Vegetation Dynamic of Southern Sistan during the Bronze Age: 
Anthracological Studies at Shahr-i Sokhta 

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To recognize the dynamic of vegetation in eastern Iran as well as to ascertain interactions of human societies with their environment, the present study is carried out on charcoal samples collected from Shahr-i Sokhta dated back to the Bronze Age. This research will present two different vegetal formations used by the inhabitants of Shahr-i Sokhta: riparian formation with species such as tamarisk (Tamarix) and willow (Salix) and steppe taxa like Chenopodiaceae and saltwort (Salsola). By comparing charcoal data with those of present flora, certain changes concerning the vegetation structure in this part of Iran have been identified. These changes are best explained in terms of anthropogenic or environmental factors. The major presence of riparian taxa in the studied samples indicates that Sistan had favorable environmental conditions in the third millennium B.C. The study also concludes that the ancient vegetation of southern delta of Sistan have been relatively richer than the existing situation.

Keywords: Anthracology, Vegetal Structures, Bronze Age, Iranian Plateau, Sistan.

Introduction

In the Sistan region, the first archaeobotanical studies were started with the investigations of L. Costantini, especially on a rich archaeobotanical assemblage coming from the residential area and the graveyard of Shahr-i Sokhta. These analyses led to identification of three species of wheat (Triticum dicoccum, T. compactum and T. sphaerococcum), two species of barley (Hordeum vulgare subsp. distichum and H. vulgare subsp. hexastichum), lentil (Lens culinaris), flax (Linum usitatissimum), coriander (Coriandrum sativum), cumin (Cuminum cyminum), Cucurbitaceae family (Cucumis sp.) as well as wild pistachio (Pistacia atlantica/P. kinnjuk). The xylological studies has proved the exploitation of woody species like poplar (Populus), salt tree or saxaul (Haloxylon), Ash (Fraxinus), tamarisk (Tamarix), maple (Acer), hackberry (Celtis), date palm (Phoenix dactylifera), pistachio (Pistacia), elm (Ulmus), grapevine (Vitis vinifera) and exotic woods such as sissoo (Dalbergia sissoo), redwood tree (Adenthera cf. pavoniana) and haldu (Adina cf. cordifolia) at Shahr-i Sokhta (Biscione et al. 1974; Costantini et al. 2003).

The important presence of grape at Shahr-i Sokhta shows that it played a major role in the agricultural practices of the inhabitants (Costantini 1977: 162-168-170; Costantini and Dyson 1990: 66; Sajjadi et al. 2003). The wood remains of date palm (Phoenix dactylifera) and its carbonized stones have been discovered at Tepe Konar Sandal, in the Jiroft plain (Tengberg 2008), Shahr-i Sokhta, in parallel with Tepe Yahya, in the Soghan Valley and Miri Qalat in Pakistani Makran (Costantini and Costantini-Biasini 1985: 22). According to the archaeobotanical data Phoenix dactylifera could be domesticated in the south east of Iran (Zohary and Hopf 2000).

The archaeological evidence indicates that the people of Shahr-i Sokhta used these plants for different purposes such as fuel wood, manufacturing wooden tools and objects (like combs, boxes and figurines) and roofing of the rooms (Costantini 1979: 106-108).

To complete paleo-environmental studies, to have a good knowledge of vegetation history and also to understand the exploitation of the plants by man in Sistan, in this research we will focus on the study of charcoal remains coming from various archaeological contexts at Shahr-i Sokhta.

Present-Day Vegetation of Sistan

Climatologically speaking, Sistan is located in...
the Asian desert belt, with a semi-desertic climate. This region suffers from low precipitation (max. 128.7 mm/year and min. 8.7 mm/year) and the main source of life is the Hilmand River (Darvishzadeh 1991: 219) which has changed the direction several times (fig.1). Its main shift occurred at the end of the 3rd millennium B.C.

The average temperature in July is about 45° C while in January it descends to 7.5° C (Meder 1977: 61; Sobhkhyzi et al. 2006: 22). The strong winds, sometimes reaching 150 km/h, have an important impact on the environmental conditions. The wind of 120 days (or the wind of lavar) that blows from north-west to the south-east during summer, led to a serious erosion of the land (Jux and Kempf 1983: 17-20).

