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Chronology of buried soils, forest fires and extreme migration of dunes on the Kuršių nerija spit (Lithuanian coast)

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Our understanding about catastrophic Forest Fires and extreme activation of aeolian activity results from new studies of buried soils in dunes of Kuršių nerija (Curonian spit), radiocarbon dating of charcoal and humus of buried soils, burned wood remains and charcoal findings in upper part of palaeosoils, as well as from palynological studies, historical information, geophysical and palaeoenvironmental markers.

The Kuršių nerija spit during Litorina ($L_{2–3}$) transgression phases (6,100–5,200 BP) and Postlitorina transgression peak (4,000–3,500 BP) were formed. After the regression of the second Litorina stage, at about 6.0–5.9^{14}C kyr BP, intensive aeolian processes, took place. Influence of aeolian processes in the development of Kuršių nerija spit until today remained (Stančikaitė 2006). The data of radiocarbon dating of the six buried palaeozol soils confirmed different ages of aeolinian dunes activation (Fig. 1). Intensification of soil-forming and aeolian processes in different parts of the Kuršių nerija spit took place at different time intervals. The most ancient soils with the archaeological findings were dated 4,630 and 4,035 years ago (Table 1). The first human settlement on the spit after its formation (about 5000 BP) has been dated. A stead population there from the Neolithic onwards had existed. Gudelis (1998)

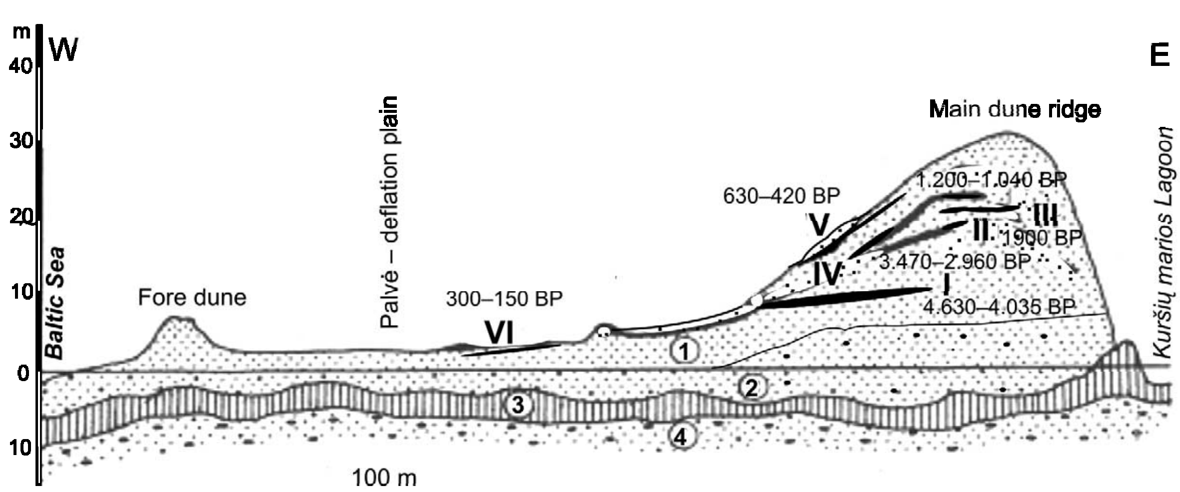

Fig. 1. Cross-section of the the Kuršių Nerija spit. Stratigraphy (from the top)
1 – aelian (wind-blow) sand, 2 – predominantly aelian sand now lying below NN (±0), with inter-calations of marine and lagoonal sand, gravel and silt/mud lenses, 3 – lagoonal gyttja/calcareous mud of late Atlantic and relatively early Subboreal age, 4 – older Atlanticmarine sediments. I, II, III, IV, V and VI – dune buried forest soil horizons of varying ages

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proposed a hypothesis, that a catastrophic dune forest fire was the main reason for the abrupt disappearance of the Late Neolithic residents on the Kuršių nerija (Curonian spit). The event probably occurred about 4,500–4,300 BP. The semiarid climate of Subboreal period, the frequent winds and dominance of pine forest and shrub/grass vegetation would all have favoured the rapid spread of fire. The catastrophic fire and its consequences, devastation and deforestation would have been the main reason in the depopulation of spit for a long time.

