ARCHAEOLOGICAL EVIDENCE OF DUNE FORMATION ON THE WEST PONTIC COAST IN THE 4TH-3RD CENTURIES BC

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In 1996-98 archaeological excavations of the necropolis at Kalfata in the vicinity of the ancient Greek colony of Apollonia Pontica (modern Sozopol) on the Bulgarian Black Sea coast have taken place. This town was founded by Greek colonists from Miletus at the end of the 7th century BC (Panayotova 1998, 97-113; Tsetskhladze 1998, 9-68). The excavations provided evidence for climate changes on the West Pontic coast in the 4th-3rd centuries BC or may even indicate weather modification over a much larger area.

1. Archaeological excavation: sites and graves

The site of the necropolis is 150 m from the present day sandy beach, at the foot of a hill. A number of dry graves were discovered several meters beneath the surface (Fig. 1) in the course of numerous excavations during the last century (Panayotova 1998, 97-113).

Panayotova reported that many other graves on the top of the hill had been destroyed during the construction of the coast road, some years ago (Panayotova 1994, 125-30; Panayotova 1998, 97-113). She dated the burials to the 5th-2nd centuries BC and hoped that the Kalfata necropolis was the burial place of the first Ionic settlers. But it proved mainly to have been used for 60-70 years in 4th-3rd centuries BC by a particular family.

The graves had been dug to a depth of 1.5-1.8 m under the surface, which is now 3-4 m beneath the dunes. They remained in good condition thanks to the fact that they were lined and covered by white limestone slabs, whose appearance suggests that they had never been exposed to weathering since the burials were made. There are no signs of the effects of air, sunshine, moisture or water. This indicates that the slabs had never been submerged by seawater and that the graves have always been above sea level, irrespective of changes. It is very likely that the tombs were also outside the range of the capillary rise of the ground water. Since the excavation of the graves some two or three years ago, irreversible changes to the colour and form of the stones have taken place through exposure to rainfall, sunshine, atmospheric moisture, dust, and pollution (Panayotova 1998, 97-113). Below the sand cover, the soil in which the tombs had been dug consists of a brown

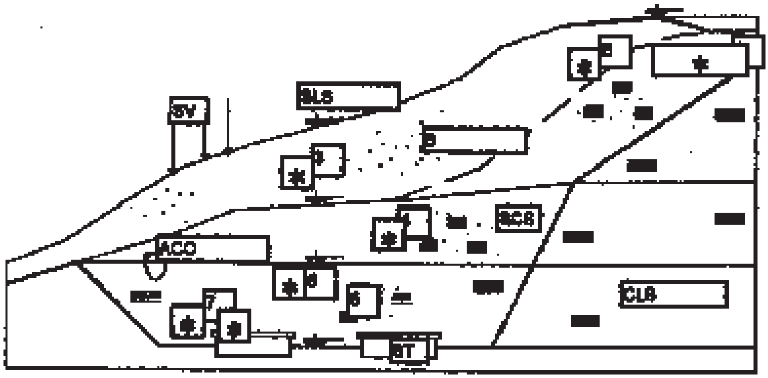

Fig. 1 a.

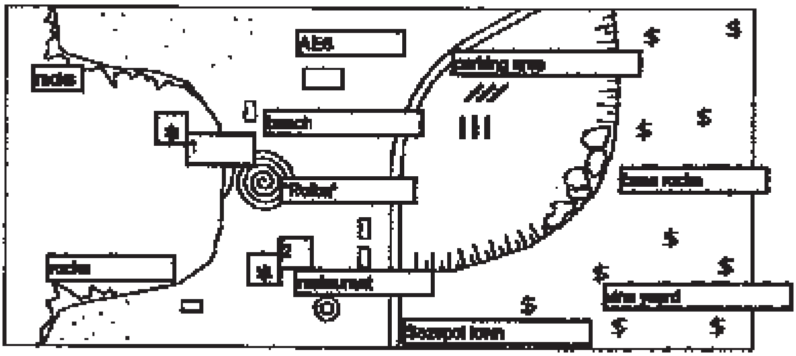

Fig. 1b. Scheme of cross section on the archaeological site "Kalfata" near the town of Sozopol.

where:

ACO Ash container
ASS Archaeological excavation site
CLS Clay soil
S Sand
SCS Sandy-clay soil
SLS Soil layer surface
ST Stone tomb
SV Steppe vegetation
1,2,3...7 Sample point
35 m Height above sea level (rough assessment)

Fig. 1. Plan and section of the necropolis.

sandy-clay layer partly formed of particles of weathered trahandesites-base rocks, which are widely spread throughout the area. The same soil is found further to the west on the top of the hill where now vineyards and orchards grow. It is very suitable for agriculture and other vegetation, strong requirements for a place of habitation. The remains of a fire have been found here.

