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PALAEOGEOGRAPHIC EVOLUTION OF THE KERINTHOS COASTAL AREA (NE EVIA ISLAND) DURING THE LATE HOLOCENE

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ABSTRACT

Preliminary results of a detailed study on the palaeogeographic evolution of the Kerinthos coastal archaeological area (N. Evia island) are presented. The coastal setting of Kerinthos has been subjected to important changes during the Late Holocene, under the influence of eustatic sea-level rise, progradation of the Voudhoros river alluvial plain, and tectonic uplift. Subsurface stratigraphic data indicate that Peleki, a naturally sheltered coastal embayment that has been partially infilled by Voudhoros alluvia since at least the Classical period, had been previously a shallow, low-energy brackish water coastal environment - since at least 5000 B.P. Coastal tectonic uplift of the order of 3 m during the last 5 millennia is inferred from ^{14}C dated marsh deposits (0.6 mm/yr minimum mean uplift rate).

KEY WORDS: Coastal geomorphology, geoarchaeology, coastal stratigraphy, coastal tectonic uplift, Holocene, Kerinthos, Voudhoros, Evia, Aegean, Greece.

1. INTRODUCTION

The Kerinthos archaeological area is located on the Aegean coast of north Evia (Fig. 1a/b). Little is known about the main ancient settlement and the occupation in the surrounding area. Kerinthos first appears in literature in the "catalogue of ships" in Homer's *Iliad* (B 538), as one of the cities that contributed ships to the Trojan expedition. Since then it was closely related to the sea –"ἔφαλος"(=on the sea) is its homeric epithet-, however it is only briefly mentioned in later ancient texts (Sapouna-Sakellaraki, 1996). From archaeological surveys it is known that the area could have been occupied since the Neolithic period and uninterruptedly up to the Hellenistic and Roman periods (Sackett et al. 1966, Hope-Simpson & Dickinson, 1979, Sapouna-Sakellaraki, 1996). Today Archaic (or Classical) fortification ruins and much earlier defence structures –"Cyclopean" walls- point to the location of the ancient acropolis, on top of limestone coastal cliffs (Kastri) at the area of Peleki (Fig. 1b, 2). To the W and WNW, extends the alluvial plain of the Voudhoros river, which debouches just west of the ancient acropolis.

A detailed geomorphological field survey of the broader coastal was carried out, and three shallow (4m) boreholes were drilled in the Peleki embayment -a site well suited to have been the ancient port of Kerinthos- in order to study the sedimentation sequence under the Voudhoros alluvium cover, and detect palaeo-environmental changes during the late Holocene.

2. GEOMORPHOLOGICAL EVOLUTION OF THE BROADER COASTAL AREA

A most important agent of coastal change in the broader Kerinthos area during the Late Holocene, is the Voudhoros river. Voudhoros is the product of the confluence of rivers Nileas and Kireas, that constitute the largest drainage network in Evia island, with a watershed of 360,5 km^2 (Fytrolakis et al., 1988, Leontaris & Gournellos, 1991), extending on a variety of alpine and post-alpine formations : carbonates of the Sub-Pelagonian unit, ophiolites and melange, and Neogene fluvio-lacustrine deposits of the Limni-Histiaia basin (Katsikatsos et al., 1980, 1981). The large watershed area and dominance of easily erodible ophiolites, melange, and Neogene deposits, result into a high sediment flux in the coastal area.

Around 7000-5500 yrs BP, when the rate of the global sea-level rise started to decelerate, most of the area covered today by the coastal plain alluvium must have been a marine bay, as Fytrolakis et al. (1988) have suggested, reporting sands with marine bivalves and gastropods, presently at 1.3 m below m.s.l. in a borehole 900 m away from the coastline. Since the deceleration of the Holocene transgression, progradation of the Voudhoros

