive layers of vegetables and soil, in a well-defined distribution. The plants of each vegetable layer consist of branches and thick roots of *Manihot esculenta* (yucca), *Baccharis latifolia* (chilcas), *Gossypium bardadense* (cotton), *Phaseolus lunatus* (pallar) and *Phaseolus vulgaris* (bean), among others. Finally, a dense layer of *Canna indica* (achira) leaves seals the vegetal layer (Godoy, 2014; Ledezma, 2014; Muñoz and Fernandez, 2014).

The apparent homogeneity of the vegetable layers indicates that the construction of *túmulos* may have a pattern (Focacci and Erices 1972; Muñoz 1980; Santoro 1980, 1981; Soto-Heim, 1987; Romero *et al.*, 2004; Muñoz and Zalaquett, 2011; Godoy, 2014; Muñoz and Fernandez, 2014; Muñoz and Gutierrez, 2014). In order to specify this interpretation, herein we present the study of the elemental composition and chemical distribution of the layers of *túmulos* Nº 1 and Nº 2 of Az-67, after studying the silicate fraction and the soluble fraction of these archaeological soils.

Materials

The archeological soils (Table I) were compared with non-archaeological reference columns (indicated by numbers 1 to 4), taken 10m north of *túmulo* Nº 1 of Az-67. Samples of two columns of *túmulo* Nº 1 were studied: 15 archeological strata (identified by numbers 5 to 19) from a central 'column A' in the E2 grid (Figures 2a and 2b), and one sample of non-archaeological soil from column B in the B1 grid (number 20) located under the artificial mounds (Figure 2b). In *túmulo* Nº 2 of Az-67 one small 'column C' was excavated in the C1 grid (Figure 2b) with five archaeological strata (numbers 21 to 25). In addition, one sample of non-archeological soil located under this artificial mound was excavated in this grid (number 26).

Methods

The samples were studied *in situ* and in laboratory with several analyses for silicate fraction and/or soluble fraction of these soils according to Jackson (1970), Espina (1971), Foth (1986), Thomas *et al.* (1988), Barba (1990), Barba and Ortiz (1992), Middleton and Price (1996), Aston *et al.* (1998), Entwistle *et al.* (1998), Knudson *et al.* (2004), Sadzawka *et al.* (2004), (2006) and, Doussolin and Quezada (2008). The quantitative analysis of elemental composition of these samples was performed in an atomic absorption spectrophotometer (AAS) Varian 220; a molecular absorption spectrophotometer, UV-VIS range (AEM), 401 Genesis; a plasma atomic emission spectroscope inductively coupled with an optical emission spectrophotometer detector (ICP-OES) Varian. Aluminum, silicon, iron,

TABLE I
LOCATION OF THE SAMPLE BETWEEN THE PLANT LAYERS WITHIN THE Az-67 *TÚMULOS* AND REFERENCE SITES.

Nº	Analyzed in	Sediment	Grid	Column	Area	Location of sample between vegetable layers inside the *túmulos*
1	*In situ* /Lab.	Natural	Reference		30 x 30	Level 1 (0-5 cm)
2	*In situ* /Lab.	Natural	Reference		30 x 30	Level 2 (0-10 cm)
3	*In situ* /Lab.	Natural	Reference		30 x 30	Level 3 (10-13 cm)
4	*In situ* /Lab.	Natural	Reference		30 x 30	Level 4 (13-18 cm)
5	Laboratory	Mound1	E 2	A	30 x 30	Superficial sediment
6	Laboratory	Mound1	E 2	A	30 x 30	Sediment between layer 1 and 1a
7	Laboratory	Mound1	E 2	A	30 x 30	Sediment between layer and 1b
8	Laboratory	Mound1	E 2	A	30 x 30	Sediment between layer 1b and 2
9	Laboratory	Mound1	E 2	A	30 x 30	Sediment between layer 2 and 2a
10	Laboratory	Mound1	E 2	A	30 x 30	Sediment between layer 2a and 3
11	Laboratory	Mound1	E 2	A	30 x 30	Sediment between layer 3 and 4
12	Laboratory	Mound1	E 2	A	30 x 30	Sediment between layer 5 and 5a
13	Laboratory	Mound1	E 2	A	30 x 30	Sediment between layer 5a and 6
14	Laboratory	Mound1	E 2	A	30 x 30	Sediment between layer 6 and 6a
15	Laboratory	Mound1	E 2	A	30 x 30	Sediment between layer 6a and 6b
16	Laboratory	Mound1	E 2	A	30 x 30	Sediment between layer 6b and 6c
17	Laboratory	Mound1	E 2	A	30 x 30	Sediment between layer 6c and 7
18	Laboratory	Mound1	E 2	A	30 x 30	Sediment between layer 7 and 8
19	Laboratory	Mound1	E 2	A	30 x 30	Sediment between layer 8 and 9
20	Laboratory	Mound1	B1	B	30 x 30	Sediment sterile column (soil underneath the mound)
21	In situ	Mound 2	C 1	A	30 x 30	Superficial sediment (0-10 cm) North Sample
22	In situ	Mound 2	C 1	A	30 x 30	Sediment of layer 1
23	In situ	Mound 2	C 1	A	30 x 30	Sediment level 2 (20 cm)
24	In situ	Mound 2	C 1	A	30 x 30	Sediment of layer 2
25	In situ	Mound 2	C 1	A	30 x 30	Sediment level 3
26	*In situ* /Lab	Mound 2	C 1	A	30 x 30	Sediment level 4 (sterile under the mound)

