THE SHORELINE DISPLACEMENT DATING OF PREHISTORIC DWELLING SITES IN ISO-SAIMAA

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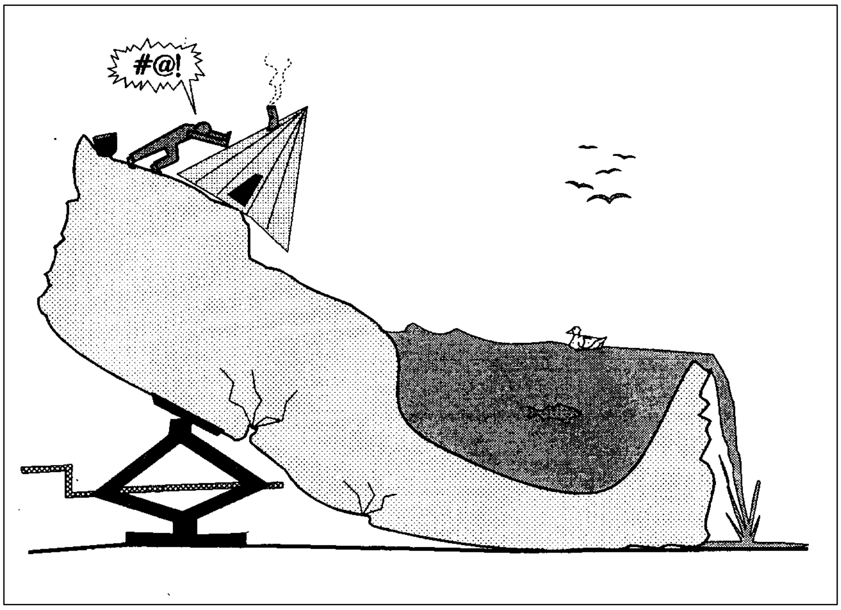

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Contents

Includes: 26 figures, 24 diagrams, 14 tables and 3 maps

Abstract

The History of Lake Saimaa is well known from the late glasial period to the phase of the highest shore just before the formation of the river Vuoksi. The highest shore is called Great Lake Saimaa shore and it is well known and uniform formation around Lake Saimaa. The Great Lake Saimaa -phase ended during the typical comb ceramic period when new outlet penetrated through the Salpausselkä I end moraine at Vuoksenniska SE-Finland. Continious regression have occurred since the Vuoksi catasthrope.

According to earlier investigation it was not expected to find any younger uniform synchronous shore levels. The purpose of this study is to find shorelines of reasonable synchrone with which it is possible to date prehistoric dwelling sites younger than typical comb ceramic in the Iso-Saimaa area. The main topic of this study is to construct a distance diagram based on arcaheologically relatively dated shore observations. A method to create a time-gradient curve and shoreline displacement curves for certain locations is studied as an application of main topic.

During fieldwork in 1992 and 1993 cliffs in over 100 sites were leveled. With the aid of collected new shore observations, practical tests and litterature was examined a vertical range of shore formations that have been born almost the same age. This range was then used in determining the synchrone shore levels. Shore observations were first ordered according to some well formed reference cliffs which were ranked according to their ceramic material. With the aid of a computer program, specially tailored for this study, shorelines were determined according to regression analysis of the bases of cliffs. The dating method was then constructed using the elevations of the prehistoric sites on the top of cliffs. With few C14 datings and landuplift calculations a preliminary time-gradient curve was constructed to get absolute datings for determined shore phases as well as for different ceramic periods.

In the resulted distance diagram is seen ten ancient shore lines of Lake Saimaa after the Great Lake Saimaa phase. The highest waterlevel of Great Lake Saimaa appeared to be at higher elevation than uniform traditional highest shore. The violent collapse of two meters in waterlevel of Lake Saimaa due to formation of the new outlet occurred 6000 years ago well above the level of the cliff formations that were earlier thought to represent the highest waterlevel. A second collapse of waterlevel occurred during the transition fron Neolithic to Early Metal Age at about 4000 years before present.

The Shoreline displacement dating of prehistoric dwelling sites in Iso-Saimaa

1. Introduction

The Postglasial Development of Lake Saimaa has been under investigation by geologists for nearly 100 years. The development of Saimaa is well known from the Salpausselkä stage to the formation of the river Vuoksi during the Comb ceramic period. The highest shoreline before the formation of current outlet is called the **Great Lake Saimaa phase (GLS)**. The interest of geologists ends where the interest of archaeologists begins. The Shoreline displacement of Saimaa from the GLS level to the present water level has not yet been investigated.

In early seventies Dr. Ari Siiriäinen and Mr. Christian Carpelan, Lic.Phil., began a project to study this question. They leveled raised beaches in the Saimaa region. However the project was laid aside for several reasons until it was revived in 1992 as a part of the Saimaa Project of the Department of Archaeology of the University of Helsinki.

The basic purpose of this study is to create a shoreline dating method for ancient dwelling sites in the Lake Saimaa area. This is attempted to achieve by constructing a *distance diagram* of the raised beach observations below the highest shore level preceding the creation of the Vuoksi outlet.

The main problem in constructing distance diagram is to find and determine *synchronous shore formations* around the Saimaa area. This is tried to achieve by ranking and comparing shore observations with relatively dated archaeological material. It is essential to get acquainted with the *land uplift*. Also the *formation and development of shores* have to be studied. The basis of the whole dating method is the strict *connection of ancient dwelling sites to the shoreline*. This primary hypothesis has to be kept in mind through the investigation process.

Most important Saimaa research has been carried out by geologists Aaro Hellaakoski, Veikko Lappalainen and Matti Saarnisto. These earlier investigations are referred only limitedly in this study. Attention to these studies is mainly restricted to those few mentions about the post GLS observations and to the main clauses about the formation of Vuoksi and GLS-shores.

Many other Geologists, not mentioned here, carried out smaller studies concerning the post glacial development of Lake Saimaa. Meinander gave an archaeological view to the development of Saimaa in 1947. Otherwise archaeologists have not yet published new and mentionable aspect concerning the development of Saimaa nor methods of using shore line displacement as a dating method in the Saimaa area.

In other water basins synchronous shore levels were investigated and resolved by using different methods. For instance Heikkinen and Kurimo (1977) have settled the history of Lake Kitka with trend-surface analysis. Åse (1980, 1984) has explained phases of the Litorina sea by examining the deviation of the elevations of morphologically ranked shore formations. Studies of Siiriäinen, concerning the shore line displacement as a dating method of prehistoric dwelling sites at the Baltic coast (1969, 1971, 1972, 1978) and lake Ladoga (Saarnisto & Siiriäinen 1970), serves as a basis for this study. Siiriäinen has also studied archaeological background of meso-neolithic boundary in the view of the shore line displacement of Lake Päijänne (1970). Matiskainen has made investigation, based largerly on archive material, about ancient sites and shorelines of Lake Päijänne (1978). Matiskainen constructed a distance diagram from archaeologically grouped shore observations of the Lake Päijänne area. This short study of Matiskainen was stressed to early Neolithic sites. Later Matiskainen has discussed about Mesolithic shores and their datings in the lake area of the central Finland (Matiskainen 1987).

1.1. Investigation process

This study consists of four parts: *The Collection of Data* during which earlier investigations, papers, notes and observations were assembled. During the field work period new data was collected from the investigation area. Assembling and classification of new and old data and making of obligatory reports and catalogs took about 20 weeks. The second part was *The Constructing of Tools.* A huge amount of work was done in writing computer program code to make specially tailored programs for this study. A database was created to collect all relevant shore data in digital form. This database was joined to the Saimaa-database of the department of archaeology in which is stored the information about all prehistoric finds, sites and locations found from the Saimaa area. Several computer programs were made in order to handle, establish and publish collected shore data and other data sets concerning surveyed sites. With the aid of computer "tools" followed *The Creation of Method* working phase. After that was finally made a synthesis, *The Application Study*, during which the method was tested and used in dating of sites. The whole process demanded more than one year all day work.

1.2. Investigation area

Lake Saimaa reaches at present from the north side of the City of Iisalmi to the City Lappeenranta in SE Finland (400 km). It consists of several parts each on different shore level elevations. The largest part, so called **Iso-Saimaa** (to SE from the Mikkeli-Varkaus-Joensuu line) is at an elevation of about 76 m above sea level. The second largest part of Saimaa, lakes Suvasvesi and Kallavesi, is four meters above Iso-Saimaa. The most north western part is at 89 meter's altitude. Several smaller lakes, more or less above the level of Saimaa, are connected to it via rivers and rapids.

The investigation area of this study is restricted to the area of Iso-Saimaa (Map 1). This restriction is partly due to practical and economical reasons. I have personally quite a good knowledge and lot of experience of prehistoric sites in this area. The area is largely the same than the operation area of Savonlinna Museum, which is accompanied in the project. Museum gave us help, like free accommodation during the field work and good information about ancient sites and their locations. The field work course, an excavation, of Helsinki University was committed in Rääkkylä, in northern side of Iso-Saimaa area. That work gave also "synergy benefits" to this study. Field work, especially traveling expenses, was partly connected to other activities in the area.

The most important reason for selected investigation area was the fact that this kind of investigation and planned method will need a mass of observations from certain kind of sites situated on certain shore formations. In northern Saimaa area we know less than 150 prehistoric sites of all types. Most of these sites are located in an area north of Kuopio, or at shores of lakes that have been only limited time as a part of Lake Saimaa. A large and significant area between Varkaus and Kuopio is poor of known sites. From Iso-Saimaa area we know more than 500 prehistoric shore-bound hunter-gatherer sites (in 1993). Many of these sites are dated according to ceramic finds. A lot of sites are locating at low elevations. It was excepted that these sites might be dated to late Neolithic or to metal periods.
The difference in amounts of sites between Iso-Saimaa and rest of the Saimaa area is explained entirely by intensive surveying work committed by Savonlinna Museum during last years.

Since this investigation deals largely with the *development of method,* it was aimed to start in easier area. In northern Saimaa we have to focus on matters and phenomena that do not exist in the Iso-Saimaa area (at least not in such a large scale). These extra topics in northern Saimaa are: curving land uplift isobases; highest GLS shores are formed during different age; Saimaa consists of several lakes that have isolated from Great-Saimaa during different ages. Iso-Saimaa is clear and independent entity in the view of this study
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Map 1 Watershed of Saimaa

Red line is the base line used in this study. Iso-Saimaa are areas number:

1.3. Field work.

During the summer 1992 two groups leveled sites in the investigation area during one month. One group was lead by author and we leveled sites south of Mikkeli-Enonkoski-Kerimäki zone. Another group was lead by Mika Lavento, and they leveled sites on northern side of the investigation area. Some leveling and surveying work was committed later in 1992 and 1993 by Petro Pesonen and author. About 150 sites were surveyed. Levelings were made on 100 sites. During the field work more than twenty completely new dwelling sites were located. New material and observations were found from many previously known sites. Most of the field work was financed by the University of Helsinki. A lesser part of the field work was supported by Microlith ltd.