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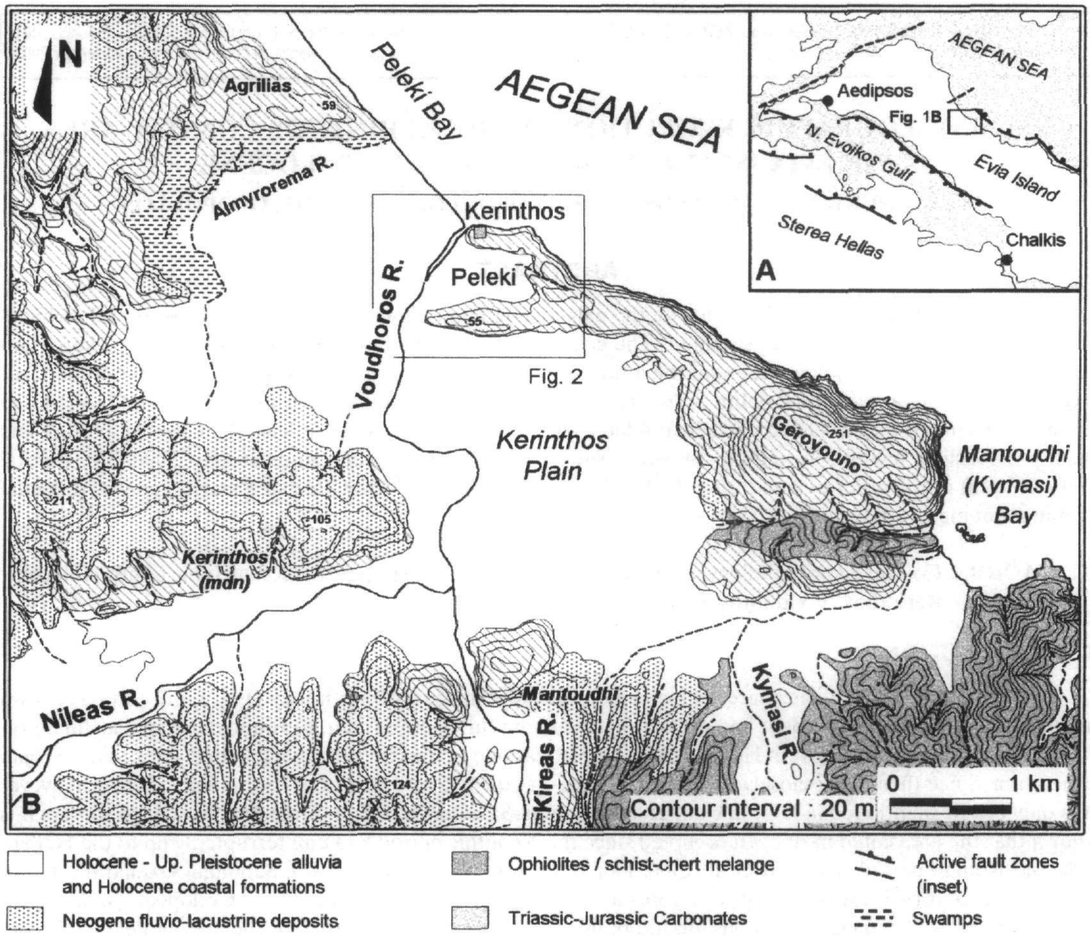

Fig. 1. (A) Location map and active fault zones. (B)Topography and lithology of the Voudhoros plain surrounding area (Katsikatsos et al., 1980, 1981).

alluvial plain was allowed, resulting in the gradual infill of the bay (the NW was only partially filled).

Apart from the interplay between eustatic sea-level rise and progradation of the Voudhoros alluvial plain, another important factor affecting the coastal evolution is tectonic uplift realised by an active offshore fault-zone, paralleling the Aegean seaboard of Evia (Fig. 1a - e.g. Roberts & Jackson, 1991). Recent coastal uplift was observed at Kymasi (Fig. 1b), where abrasion platforms around the base of ophiolite sea-stacks and at the SE end of the bay were found uplifted by about 35 cm. Beachrocks inside the bay were found elevated by about 30 cm a.m.s.l. and at a small cove at the NW end of Kymasi, two wave-cut notches were observed in limestone (20 and 60 cm a.m.s.l. respectively). At the Kerinthos site (exactly at the mouth of Voudhoros), remains of an uplifted abrasion platform were found at about 30 cm a.m.s.l., together with an ill-preserved notch. Stiros et al. (1992) carbon-dated *Lithofaga* shells from the Kymasi notch (510-380 BC), that, according to the same authors, corresponds to an uplifted shoreline that can be observed almost continuously for about 70 km in the Evian coast. No historical accounts of the earthquake responsible for its uplift exist, which, according to Stiros et al. (1992) could have been of magnitude greater than Ms 7.0.