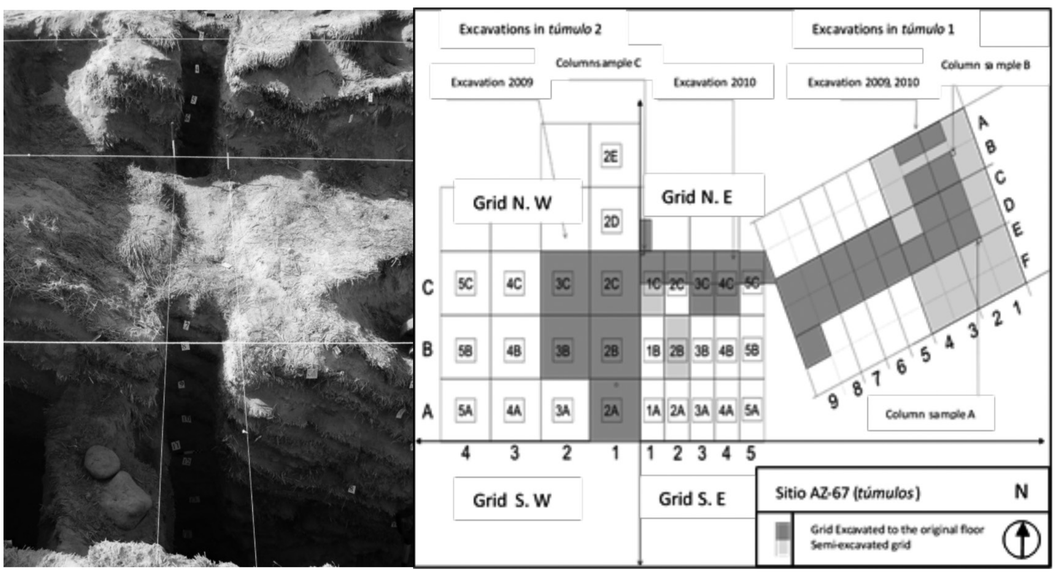

Figure 2. a) Column A of *túmulo* Nº 1 and b) original site drawing showing the excavated columns.

potassium, phosphorus, nitrate, organic matter (OM), organic carbon (CO), electrical conductivity (EC), pH and phosphate were determined in situ (Table II). Phosphorus, iron, potassium, nitrate and organic carbon (CO), besides EC and pH were determined in the soluble fraction (Table III). Aluminium, silicon, magnesium, manganese and iron were determined in the silicate fraction (Table IV).

Results

Analyses performed *in situ* in column C of the C1 grid from *túmulo* Nº 2 (Table II) show a relative homogeneity of the different samples of *túmulos*. Also, the difference in EC values between the archeological samples of column C and the non-archaeological sample (nº 26) is noticeable. In addition, the difference between archaeological columns C with the reference columns is significant. In the laboratory analysis, similar differences were found between the archaeological samples of column A and C and the non-archaeological samples (nº 20 and nº 26), located under *túmulos* Nº 1 and Nº 2. Also, all archaeological samples were poorer in salt content as compared to sterile soils of this area. In the soluble fraction of soil the enrichment of potassium, a more alkaline pH and the higher values of carbon in the archaeological samples of *túmulo* (Table III) are probably due to the mineralized organic matter from the vegetable and cultural remains. The available phospho-