2. Earlier investigations

2.1. Post Glacial Development of Saimaa

The main factor in the development of Lake Saimaa is the land uplift of Fennoscandian crust. The rate of land uplift is greater in SE than in NW parts of Lake Saimaa. Because of differences in the land uplift rate, ancient shore formations of the same age are inclined towards smaller land uplift (SE). An older shoreline has greater gradient (inclination) than younger, because the older shoreline (or formations representing it) has been raised longer time and the difference in elevations within the shore marks of the same age in SE and NW have had more time to emphasize.

The following short introduction to the post glacial development of the Saimaa lake basin is based on Matti Saarnisto's comprehensive study published in 1970:

Highest shorelines in southern and eastern parts of Saimaa are shores of the Baltic Ice Lake, from the period when the ice sheet was between the Salpausselkä I and II end moraines. After the Salpausselkä-stage water level sank rapidly about 28 meters due to the opening of so called Billingen Port in Central Sweden. After that a dammed ice lake existed in southern and eastern part of the Saimaa area. Shorelines of these early phases are deeply inclined at high elevations in south eastern Saimaa. Ice lakes were soon connected to the Yoldia Sea and the water level dropped to the elevation of about 60 m above present sea level (those shores are now under the present water level of Lake Saimaa).
Southern Saimaa was isolated from the Yoldia Sea about 9500 years ago. The final isolation of the whole Saimaa Lake system from the Ancylus Sea occurred about 8000 years ago. The first outlet of the ancient Lake Saimaa was north at Pielavesi area.

Land uplift is much stronger in the north than in the southern part of the lake area. Continuous transgression began in the area south of the Pielavesi outlet and gradually the independent lakes in water system were joined while water level rose. About 6000 years ago (in C14 years) water level reached almost its highest point and the so called Suursaimaa (Great Lake Saimaa, GLS) was formed. Soon water level rose over the Matkuslampi threshold in Ristiina and quite soon after that over the Kärenlampi threshold near Lappeenranta. The water level began to sink at the area northwest of the Matkuslampi outlet, while transgression still occurred in the area southeast of Matkuslampi.

The Pielavesi outlet in north dried and finally after that the transgression reached the top of the first Salpausselkä at Imatra and the River Vuoksi was formed and continuous regression of Saimaa began. The highest GLS-shore is metachronous. To the NW side of the tiliting axle, at the landuplift isobase level of Matkuslampi outlet, the highest shore is about 5500 C14 years old and at SE side of the axle it is about 500 years younger. The highest GLS shore is near Vuoksi about four meters and in Savonlinna about nine meters above present water level.

The formation of the river Vuoksi occurred during the typical comb ceramic period. Sites older than that in SE-Saimaa are under present water level or under the transgression and regression deposits between the GLS-level and the present water level.

2.2. Formation of Vuoksi, the end of GLS

According to **Hellaakoski** (1922: 20) at the place where Great Lake Saimaa penetrated through the Salpausselkä end moraine the lowest altitude of the cutted proximal edge of the esker is at 82.9 m asl., and on the opposite shore of the river mouth at 81.9 m asl. Hellaakoski points out that the threshold could have been at a little lower altitude than is now visible at the present river banks. Hellaakoski measured the altitude of highest GLS shore formations near the outlet at 79.5 m asl. (Op cit.: 31).

Hellaakoski (1922: 97-99) explained the difference between the altitude of the highest GLS shore and the altitude of the threshold as follows:

> ... transgression was slow but gradual. Finally water level rose to the GLS-level (79.5 m asl), to about two meters below the threshold at Vuoksenniska. The average height of annual flood in Saimaa is slightly about 0.30 meters. In 1899 unexpectedly strong flood rose 1.7 meters over normal water level, and over 1.4 meters above current shore formations of that day. During the phase when water level had reached GLS-level, a sudden annual flood, greater than normal spring flood equal to the flood in 1989, caused water level to rose to a level about one meter below the threshold. At that kind of situation the threshold was only 30 meters wide. The pressure of water simply broke the esker, and the formation of the river Vuoksi began. The morphology of the river mouth indicates that the incident was sudden and rough.

Hellaakoski determined that the gradient of one synchronous GLS-shore is curved. From the regression value of 0.104 m/km at the most SE part of the lake to the value of 0,186 m/km at the most NW edge of the lake system (1922: 104). Later Hellaakoski presented a GLS gradient value of 0.110 m/km to the area between Ristiina and Rantasalmi at NW to Vuoksi at SE. The Gradient of SE-part of the Saimaa appeared to be straight line. It also appeared that GLS-shore is not synchronous. The GLS-shore is older In the NW-part of the lake and its gradient is steeper than in south (Hellaakoski 1934, 1936: 77-88, 1949). The metachronous nature of the GLS-shore was then also confirmed and precised archaeologically by Meinander (1949) and stratigraphically by Okko (1947), Donner (1957) and Sauramo (1958: 338). These works of geologists were based on bog profiles near Kuopio in northern Saimaa and one in Puumala southern Saimaa.

Hellaakoski dated relatively the formation of Vuoksi by startigraphical means to the end of the pollen zone VIII, to the age of typical comb ceramics.

Donner postulated (1957: 30) that the shift of the Saimaa outlet from Pielavesi in north to south in Ristiina, Kärenlampi and Vuoksi occurred during a very short time at the pollen zone boundary VIII / IX.

Lappalainen (1962) investigated the most South-Eastern part of Saimaa, around Lappeenranta and Taipalsaari. GLS-shore formation observations of Lappalainen were equal to observations of Hellaakoski. According to Lappalainen Saimaa reached its highest post-glacial position near the pollen zone border VIII/IX, but still clearly before. The bog stratigraphy indicated that water stayed at that level for some time. However Lappalainen noticed that strong terrace forms of the GLS-stage does not prove that. He argued whether these terrace forms could be considered at all as a sign of transgression (:82).

Lappalainen calculated the gradient value of GLS in his investigation area to be 0.090 m/km. He constructed a time-gradient curve for the most Southern part of Saimaa. According to his curve the absolute dating of the Vuoksi catastrophe occurred in 1800 BC (:93).

The reason for the breakthru of Saimaa through the damming esker was besides the rising waters, caused by land tilting and increasing humidity of the climate. According to Lappalainen the water level didn't have to rose over the esker. Increasing water pore pressure, erosion and dynamic pressure of ground water caused by rains and transgressing lake water caused the breaking of the dam (:94). The dam broke in several places, but side channels dried quite soon (:95).

Saarnisto summarized earlier investigations and made a considerable amount of new stratigraphical analyses in an article published in 1970. This investigation was a climax of a hundred years of research work concerning the history of Lake Saimaa. Saarnisto used new methods, C14 analyses, in dating bog profiles.

Saarnisto noticed that a pure pollen stratigraphical dating leads to too young dating. The highest shore of Great Lake Saimaa is metachronous. It is oldest to the north-west of Pielavesi outlet. Gradient value of this 8000 years old shore is about 0,180 m/km. Between Pielavesi and

Matkuslampi the highest shore is about 5500 years old (in C14 years). The gradient of this shoreline is about 0.140 m/km. Between Matkuslampi and Vuoksi the highest shore is about 5000 years old (in C14 years), the gradient of which is about 0.105 m/km (Saarnisto 1970: 78-79, and Appendix VII).

Later Saarnisto (1973) used a trend surface analysis to find a mathematical form for the GLS-shore level. Results showed that there is a broad zone in southern lake Saimaa where GLS-shore is little curved (area NE from zone Joutseno-Savonlinna). The gradient values began from 0.095 m/km in SE to 0.119 m / km in NW (on line Savonlinna-Enonkoski-Joensuu).

2.3. GLS-shore formations

Saarnisto (1979: 29) summarizes the shore observations of Hellaakoski (1922, 25-27) as follows: "*In the South-Saimaa area the rows of ice pushed boulders are uniform and the slope of cliffs is in places between 30° and 35°, whereas the northern side of Iisalmi (Pielavesi outlet) it is at most 15° to 20°. The clear-cut character of the shore in the south is due to the transgression and the fact that when Vuoksienniska outlet was breached the water sank rapidly.... The Preservation of such a distinct raised beach .... during a slow drainage is unlikely."*

Hellaakoski measured heights of the GLS-cliffs to be among 3 - 23 meters in the area between Kuopio and Imatra (1922: 86). The average height of these 40 measured cliff is 8 meters. In southern Saimaa average height is 10 meters and in north near Kuopio 6 meters. As noted before, Lappalainen suspected these formations to be caused purely due to the transgression.

2.4. Shoreline development after GLS

In Kyläniemi at southern Saimaa **Hellaakoski** measured several post-GLS shore formations at about 80.0 m asl. (2-2.3 meters below GLS-level). At Rokansaari he observed two different lower formations. In several places all around Saimaa, from Lappeenranta to Iisalmi, Hellaakoski noticed and measured shore formations at about 2-2.3 meters below the GLS-level (Hellaakoski 1922).

Hellaakoski (1922: 32-37) has observed at Taipalsaari Kattelussaari a shore formation at 77.3 m asl altitude (3.5 m below GLS-level). He also noticed some other weak shore formations below GLS level at Kattelussaari, but not measured them. At Varparanta, NW of Savonlinna he measured a shore formation located 6.5 meters below the GLS-level, at about 80 m asl (1922: 61).

At Repomäki in Joroinen Hellaakoski noticed a shore formation 5.3 m below GLS at 85.6 m asl., and another shore mark 3.3 m below GLS at about 86.6 m asl. (:63). At Ristiniemi south of Kuopio he measured a formation 3.3 m below GLS (:64). At Kitee Puhos Hellaakoski noticed a shore formation only 1.1 meters below GLS at 81.4 m asl (1922: 51).

Hellaakoski assumes that the difference of about two meters from GLS-shores to the next more or less uniform shore formation level indicates the rapid and catastrophic sunk of the water level due to the formation of Vuoksi (1922: 106). The regression of water level must have been very rapid and instant, because both shores, GLS and the shore two meters below it (GLS-1), have the same gradient and thus there is no noticeable difference in their age (1936: 77, 81). After the sudden two and a half meter collapse of water level, the regression continued gradually to the present situation.

Hellaakoski noticed numerous shore formations, "half-terraces" as he wrote, between the present water level and the level after Vuoksi catastrophe. He considered that these modest formations are only local phenomena, and that it is not possible to put them into any clear order to conform certain synchronous water level (1922: 99).

Lappalainen (1962) noticed shore level formations on the elevations between one to two meters below the GLS-level. He explained that these formations are developed during a short halt of regression after Vuoksi catastrophe. Lappalainen observed also weak shore formations more than two meters below the GLS-level. According to Lappalainen the water level fell abruptly right at the beginning of the formation of Vuoksi and then soon slowed down (:24, 95). Weaker formations represents sudden halts or floods during slower but still quite rapid regression period. Lappalainen observed from the bog profiles marks of transgression after the formation of Vuoksi. This transgression occurred after the middle of Sub-Atlantic period during the pollen zone IX. The rise of the water level was assumed to have been about two meters (:102).
Lappalainen summarized the post-GLS development of Saimaa in his investigation area as follows:

> ... the water level sunk at once about one meters and after that a regression occurred, quite fast and gradual to the level of 75.5 m asl at Taipalsaari (which corresponds less than 74 m asl. at the mouth of Vuoksi). This regression of almost six meters happened in quite a short period close to the pollen zone border VIII/IX. Then during the pollen zone IX it might have began a transgression of more than two meters. This probable transgression reached its highest point at about 78 m asl. and then immediately constant regression continued to the present water level. Transgression was caused by the tilting of Earth's surface and slowing down of the erosion in the outlet channel (:103, fig 26 p. 79).