The oldest buried soil horizon contains an abundance of charcoal, wood fragments and ash. Archaeological findings, fashioned from rock pebbles and pieces of amber, show traces of high temperatures and spread rapid of forest fire of long duration in Kuršių nerija (Gudelis 1998).

The younger buried soils are less well developed. Results of the radiocarbon dating show the following I–VI periods of the soil formation: 4.6–4.0 kyr BP, 3.4–2.9 kyr BP, 1.9 kyr BP, 1.2–1.0 kyr BP, 0.6–0.4 kyr BP and 0.29–0.12 kyr BP.

Many layer structure of the investigated aeolian dunes was established after the application of geophysical survey (Buynevich et al. 2007a, b). Geophysical profiles reveal distinct transitions between aeolian sands of different age generations of Kuršių nerija (Curonian spit) dunes. Within 30–40-thick dune sand cover lateral accretion surfaces indicate the change of direction of dune migration before and after the formation paleosoils.

According results of optically stimulated luminescence (OSL) dating the palaeosoils of IV–V layers dated by ^{14}C (Table 1) are covered by dune sands du-

Table 1. ^{14}C dates of different laboratories from buried soils of Kuršių nerija (Curonian spit)

Gerasimov et al. 1980, Chichiagova, Cherkinski 1988	Gaigalas et al. 1991, Banys et al. 1991, Rimantienė R. 1989	Moe et al. 2005	Buynevich et al. 2007	Buried soils horizons	
	Recent soil, Sample 1, Wood and Sample 2, Peat, Vingiakopė; Sample 1, Wood, Pervalka				Recent soil
	290±90 340±90 Wood, Pilkopa			VI	Subatlantic period
500±70 Wood in podzol soil, SW from Juodkrantė; 630±90 Charcoal from upper buried soil, western slope, Vingiakopė	560±70 Sample 3, Wood, Pervalka	735±40 Small charcoal pieces from heathland, Vingiakopë	850±35 Sample P1 Charcoal, Nagliai	V	
1140±70 Charcoal from upper buried soil	1040±90 Sample 4, Wood Pervalka 1200±90 Peat, Sample 3, Vingiakopė		1350±45 Sample 2 Charcoal, Nagliai	IV	
		1900±40 Small charcoal pieces from heathland Vingiakopė		III	
2960±90 Charcoal from average thick, buried soil	3470±70 Charcoal, Nida			II	Subboreal period
4025±90 Charcoal from buried soil, Vingiakopë	4630±120 Wood, Charcoal, 4620±110 Charcoal, 4460±110 Charcoal, Nida			I	

ring three different intervals of aeolian activity at about 1.5, 1.0 and 0.5 kyr BP (Table 2). Formation of coastal dunes in Lithuanian is closely related with different stages of development of the Baltic Sea. The periods of aeolian activity were different for massifs of continental dunes started in Late Glacial and dunes on the Kuršių nerija after the climatic optimum of Holocene (Bitinas 2004).

A number of Curonian villages by migrating dunes were buried (Table 3) after the fire marked by charcoal pieces in upper part of buried soil IV (Fig. 2). A new ^{14}C dating results in Table 3 was carried out in the Gliwice Radiocarbon Laboratory, Head Prof. Anna Pazdur. The Medieval period of activation of aeolian processes caused by forest fires and lumbering in studied area of Vinkis – Agilos-Naglis aeolian dune massif. Rapid climate shifts have been recognised as important driving factor of aeolian dune dynamic.

Podzols were eroded or overlain by sand. The surfaces of the podzols indicate the location of the ancient dunes before deforestation. Podzolization is the main trend in the evolution of the soils of Kuršių nerija, but that mature soils are rare. The study palaeosoils can be classified into three development stages depending on vegetation succession: initial, intermediate and mature. The palaeosoils and aeolian dunes consisted of medium-grained sand (85–90%) dominated by quartz (85–90%), feldspars (5–8%) and dark heavy minerals (5–7%). The soils were extremely poor in nutrients (Ca, K, Mg, Na).

