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Identification of Anthropological Landscapes and Human Activity in Georgia in Correlation with Holocene Black Sea Level Fluctuations

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Abstract: The database of palynological studies of marine, lagoon, alluvial and bog sediments of the Black Sea coastline on the territory of Georgia includes 26 profiles of Holocene sediments. Analysis and synthesis of pollen diagrams allowed us to make a stratigraphic subdivision of Holocene sediments and reveal climatic fluctuations for the last 10 000 years. The most informative pollen spectra were those of marine formations with no gaps in sediment accumulation. Three main stages of climate warming have been revealed, reaching a maximum in the periods 6000-5500 BP, 3800-2400 BP and 1350-600 BP. Rather significant warming is indicated for the Middle Ages (7^{th}-11^{th} cent. B. C.). In all these periods the Black Sea level on the Georgian coast was some metres higher than previously. During climatic optima new cultures appeared in the Georgian archaeological record. Early agriculture penetrates not only into the middle mountain belt, but also into higher areas.

Keywords: Palynology, Black Sea, Marine Sediments, Database, Palaeoecology

1. Introduction

In Georgia, palynological studies of Holocene marine sediments began in the early 1970s [1]. Extensive drilling of the Black Sea shelf and estuarine sediments was performed as part of engineering-geological surveys near coastal resorts and sanatoriums (Fig.1). The substantial body of core material was collected and studied using many methods of the natural sciences, including palaeogeographical, paleontological, geomorphological, geochronological, and climatostratigraphical methods [2,3,4,5,6,7,8]

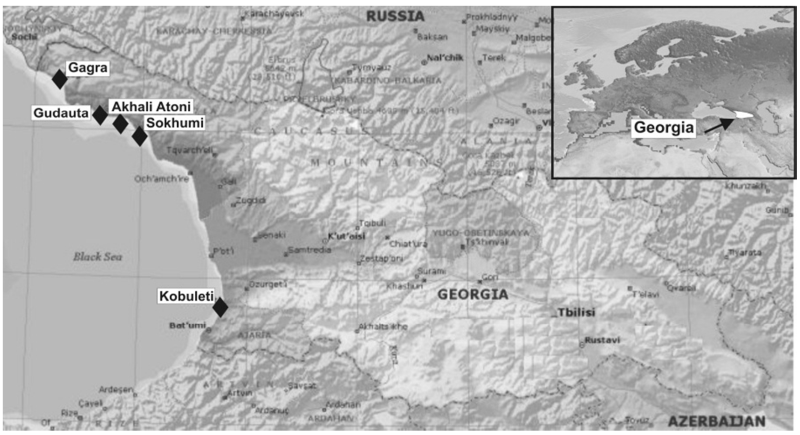

Fig. 1. *Map of Georgia and the location of the profiles studied.*

Palynological and sedimentological results showed that the Black Sea reached its lowest level 18 – 17 thousand years ago. During this regression, corresponding to the last phase of the Würm Ice Age, the sea level was 120 m lower than today.

Cooling was followed by intensive warming, glaciers began to melt and the New Black Sea transgression began. By the onset of the Holocene (10 thousand years ago) the sea-level rose by nearly 70 m [9]. How sea-level changes developed later, the climate in different Holocene transgression phases and the human activity at the very beginning of the Holocene and in all the subsequent periods in the mountains of Georgia – these are the points we will try to address in the present paper. The Caucasus and Georgia in particular, is the region where the manufacturing economy that forms the basis of civilization originated during the first stages of the Holocene [10].According to radiocarbon dates, early agricultural settlements in the southern part of Georgia are dated to the 60-54 centuries B.C. [11].

2. Material and Methods

Physical-geographic conditions adjacent to the easternmost coast of the Black Sea are characterized as follows. The length of the coastline is 355 km. Mountain ranges of the Caucasus hug the coast, especially in the northern part (Gagra range). The Bzyb, Kodori and Meskheti ranges ring the Black Sea shore. The maximum altitudes of these mountains are 2756 m (Bakhmaro) and 3309 m (Khojali).

The climate is very mild. Average annual air temperature in the coastal lowlands is +14°C, +15°C. At an altitude of 900-1000 m, it decreases to +9°C and, at an altitude of 2000 m, +3,5°C. Above 2600 m the annual temperature is below zero. Precipitation is more plentiful in the southern part than in the north, and reaches 2600-2700 mm in the Kobuleti region. In Gagra and Sokhumi, average annual precipitation totals 1500-1400 mm [12]. This index is even lower in the Gudauta area (~1000 mm).The humid climate has led to the development of an extensive hydrographic network in the region. There are many large rivers, including the Kodori, Bzyb, Kelasuri, Choloki and Kintrishi.