Saarnisto (1970: 63) located post GLS-shore level marks from a bog profile of Puntusensuo Kerimäki. A c14 dating from equisetum layer, which was positioned 5.5 meters below the GLS-level was 3635+-100 BP. At that time water had been drained to an extent where equisetum could accumulate (i.e. sunk at least 2-4 meters) and the bog was isolated from lake. Another c14 dating from Sarkalahti at Varkaus showed overgrowing in 2460+-130 BP, about 10 meters below the GLS-shore level. Sarkalahti is situated north of Varkaus at the Lake Unnukka (now 81 m asl.). After that point no considerable draining occurred at this place. This and some other profiles showed that somewhat before zone boundary VIII/IX, approximately at the beginning of the Sub-Atlantic time waters of nortehern Saimaa separated from southern Saimaa in Varkaus.

Saarnisto accepted earlier considerations of sudden and abrupt 2-2.5 meters fell of water level due to the Vuoksi catastrophe (1970:78). When dating Astuvansalmi rock paintings, Saarnisto (1969) approximated the water level sunk to be three meters from the GLS-1 level during 1000 years (the GLS-level is at 86.6 m asl, just after catastrophe it was at 84 m asl. and then after 1000 years of regression at 81 m asl. at Astunvansalmi in Ristiina)

The transgression during Sub-Atlantic phase that Lappalainen suspected, was explained by Saarnisto as a "normal" change flood, like the one in 1899. Thin layers of sand overlying organic material in bogs do not have neither chronological nor regional significance, wrote Saarnisto (1970:64).

3. Shore formations

3.1. Formation processes

This investigation relies largely on observations of raised beaches, shore cliffs, on which pre-historic dwelling sites are located. These shores have been ancient sandy beaches, often on slopes of an esker or another kind of glasiofluvial formation. In this chapter i examine shore formations and factors that lead to different kind of shore profiles on mineral sandy soils.

A shore profile on mineral soil is formed by waves. *Constructive* waves are followed relatively weak backwash and material (likely coarser grains if soil consists of mixed grain size) tend to accumulate on to washing limit and to form a stranded wall (a berm). *Destructive* waves cause strong backwash, downward (seaward) motion of material. Storm waves during high tide attack the berm carrying part of it away.

A relatively steep slope favors *destructive* waves and removal of sediment from the landward side, so that slope becomes less steep. Gentle slope favors *constructive* waves and beach deposition on the landward side:

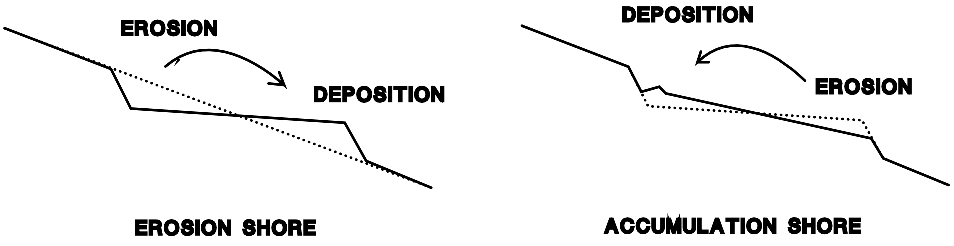


Fig 1. Holmes 1977, p.808, fig. 609 and 611

In a stable water level condition constructive and destructive forces alternate with seasonal higher and lower water level periods. Between these forces a shore profile tends to form a state of equilibrum, when the shore floor is in such a gradient that material is able immediately to move away. Waves will modify a steep slope to a gentle slope and controversially a flat shore profile steeper. Seasonal changes in water level and in wave force continually reshapes a shore profile and a real equilibrum could exist only during a short period. Onshore gales whip destructive waves and strength the rate of backwash. Controversially offshore wind causes the material move onshore. A beach formation by a catastrophe, like a storm, might create a well formatted and strong shore profile. Beach removal by such a catastrophe takes a long period to be normalized by controversially forces, if it could be recovered at all (Holmes 1977: 808-816, Uusinoka 1981: 60).

Winter ice deformates shore profiles. Ice thrust processes on sandy shores push ramparts on gently sloping shores. On stony slopes stone ramparts are formed. Generally roots of these ice deformed formations, stone belts or boulder belts, are at a little higher elevation than "normal" water level (Hellaakoski 1922: 24, 1932: 6).

ALESTALO & HÄIKIÖ 1977: 64

Fig. 2

Alestalo and Häikiö discovered that rising water (a flood caused by melting snow) causes ice thrust formations to extend furthest from the mean water level in vertical and horizontal direction. In some lakes they have observed highest sections of shore ramparts to reach as far as 1.5 - 2.5 m above the mean water level. Like catastrophe formations caused by storms also such ice born formations will probably remain unaffected a considerably long time. On gently sloping shores rising water caused opposite phenomena; no deformation occurred at all (Alestalo & Häikiö 1977: 85).

Åse (1980,1984) has investigated marks of eustatichal transgressions from shores of the Litorina sea in central Sweden. He developed a method to distinguish uniform synchronous shore marks caused by a transgression (but no necessary real rising of water due to the neutralizing effect of land uplift, but a delay in regression) from shore marks left by occasional gales. He describes that broad terraces that can be followed or traced over large areas and which appear very frequently on slopes facing in all directions must be considered indications of stagnant or slightly rising water level. The preservation of a sound terrace (i.e. a shore cliff and a shore floor terrace; noticed by author) is possible because of relatively fast shore displacement followed the formation.

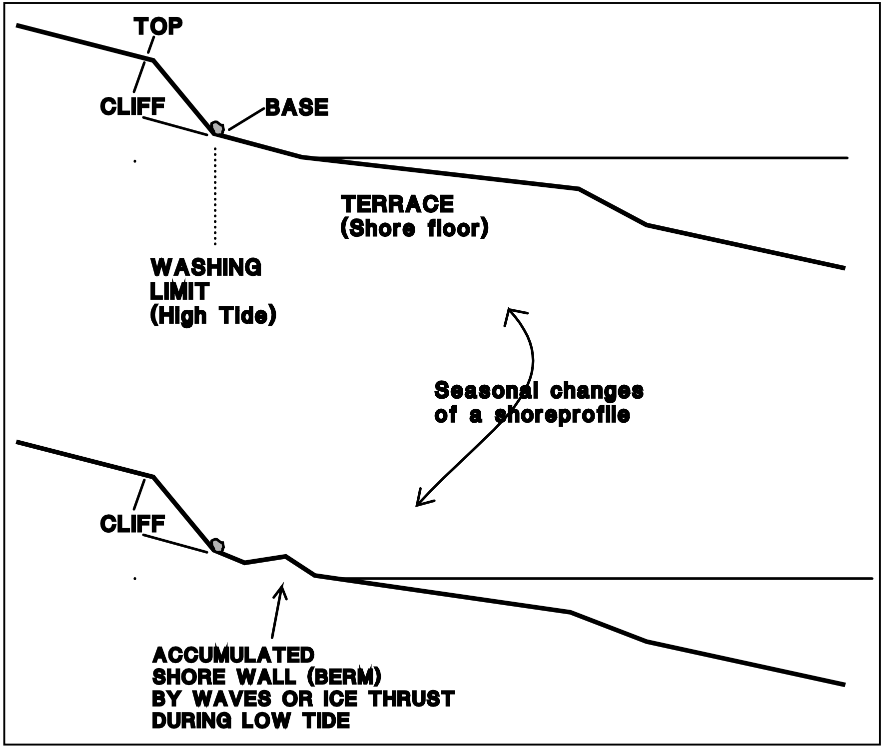
Åse surveyed shore marks on slopes of eskers and ranked them in a scale of 1-3. Then he presented these weighted observations in histograms (values that are close to certain land uplift isobase are in the same diagram), where in the x-axis is the elevation in 1-2 meters' intervals. The sum of unit values is in the y-axis. In resulting histograms (frequency deviations) transgressions were seen as a "spikes", an accumulation of unit values. Diagrams from different isobases was then compared and corresponding elevations of transgression shores were connected. The spikes, uniform accumulations of the Litorina shores, were then attached to known Litorina phases.

Åse points out that it is hard to tell whether a single ancient shore mark on the slope of an esker is formed during rising sea level or during stillstand or even during slightly shrinking water. That have to be analyzed by stratigraphical investigations (Åse 1984, also Uusinoka 1981: 62).

Åse has observed that corresponding synchronous shore terraces of the Litorina sea are at a little higher elevation on a steeper side of an esker than on a gently sloping side (1984: 136).

Varjo (1964) has investigated the recent shore morphology of lake Puruvesi in eastern Saimaa. He observed a clear correlation between the width of the open sea in front of the shore and the elevation level of the beach scarp (i.e. the base of a cliff) from the average normal water level. On erosion shores beach scarp is situated generally at higher level adjoining wide open sea and at lower level by narrow waters. Generally the base of a cliff is at little higher elevation than the mean high water level, that is in Saimaa about 30 cm above mean normal water level. The average of differences in beach scarp's elevation level from the normal water level is about 40 cm when the extend of open sea rises from 200 m to more than 15 kilometers in front of the beach. This difference of elevations of beach scarps comes from the differences of the heighst of possible highest wave, that can reach to the height of 0.6 m at narrow waters and to about 1.5 m at wide open waters. On sandy shores the beach scarp is generally at lower elevation compared to till, gravel and boulder shores. The beach scarp elevation above mean water level varies on the shores of Puruvesi from 20 cm to 90 cm (Varjo 1964: 42-47). The average difference above and below mean water level of short term annual highest floods and lowest tides was about 1.2 meters during 1901-1950. These temporal floods and low waters did not affect considerably to the elevations of beach scarp nor to the elevation of "strandwaldgrenze" (Varjo 1964: 37-38).

Fig. 3. A well-formed shore on a sandy slope. Combined according to Hellaakoski (1922: 26), Varjo (1964), Holmes (1977 : 811) and Aartolahti (1979: 85):



(Base of the cliff = "beach scarp", German = "Ansatz des Kliffes", Swedish = "strandhak", Finnish = "äyräs" or "törmän tyvi")

Different local conditions affect to the shape of the shore profile during different seasons: an angle of slope, a shape of slope, soil compounds and granularity, extent of open sea, wind directions, weather conditions etc. Anyway, shore deformation on sandy slopes might be quite fast in favorable conditions.

3.2. Shore profiles of transgressive and regressive water level

Shore profile formations in this chapter (figs. 4-8) are based on conclusions i have drawed from previously cited papers and from some practical tests. Tests were constructed in a baby pool filled with sand that was molded to demonstrate shore slopes of different gradients. These tests were not strictly scientific, since i did not commit exact measurements. Test observations were made only by eyes and rough measurements. However, resulted shore profiles in figures 4-8 exists also in real nature, in forms of different combinations and variations due to local conditions.