3. THE PELEKI (KERINTHOS) EMBAYMENT

The hilltop on which the Kerinthos acropolis is built, is overlooking to its immediate south the area of Peleki (after which the Peleki bay was named), a 500 by 380 m embayment flanked by two elongate E-W trending limestone promontories (Fig. 2). Peleki is a Pleistocene depression filled today with Voudhoros alluvium, the formation of which was passively directed by E-W striking faults (Katsikatsos et al., 1980).

It is highly probable that the coastal geography was different in ancient times, as it has been found to be the case in many other coastal plain environments (e.g. Kraft, 1972). Peleki is reasonably expected to have been a coastal embayment -that would provide excellent natural shelter in the otherwise inhospitable Aegean coast-, with the Kerinthos acropolis strategically positioned to watch over ancient port facilities inside it.

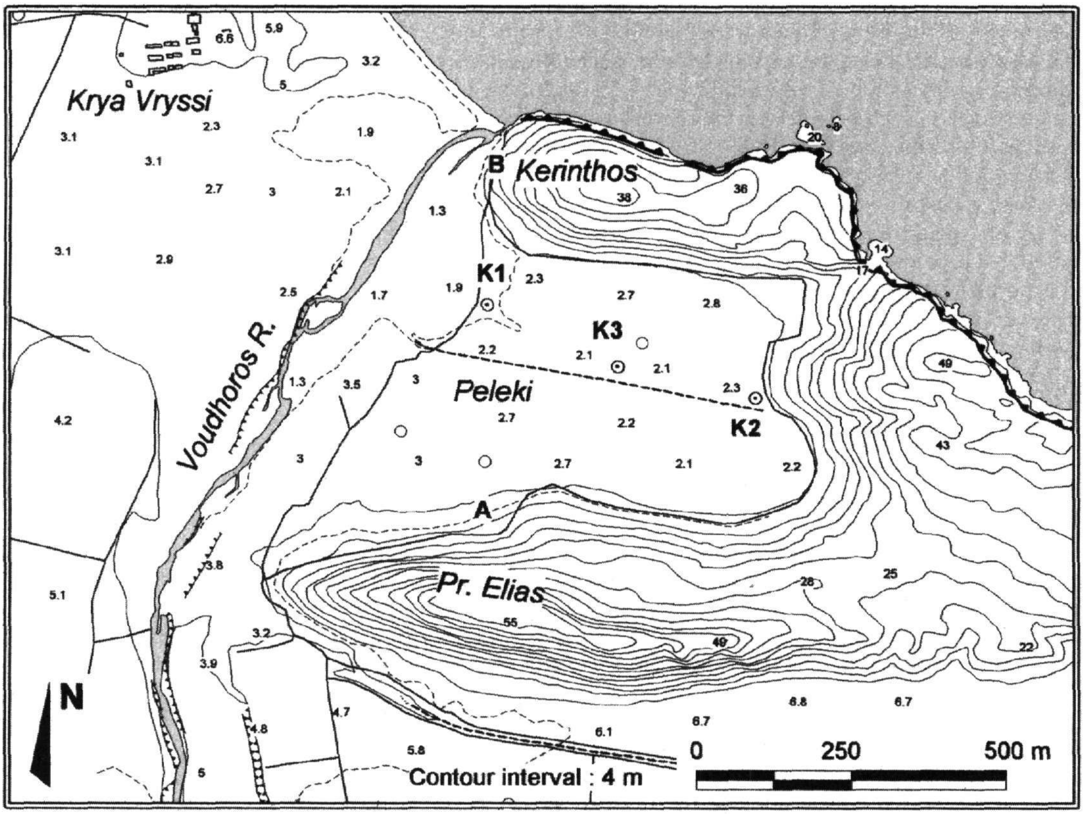

Fig. 2. Detailed topography of the Kerinthos archaeological area (Peleki embayment), from 1:5.000 maps of the Hellenic Army Geographical Service.