Table 1. *Database of the Profiles Studied.*

Permanent stationNameGeorgia:	Date and sampling frequency of profiles	Lower depth of profiles	Number of samples	Sediment type
Gagra area:				
Gagra-603	1981, every 50 cm	25,5m	5	Marine
Gagra-1	1971, every 10 cm	70cm	10	Marine + peat
Gagra-607	1981, every 50 cm	37m	12	Marine
Gagra-609	1981, every 50 cm	15m	12	Marine
Gagra-613	1981, every 50 cm	32m	9	Marine
Gagra-424	1978, every 50 cm	12m	5	Marine
Gagra-471	1978, every 10 cm	28m	66	Peat
Gudauta area:				
Gudauta-120	1983, every 50 cm	9,5m	17	Marine
Gudauta-521	1983, every 50 cm	31,8m	20	Marine
AkhaliAtoni area:				
AkhalAt-511	1984, every 10 cm	21,1m	35	Marine
AkhalAt-55	1982, every 50 cm	24m	12	Alluvial
AkhalAt-128	1983, every 50 cm	9m	6	Alluvial
AkhalAt-182	1983, every 50 cm	16m	7	Alluvial
AkhalAt-149	1983, every 50 cm	17m	4	Alluvial
AkhalAt-239	1983, every 50 cm	12,5m	8	Alluvial
Sokhumi area:				
Sokhumi-721	1980, every 10 cm	21m	60	Marine
Sokhumi-723	1980, every 10 cm	26m	50	Marine
Sokhumi-36	1980, every 10 cm	45m	120	Alluvial + peat
Kobuleti area:				
Kobuleti-22	1984, every 10 cm	22,6m	99	Marine
Kobuleti-35	1984, every 10 cm	120m	120	Alluvial + peat
Kobuleti-39	1984, every 10 cm	27m	25	Alluvial + peat
Ispani II	2003, every 10 cm	9,5m	47	Peat
Supsa-1	1972, every 20 cm	6,5m	33	Alluvial + lake
Supsa-2	1972, every 20 cm	7,8m	42	Alluvial + lake
Supsa-3	1972, every 20 cm	3m	17	Alluvua;
Supsa-4	1972, every 20 cm	2,1m	17	Alluvial

Vegetation in the coastal lowlands is of secondary character; however, around the estuaries of the larger rivers, forests of

Alnusbarbata are preserved. Relict *Pinuspithyusa* grows on limestone slopes at Pitsunda Cape. At an altitude of 300 – 700 m, low mountain Colchis forests with predominance of oak (*Quercusiberica, Q.imeretina, Q.hartwissiana*) and chestnut (*Castanea sativa*) occur. At higher altitudes, *Carpinus-causasica* becomes a prevalent species in broad-leaved forests,while above 1000 m *Fagus orientalis* is dominant. Beech-dominated forests occupy nearly half of the forest area, as they do throughout Georgia. *Abiesnordmanniana*, which ascends to the upper tree limit (1800 – 2200 m), is widespread in the mountain forest belt. In the higher mountains, dark coniferous forests of *Piceaorientalis* and *Pinussosnowsky* are recorded [13].

Subalpine vegetation is formed at the timberline of beech and birch elfin woodland at an altitude of 2200 – 2400 m. Above this altitude subalpine and alpine meadows appear. The subnival and nival vegetation belt is located above 2700-2800 m.

More than 2000 plant species are distinguished in the regional flora, including 450 Colchic endemic species. There are also many Tertiary relicts, which is peculiar for this unique Colchis refugium.

The investigation covered five areas of the eastern part of the Black Sea (Fig.1), where many boreholes were drilled during voyages of the “Geokhimik”. Drilling was performed with a Russian-made “UGB” drill, with a core diameter of 10.8 cm.

The Black Sea shelf sediments studied comprise mostly fine grained sands, silt and clay. The depth of Holocene sediments in the region varies from 17 m (borehole 120) to 27.8 (borehole 511). Material from 26 boreholes was studied palynologically; 7 of these were located in the Gagra area, i.e. boreholes 603, 607, 609, 613, 424 and Gagra-1. Borehole 471 was drilled nearby in the continental zone (Table 1).

To the south-west of Gagra lies the Gudauta shelf zone, where boreholes 120 and 521 were drilled to a depth of 9,5 and 31,8 m respectively.

In the Akhali Atoni area, borehole 511 (at a depth of 21.1 m) was collected. Boreholes 55, 39, 182, 128 and 149 were drilled nearby on the alluvial-marine terrace.

Boreholes 732 and 721 come from the Sokhumi coastal area, at a depth of 9.8 and 14.9 m on the shelf, where Holocene sediments are represented most completely. Borehole 36 was drilled here in the continental part near the shelf (Table 1).

The Kobuleti area lies on the southernmost sector of the Georgian coastline. Here borehole 22 was drilled between the Choloki and Kintrishi river mouths at a depth of 7.3 m on the shelf. Boreholes 35 and 39 come from the continental part. ProfilesIspani II, Supsa 1, 2, 3, 4 were also studied in this area.

Table 2 gives the results of radiocarbon dating of organic remains found in these marine and continental sediments (Uncalibrated age, ^{14}C yr. BP).

Table 2. *Radiocarbon dating of borehole sediments on the shelf of the Black Sea (eastern part).*

Borehole	Core depth (m)	Material analyzed	Age (^{14}C yr_{BP})
Gagra-416	4,5	Peat	2450±80
Sokhumi-723	6,4	Shell	3335±50
Sokhumi-723	7,5	Archaeolog.	3500±50
Gagra-1	6,5	Peat	3690±120
Gagra-609	24,4	Shell	4000±140
Gagra-607	21,1	Shell	4140±160
Akhali Atoni-55	15	Shell	5200±80
Gagra-607	34,5	Shell	5410±320
Sokhumi-723	11,2	Shell	5540±60
Akhali Atoni-55	23	Shell	6780±120
Sokhumi-723	14	Shell	7630±250
Sokhumi-723	20,1	Shell	8690±300
Sokhumi-722	26	Peat	9310±80
Gudauta-120	17	Shell	11000±150
Supsa-1	2,20	Wood	1260±120
Ispani-II	5,20	Wood	1940±40
Ispani-II	6,95	Wood	4060±40
Ispani-II	9,45	Wood	4900±40

3. Results and Discussion

Palynological analysis of Holocene sediments in 5 study areas showed that, in the more complete pollen diagrams, 5 regional palynozones can be distinguished (Fig. 2, 3, 4, 5).