2. Sand cover

The sand covers the area from the shore to the summit of the nearby hill, which is about 35 m above the present-day sea level (Fig. 1). On the top of the hill, the sand cover ceases, but up to this point it is homogeneous and shows no signs of stratification or contamination with rocks, gravel, trees, vegetation or other materials. Above the necropolis, the depth of the sand cover reaches 2.5-3.0 m.

A number of sand and ground samples have been taken at various depths across the area under study. Analysis has revealed that the sand above the tombs shares the same granulometric composition, relative density, salinity, organic, shell, and quartz content as the present-day beach sand (Table 1).

Microscopic analysis of dune samples (at the Sediment Transport Laboratory of the National Institute of Meteorology and Hydrology, Sofia) showed that the sand consists mainly of quartz and broken mussels. There are minor traces of light minerals such as mica (muscovite) and feldspar, of heavy minerals, and some traces of garnet, magnetite, amphibole, etc. The lack of other minerals or organic matter indicates that the rock weathering processes had temporarily ceased.

Two types of quartz grains have been identified. The majority are mat white, with highly smoothed sides, possibly formed by long-term exposure to surface winds. On some, a clay film can be found. This could be evidence that a warm and humid climate prevailed during their exposure. A complex of chemical and photochemical weathering processes had taken place, with a high rate of degradation. Furthermore, the clay film was not a continuous cover but fragmented, possibly the result of climate changes or seasonal fluctuations in the weather. There was also a very modest persistence of transparent, coarse quartz particles with a rough and very specific surface.

Now some conclusions about dune formation can be drawn, based on the integral grainsize curves of dune sand (Table 1). The first is that we have here a well sorted, homogeneous, non-cohesive amount of material. More than 90% of the samples are composed of grains 0.2-1.0 mm in size. Such exact grading of sand particles can only be achieved in the case of a long distance sediment transport, caused by sea currents of a steady velocity and with a capacity to move material of this particular size.

The larger particles were left on the site, unaffected by the current, while the smaller grains were probably carried away into deeper waters. This indicates a marine origin for the larger part of the sand cover, and contradicts Rozhdestvenskiy's view that the sand on the local banks in the area south of

Sample No	Sample type	Total weight	Size intervals in [mm]								Salinity	Organic content	Specific weight
		[g]	<0.063	0.063	0.1	0.2	0.5	1	2	5		[%]	[g/cm3]
N1		488.00		1.00	2.00	92.00	332.00	53.00	8.00				
under w.	sand		0.00	0.20	0.41	18.85	68.03	10.86	1.64	0	xxx	1,60	2.52
dune			0.00	0.20	0.61	19.47	87.50	98.36	100.00	100.00			
N2		234.00		2.00	2.00	73.00	142.00	10.00	5.00				
beach	sand		0.00	0.85	0.85	31.20	60.68	4.27	2.14	0	xxx	1.60	2.63
			0.00	0.85	1.71	32.91	93.59	97.86	100.00	100.00			
N3		199.00	2.00	2.00	4.00	60.00	121.00	10.00					
dune	sand		1.01	1.01	2.01	30.15	60.80	5.03	0.00	0	xx	1.43	2.66
			1.01	2.01	4.02	34.17	94.97	100.00	100.00	100.00			
N4		401.50	1.50	4.00	15.00	80.00	96.00	70.00	85.00	50.00			
ditch	sand		0.37	1.00	3.74	19.93	23.91	17.43	21.17	12.453	x	3.14	2.57
	clayey		0.37	1.37	5.11	25.03	48.94	66.38	87.55	100.00			
N5		337.00	5.00	4.00	10.00	31.00	72.00	65.00	95.00	55.00			
ditch	dark		1.48	1.19	2.97	9.20	21.36	19.29	28.19	16.320	x	3.95	2.59
	clay		1.48	2.67	5.64	14.84	36.20	55.49	83.68	100.00			
N6		281.00	2.00	2.00	5.00	80.00	167.00	20.00	5.00				
ditch	sand		0.71	0.71	1.78	28.47	59.43	7.12	1.78	0	x	1.46	2.52
			0.71	1.42	3.20	31.67	91.10	98.22	100.00	100.00			
N7		236.00	5.00	4.00	5.00	40.00	67.00	45.00	55.00	15.00			
ditch	sand		2.12	1.69	2.12	16.95	28.39	19.07	23.31	6.36	x	3.30	2.62
	clayey		2.12	3.81	5.93	22.88	51.27	70.34	93.64	100.00			
A		349.00	4	5	15	110	130	35	30	20			
hill	soil		1.15	1.43	4.30	31.52	37.25	10.03	8.60	5.73	x	2.26	2.66
			1.15	2.58	6.88	38.40	75.64	85.67	94.27	100.00			
B		126.00	4	4	5	10	12	16	45	30			
hill	weath		3.17	3.17	3.97	7.94	9.52	12.70	35.71	23.81	x	0.61	2.62
	rocks		3.17	6.35	10.32	18.25	27.78	40.48	76.19	100.00			