TABLE II
FIELD ANALYSIS OF THE REFERENCE COLUMN AND COLUMN TERRAIN ON THE C1 GRID OF *TÚMULO* 2

Nº	Sample	EC ($mS \cdot cm^{-1}$)	pH	Phosphate
2	Ref level 2 (0-10cm)	56.76	6.0	0.5
3	Ref level 3 (10-13cm)	71.20	6.0	-
4	Ref level 4 (13-18cm)	57.36	5.0	-
21	Superficial (0-10cm)	35.48	6.0	0.5
22	Layer 1	46.76	6.0	-
23	Level 2 (20cm)	33.68	5.0	-
24	Layer 2	30.74	5.0	-
25	Level 3	29.76	6.0	-
26	Level 4	85.20	6.0	0.5

TABLE III
ANALYSIS OF THE ORGANIC MATTER OF REFERENCE COLUMN (1-4) AND OF COLUMN A OF GRID E2 OF *TÚMULO* 1 (5-19)

Sediment	P-disp Olsen mg·kg^{-1}	P total mg·kg^{-1}	Fe mg·kg^{-1}	K mg·kg^{-1}	NO_3^- mg·kg^{-1}	C %	pH	CE mS·cm^{-1}
1	9.51	80.15	-	22.00	398.91	0.041	7.14	51
2	5.87	107.89	0.38	720.00	448.39	0.087	7.17	65
3	2.42	126.39	-	737.00	529.00	0.128	7.21	52
4	2.60	109.88	-	651.00	553.63	0.140	6.75	33
5	5.51	95.1	0.45	1181.21	364.05	0.523	6.73	77
6	2.85	98.74	0.07	1064.06	479.64	0.285	7.72	31
7	5.42	90.15	0.10	1053.31	436.81	0.047	7.54	23
8	2.98	94.11	-	1064.06	546.51	0.087	7.29	27
9	1.71	101.62	0.46	1033.00	620.57	0.209	7.25	25
10	6.94	80.26	0.31	1013.00	480.50	0.035	7.21	25
11	14.85	67.89	0.25	1171.11	801.08	0.093	7.30	27
12	1.27	92.73	0.28	937.00	621.44	0.087	7.14	27
13	0.53	113.51	-	957.00	428.94	0.087	7.36	18
14	3.02	95.34	0.61	1160.79	356.51	0.442	7.34	17
15	10.14	66.91	0.13	1128.55	481.94	0.355	7.91	19
16	14.94	64.62	0.22	1107.05	313.80	0.076	7.66	22
17	8.45	82.07	0.16	1128.55	427.42	0.064	7.10	19
18	2.58	93.21	0.78	1139.29	460.81	0.110	7.50	27
19	9.96	78.83	0.63	1397.25	249.96	0.052	7.28	31

rus seems to have been strongly influenced by environmental surface phenomena (samples 1, 5, 11).

The silicate fraction showed no major differences between archaeological and sterile soil samples (Table IV). However, the concentrations of Si and Al suggest two deposition events in the mound. Si increased from samples 6 to 9 while Al did from samples 5 to 9, and then remained high down to sample 13. Both concentrations decreased in sample 14, and then increased again in the lower strata (samples 15-19).

The analysis of the texture (Table V) shows a decrease of silt and clay in the archaeological sediments of the column A of *túmulo* 1 (6 to 15) as compared to the reference sediments (1 to 4). Finally, the presence of quartz and other crystals with semi-rounded edges (Figure 3) in archaeological soils (absent in the reference column or the sterile samples) supports the presence of soils with evidence of erosion.

Discussion

In situ analyses show that the archaeological samples of the *túmulo* have lower salt concentrations than sterile soil, except evidently the superficial strata of the mound, associated with environmental dynamics. Also, the chemical distribution of the soluble fraction in the *túmulos* is probably due to the mineralization of the organic matter present in the structure of the mound. The data of the silicate fraction show that all the layers of the artificial mound, sterile strata and reference column are chemically homogeneous, with similar and local origins. This information helps understand the impoverishment of salts in the archaeological strata.

The presence of quartz and other crystals with semi-rounded edges in archaeological soils (absent in the reference column and the sterile samples) supports the presence of soils with evidence of erosion in archaeological strata of quartz and other crystals with semi-rounded edges, which is characteristic of alluvial and/or fluvial soils, which usually have low concentrations of salts due to the action of water.