Palynozone I is assigned to the Pre-Boreal period, palynozone II to the Boreal period, palynozone III to the Atlantic period, palynozone IV to the Sub-Boreal period and palynozone V covers the Subatlantic period.

Palynozone I differs from the underlying Late Dryas sediments its greater representation of thermophilous arboreal taxa such as chestnut and oak (Fig.2). However, this zone is indicated by a *Fagus-Carpinus-Abies*association. Note for comparison that in the Late-Dryas only high mountain vegetation elements prevailed. Palynozone I is divided into two subzones, the first reflecting more arid climatic conditions compared to the second. Redeposited pollen is found in significantly less quantities (up to 25 – 27% of the total pollen) in Pre-Boreal strata compared to Late Dryas (up to 46%).

Palynozone II covers the Boreal period and is indicated by an *Abies-Fagus-Picea*association. In all diagrams, pollen representing piedmont forest elements decreases, while high mountain forest indicators increase. In the Gagra area, where high mountains front the coast, subalpine vegetati vegetation (e.g. birch) is also clearly reflected in the spectra. This is the “coldest” palynozone, and divided into three subzones. The first and the third subzone exhibit stronger climate aridity than the second subzone. It should be mentioned that in this palynozone redeposited pollen reaches maximum values – up to 60-62% of the total pollen sum.

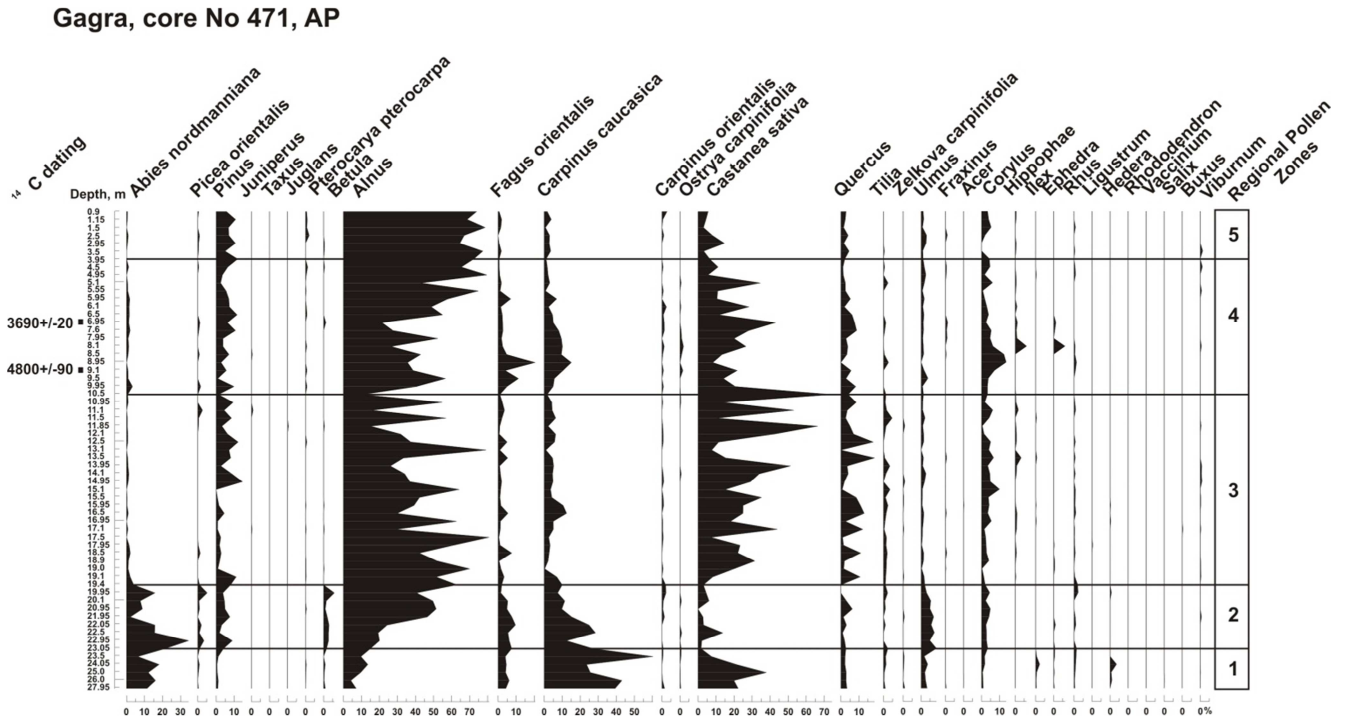

Fig. 2. *Palynological diagram of lagoon and bog sediments from the Kolkhidka river mouth (Gagra area) exposed by borehole 471.*