Although no systematic excavations have been carried out in the recent alluvium inside Peleki, abundant surface finds (Choremis, 1971), and more recent unpublished material suggest that at least its northern part was a cemetery during the Classical period (5^{th}-4^{th} cents. B.C.). This implies that the infill of the embayment was already complete by that time. What is of particular interest, is the fact that no earlier findings have been reported from inside the embayment but only at more elevated areas at its periphery, where trial excavations by Sampson (1973-74, 1975a/b) yielded ruins and burials of the Middle Helladic period (1800-1500 BC) – sites A and B in Fig. 2.

4. BOREHOLE DATA

In view of the lack of specific historical accounts and of systematic archaeological excavations, a subsurface stratigraphic study inside Peleki was decided, in an attempt to determine the timing of its infill by Voudhoros alluvium and previous environmental conditions. In order to obtain information about the Holocene stratigraphy under the recent alluvia of Voudhoros, three 4 m boreholes were drilled with a portable Eijkelkamp percussion drilling set along the central axis of Peleki (Aug.-Sept. 2000, locations in Fig. 2). K1 was drilled at the mouth of the embayment, K2 at the head of the embayment, and K3 in-between the first two. Apart from field descriptions of the retrieved stratigraphic successions, selected samples from the cores were analysed for grain size, micro and macro-fossils, and other inclusions. Identification of ostracods and foraminifera was based on scanning electron microscope photographs of specimens found in various coastal areas in Greece (Tziavos, 1996, Niemi, 1990, Kambouroglou, 1989 and Tziavos, 1978) and standard reference works. Two samples of organic remains were sent to a laboratory for ^{14}C dating.

All three successions (logs in Fig. 3) ended in fine-grained brown-coloured overbank deposits of Voudhoros, plus colluvium in K2 -which is near the base of a slope-, bearing an imprint of pedogenesis. In K1, the lowest unit consisted of well sorted, rounded gravel at its bottom with a maximum size of 5 cm -the coarsest sediment in all three cores-, grading upwards into cyanish-grey coloured silty fine sand. Sample K1-8 from this unit contained a lot of plant remains but it was extremely poor in microfossils, with only a few fresh-water ostracods (*Candona compressa*, Koch). After a transitional zone of about 20 cm, 1 m of cyanish-grey fine-grained deposits were encountered (K1-7, 95% silt+clay). These were rich in organic remains (rotten wood, roots), and fresh water ostracods (*Candona compressa*, Koch). The litho- and bio-facies of K1-7 indicates a very low energy, oxygen-deficient and low salinity environment (marsh).

A large piece of wood from this unit (sample K1-7) was ^{14}C dated[4] (^{13}C corrected, error +/- 1s) at 1040 +/- 90 years BP, an age that could be in conflict with the archaeological data, that unequivocally speak of Classical tombs 0,5 - 1 m below the surface inside the Voudhoros overbank deposits in the vicinity of K1 (Choremis, 1971) and at several other sites in Peleki. Hence, unless the archaeological data are reinterpreted differently in the future, or, until new boreholes are made close to K1 and more ^{14}C dates are obtained, the age of K1-7 should be considered problematic - even though the sample, a large piece of wood, was ideal for ^{14}C-dating.

Borehole K2 could not penetrate beyond 1.50 m below m.s.l., probably because bedrock was encountered, since the site was only a few meters away from the limestone slope. The retrieved succession consisted of a 1,4 m-thick unit of cyanish-grey sandy clay+silt at the bottom, coarsening upwards into silty fine sand of the same colour. This unit was overlain by 70 cm of greenish-grey silty fine sand, rich in organic remains at the first 20 cm, fining upwards into sandy silt+clay. A sample of organic remains (K2-7) was ^{14}C dated[5] at 4910 +/- 60 years BP (^{13}C corrected age, error +/- 1s).