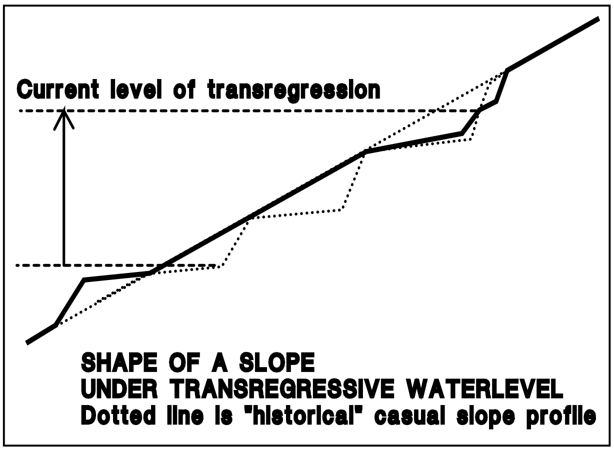


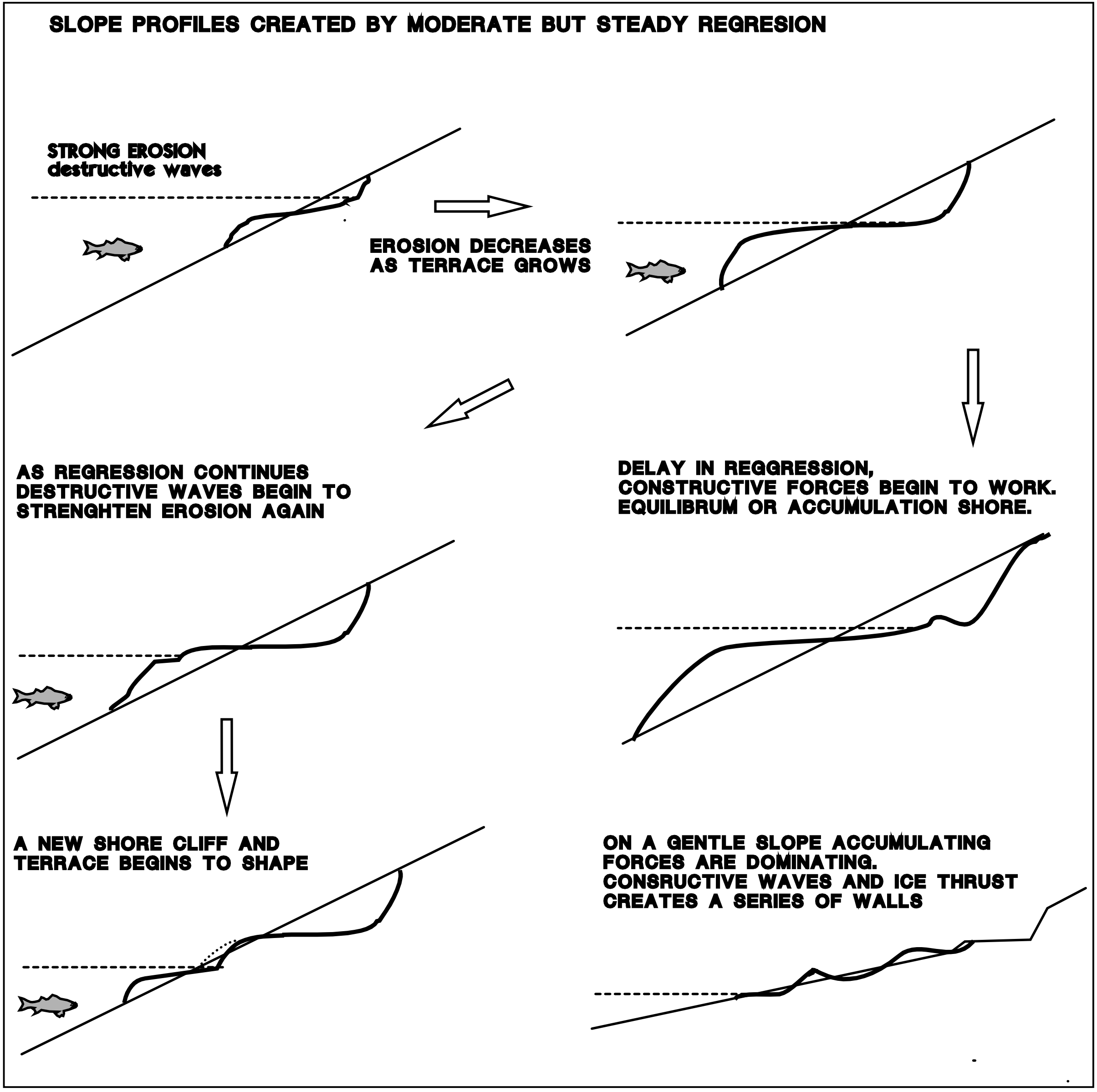
fig 4

Transgerssive water level do not affect considerably to the resulting shape of a slope. Rising water wears down a slope just at that level where the shore line currently is situated. The eroding cliff "climbs" up hillside and backwash of the material fills previous cliff. If the transgression is continuous no equilibrum shores nor accumulate shores could exist. On quite gentle shores during slow regression rate marks of temporary accumulation walls and ramparts will vanish due to washing of rising water. The steeper is the slope the deeper is the "shore hole" in the side of an esker. Waves are more destructive on sheer slopes and thus erosion is faster than on gentle slopes. It seems also that the inclination of a hill side slope does not affect to the shape of the resulting slope **under** transgressive water level. Evidently only marks and formations of the highest shoreline can survive during or after a transgression. If the transgression delays or a violent storm occurs, a smoothened sign of that shore formation might stay on a slope profile below transgressive water level. The slope profile of an esker is at almost virgin condition after transgression, except the scar cutted by the highest shore level.

According to pool tests the shape of a cliff caused by transgression is quite steep and sharp, regardless of the gradient of the slope. On steep slopes the eroded cliff was higher than on gentle slopes. The highest water level was during rapid transgression at near the top of the currently eroding cliff, at considerably higher level than the base of the same cliff. According to this observation the shore mark, the base of the cliff, originated by a transgression do not show the highest water level but the level somewhat below the highest water level. This shore formation is then further affected by regression of water, that doubtless will more or less distort the original transgression profile. Scenarios of resulting transgression-regression shore formations are described in figures 7 and 8.

Regressive water level cuts its marks to slopes of an esker. The shape of a shore profile denies on the original gradient of the slope and the speed of the regression:

Fig 5



Steady continuous regression will produce a step-like series of cliffs on the slope of an esker. This kind of well-preserved "shore-steps" can be seen in many places around Lake Saimaa. During the leveling work of cliffs in 1992 we did not measure the inclination of slope nor the horizontal distance from lowest cliff to highest cliff. An exact inclination of an original slope that has deformed to step-like cliff series could not be calculated from collected data.

A rough estimation of the sloping gradient of step-like hillsides varies from 5° - 15° (/360°). On steeper slopes cliffs will exist more randomly, terraces are narrower and cliffs higher than on more gentle slopes. When the gradient of hillside decreases to five degrees or less, accumulation formations will exist. Sometimes accumulation walls exist in similar step-like sequences like cliffs. The height of a single cliff varies from 0.5 m to 1.8 m in step-like cliff series formations. Most common height of a single cliff is about 1 m. General trend seems to be that the deeper is the slope the higher is a single cliff. When the inclination of a hillside rises over 15°, shore cliff serieses could not have been formed and cliffs will become high and infrequent.

Estimated horizontal widths of continious cliff serieses from the lowest cliff to the highest cliff deviates from 20 to 100 meters and accordingly elevation differences varies from 5 to 10 meters. The sloping angle of a single cliff is different matter and not discussed here.

Shore profiles of regressive water level on a sheer slope:

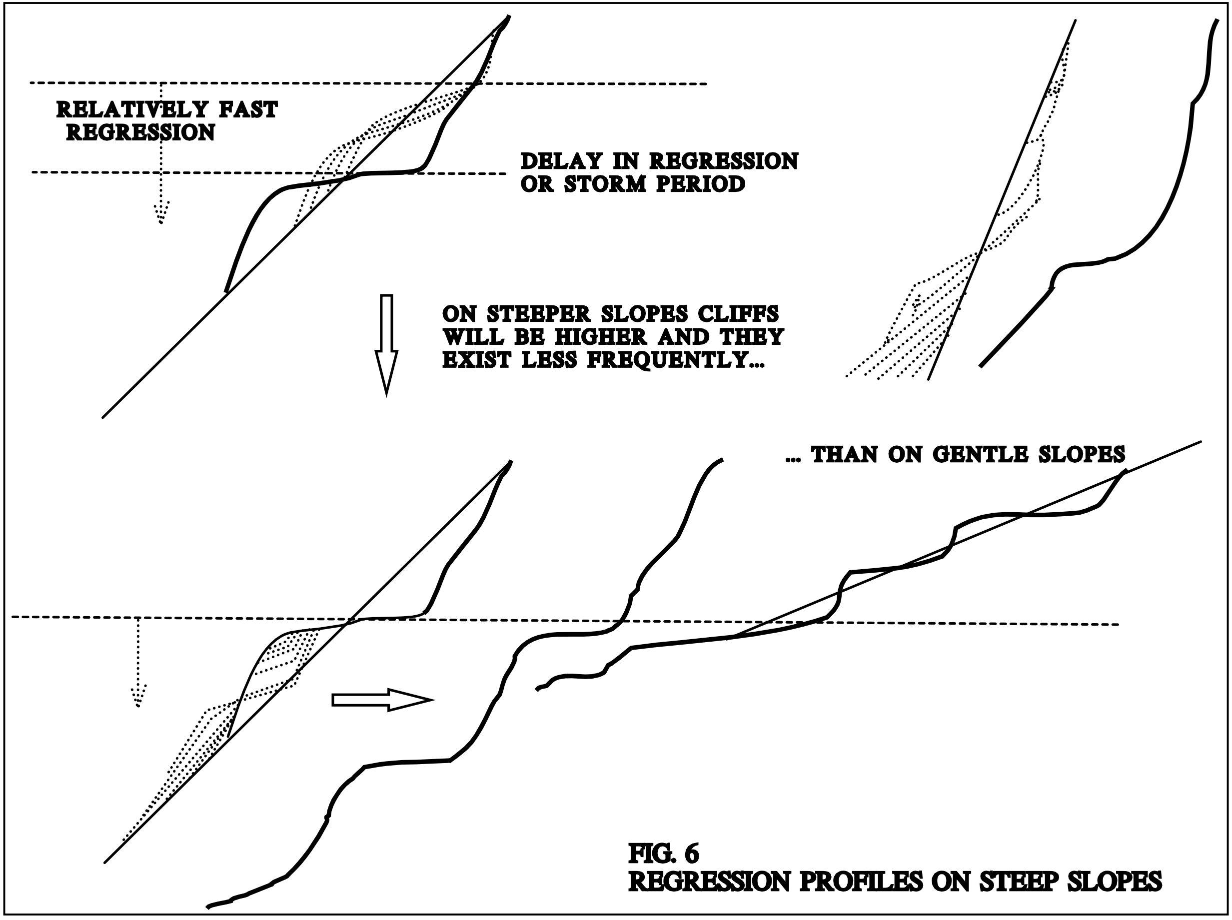


FIG. 6
REGRESSION PROFILES ON STEEP SLOPES

It is worth to notice that during "pool tests" the highest transgression shore was always most impressive and clearest shore formation. However, heavy and long-term storm (i.e. waves) during continuous regression might create as magnificent formation than the highest shore is. It is obvious that delays in regression or temporary arise of water level will also erect the shore profile.