The vegetation of the Sistan plain is influenced by these climatic conditions. This situation had allowed the growth of plants (like tamarisk) that are resistant to a dry climate and saline soils along the active and dried bed of rivers and irrigation canals (Costantini and Tosi 1978: 176-179; Sobhkhyzi et

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Fig.1: Hydrological map of Sistan (After: Whitney 2006).
In general, the present flora of Sistan is dominated by halophyte and xerophyte plants (fig. 2) such as Aeluropus littoralis, Aeluropus lagopoides, Alhagi camelorum, Haloxylon ammodendron, Salsola spp., Tamarix spp., Imperata cylindrica, Calligonum and Prosopis stephaniana. Salt tree and tamarisk are the sole species that can resist these conditions, especially the violent winds.

Hamoun vegetation is different from the plain and includes aquatic plants or hygrophilous taxa like Typha angustifolia, Phragmites australis, Cyperus longus, Butomus unbellatus, Juncus maritimus, Arundo donax, Alisma, Plantago, Cynodon dactylon, Cyperus rotundus and Scirpus sp. (Noori et al. 2008: 88; Costantini and Tosi 1978: 179).
Four main periods have been proposed for the site based on calibrated dates, covering a span of time from 3200 to 1850 B.C. (period I, 3200-2800 B.C., period II, 2800-2500 B.C., period III, 2500-2300 B.C and period IV, 2300-1850 B.C.). Studies show that in the early period (period I) of settlement the people of Shahr-i Sokhta were engaged in cultural interactions with the people of eastern Iran, Baluchestan and Central Asia (Salvatori and Tosi 2005).

Several hundred of the Bronze Age sites around Shahr-i Sokhta, reveal that in the third millennium B.C. the Sistan plain was densely inhabited by farmers, herders and artisans, using vegetal resources. The site was abandoned by the beginning of the second millennium B.C. following a change in the river bed.

Material and Methods

In this research, a rich corpus of charcoals, collected from Shahr-i Sokhta during the fall of 2006, has been studied. In Iran, some archaeological sites, dated back to the Bronze Age, such as Tall-i Malyan (Miller 1985), Tepe Danghani (Tenberg 2008), Tepe Sialk (Shirazi and Tengberg 2012) and Konar Sandal (Shirazi 2012) offered such a well preserved organic material.

317 liters of sediments, coming from various archaeological contexts (rooms, floors and hearths) at the Industrial Zone, the Monumental Zone, the Eastern Residential Area and the Graveyard have been analyzed. The charcoals have been separated from sediments by means of two sieves with different meshes (2 to 6 mm) without flotation. This method was adapted because of difficult accessibility to the water on the site. The identification of charcoals has been realized in the archaeobotanical laboratory of UMR 7041, Maison de l’Archéologie et de l’Ethnologie de René Ginouvès of Nanterre in France.

In general, the charcoal fragments were in a good state of preservation and were enough large for observation and identification. The observation of charcoals has been possible by means of a reflected-light microscope allowing magnifications from 50x to 1000x. Three sections of the charcoals (transverse, tangential and radial section) were illustrated through photos taken from an electronic microscope of the Muséum National d’Histoire Naturelle of Paris. Several wood atlases (Vernet et al. 2001; Pajouh and Schweingruber 2001; Niloufari 1985) as well as a reference collection were used during the identification task.

Archaeobotanical Assemblage

In total, 1493 charcoals have been studied resulting in identification of various taxa such as tamarisk (*Tamarix*), willow (*Salix*), goosefoot family (*Chenopodiaceae*) and saltwort (*Salsola*). It is worthy to point out that 11 charcoal fragments remained undetermined because of the lack of the reference or their conservation state and therefore their percentage has not been included in the total calculations (Tables. 1 - 2). The main anatomical requirements as well as the ecological requirements of the above-mentioned taxa are briefly presented below.

*Tamarix* sp.

Tamarisk dominates the anthracological (charcoal) spectrum of Shahr-i Sokhta with 86% of studied fragments for the Eastern Residential Area and the Industrial Zone and 74% of samples coming from the Monumental Zone. Tamarisk is a small tree or shrub with much reduced scale-like leaves. The inflorescences are of feathery aspect and bear numerous minute white and pinky alternate hermaphrodite flowers. This plant is a xerophyte that grows on saline, sandy or alluvial soils. The desertic climatic conditions and the humidity of the soil are very important for the growth of tamarisk. More than twenty different species of tamarisk (*Tamarix*) genus of the Tamaricaceae grow in Iran (Sabeti 1994: 728). Certain types of tamarisk can tolerate average precipitation of 100 mm/year and can tolerate both drought and periodical inundation.