Samples K2-8 and K2-9 were taken from distinct 10-cm horizons in the lower unit, very rich in small (up to 1 cm) in situ marine to brackish water bivalves and gastropods (*Cerithium sp.)* and benthic foraminifera (*Ammonia becarii*, Linne, *Elphidium fichtelianum*, D'Orbigny, *Quinqueloculina sp.*). Also, abundant fresh and brackish water ostracods were present (*Candona compressa*, Koch, *Ilyocypris sp.*, *Cyprinotus salinus*, Bady, and fewer *Loxoconcha sp.* and *Pseudopsamocythere sp.*). As a whole, the lower unit of K2 is interpreted as a low-energy brackish to fresh water environment, with occasional increases in salinity (permitting the development of the brackish to marine macro and micro-fauna in horizons K2-8 and K2-9, which is absent in the rest of the unit). Sample K2-3 from the upper unit included low-salinity brackish water ostracod fauna (*Ilyocypris sp.*, *Candona compressa*, Koch, *Cyprideis torossa*, Jones) and *Ammonia becarii* (Linne), indicating a fresh to brackish water environment.

Borehole K3 could not reach deeper than 1.90 m below m.s.l., because a very hard horizon was encountered. Since not even chips of this material could be retrieved, it is not known whether it was e.g. a beachrock. The succession above it began with 60 cm of oxidised greyish-yellow medium to coarse sand (fines 20%), characterised by absence of microfossils. Overlying this unit in sharp contact were 50 cm of cyanish-grey medium to fine sand with increased fines (40%), containing organic remains (plant remains, pieces of wood) and fresh to brackish water ostracods (*Cyprideis torossa*, Jones, *Candona compressa*, Koch). Calcareous oogonia (spore sacs) of the green algae *Chara sp.* were also abundant, indicative of clear fresh water or low salinity brackish water. In sharp contact above came 20 cm of greyish yellow fine and medium sand (55 %) and 45 % silt+clay (K3-7), containing plant remains and similar ostracod fauna (*Cyprideis torossa*, Jones and *Candona compressa*, Koch) and *Chara sp.* Overlying K3-7 were 50 cm of greyish-yellow (oxidised) fine and medium sand (25% fines), containing no microfossils, like the unit of K3-10. Finally, 60 cm of greenish-grey coloured fine sands and silts were encountered – sample K3-4 from this unit also contained no microfossils.

5. DISCUSSION – CONCLUSIONS

The stratigraphy of the boreholes inside Peleki, is characterised by significant lateral facies changes underneath the overbank deposits of Voudhoros. In an overall sense, the dark-coloured silts/clays and fine sands rich in organic matter and containing predominantly brackish water microfossils were deposited in a shallow, protected, marshy coastal environment. This environment was established at least since 5000 years BP, as the ^{14}C age of K2-7 indicates.

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[4] Lab. No. GX-27132 (Geochron Laboratories).

[5] Lab. No. GX-27281 (Geochron Laboratories).