3.3. Formation of the highest shore

As i noted before, a beach scarp indicating the highest shore level does not essentially represent the highest water level. In scenarios represented in figures 7 and 8, the highest beach scarp is more or less below the highest water level. Only in the case of very slow and steady transgression the highest beach scarp might show real highest water level. Final position of the highest cliff is determined by regression after transgression. If regression halts above the original transgression-born beach scarp, it will be over deposited and destroyed. It is quite possible that **the highest cliff is actually a mark of the first delay in regression**, if not a mark of the last delay in transgression. **Fig. 7**

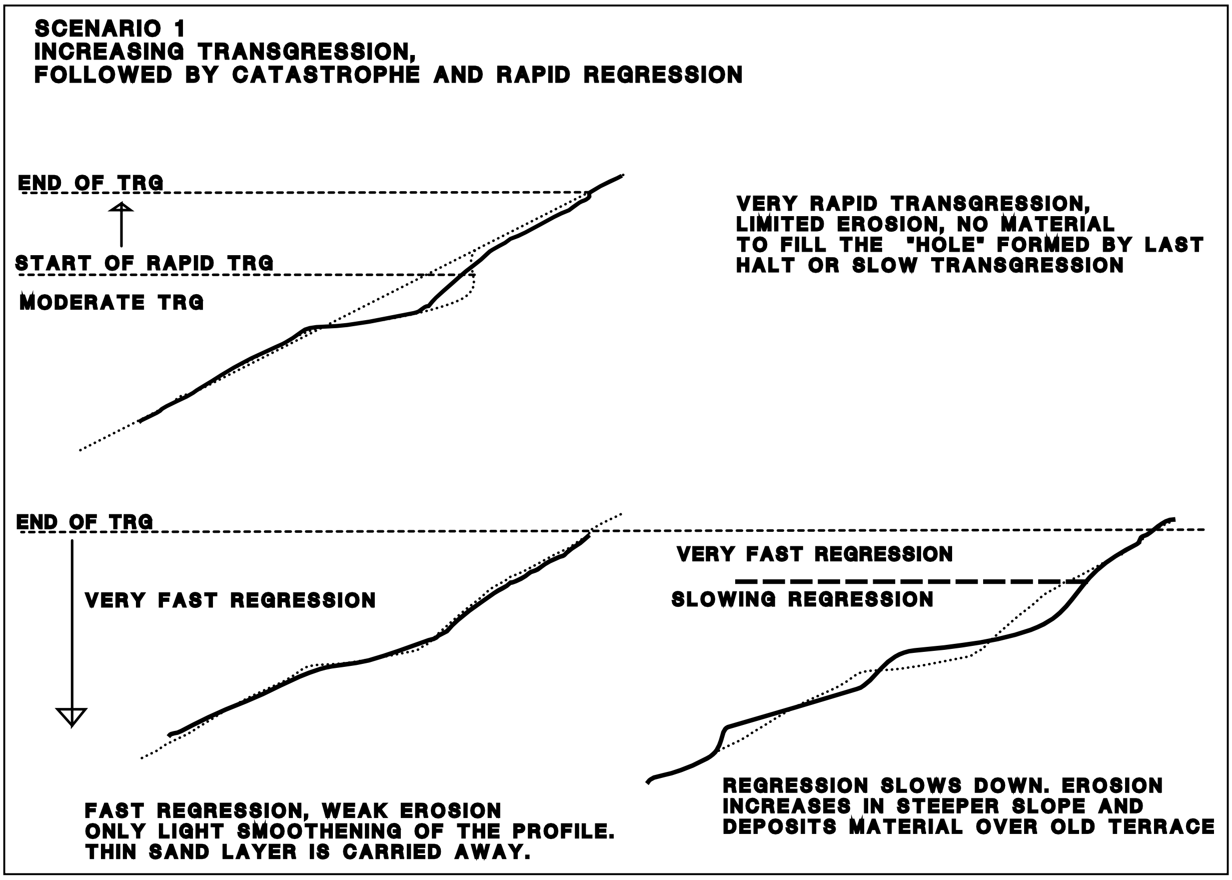
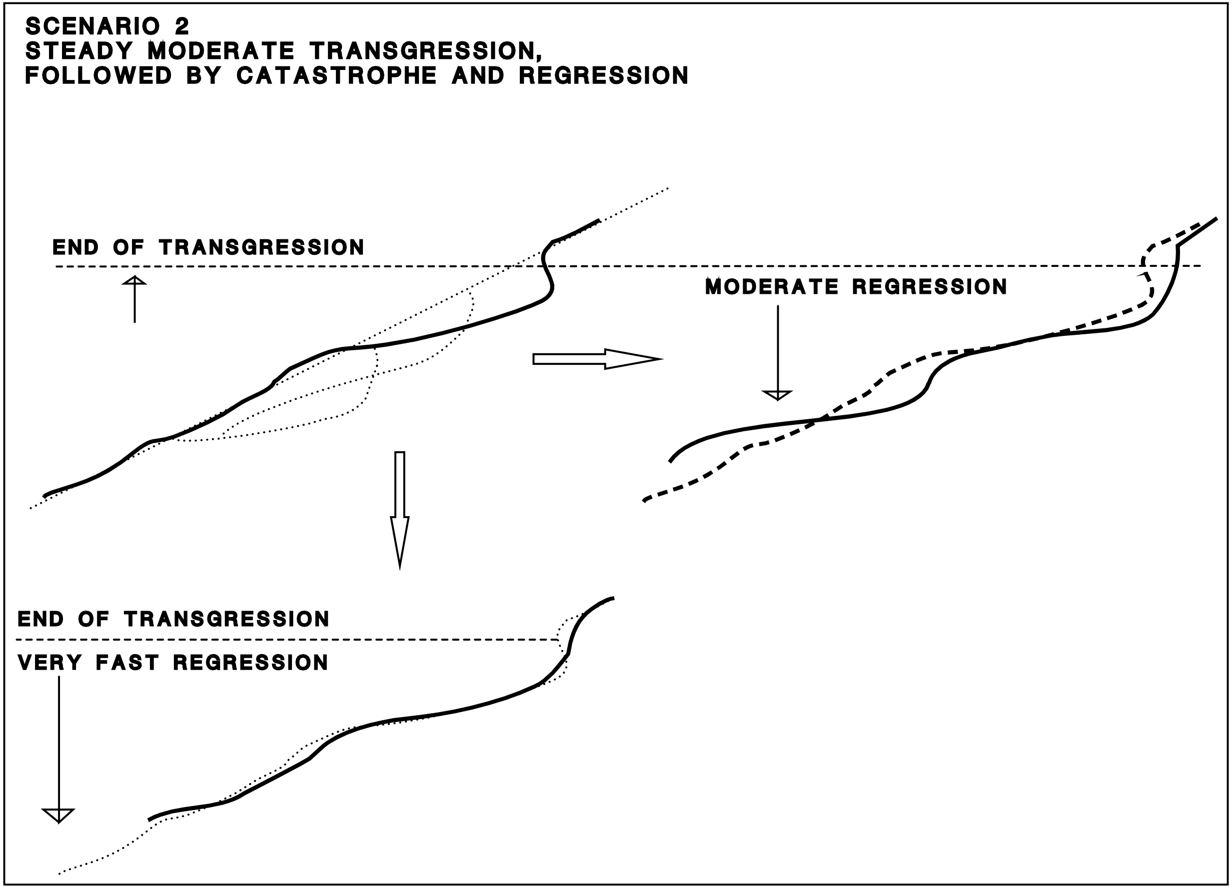

SCENARIO 1
INCREASING TRANSGRESSION,
FOLLOWED BY CATASTROPHE AND RAPID REGRESSION
END OF TRG
START OF RAPID TRG
MODERATE TRG
VERY RAPID TRANSGRESSION, LIMITED EROSION, NO MATERIAL TO FILL THE "HOLE" FORMED BY LAST HALT OR SLOW TRANSGRESSION
END OF TRG
VERY FAST REGRESSION
FAST REGRESSION, WEAK EROSION ONLY LIGHT SMOOTHENING OF THE PROFILE. THIN SAND LAYER IS CARRIED AWAY.
VERY FAST REGRESSION
SLOWING REGRESSION
REGRESSION SLOWS DOWN. EROSION INCREASES IN STEEPER SLOPE AND DEPOSITS MATERIAL OVER OLD TERRACE

Fig. 8


SCENARIO 2
STEADY MODERATE TRANSGRESSION,
FOLLOWED BY CATASTROPHE AND REGRESSION
END OF TRANSGRESSION
MODERATE REGRESSION
END OF TRANSGRESSION
VERY FAST REGRESSION

4. Land uplift

Land uplift has been ongoing in Finland since deglaciation. The rate of the land uplift is usually displayed as contour maps, where points of similar quantity of land uplift are connected with contours. The rate of the land uplift is constantly decreasing. The directions of land uplift contours that presents the inclination of crust is supposed to have been likely the same all the time (Donner 1976: 187). Thus it is also probable (but not sure) that the difference in land uplift between different points have been the same and that the distances between contours have been the same (or about the same) through the time.