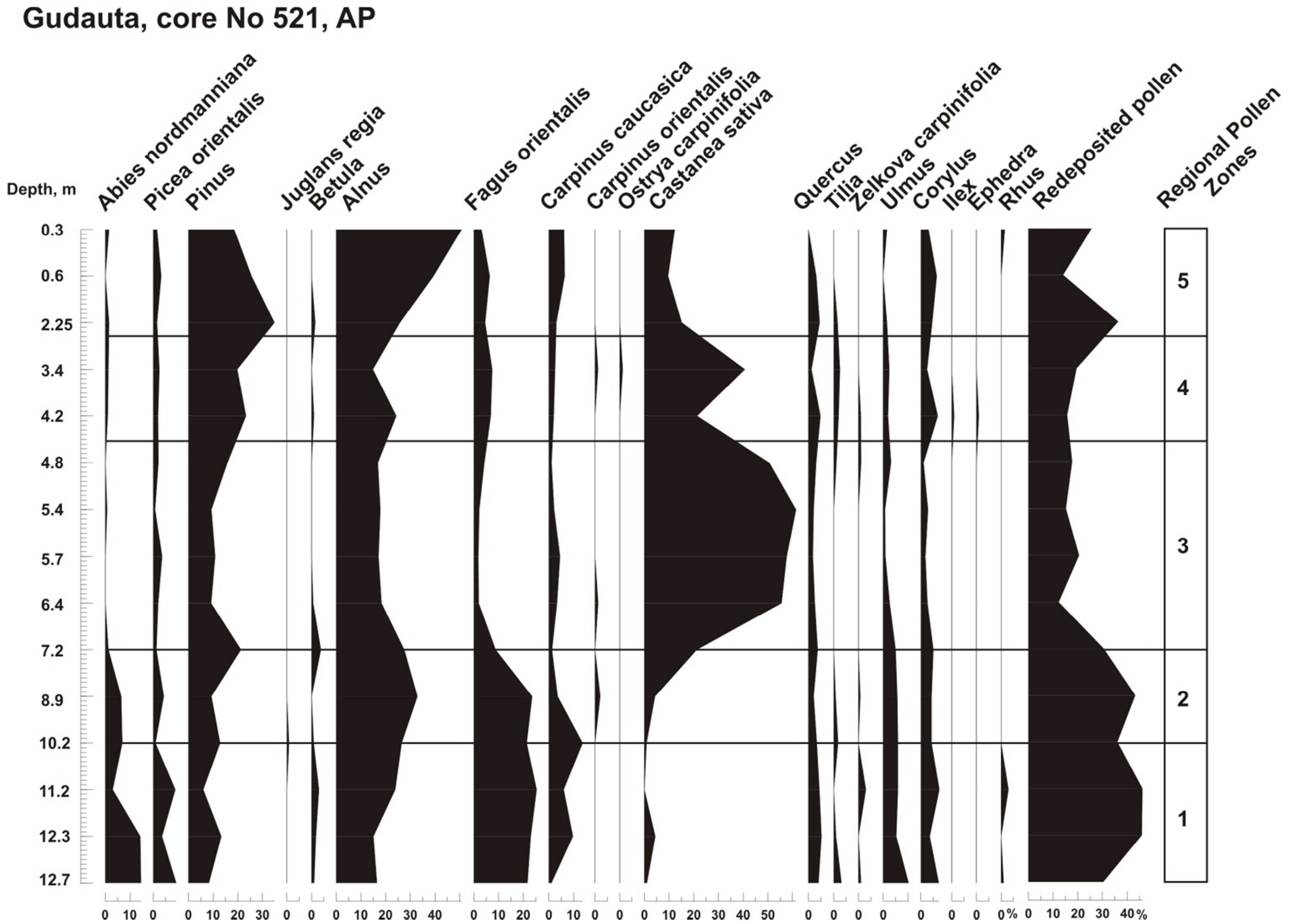

Fig. 3. *Palynological diagram of marine sediments onn the Gudauta shelf exposed by borehole 521.*