The examined palaeosoil IV show well developed profile with a thick organic layer of reach humus and clear eluvial and illuvial horizons with ferric and aluminium properties (Fig. 2). The fossil soil was situated on the western slope of the Migrating dune. The podzol showed a splendid white black sand layer followed by a very solid, dark to nearly black organic and ferric accumulation illuvial layer ("Ortstein"). This type palaeosoil indicate the presence soil before the disastrous deforestation of the Middle Ages. The development of mature podzol profile takes up to 1100–1600 years (Peyrat 2007). Moderate podzolised soils required 600 to 88 years for their formation. The initial podzol stage is reached after about 100 years. A period of 1000 years for the distinction of podzol characteristics need. The initial stage is presented in some soils. These soils develop in poorly

Table 2. Results of OSL dating of aeolian deposits (Bitinas 2004)

Borehole No.	Depth, m	Laboratory code	U (ppm)	Th (ppm)	K (%)	D a. (μGy/a)	D acc. (Gy)	Age, ka
30 / 26249 Pervalka	2.0–2.3	Tln-1235	0.74±0.05	1.44±0.08	0.76±0.04	1.72±0.04	0.86	= 0.5
	4.8–5.0	Tln-1236	0.73±0.05	1.24±0.07	0.70±0.04	1.66±0.04	0.83	= 0.5
	7.8–8.2	Tln-1237	0.68±0.05	1.55±0,09	0.63±0.04	1.59±0.03	0.80	=0.5
	11.9–12.2	Tln-1238	0.48±0.04	1.37±0.08	0.70±0.04	1.59±0.03	0.80	= 0.5
	15.3–16.0	Tln-1239	0.47±0.04	1.24±0.07	0.52±0.03	1.41±0.03	0.71	= 0.5
	17.7–18.0	Tln-1240	0.50±0.04	1.09±0.06	0.58±0.03	1.35±0.02	1.35	=1.0
	22.3–22.6	Tln-1241	0.49±0.04	1.28±0.07	0.46±0.03	1.26±0.02	1.26	=1.0
	25.6–26.0	Tln-1242	0.25±0.02	0.55±0.03	0.57±0.03	1.25±0.02	1.88	=1.5

Table 3. New ^{14}C dates from studied area Vinkis – Agilos-Naglis. BC/AD calibration is in accordance with Stuiver and Becker (1993)

No.	Sample name	Material	Lab. No.	Age ^{14}C (BP)	Calibrated age range 68%	Calibrated age range 95%
1	Vinkis 4/~3 m	Wood pieces	17430	125 ± 95	1680AD (26.8%) 1780AD 1800AD (41.4%) 1940AD	1630AD (95.4%) 1960AD
2	Vinkis 2/0.75 m	Charcoal	12919	420 ± 45	1430AD (60.0%) 1510AD 1600AD (8.2%) 1620AD	1410AD (73.4%) 1530AD 1550AD (22.0%) 1640AD
3	Naglis 2/0.43 m	Charcoal	GdS–571	590 ± 30	1313AD (51.5%) 1358AD 1388AD (16.7%) 1403AD	1298AD (68.0%) 1370AD 1380AD (27.4%) 1413AD
4	Naglis 3/0.49 m	Wood	GdS–572	630 ± 30	1295AD (26.1%) 1319AD 1351AD (42.1%) 1391AD	1287AD (95.4%) 1399AD
5	Vinkis 3/0.75 m	Soil humus	12920	970 ± 50	1010AD (23.3%) 1060AD 1070AD (44.9%) 1160AD	980AD (95.4%) 1190AD
6	Naglis 1/0.3 m	Buried soil organic	GdS–570	1050 ± 30	976AD (68.2%) 1020AD	898AD (10.9%) 920AD 945AD (84.5%) 1027AD