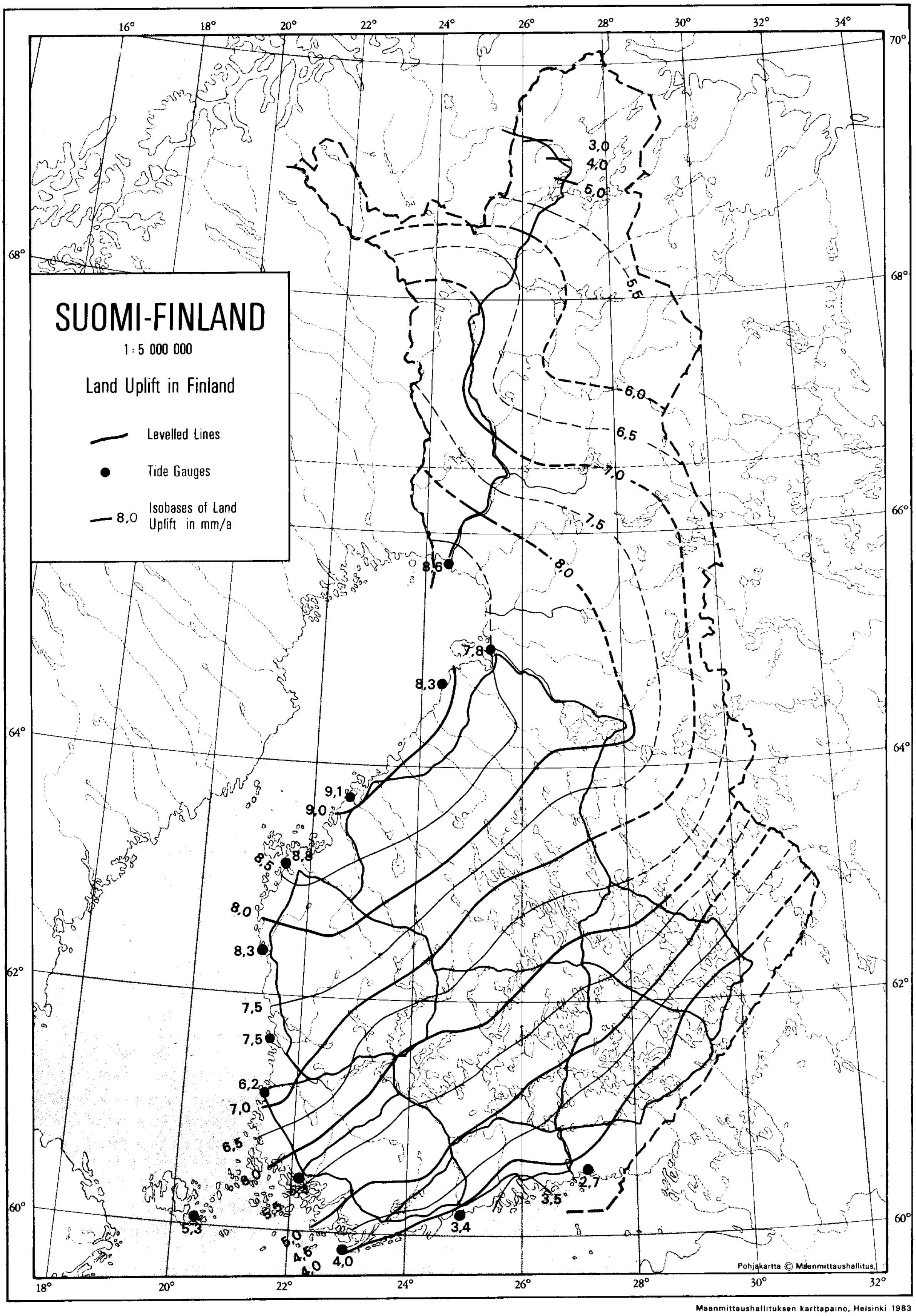
Suutarinen has recomputed the land uplift values in 1983. The basic data was the same than in Kääriänen's original calculations in 1966. Land uplift contours are somewhat different in these presentations. Contours in the map of Suutarinen (Map 2) are smoother than in the map of Kääriäinen (Map 3) and they are also located slightly differently. Differences of the land uplift values between these two calculations are greatest just in southeastern Finland. In the eastern part of Saimaa, east side of the zone from Ruokolahti-Sulkava-Savonlinna, uplift contours are significantly different in these two maps. In both maps contours begin to curve otherwise and distances between contours vary from those in western side of the mentioned zone. In Suutarinen's map this difference between western and eastern side of southern Saimaa is not so dramatic than on Kääriäinen's map. This difference, whatever it really is, can be seen in previously cited trend-surface investigation of Saarnisto in 1972.

The investigation area of this study is between the 3.0 mm/year and 5.0 mm/year land uplift contours in Kääriäinen's map. Contours in the map of Suutarinen does not extend to most southeastern parts of the investigation area. The NE-border of the investigation area is about the same than 5.5 mm/year contour in Suutarinen's map. The exact value of land uplift in certain location and time is not important data from the point of view of this investigation. What matters is the difference in land uplift rate between two points. When these points are projected to a distance diagram the distance between land uplift contours is significant subject. The difference in land uplift rate between Taipalsaari (north of Lappeenranta) and Mikkeli is according to Kääriäinen about 1.2 mm/year and according to Suutarinen about 1 mm/year. Between Savonlinna and Varkaus the difference is 1.8 mm/year and respectively 1.5 mm/year. These differences have been estimated from large scale isobase maps and thus they are in practice hardly noticeable.

It is also perceptible that the smallest land uplift in the whole Saimaa region is just around the mouth of Vuoksi (Map 3, contour 2.8 mm/year), and it is not as small in any other shore of Lake Saimaa.

Map 2

Land uplift isobase map of Suutarinen 1983

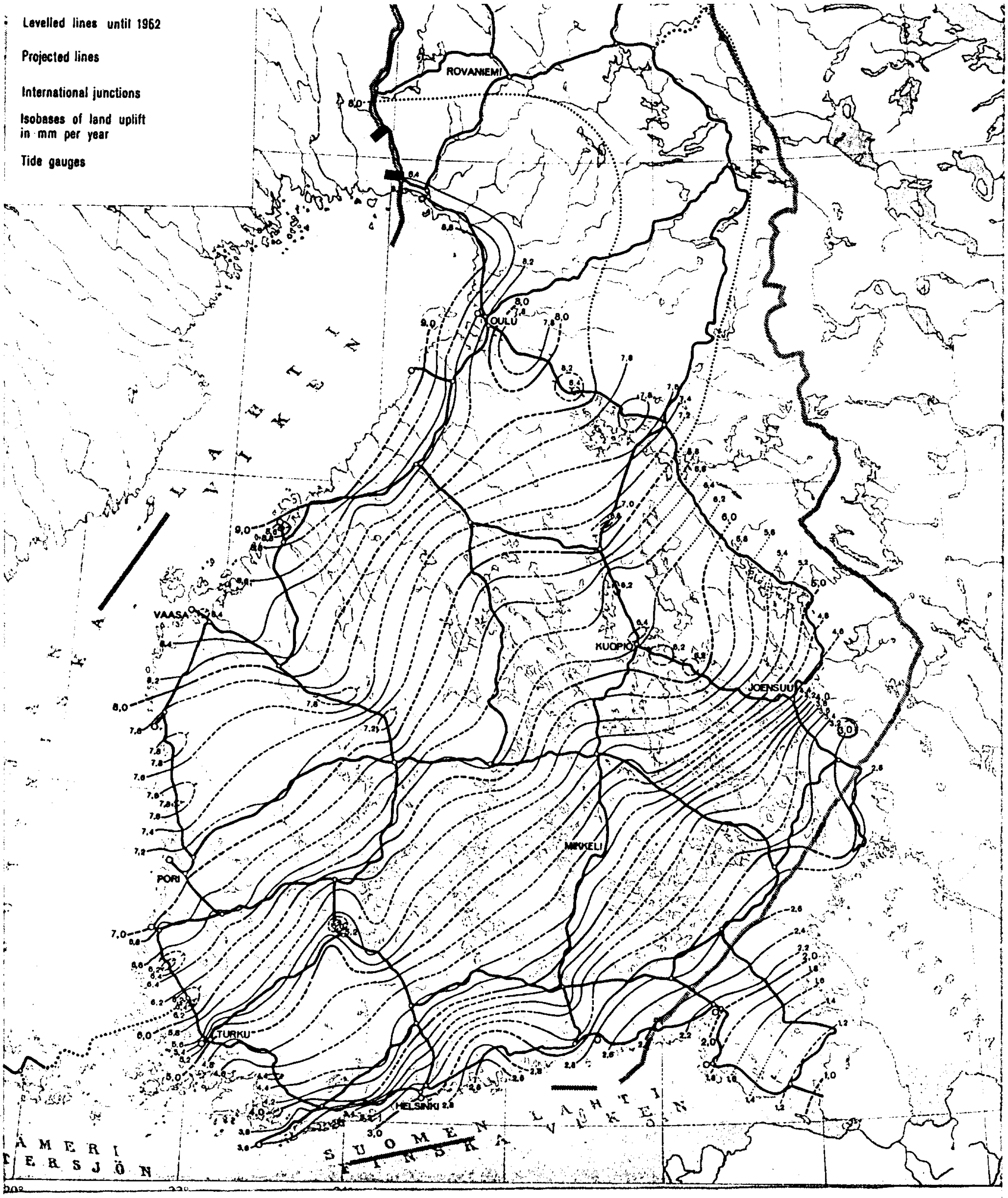


Maanmittaushallituksen karttapaino, Helsinki 1983

Base line of this study is red line

Map 3

Land uplift map of Kääriäinen 1966.



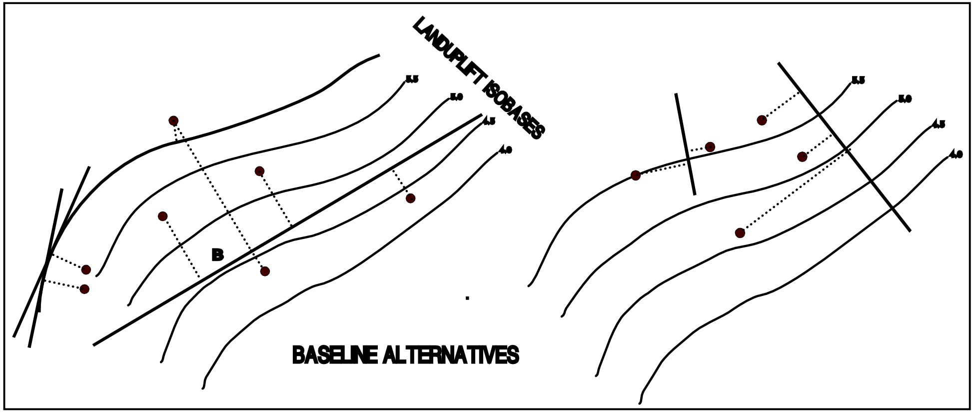
5. Distance Diagram

In a distance diagram the elevation of a shore is projected to y-axis (vertical axis) and the distance from the baseline to x-axis (horizontal axis). The direction of distance measurement is at right angle to the selected baseline. In distance diagram the present situation (i.e. shoreline) is straight and horizontal line. Synchronous ancient shorelines will come up as inclined lines (or curves as well) when shore marks of the same age are connected. The older is a shoreline, the greater gradient it will have in a diagram. A good overview of constructing a distance diagram is given in Donner 1976.

There is many ways to project distance values to x-axis and to settle a baseline. Siiriäinen (1969) used curved baseline that followed smoothened to a certain land uplift isobase. In Siiriäinen's studies the investigation area was the whole Finnish coastline of the Baltic Sea. In such a case the baseline was a compromise, that would take on account the curving land uplift isobases over large and wide area. Saarnisto used as a baseline a straight line that was at right angle to well known Great Lake Saimaa isobases and at the same time at right angle to the main trend of present land uplift (Saarnisto 1970: 17). Shore observations were projected to that line and the value of distance was read from the baseline itself. Saarnisto points out that the ancient directions of land uplift isobases would be conceivable but GLS isobases are based on huge and sound material and by that sense the use of a baseline or several baselines that follows strictly present curved isobases "... *would lead to irregularities in the geological shorelines because of the irregularity of the isobases, but that is something that the regular system of Suursaimaa (GLS) shore would not support...*".

The problem of curved isobases is not very significant in the area of this study, especially in the view of land uplift isobases of Suutarinen. It has to be kept in mind that isobases in these land uplift maps are calculated ones, and they are exact reality only at leveling points.

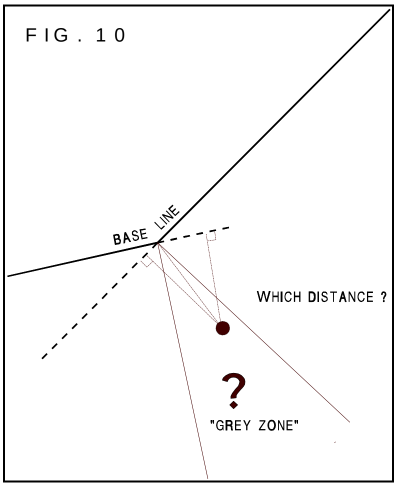
Fig 9.