The texture data implies that the soil used in the construction of the *túmulos* of Az-67 has been slightly modified in its composition. Thus, it is probable that in the construction of these ritual and artificial mounds soils from near water sources were used as well as soils from around the *túmulos*, which are richer in salts. This mixing process produced structural layers that have been depleted of salt with respect to the soils of the area where the *túmulos* were built.

The gradients of Si and Al concentrations in the silicate fraction data of archaeological strata of column A are of interest because this fraction is

TABLE IV
LABORATORY ANALYSIS OF REFERENCE COLUMN (1-4) AND COLUMN A OF GRID E2 OF *TÚMULO* 1, (5-19)

Sediments	%Si	%Al	%Fe	%K	%Mg	%Mn	%Ti
1	33.18	12.19	1.66	0.13	0.89	0.04	0.25
2	26.35	11.04	1.18	0.11	0.51	0.03	0.24
3	30.96	10.11	1.46	0.12	0.71	0.04	0.29
4	32.14	9.96	1.39	0.11	0.69	0.04	0.25
5	30.00	7.14	0.62	0.11	0.54	0.03	0.21
6	28.63	8.31	0.67	0.12	0.72	0.04	0.24
7	29.29	8.27	1.50	0.13	0.70	0.04	0.24
8	31.20	9.83	1.44	0.13	0.69	0.04	0.24
9	33.45	10.45	1.31	0.12	0.62	0.04	0.25
10	32.78	10.14	1.41	0.13	0.67	0.04	0.25
11	33.17	10.08	1.45	0.13	0.70	0.04	0.26
12	33.64	9.68	1.44	0.13	0.70	0.04	0.23
13	31.86	10.39	1.57	0.14	0.76	0.04	0.27
14	25.58	8.82	1.36	0.11	0.60	0.04	0.23
15	28.99	8.89	1.37	0.11	0.58	0.04	0.25
16	32.63	8.82	1.22	0.12	0.53	0.03	0.21
17	32.14	10.78	1.25	0.11	0.59	0.03	0.24
18	33.18	10.94	1.23	0.10	0.55	0.03	0.21
19	32.99	11.14	1.57	0.12	0.80	0.04	0.28

TABLE V
TEXTURAL CLASS ANALYSIS ACCORDING TO THE BOUYOUCOS METHOD

Nº sample	Sand (%)	Silt (%)	Clay (%)	Texture Class
1	70	20	10	Loam-Sandy
2	71	19	10	Loamy-Sandy
3	73	17	10	Loamy-Sandy
4	72	18	10	Loamy-Sandy
5	69	9	22	Loamy-Sandy-Clay
6	77	20	3	Loamy-Sandy
7	79	17	4	Loamy-Sandy
8	81	15	4	Loamy-Sandy
9	79	17	4	Loamy-Sandy
10	79	16	5	Loamy-Sandy
11	79	16	5	Loamy-Sandy
12	79	16	5	Loamy-Sandy
13	80	15	5	Loamy-Sandy
14	78	17	5	Loamy-Sandy
15	78	17	5	Loamy-Sandy
16	79	17	4	Loamy-Sandy
17	78	16	6	Loamy-Sandy
18	78	16	6	Loamy-Sandy
19	79	16	5	Loamy-Sandy
20	66	24	10	Loamy-Sandy
26	71	19	10	Loamy-Sandy

Figure 3. Photograph of the presence of quartz and other crystals with semi-rounded edges on the ground associated with the *túmulo*.

chemically enriched by the passage of long periods of time (Zhang *et al.*, 2007). Thus, the observation of two concentration gradients suggests two possible construction moments in several generations of individuals. This idea, which is particularly interesting, evidently needs further study.

Final Comments

The local construction of the *túmulos* of Az-67 was carried out with raw materials from the area, which included mixing soils of the river bank with the ground that surrounded the *túmulos*. Thus, the symbolic elements could link different local areas. In addition, these mounds were probably made in two phases, with established patterns and over a long time. Besides these particularities of the artificial mounds of AZ-67, this ritual place is related to funerary rituals, ancestors and the freshwater hydrological resource. Consequently, the symbolism of the *túmulos* is complex, considering the task-scape variety of raw materials from different locations used in their construction.

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