Table 1.

Burgas area originated from weathered rocks of the surrounding lands (Rozhdestvenskiy 1986, 189). Such a hypothesis is very unlikely as the content of the sand samples observed at the place of study could not have been achieved by the movement of the particles the short distance from the adjacent banks to the bay.

The high salinity of the sand prevents vegetation growth on the dune surface; thus, except a few bushes of steppe vegetation, which grows under highly unfavourable conditions, no organic matter could be detected. Due to this, no biological stabilisation of the deposited sands has taken place.

3. Interpretation of data: facts and hypotheses

3.1. According to Rodev (Rodev 1985, 182), after the 7th century BC the region was subject to the Lazsky Transgression – a steady rise of the sea level (other archaeologists aver the 5th century BC to be the time that the sea level was lowest and the cold most severe).

As a result, the Geta and Milos ridges near Sozopol were completely submerged, also the road that had linked the town to the neighbouring islands of St. Ciril and St. Ioan. It is likely that some low lying houses near the coast were completely submerged and their inhabitants forced to seek a safer location for themselves and their necropolis (Mihova 1998, 182). Poroganov (1998, 15-9) assumes a shift of the site of Apollonia Pontica and some other west coast colonies in the 2nd century BC, caused by the inundation of the area.

3.2. During the same period, some strong earthquakes affected the west coast of Pontus. Rangelov (1998, 46-51) has collected valuable information on Bizone (modern Kavarna), and some other settlements (Mesembria, Apollonia Pontica, and Achtopol) were partly demolished around the 1st century BC. After a strong earthquake it is very likely that the morphology of the sea area around Sozopol changed and gave the Bay of Sozopol a more open mouth in which sea currents had free access. The highly fragmented rocks on the hill west of Harmanite Bay, next to the necropolis, are silent witnesses to this dynamic period.

3.3. The rise in the sea level which started in the 7th-5th centuries BC is an indication of the beginning of an intensive period of glacier melting, resulting in an increase of water filling the Black Sea faster than its outflow could empty it. A tentative change of climate to warm and humid weather had begun. Floods on the continent strongly eroded the soil cover and formed great quantities of river sediment. This entered the Black Sea and silted it up. So, the Harmanite Bay south of Sozopol was inundated by sand.

To summarise, the Phanagorian Regression has given way in the 7th-5th centuries BC to the Lazsky Transgression, accompanied by warm and humid weather and strong winds (Gamkrelidze 1992, 101-9; Khakhutaishvilli 1984, 146-51; Mihova 1998, 64-70; Poroganov 1998, 15-9; Tsetskhladze 1997, 121-36). This caused strong erosion on the watersheds and a great inflow of river sediments to the Black Sea. Some of the sediment was transported along the coastline, forming currents which pushed the sand on the beaches. The accumulated sands were blown westward to form dunes on the shore. Gamkrelidze and Tsetskhladze have described and dated the same processes on the east Black Sea coast, which proves the spread of climatic changes and earthquakes through the region (Gamkrelidze 1992, 101-9; Tsetskhladze 1997, 121-36).

Much stronger winds began to blow in the 4th-3rd centuries BC, after the climate change of the 7th-5th centuries BC, and led to the formation of dunes, the demolition of houses, and the coverage of the necropolis. This situation is well attested; graves of the 5th century BC have mostly been robbed, those of the 4th-3rd centuries BC remained undisturbed.

Once the inundation had begun, together with a continuing rise of sea level, the people departed an area which had turned into a highly unfavourable place for living. They left behind many reminders of their existence, untouched; or to put it in another way, the dune preserved most of the remains of human life before the 4th-3rd centuries BC.