The wood of the tamarisk tree is diffuse to semi-ring-porous, with distinct growth ring. The vessels
are solitary and sometimes in multiple of 2-3 cells in the transvers section. It is characterized by large (until to 20 cells) and heterogeneous rays. Parenchyma cells are typically storied in the tangential section (fig. 3, Nos: 1-3). But it is very difficult to separate different species of genus *Tamarix* according to their characteristics (Neumann et al. 2000). Because of large numbers of possible species in the Iranian territory, important intra-specific variability and resemblances, our identification is limited to the genus only.

**Salix sp.**

Willow is represented by 5% of studied fragments for the Industrial Zone as well as the graveyard and 24% of samples coming from the Monumental Zone. The willow, of which several species are native to Iran, are shrubs or trees with deciduous, lanceolate leaves. Their flowers are produced on catkins. It is a hygrophilous plant that grows near the shores of the fresh water lakes and along the river banks as well as humid pastures.

The wood of willow is characterized by diffuse vessels, rarely solitary or grouped in radial rows of 2-4 cells or clustered in 2-8 cells in the transverse section. The rays are mostly uniseriate, rarely biseriate and heterogeneous in tangential section (fig.3, Nos: 4-6)

### Chenopodiaceae

A small percentage (7%) of the charcoal in the Industrial and the Monumental Zones at Shahr-i Sokhta has been identified as members of the goosefoot family. This family has a large distribution over the continents and especially in the Middle East and Central Asia. In Iran, this family is represented by diverse species in the desertic landscapes like *kavir Namak* and steppes (Sabeti 1994: 682).

### Table 1: Results of the charcoal analysis at the Western Industrial Zone and the Eastern Residential

<table>
<thead>
<tr>
<th>Vegetal formations</th>
<th>Taxa</th>
<th>Period II (2800-2500 B. C.)</th>
<th>Trench</th>
<th>WIZ</th>
<th>ERA</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steppe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>cf. <em>Salix</em> sp. (saltwort)</td>
<td>6</td>
<td>6</td>
<td>52</td>
<td>64</td>
<td>5%</td>
</tr>
<tr>
<td>Total steppe</td>
<td></td>
<td></td>
<td>15</td>
<td>22</td>
<td>70</td>
<td>3</td>
</tr>
<tr>
<td>Riparian forest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cf. <em>Salix</em> sp. (willow)</td>
<td>22</td>
<td>17</td>
<td>21</td>
<td>2</td>
<td>62</td>
<td>5%</td>
</tr>
<tr>
<td><em>Tamarix</em> sp. (tamarisk)</td>
<td>310</td>
<td>344</td>
<td>289</td>
<td>53</td>
<td>50</td>
<td>1046</td>
</tr>
<tr>
<td>Total riparian forest</td>
<td></td>
<td></td>
<td>332</td>
<td>361</td>
<td>310</td>
<td>55</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cf. Monocotyledone</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>TOTAL</td>
<td>347</td>
<td>383</td>
<td>380</td>
<td>58</td>
<td>50</td>
<td>1218</td>
</tr>
</tbody>
</table>

### Table 2: Results of the charcoal analysis at the Monumental Zone.

<table>
<thead>
<tr>
<th>Vegetal formations</th>
<th>Taxa</th>
<th>Period II/III (2800-2300 B. C.)</th>
<th>Trench</th>
<th>MZ</th>
<th>Tomb</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steppe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cf. <em>Salix</em> sp. (willow)</td>
<td>6</td>
<td>140</td>
<td>50</td>
<td>10</td>
<td>6</td>
<td>64</td>
</tr>
<tr>
<td><em>Tamarix</em> sp. (tamarisk)</td>
<td>148</td>
<td>140</td>
<td>50</td>
<td>10</td>
<td>6</td>
<td>260</td>
</tr>
<tr>
<td>Total steppe</td>
<td>6</td>
<td>188</td>
<td>50</td>
<td>10</td>
<td>6</td>
<td>264</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>188</td>
<td>50</td>
<td>10</td>
<td>6</td>
<td>264</td>
</tr>
<tr>
<td>Undetermined</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16</td>
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</tbody>
</table>
Fig. 3: *Tamarix* sp. & cf. *Salix* sp.
The wood of Chenopodiaceae, used as a combustible, is characterized by the absence of rays and conjunctive parenchyma in tangential section. In the transverse section, the included librers present a concentric pattern (fig. 4, Nos: 1-2).