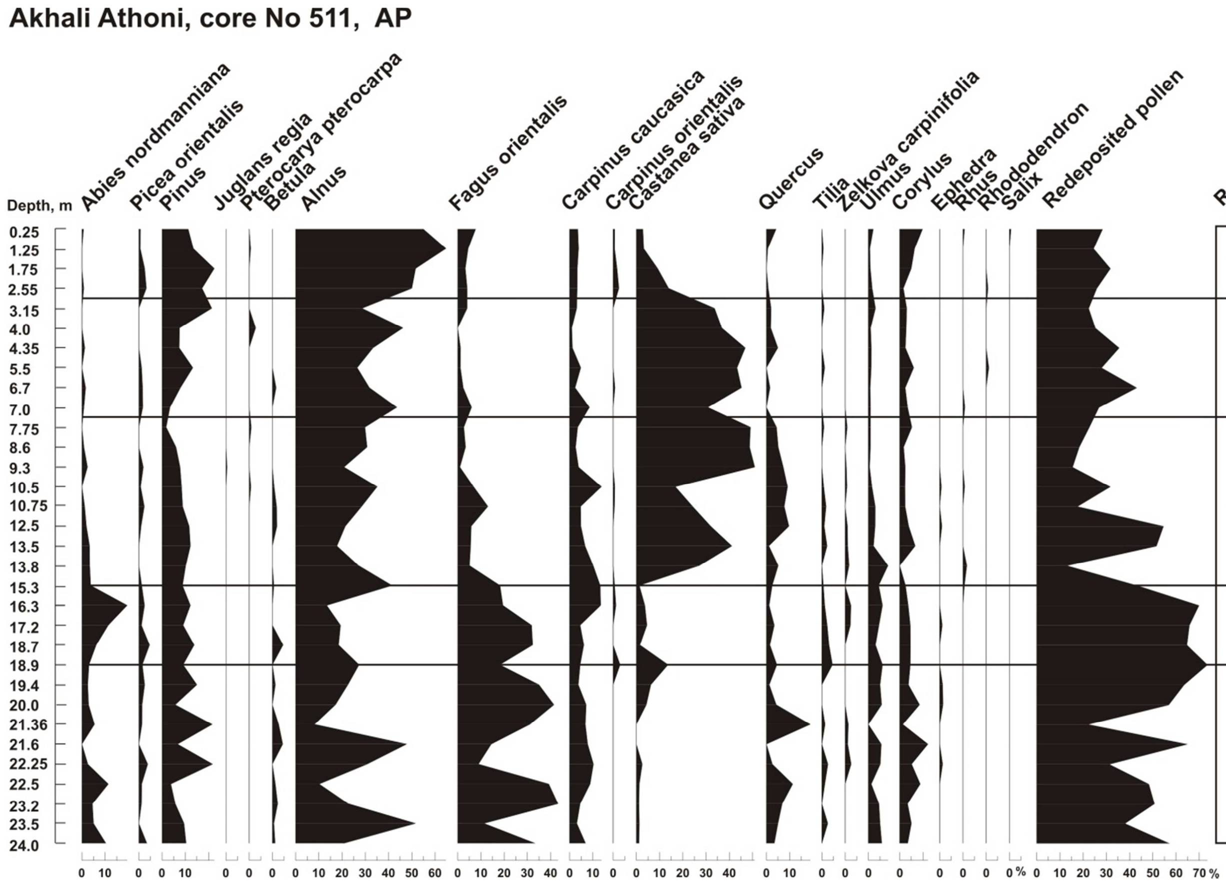

Fig. 4. Palynological diagram of marine sediments on the Akhali-Atoni shelf exposed by borehole 511.

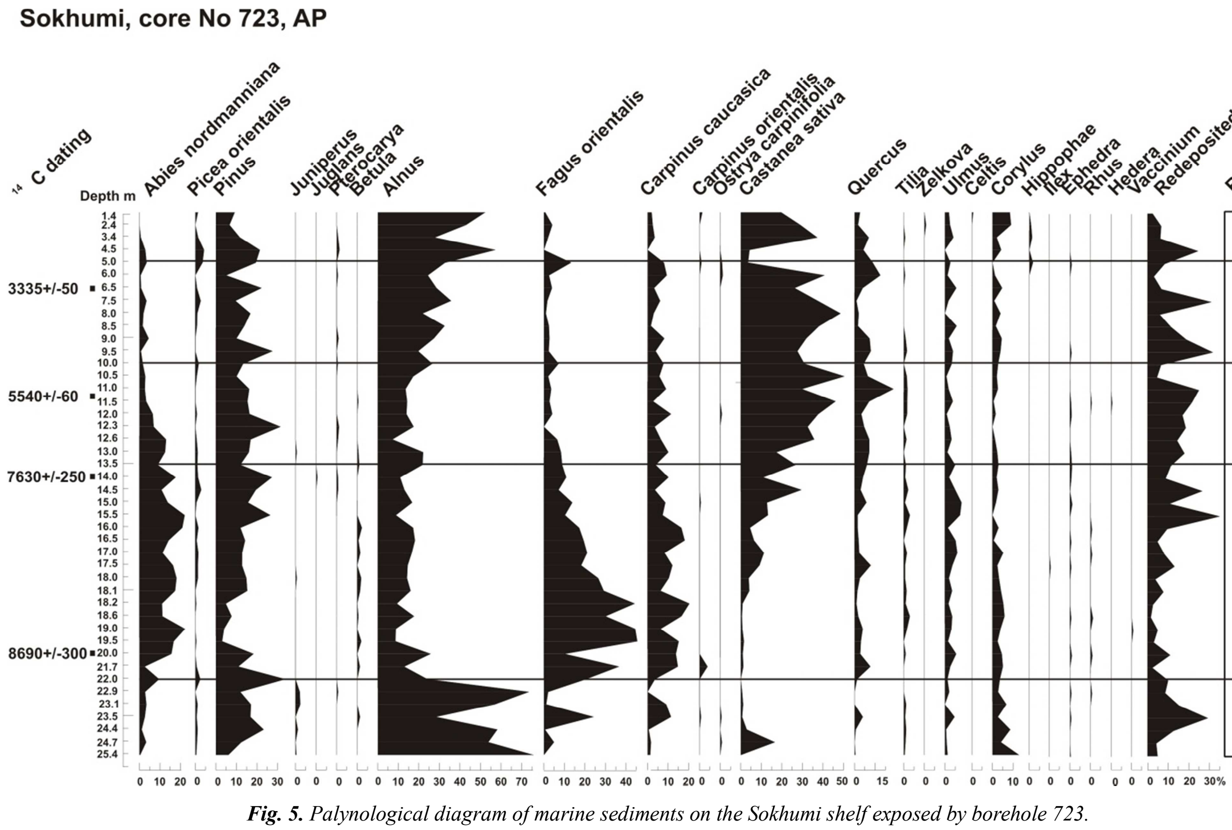

Fig. 5. Palynological diagram of marine sediments on the Sokhumi shelf exposed by borehole 723.