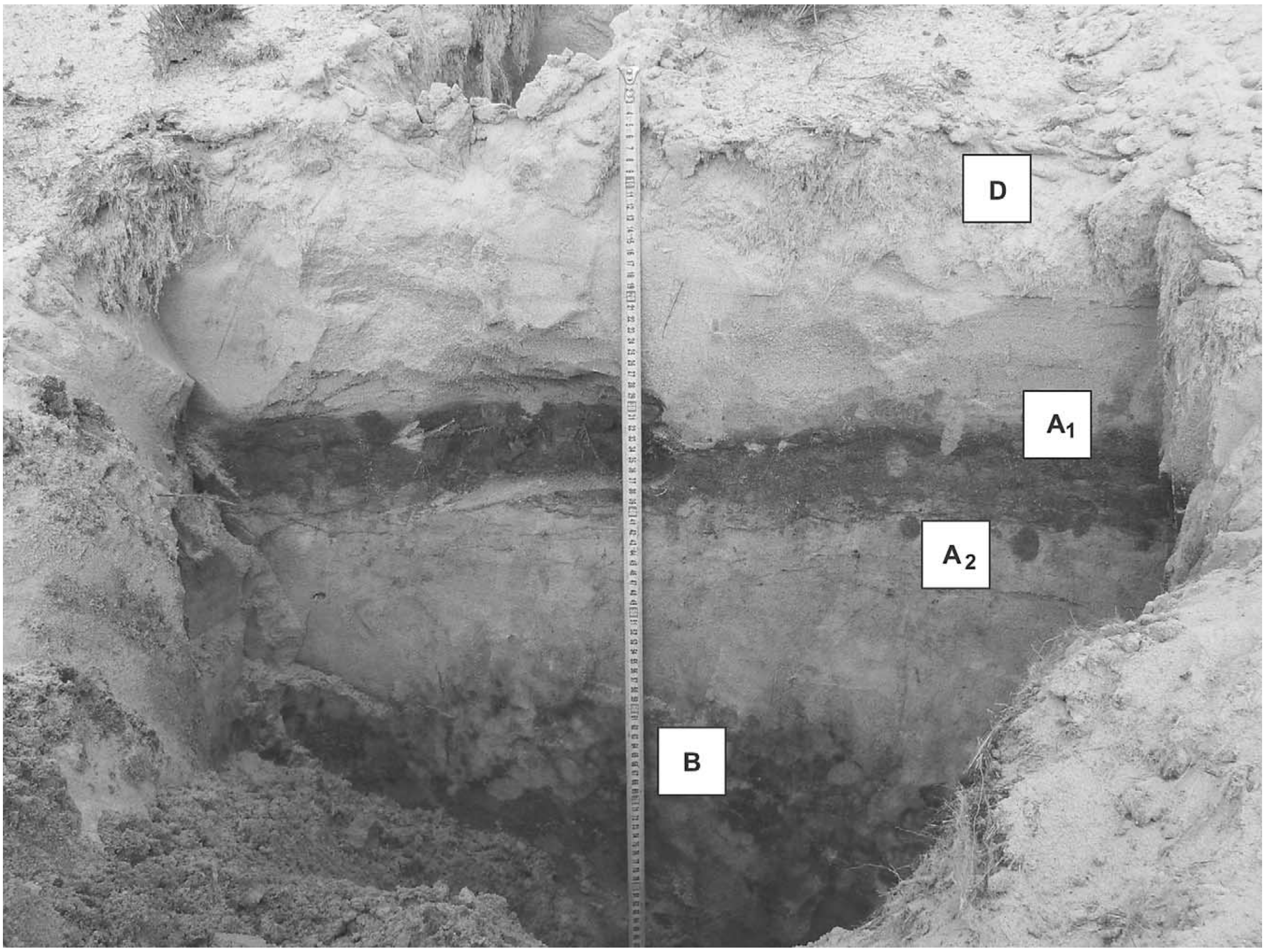

Fig. 2. Buried soil in Vinkis dune. D – dune cover sand. The ancient soil layers: (A_1) the forest litter (humus layer) with charcoal small pieces (980–1190AD), (A_2) a podzol layer, which is composed of grey fine sand, and (B) an illuvial horizon, which is of reddish and brown colour due to high content of iron and manganese. Photo by Alfred Uchman, 2006

vegetated area exposed to strong winds, sand burial and erosion. They are characterized by primary, often invisibles humus accumulation.

Climate deterioration during the Little Ice Age and forest fires were the cause of the new dune migration. The recent represent soil development on the dunes since 18th and 19th centuries. Reforestation and fixation of Migrating dunes initialised recent soil development. The short period for soil formation led to the development of a weak profile. At this example time can be regarded as the limiting factor of podzolization.

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