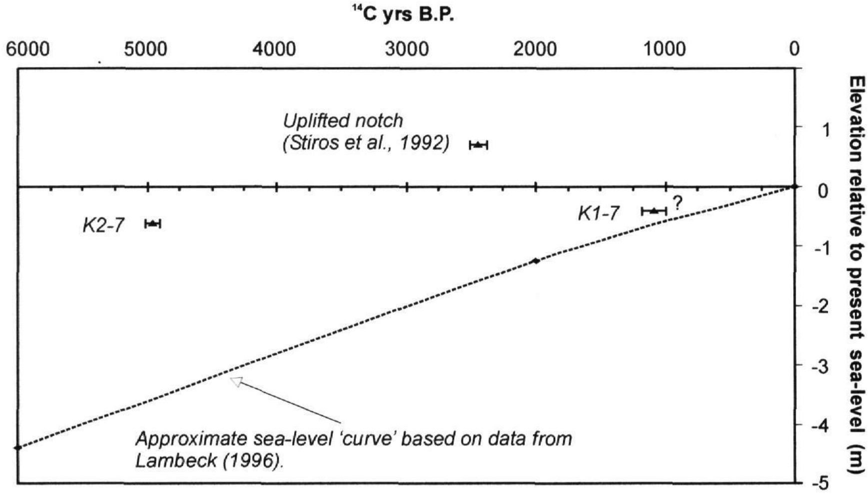

Fig. 4. Approximate sea-level 'curve' (data from Lambeck, 1996), and elevations of ^{14}C dated horizons. The uplifted notch dated by Stiros et al. (1992) is also plotted. Error bars indicate the accuracy of ^{14}C dates.

Given the inherent complexity of such transitional sedimentary environments (Reineck & Singh, 1973), until more cores are sampled to allow the establishment of a more complete 'stratigraphic section' along -and across- the Peleki embayment, any interpretation of the details of the presented data can only be considered preliminary. The main question of interest here is the origin of the coarser sediments that were encountered in the boreholes. These contained no traces of marine fauna (reasonably to be expected should they were of marine origin), something that could be indicating they are deposits of Voudhoros -e.g. flood surges inside the shallow-water Peleki embayment.

An interesting outcome of the subsurface study was the evidence for significant tectonic uplift of the coast, a factor acting in favour of the Voudhoros plain progradation and infill of the Peleki embayment. The present elevation of the contact between the Voudhoros overbank deposits and the underlying brackish water sediments, is systematically above present sea-level by at least 30 cm - a conservative figure measured above the possible error margin in the determination of the borehole elevations, which was based on spot heights of very accurate HAGS 1:5.000 maps. More specific information, concerning the total amount of coastal uplift in the last 5 millenia can be extracted from the ^{14}C age of K2-7, by comparing the present elevation of the sample to a Holocene sea-level curve (Fig. 4). Data from Lambeck (1996) were used to plot the approximate 'curve' of Fig. 4, which is accurate enough for our purposes and shows that when K2-7 was deposited, sea-level was about 3,6 m lower than present. The present elevation of K2-7 (-0.6 m) implies uplift of the coast by 3 m above the sea-level at the time of deposition. This is a minimum figure -because the depth of water during the time of deposition of K2-7 and the subsequent sediment compaction that has taken place since is not known-, and translates to a (minimum) mean uplift rate of 0.60 mm /yr for the past 4960 yrs (0.67 mm/yr if 30 cm of water depth is assumed for K2-7). The notch dated by Stiros et al. (1992) at Kymasi, is about 2.2 m higher than sea-level at the time of its formation (Fig. 4), yielding a mean uplift rate of about 0.9 mm/yr for the past 2445 yrs. This rate is significantly high, and comparable to long-term uplift rates in the southern margin of the Corinth Gulf (1.1 mm/yr being a conservative figure for the Helike fault - McNeill et al., 2000). Even if the above two figures are crude first estimates based on a low-accuracy sea-level curve, their difference could still reflect changes in the rate of coastal uplift during the Holocene.

Another point of interest is the possibility of identifying palaeoseismic events from the stratigraphic record, since the sequences preserved in coastal wetlands can potentially 'document' earthquake-induced changes (e.g. Cundy et al., 2000), especially if coseismic uplift is large, as Stiros et al. (1992) propose. In the Peleki sequences, unambiguous indications of emergence episodes could not be identified - e.g. subaerial deposits intercalated in the brackish sediments; however, more detailed analyses could yield fruitful results in the future.

With the preliminary data at hand, it is inferred that coastal uplift may have been accommodated in several episodes uplifting by a few tens of cm each time, rather than a few events of metre-scale coseismic uplift as suggested by Stiros et al. (1992), that would probably uplift the deposits above sea-level – at least as far as the Peleki area is concerned. Another possibility would be that coseismic uplift is superimposed on significant slow nonseismic movements, as proposed e.g. by Stewart (1996) for the Helike fault (Corinth gulf).