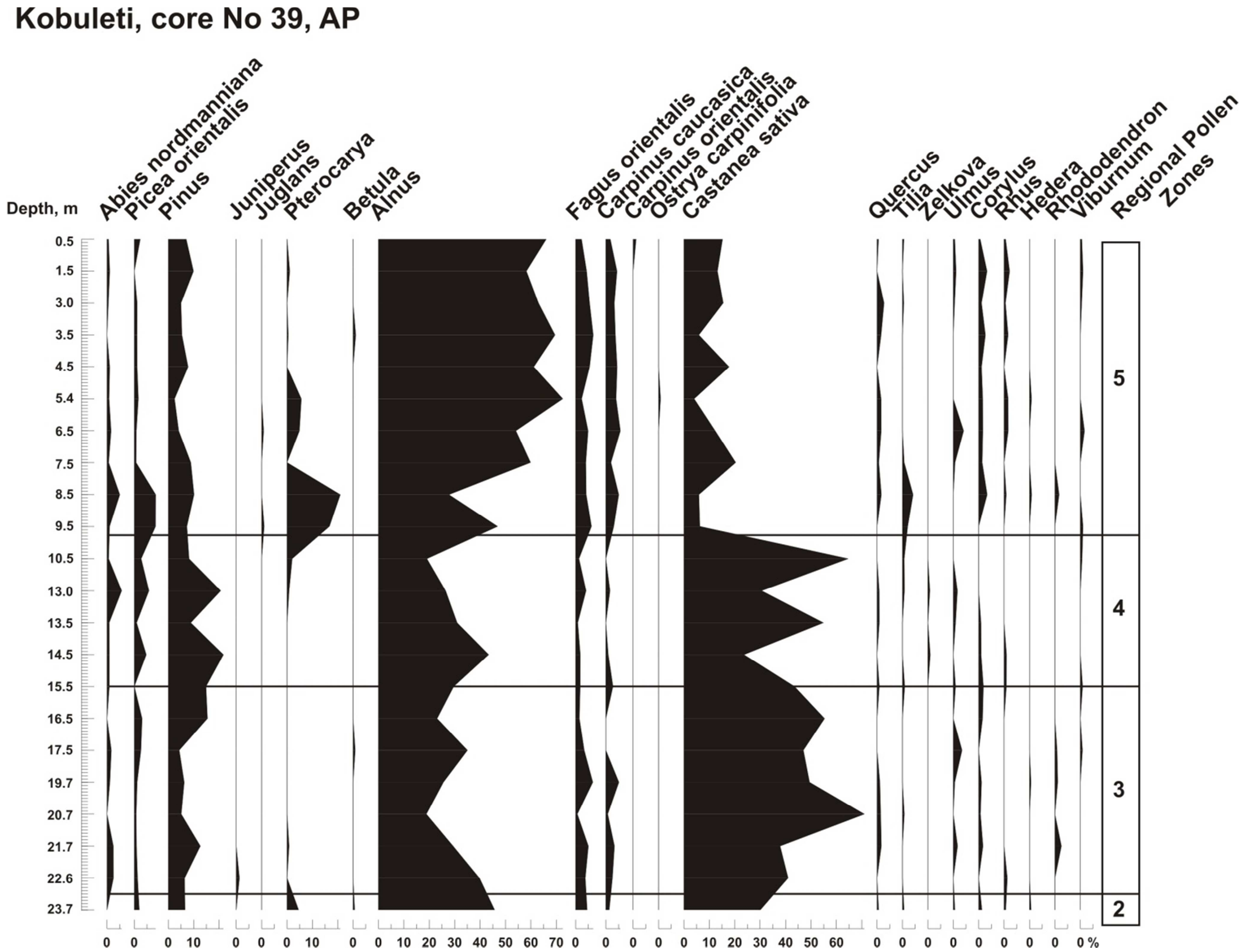

Fig. 6. Palynological diagram of marine sediments on the Kobuleti shelf exposed by borehole 39.

Palynozone III reflects radical changes in pollen assemblages and corresponds to the Atlantic period. In almost all the study areas, pollen diagrams show a prevalence of chestnut and oak pollen. This zone is indicated by *Castanea-Alnus-Quercus* throughout Georgia. The occurrence of thermophile species, such as *Pterocaryapterocarpa, Juglansregia, Tiliacaucasica*and *Zelkovacarpinifolia*, increases significantly. This palynozone is divided into three subzones, the second exhibiting some climatic cooling represented in the diagrams by an increase in high mountain forest elements (fir, beech, spruce). As a whole, the Atlantic period was the warmest and most humid period during the Holocene in this region. Maximum warmth and humidity occurred in its second half. The amount of redeposited pollen in sediments of the Atlantic period decreases significantly (<20%).

Palynozone IV in the study area has no equivalent in Blytt-Sernander terminology. This may be explained by a stronger anthropogenic effect of spatially variable impact. Nevertheless, the diagrams clearly show an increase in the pollen of cold-loving vegetation components and a decrease in the pollen of heat-loving species. The spectra also suggest an increase in climate aridity. *Alnus* pollen becomesdominant along the coast, which together with an increasingrole of *Pteridiumaqulinum* and *Rhododendron luteum*, indicates forest felling and swamp drainage. Subdominants include beech and fir, while pine is also prevalent. The climate of the first half of the Sub-Boreal period on the Black Sea coast of Georgia was more arid compared both to the previous and subsequent periods. The palynozone is divided into two subzones in some diagrams, where the first half is distinguished by stronger aridity than the other. The amount of redeposited pollen is up to 45%.

Palynozone V corresponds to the Subatlantic period. It is indicated by a*Alnus-Pinus-Castanea* association in the northern part and *Pinus-Alnus-Castanea* in the southern part (Kobuleti area). High mountain vegetation indicators decrease to minimum values in palynozone V. Fir, spruce and birch pollen is found only as single grains. In the Gagra area, which has been more thoroughly investigated, palynozone V is divided into three subzones. The second subzone reflects warmer and more humid climatic conditions. *Pterocaryapterocarpa* pollen content increases rather significantly and redeposited pollen are few throughout the whole palynozone (up to 20%).