*Salsola sp.*

Saltwort is represented in the anthracological spectrum of Shahr-i Sokhta with a minor importance (4%). This annual or perennial herbaceous plant has articulated internodes and alternate leaves. The wood of saltwort is characterized by the absence of rays and the presence of conjunctive parenchyma in tangential section. In the transverse section, included librers have a concentric pattern (fig. 4, Nos: 3-4).

*Fig. 4: Chenopodiaceae & cf. Salsola sp.*
Discussion

The identified taxa at Shahr-i Sokhta belong to two main vegetal formations. The first one is hygrophilous formation that is dominant and is represented by trees and shrubs such as tamarisk (Tamarix) and willow (Salix) (fig. 5). From an ecological point of view, certain species are adapted to difficult environmental conditions. For example, tamarisk trees are generally both drought and flood tolerant. It can also survive and resist salinity of soil and regenerate quickly from cutting. This genus is found in various environments but they mostly exist along rivers and watercourses. At present, in the Sistan plain different species of tamarisk like Tamarix kotschyi, T. ramosissima, T. florida, T. passerinoides, T. aphylla and T. stricta grow along Hamoun shores and nearby region with hard soils and high degree of salinity (Sabeti 1994; Sobhkhzyzi et al. 2006; Noori et al. 2008: 90-99). Today, the hygrophilous formation is localized more or less along the Hilmand and the shores of Hamoun Lake (Nyzars). It forms a kind of forest gallery hosting birds and other wild animals that could be considered as a nourishment source for the ancient people of Sistan. The major presence of hygrophilous taxa also indicates the existence of a

Fig. 5: Anthracological diagram of Shahr-i Sokhta.
permanent water source (Rud-i Biyaban) near the protohistoric site of Shahr-i Sokhta.

The second vegetal formation is steppe/desert formation (fig. 5) and is represented by the goosefoot family and saltwort (Salsola). It is possible that the rarity of halophilous species reflects a favorable environment and less salinity of the soil in the Bronze Age in Sistan. According to our data, close to the hygrophilous formation, there were semi-steppe zones where halophilous plants grew, used as fuel wood. Nowadays, different types of Chenopodiaceae grow in Sistan such as Salsola aucheri, S. arbuscula, S. arbusculiformis, S. crassa, S. tomentosa, S. cyclophylla, Artemisia sieberi, A. deserti, A. aucheri, Haloxylon ammopseudon and H. persicum. Léonard describes also a halophilous sub-desert vegetation including Artemisia, Tamarix aucheriana and Tamarix dubia in the east of Nehbandan mountains between Dasht-i Kavir and Dasht-i Lut (Léonard 1983: 72).

Our observations indicate that today, the hygrophilous formation has been replaced by steppe formation, especially near Shahr-i Sokhta. It seems that the environmental factors (successive dryness periods) and human impact played an important role in the degradation of vegetal structures in Sistan.

Apparently, the inhabitants of Shahr-i Sokhta had chosen various woods for different uses. It seems that the main principal fuel wood at Shahr-i Sokhta was tamarisk because it is not suitable for manufacturing of wooden objects. On the contrary, they preferred to exploit the wood of ash and poplar for making animal figurines, fire sticks, combs, spindles, weaving hooks etc (Costantini 1979).

Conclusion

Anthracological analysis of Shahr-i Sokhta has been done to get a better understanding of the vegetative dynamic of the Sistan plain in the Bronze Age. This study, in parallel with other archaeological investigations realized previously, indicates that in the end of 4th and the beginning of 3rd millennium B. C. Sistan region and therefore Shahr-i Sokhta benefited from a more favorable environment and sufficient water sources as well as rich vegetation than today.

The comparison of the ancient vegetation with the actual situation shows that nowadays flora has completely deteriorated because of changes in the watercourses. This deterioration is best explained in terms of anthropogenic or environmental factors.

According to our studies, the variety of identified species at Shahr-i Sokhta are limited and therefore do not reflect precisely the flora of Sistan in the Bronze Age. At the moment it is not possible to reconstruct completely the ancient vegetation of this part of Iranian Plateau. For giving more precise indications on the matter it will be better to enlarge the paleo-environmental sampling zones (especially anthracological) not only at Shahr-i Sokhta but also on the other archaeological sites of the Bronze Age in Sistan. In a precise chronological framework and archaeological contexts, the samplings must be ensured through a systematic method.

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