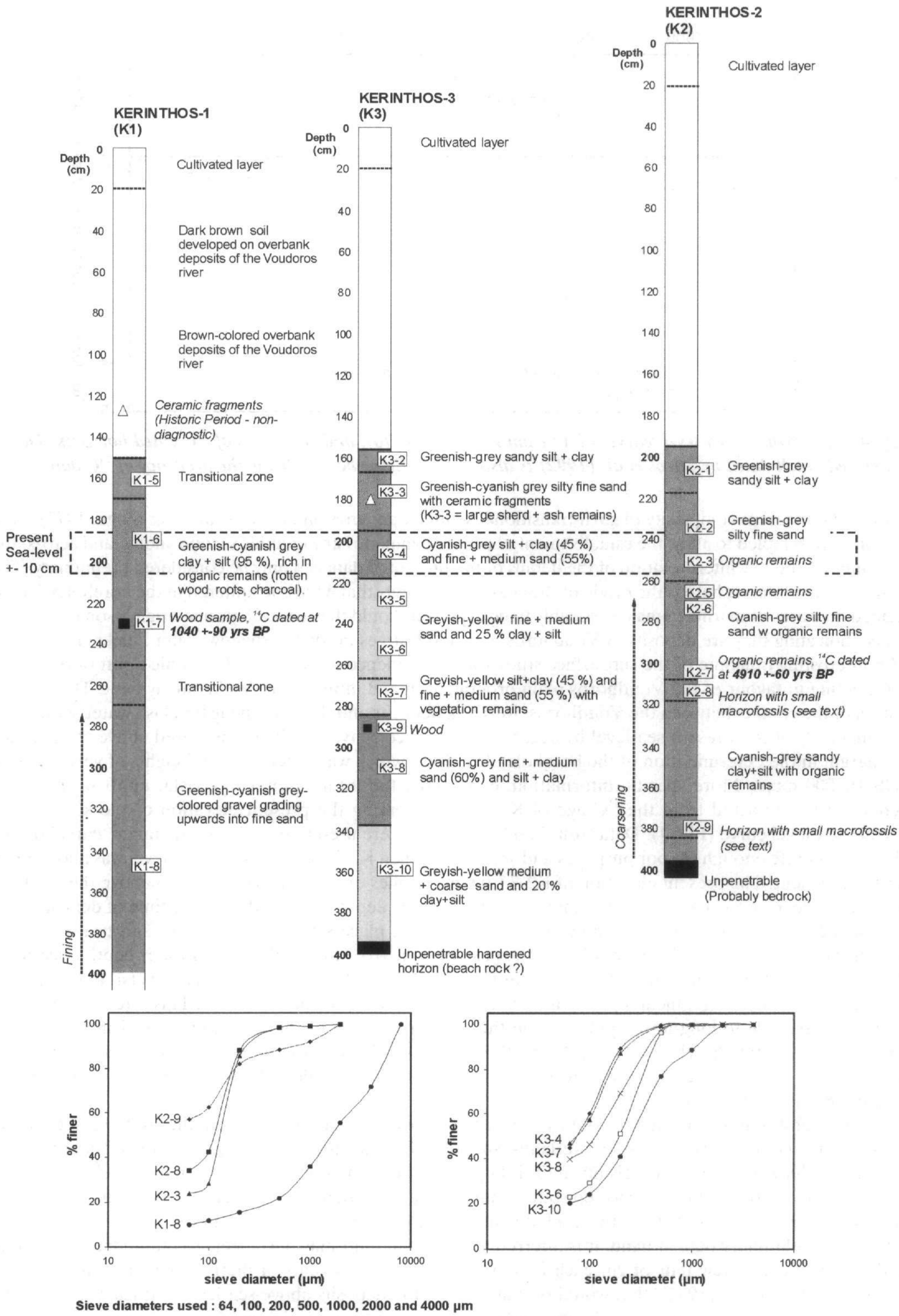

Fig. 3. Borehole logs and cumulative grain-size distribution curves for selected samples.

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