The occurrence of distinct palynozones is due to vegetation and climate dynamics in the eastern part of the Black Sea coast during the Holocene. The close proximity of mountain ranges facilitated a detailed and clear reflection of change in all the altitudinal vegetation belts of the region. This is explained by the specific character of pollen spectra of marine sediments where regional vegetation is more clearly reflected compared to the spectra of continental deposits.

4. Conclusions

The regional palaeozones derived from analysis of marine, lagoon and alluvial sediments represent the major events in the Holocene development of vegetation in the Caucasus region.Marine sediments, in particular, show major shifts in species dominance that reflect changes in vegetation in all altitudinal belts, thanks to the proximity of mountain ranges to the Black Sea. In this case the Black Sea can be regarded as a natural pollen trap in which pollen accumulated for the last ten thousand years. Importantly, there are no gaps in the record and therefore we have a complete and detailed picture of palaeoecological events. Statistical processing of the palynological material using the software "Paleoclimate 1" [14] allowed us to reconstruct quantitative indices of the climate and to reconstruct oscillations of the upper tree limit in response to climatic fluctuations[15,16]. In addition to marine palynospectra, palaeoecological reconstruction also incorporates pollen data from alluvial and lagoon sediments along the coastline and from the high mountains of Abkhasia [16].

At the first stage, very early in the Holocene, sedimentological data [9] indicates that the Black Sea level was lower than nowadays by 50-60 m. The timberline was 800 – 850 m lower than now [17] However, comparing pollen spectra dated 10 000 BP with those of the Younger Dryas, it is clear that the areas of broad-leaved forests with hornbeam, oak, chestnut and wing-nut expanded. This process was due to warmer, wetter climatic conditions. During the Younger Dryas, July mean temperature on the coast was reconstructed at 18.3^{o}C, while in the Preboreal it rose to 23.3^{o}C.

The second stage of landscape development corresponds to the Boreal period when the process of warming was interrupted by short-term cooling. The sea-level lowered by approximately 1 – 1,5 m. The timberline also descended significantly. Forests with beech and fir broadened. Reconstructed temperatures on the coastline were 19.4^{o}C in July and 3.3^{o}C in January (mean annual temperature 10.7^{o}C). Precipitation was about 1827 mm per year.

The third stage occurred during the warming of the Atlantic period. This stage was quite long and resulted in rather substantial changes in altitudinal vegetation zones. Rapid ascent of all vegetation belts initiated during this stage. Upper mountain belts of dark coniferous forests migrated upslope and narrowed in their altitudinal range. At the same time, the area of broad-leaved chestnut, oak, wing-nut and zelkova forests expanded substantially [18]. Paludification of the coastline led to the expansion of boggy areas. Temperatures and humidity increased, reaching a maximum 6000-5500 years ago. Compared with the Boreal, winter temperatures on the coastline nearly doubled and reached 6 – 6.5^{o}C. In the mountains remote from the sea climate warming was very intensive. In Abkhasia and Adjaria the timberline ascended 300 m during the peak of the Holocene climatic optimum, while in the mountains of the South Georgian Upland it ascended no less than 400-500 m.

The sea level during the Atlantic period rose rapidly and, between 6000-5500 years, exceeded its present-day level by some metres.

It was under the warm and humid conditions of the Atlantic period that the first early agricultural settlements appeared in the south-east of Georgia. Palynological studies of cultural layers in the settlement mounds of Gadachrili Gora and Arukhlo, dated to the 6th-5th millennia B. C., indicated a warmer, more humid climate. In place of the present-day steppes there grew forests of alder, wing-nut, hornbeam and oak. Humans, besides grain-growing, were engaged in viticulture. In the lower layers of Gadachrili Gora, a piece of loom-woven flax fabric was found and imprints of hand-knitted flax fabric were discovered in ceramic vessels. These finds, as well as macroremains of toadflax seeds [19], suggest the existence of local weaving. Toadflax, *Linumusitatisimum,* grows only under humid climatic conditions [20]. Microremains of numerous flax fibres and woolen fabric, including coloured fibres, were also revealed during the palynological study of material (cultural layers and pot contents) from Neolithic layers at these sites. Pollen analysis of organic material found in ceramic vessels provides evidence of beekeeping.

Data from the investigation of archaeological monuments in the South Georgian Uplands are also very interesting. Material from the Early Kurgan epoch of Javakheti (beginning of the third millennium B. C.) shows the existence of agriculture at an altitude of 2000-2800 m. In this period forest vegetation with oak and lime occurred at these altitudes [22,23], whereas today these forests occur at lower altitudes: 1700-1800 m [23,24]

During the Atlantic period, the process of warming was interrupted twice by mild, short cooling. This process is seen in the curves of both timberline oscillations and Black Sea fluctuations [9,14].

The fourth stage in landscape development is characterized by significant climate cooling, causing the Phanagorian regression in the Black Sea. In the Subboreal period, erosion processes accelerated, indicated by the increase in redeposited pollen in marine sediments. This increased erosion is explained by base-level lowering in Colchic river systems.

This period witnessed a lowering of zonal vegetation belts. The timberline was 600-550 m lower than nowadays. At the same time, the area of chestnut and other thermophilous species decreased, as indicated in all pollen diagrams. Cooling was accompanied by a moderate decrease in humidity.