5.1. Baseline, x-axis

The baseline of this study is determined as a straight line that follows roughly Suutarinen's 5.0 mm/year isobase. This isobase curves slightly near Mikkeli and Outokumpu. These bends of the isobase are on edges of the investigation area. I examined first a three-part baseline, that declines at these mentioned stretching points of the 5 mm/yr isobase, following fairly strictly the isobase contour. This lead to some difficulties in measuring distances of observations which were near the angle-zone of the tilting baseline (fig. 10). The resulting distance diagram and later estimation process while searching synchronous shore levels did not lead to satisfactory result. A straight line proved to be better solution than a tilting baseline, as Saarnisto has suspected. The selection of the baseline is critical decision, that will considerably affect to the resulting distance diagram.

FIG. 10



A baseline of the same direction with land uplift isobases instead of a line perpendicular to isobases was choosed due to easier calculations of distances. It is also easier to divide the investigation area into several zones perpendicular to isobases if we want to observe the influence of curving land uplift isobases in different areas. In the future it is aimed to test the effect of strongly curved land uplift isobases in eastern Saimaa, shown in Kääriäinen´s map, and also other irregularities in land uplift isobases to the distance diagram.

The baseline is tied to coordinate system used in Finnish base-maps ("yhtenäiskoordinaatis-to"). The baseline goes from the coordinate point x 6818 26, y 3498 52, that is located in SW corner of the investigation area in the border of Mäntyharju and Ristiina at Suuri-Ruotamo lake, to the point x 6958 25, y 3628 65 that is located between Joensuu and Outokumpu at Viinivesi Viitalahti. The formula of the baseline in the coordinate system was calculated. All data, including coordinates, elevation data, artifacts etc. of leveled sites is stored in a computer database. The distance of a site from the baseline was measured automatically by computer.
The exactness of calculated distance value is less than +-50 meters. This is more than reasonable. Many sites are larger than that, also in right angle direction to the baseline.

The coordinates of previously founded sites were taken from investigation reports. Some calculated distance values appeared to be crazy. Impossible distance values lead to false coordinates. Distances were then inspected roughly by measuring them manually from the 1:400.000 map. About one coordinate pair out of 25 was documented falsely enough to be noticed in this way.

The baseline is in the zero point of the x-axis of the distance diagram. Minimum distance of this study is -30 km and maximum distance is +90 km. The Mouth of the river Vuoksi is at the distance of +90 km from the baseline, and the rapid of Varkaus is at the distance of -29 km. The length of the x-axis is thus 120 km. Ancient Matkuslampi outlet is at the distance of 12.6 km. There is a 42 km wide zone (1/3 of the whole scale) where, according to earlier investi-gations, the highest GLS-shore is older than rest of the area and also in different more sloping gradient. The tilting axle is at the distance of Matkuslampi. To the left of that the known GLS gradient is about 0.140 m/km and to the right about 0.105 m/km. The difference of the altitude between these two gradients is supposed to be at -30 km's distance about 1.5 m.

5.2. Elevations, y-axis

Leveled sites were choosed mainly on following respects:

- clear shore formation, visible base of the cliff
- site is situated on the top of the cliff
- identifiable ceramic finds from the site.
- ceramics could be connected exactly to a certain cliff.

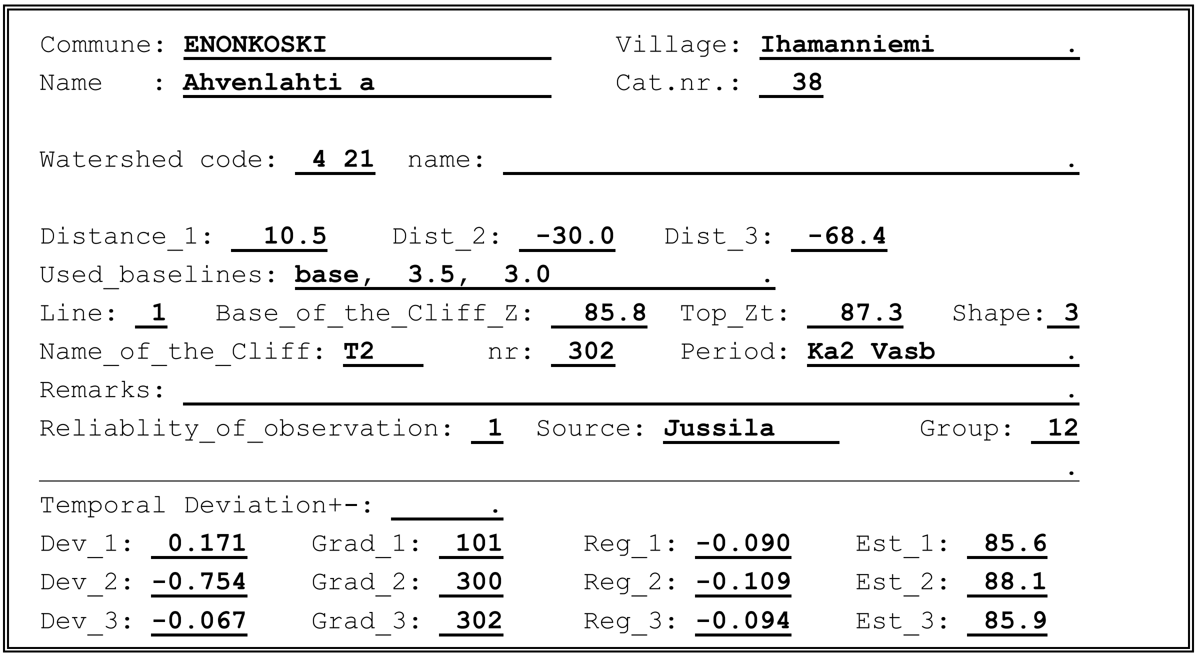
All mentioned aspects were not fulfilled in every leveled site. On a site all cliffs and other shore formations which situated between the GLS-shore and the present water level were leveled. Sometimes leveling reached well above GLS-level just for sure. In some sites leveling was restricted to only one or two cliffs due to modern constructions which have (probably) deformed the original morphology. The base and the top of a cliff were levelled. A schematic slope profile was drawd, to which is marked leveling values. In these profile drawings is presented the shape of the formations, but unfortunately not exact vertical dimensions of a slope or a cliff. The vertical scale of the slope profiles was rough. Same phenomenon (i.e. root of the cliff) was levelled several times from different points. Leveling was started from the current water level of Lake Saimaa. The exact current water level was asked by a mobile phone from the automatic phone answerer of measuring stations in Lauritsala near Lappeenranta and Arvinsalmi south of Joensuu. Water level was also asked from the waterwork of Savonlinna. At some sites official marked elevation points was used as a starting level.

Into the database was stored the mean level of the base of the cliff and lowest level of the top of the cliff, if it exists a site on that cliff. If there was no site on the cliff then the mean value of the top of the cliff was stored. The shape of a single cliff was stored in a scale of three values: 1 = very sheer, 2 = fairly sheer, 3 = gentle.

Ceramics that have been found from leveled sites were discovered. The ceramic period dating was stored into connection with the cliff on what it was founded. This appeared to be difficult in many cases. Several sites were found during quick inventing surveys. Sites are often quite large and they might reach over multiple cliffs. It was sometimes impossible to tie certain ceramics into a certain cliff afterwards. The location information of finds was sometimes so general and rough, that it was impossible to locate a site to a particular cliff and even to locate a site at all. Documents of prospecting and discovering surveys are often lacking suitable information about shore formations on the site. Even excavation reports ignore documentation of ancient shores or the shore information is hidden in maps and documents in such a way that it is impossible for outsider to distinguish it.

These difficulties came into light during the field work. In all sites we visited, several test pits were dug and open soils were thoroughly investigated to get dating material, mainly ceramics. In many sites we succeeded to find enough in-situ material to locate ceramics exactly on a specific cliff. A great help in locating of sites was given by archaeologist Timo Sepänmaa from Savonlinna museum, who has also found many of the sites in the area. Database includes also leveling data collected by Siiriäinen and Carpelan in early seventies.

Fig 11. A database card of cliff observations. It includes data and results of regression analyses (originally in Finnish). Cliff file is part of large site database, that consists of several property files, like cliff data, connected to single site object.



```
Commune: ENONKOSKI                    Village: Ihamanniemi          .
Name   : Ahvenlahti a                 Cat.nr.:  38

Watershed code:  4 21   name:                                       .

Distance_1:   10.5     Dist_2:  -30.0    Dist_3:  -68.4
Used_baselines: base,  3.5,  3.0                .
Line:  1   Base_of_the_Cliff_Z:   85.8   Top_Zt:   87.3    Shape: 3
Name_of_the_Cliff: T2       nr:  302     Period: Ka2 Vasb           .
Remarks:                                                            .
Reliablity_of_observation:  1  Source: Jussila          Group:  12
                                                                    .
Temporal Deviation+-:       .
Dev_1:  0.171     Grad_1:  101      Reg_1: -0.090     Est_1:  85.6
Dev_2: -0.754     Grad_2:  300      Reg_2: -0.109     Est_2:  88.1
Dev_3: -0.067     Grad_3:  302      Reg_3: -0.094     Est_3:  85.9
```

The leveled elevation of a beach scarp, a base of the cliff, is important data, that is represented in distance diagrams. To the accuracy of leveling information (the value in y-axis of a distance diagram) affects most the determination of the base of a cliff. In schematic shore profiles seen on figures 4-8, drawd beach scarp is clear and easy to resolve. In reality it is not always so easy. A tiny movement, a couple of decimeters, of a measuring point towards the slope might change the z-value tens of centimeters. Thick organic bottom layer, peat and herb vegetation and roots of trees affect to the decision and to the leveled elevation of a beach scarp. Experience will help in making decisions. Leveling values measured by different people might not be strictly

comparable. That is why i always used myself the measure stick and decided the exact leveling point as others read the leveling machine. In this study there is leveling data from three different men (plus data of Siiriäinen and Carpelan). The compatibility of levelings among these three groups was tried to achieve by training and working together for some period.
The error margin of leveling caused by the determination of the beach scarp is about +-20 cm.

The exact water level, the starting point of levelings, was not exactly known just at the working area. The differences in water level between official water level measuring stations during the field work period varied about 16 cm from Lauritsala to Arvinsalmi. The water level value that was used as a starting level was approximated from the two nearest measuring points, or only from the closest point. Greatest difference of water levels between two nearest measuring points (Savonlinna-Lauritsala) was 16 cm, generally about 10 cm. The error margin of the starting level is about +-7 cm. This error is greatest in the northern Puumala and Ristiina district. Water level changes from spring to autumn seen in table 1, are not necessarily comparable to changes during prehistoric times, since the lake is nowadays under the control of electric power works. The situation that water level is slightly higher in northern part of Iso-Saimaa than in southern part, near the outlet, might have existed also in prehistoric times.

1992	Arvinsalmi	Savonlinna	Lauritsala
10.6.	76.56	76.56	76.40
12.6.	76.54	76.53	76.40
20.7.	76.39	76.34	76.25
22.7.	76.38	76.32	76.22
1993			
08.09.		76.31	76.22
16.10	76.19	76.11	

Table 1
Water level m asl. N60 system

The error margin of leveling work itself is supposed to be +-6 cm. To this is included the error in determining the exact water level (which is not so very easy if there is waves on the shoreline) and reading errors. The total error margin in elevation values of beach scarps is at maximum about +-35 cm. Hellaakoski determined almost the same range (max. +-30 cm) of error for his shore observations (1922: 82).