The tree-covered hill makes one think that the wind would not have been able to carry the sand particles for more than a distance of several hundred meters. One has to multiply the wind velocity, direction, duration, and the shearing force on the sandy surface. The latter affects the ability of winds to carry particles for a distance or to form dunes by storing them along the beach. The same processes of landward movement of marine sand could be the reason for dune formation at many other places along the western coast of the Black Sea: around the towns of Apollonia, Achtopol, Mesembria, and the area of Zlatni Pyasuchi (Golden Sands), the mouth of the River Kamchia, the River Ropotamo, Shabla, the Durankulak area, and Dobrudja and north into Romania.

In the case of the low lying lands, as at Slanchev Bryag (Sunny Beach) north of Burgas Bay, the aeolian deposits might spread far west, forming a strip of several attractive dunes parallel to the shoreline.

The question arises: what caused this sudden easterly wind? Was this a local phenomenon or part of a much larger change, were the causes regional or part of a much wider development?

This brings us to global climate changes as the main factor behind the formation of the dunes. Such a supposition requires evidence from other parts of Europe and even the rest of the world.

We need to know more about how much global meteorology had shifted previously, for the Black Sea and elsewhere. It would be of great interest to find their routes and former locations, especially that of the Siberian anticyclone focal point. A shift of this point northward to its present day location would be a plausible explanation for a strong easterly wind prevailing for a long time.

It is evident that the Phanagorian Regression, when sea level fell by several meters, was followed by a period (Laszky Transgression) of several centuries of warm weather which led to glacier melting, large flows of excess water into the Black Sea, and a rise in the sea level by 4-5 m (Khakhutaishvilli 1984, 146-51; Tsetskhladze 1997, 121-36). This probably took place at the very end of the last severe cold period. Khakhutaishvilli refers to a global process of sea/ocean water level movements, which has affected human life, occupation and habitation locations.

During underwater investigation at the Bay of Sozopol, evidence was found of this period of dynamic regression/transgression, *e.g.* submerged houses and a submerged riverbed described by several authors (Khakhutaishvilli 1984, 146-51; Bozhilova/Marinova 1994, 39-50; Gamkrelidze 1992, 101-9; Georgiev *et. al*. 1994, 323-36; Panayotova 1994, 125-30).

Koshelenko and Kuznetsov (1998, 249-63), report a sea water rise of 4 m on the Taman Peninsula and the mouth of the River Kuban, during the 4th-3rd centuries BC. They point out that climatic changes were the main reason for it. All this started just after the mass Greek colonisation of the Bosporus in the first half of the 6th century BC. According to them, the rising of the sea level was caused by a steady sinking of the land at the rate of 0.5-1.5 mm a year.

More archaeological evidence came recently from the area of the Don and Dnieper deltas in the Ukraine, which were flooded by 3-4 m of seawater. Tsetskhladze (1998, 9-68) summarises a part of the information about the use of the Dnieper for commercial navigation. He describes the discovery of a single oak boat with the skeleton of a dead Mediterranean-type boatman at a place which is some 500 km distant from the nearest Greek city. Stiros and Papageorgiou (1991, 263-76) have reported a rather similar catastrophe on the island of Crete in the same period of time. All of this indicates that the climatic changes of the 4th-3rd centuries BC affected a large area. There is further support for this conclusion, such as the information provided by Popov and Mishev (Popov/Mishev 1974, 265) about the geology and tectonics of the Black Sea region. They cite historical evidence for the sinking of the mouth of several rivers, mentioned by ancient authors such as Strabo and Flavius.

The archaeological excavation in Scara Brae in Orkney, Scotland, and Lindisfarne/Holy Island in the North of England provides additional evidence (Lambrick 1992, 209-24; Maklin/Needham 1992, 9-21). Both revealed similar evidence of the rapid inundation of coastal sites by marine sands as a consequence of some climate change. The Lindisfarne inundation correlates closely to the process of dune formation in the West Pontic area. The warm period that had caused glacier melting in Central Europe (the rising of the water-level in the Danube, which is one of the main tributaries of the Black Sea) evidently spread over a wider area and should be seen as proof of continent-wide climate change. So it may be concluded that the dunes in the Kalfata area on the west coast of the Black Sea south of Sozopol, were formed as a result of continental change in the palaeoclimate and bear witness to it.

4. Conclusion

Archaeological evidence together with the sediment sampling from the site of the Kalfata necropolis indicate that the tombs were covered by marine sand in the 4th-3rd centuries BC. It is suggested that this dune formation can be associated with a climate change characterised by strong prevailing winds. The spread of dunes may have been the reason for the abandonment of the burial ground and the associated settlements before the end of 3rd century BC (when the last reported burials took place).

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