In the second half of the Subboreal period, between 3800-2400, a change in climatic conditions is observed. The Black Sea rose to levels somewhat higher than today. This warming manifested itself clearly, not only in the lowland territories adjacent to the sea [17,18,25,26,27,28]but also on the mountain plateau of Southern Georgia. Palynological studies of archaeological sites (Safar-Kharaba and Imera burials) indicate that, during the 15th-14th centuries B.C., agriculture, horticulture and viticulture were practiced at an altitude of 1700-1800 m. Forests comprised oak, lime, zelkova and other species [22]. Here, for the first time, cotton fabric and fibres were discovered, indicating a well-developed trade between India and the Caucasus [30,31].In Colchis and in the regions more remote from the Black Sea, signs of forest destruction can be observed in this stage [27].

The fifth stage coincides with the Subatlantic period. Around 2500 years ago, a short-term, but pronounced, cooling took place, resulting in sea regression. The sea level lowered nearly 20 m compared to the end of the Subboreal (Fig.2). In high mountain areas, agriculture was replaced by stock-breeding. Viticulture went into decline at high altitudes and was not even developed in the middle mountains [31].The timberline descended nearly 350-400 m compared to the present-day level. Then, five centuries later (2000 years ago), significant climate warming occurred, resulting in the Nymphaean transgression in the Black Sea. The sea level again rose some metres higher than nowadays. Climate warming was accompanied by an increase in humidity on the Black Sea coast. In antiquity, according to palynological and palaeoethnobotanical studies of cultural layers in the Eshera and Nokalakevi settlements, flax-growing was very intensively developed [32,33] Moreover, the population of Colchis of the time was engaged in grain-growing, gardening and viticulture. Cultivation of olives imported from Greece began.

With developing agriculture on the coastal lowlands and in the piedmonts of Colchis, intensive deforestation took place. This process is indicated in palynological spectra by the increasing role of pollen from secondary vegetation.

The 3th - 4th centuries A.D. were rather cool, followed by a period of warming from the 7th to 11th centuries. At that time, the population density in the high mountains increased and agriculture, including viticulture, occupied a prominent place in the economy [22,24]. The areas under olive plantations increased, as indicated by the pollen record [28].

During the 12th – 14th centuries, climatic conditions again deteriorated, but switched back during the 15th – 16th centuries, according to the palynological data. Viticulture and wine-making developed intensively in the mountains of Southern Georgia. Palynological study of material from cultural layers and vessels from the Atskuri settlement at an altitude of 1200 m showed that here, besides the vine, olives were also cultivated [34]. According to historical documents, olive plantations were also to be found in the gorge of the Khrami River, in its headwaters, and in many places of the lowland part of Colchis [35]

This rather significant and long-term warming lasted nearly 200 years and was the last warming. In the second half of the 17th century, the short-term, but very strong, global cooling of the Little Ice Age took place. Though it lasted perhaps only 40 years (1675 – 1715) [36], it exerted a strong influence on landscapes. Since then, in Atskuri and in other mountains settlements, viticulture was no longer practised [34]. Olive plantations were completely destroyed by frost everywhere in Georgia [35].

Thus, according to palynological data, Black Sea transgressive phases can be clearly identified by the combination of a vast number of pollen of thermophilous arboreal species and low values of redeposited pollen in shelf sediments. Conversely, during Black Sea regressions, the role of heat-loving elements decreases and there is a sharp increase in the quantity of redeposited pollen due to enhanced erosion caused by base-level lowering.

During the Holocene, transgressive phases with warm climatic conditions lasted longer than regressive phases. The most significant warming and sea transgression took place in the Atlantic period, lasting nearly three millennia (8000 - 5500 BP).The climatic trend was to increased temperatures and precipitation. This process reached its peak 6000 – 5500 years ago and the sea-level in Colchis exceeded its present-day level by several metres for the first time for the whole post-glacial period.

At the beginning of the Atlantic period, with the establishment of humid, warm conditions, the first Neolithic agricultural settlements appeared on the alluvial plains of Southern Kartli, where, besides grain-growing, gardening, viticulture, beekeeping and weaving were developed.During the Eneolithic period, this warming process continued and mild climatic conditions facilitated the rise of new cultures and penetration of agriculture into mountainous areas.

The second significant ingression of the Black Sea took place at the end of the Subboreal period (3800 – 2400 years ago), which was also due to climate warming. The sea level was again higher than nowadays. Broad-leaved forests with chestnut, lime, wing-nut and zelkova expanded. In the high mountains, traditional stock-breeding was replaced by agriculture, viticulture and horticulture. Trade may have developed at this time, judging by the presence of traded goods, such as cotton, in archaeological material from the 15-14th centuries B.C.

The last 2000 geological years are characterized by more frequent transgressions and climatic fluctuations, among which the rather a long climatic optimum of the Middle Ages (7th – 11th centuries) is distinguished. The last warming and significant transgression of the Black Sea lasted for 200 years and took place in the 15th – 16th centuries.

The influence of human activity on landscape development can be observed since the Subboreal period, when deforestation took place not only on the Colchis lowland, but also in the mountains of Western and Southern Georgia.

The comparison of our scheme of Holocene climate changes with similar schemes from mountain territories in southern Europe and the Near East shows a very good agreement, especially for the second half of the Holocene [36,37]. It perfectly demonstrates the global character of climatic fluctuations that had feedback effects on sea-levels in Southern Europe, including the Black Sea.

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