6. Determination of prehistoric shore levels

6.1. Synchronous shores

If the difference of the elevation of modern synchronous beach scarps varies from 20 to 90 cm due to differences in beach material and extend of open sea. This means a possibility of +-35 cm difference in synchronous beach scarp observations. If we observe the whole Iso-Saimaa area in the same diagram, the natural difference in water level near the outlet and far upstream might be about 10 cm (range +-5 cm). This increases the error margin of the elevation of a synchronous shore to +-40 cm. The previously determined error margin of leveling measurements is +-35 cm. These two elements of error might partly neutralize each other but as well emphasize the error margin.

As a conclusion of different error sources we might state that elevations of synchronous shore indicators are allowed to differ from each other at a maximum of 80 cm at the same distance from the baseline. In other words: *observations of the altitudes of synchronous shore scarps must be within the range of +- 40 cm* from suggested average shore level elevation.

In Litorina shores of Mälar Valley Åse has observed a range of 0.5 - 1 m among synchronous shore observations (1980: 212).

What we mean with the concept of "synchronous" and what is the interference of a "synchronous shore level" in years? This question is discussed more in connection with dating results. Anyway, the Synchronous Shore Level is more or less relative idea.

The uniform and well-developed GLS-shore is accessed to a certain synchronous (in Iso-Saimaa) incident, to the end of the transgression and to the formation of Vuoksi. Earlier investigations (Hellaakoski 1922, Saarnisto 1970) proclaims that weak shore marks under the GLS-shore can not be connected to any clear event nor be arranged to uniform synchronous levels like GLS shore marks.

Cliffs under the GLS level might have been formed due to occasional gales, local or more widespread incidents, occurred during different phases of regression period. We do not have to except to find uniform shorelines that are connected, for instance to a long term (again a relative item) delay in regression, or to marks left behind by temporal transgression, or to any event that is originated by common concurrent phenomena that had effected on every side of the lake basin. Instead we have to try to capture a snapshot, an image of a certain limited time span. We can try to catch almost synchrone shore levels, not exactly uniform series of shore observations. After we have found such shore levels of limited time span, we can try to resolve their rate of synchrony and examine the time scale of a particular "snapshot-shore level".

This would be an easy affair if we just use the well-known and dated GLS-shore level (gradient = 0.105) and modern shore level (gradient = 0.0) as a base level and then calculate the amount of land uplift in the opposite edges of distance diagram during different time intervals between these two known and dated shores. This plain calculating method works well if the only factor in shoreline displacement is the tilting of the crust. But this is not the case in the whole time span between the GLS and the present. The Vuoksi catastrophe itself has caused at least one significant eustathic change to shore levels of ancient Saimaa. We do not yet know if there have effected any other significant eustathic changes or constant eustathic influence to the water level after the GLS-phase.

6.1.1. Periods

The idea of determining of synchronous shore levels in this study is based on the relatively dated prehistoric dwelling sites connected to certain shore cliff. Dating of sites is based on ceramic finds. Nearly all ceramics found from levelled sites were investigated. Used periodic system is largely based on Carpelan (1979, and his special lectures in spring 1993). The identification of ceramics was made in co-operation with Mika Lavento (see Lavento 1992). Identification of the Early Asbestos Ceramics is based on works and advises of Petro Pesonen.

Most ceramic finds from the sites are found during surveying investigations, when artifacts were collected from few test pits or by quick surface collection. Ceramic material is often sparse and very fragmentary. Sometimes material was so odd that periodical identification was entirely impossible. Generally also fairly tiny fragments were identified to a certain period with reasonable (?) certainty. A false identification of ceramics and therefore a false period for a cliff is worth of consideration in this sense. However, these identification errors are assumed to be marginal in quantity and used method will itself expose most glaring errors. If there will exist a systematic identification error of ceramic period, then we must assume that the original relative periodisation of that type of ceramics is faulty or the previously proposed dating limits in relation to other ceramic types are false. The unexpected irregularities in periodisation might also be explained by temporal transgressions, if such have existed.

Since the ceramic material is generally sparse and fragmentary, the true identification of ceramic periods is rather the identification of **features** of a ceramic type. This is the case especially among comb ceramic styles and whitin late Neolithic asbestos ware.

Behind all sources of errors will breathe the basic assumption of shore-bound site. So far we do not know for sure, at least in the Saimaa area, Neolithic hunter-gatherer sites that were not situated very close to the shoreline. The used ceramic groups are supposed to belong to traditional hunter-gatherer cultures. I do not take up the question of economy and subsistence and food sources nor sedentary characterisics of these cultures. Nevertheless we know couple of dwelling sites in Saimaa that were not similarly shore-bound than traditional hunter-gatherer sites. All these non shore dwellings are dated to early metal period according to textile ceramics. Sparse surveying finds from these sites do not differ from clearly shore-bound sites of the same period. One of these textile ceramic bronze age sites is Rantasalmi [35] Lautakangas that is located almost 150 m away from estimated bronze age shore. Ristiina [29] Akanlahti site is located horizontally only about 50 meters but vertically at least 6 m from the estimated shoreline of its age (Sepänmaa & Bilund 1993). These two sites were not yet leveled. Outokumpu [7] Majoonlampi textile ceramic and Sär 2 ceramic site is horizontally at the shore but vertically at least nine meters away on a top of a sheer cliff. This is certainly not a shore-bound site in a sense of utilizing the shore in "traditional" way. At Rääkkylä [7] Pörrinmökki site textile ceramics are found from the same place and levels than Neolithic ware. Find place has not been at the shore since late Neolithic (Petro Pesonen, pers. comm.).

The used periodic system is:

Ceramic group	used abbreviation in this study
Middle Neolithic	**KN.** ("keskineolitikum")
- Early Asbestos Ceramics	**Vasb** ("varhainen asbestikeramiikka")
- Typical Comb Ceramics	**Ka2**[1]
-	if possible then also Ka2:1 and Ka2:2
Late Neolithic	**MN** ("myöhäisneolitikum")
- Late Comb Ceramics	**Ka3**[2], sometimes also non asbestos ceramics with Ka-like texture, but no features of Ka2 and Txt.
- Kierikki Ceramics	**Kie**
- Pöljä Ceramics	**Pöl**, also fragments of asbestos ceramics with no features of other asbestos ceramics groups.
Early Metal Period	**VM** ("varhaismetallikausi")
Bronze Age textile ceramics	**Txt**, **Tom**, mostly **Tomitsa** type textile ceramics, but also Sarsa ceramics at least in one case.
Sär 2 Ceramics	**Luu**, Luukonsaari ware. **Sir**, Sirnihta ware, gene-
Brz. & Early iron age	rally thin well-burned fine asbestos ceramics.
Bronze age ceramics	under the VM-type ceramics is included one fragment parallel to so called Epinneolithic ware of SW Finland, and a piece resembling Morby ware.

The basic definition criterions of features of the Late Neolithic ware are based largerly on Carpelan and Lavento as cited before and also Edgren (1964) and Siiriäinen (1967, 1984).

6.2. Regression analyses

A line representing an ancient shore level in a distance diagram could be adjusted with the aid of regression function of x- and y-axis (distance and elevation). The regression method describes how one variable depends on another. The regression line for y (elevation) on x (distance) estimates the *average* value for y corresponding to each value of x. The regression line on scatter diagram of observations (i.e. distance diagram) goes through the point of averages. Associated with each unit increase in x (distance) the slope of the regression line says how much is the *average* change in y (elevation).

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[1] Traditionally used abbreviation is Ka II. It is easier to use latin number and single string without blanks when searching and querying data from a computer database.

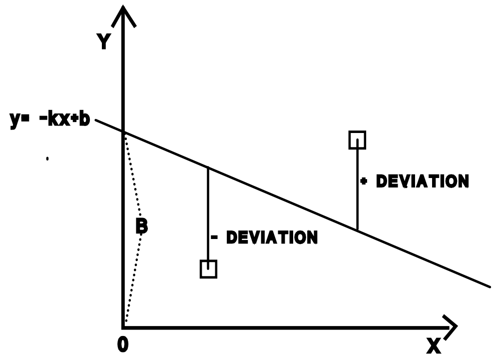
[2] Ka III, as above.

The equation of a regression line is *y = slope * x + intercept.* The intercept of the regression line is the predicted value for y when x is zero. Associated with distance diagram the equation is: *elevation = slope * distance + elevation_when_distance_is_zero.* The intercept value determines the elevation level of the regression line in a scatter diagram.

6.2.1. Method

The correlation coefficient of a regression line that represents an *average* shoreline is calculated from elevation (meters) and distance (kilometers). It is the gradient value of that shore as meters per kilometer. When we have selected somehow (approximately) synchronous shore marks we use these elevations and distances to calculate a correlation coefficient and an equation of regression line for these selected basic observations. Shore marks of the same age are then allowed to deviate from average shoreline +-40 cm. To check this we use a residual plot diagram to visualize the vertical deviation of each observation point. Observations that differ more than +-40 cm will be dropped out from this basic average shore. Then we calculate how much each shore scarp is deviating from the regression line. We can attach all those non-basic points that will match within +-40 cm range to this shoreline. The regression line is calculated again from this modified data set. This procedure is repeated until we have got a reasonable result. Shore scarps that are below the average shoreline have negative deviation value and those above have positive deviation.

Fig 12. A regression line



We can then analyze the reasonability of the calculated shoreline by studying various distinctive values of the regression function. *R.m.s error* is a "standard deviation" of regression; an error of the regression line. In distance diagram it tells how far a typical point is from the line (up or down). About 68% of the points will be within one r.m.s error of the regression line; about 95% of them will be within two r.m.s error. This is a rule of thumb that will hold for many data sets but not all. We can estimate that the resulting line is satisfactory when the r.m.s error of it is about 0.2 meters (i.e. most points are within +-40 cm range).

R.m.s = $\sqrt{1-r^2}$ * *SDV_of_y*. *Coefficient of determination (CoD)* tells how great part of the quadrate sum of y is explained by x (in percentages). it will get a value of 100% when all the points are on regression line.

All descriptions of statistics in this chapter are based on Freedman & al 1991 chapters 8-12, and Mattila 1980 p. 96-106

6.3. Searching of shore levels

6.3.1. Basic data

The raw data material consists of 297 cliffs in 115 sites. On the top of 110 cliffs is a prehistoric dwelling site and from 91 of these sites have found ceramics (Diagram 1)

From this raw data were dropped out all those cliffs that are clearly above the GLS-level. Then cliff documents were investigated critically and all obscure observations were marked out. Among these are cliffs of which might have been disturbed by recent constructions, like roads and road banks. Some observations were marked out due to confusing or otherwise unclear documents, from which one can not be absolute sure about the target of the measurements. In the sites with several different leveled lines, serieses of cliffs, some of these cliffs from different lines were combined. Those "cliffs" that will drop straight to the present water level were adjoined out (or only top of the cliff was leveled). Accumulation walls with no sites on it were dropped out.

After critical examination of observations there was left 218 cliffs in 90 sites. On the top of 84 cliffs is a prehistoric dwelling site and from 65 of these sites is ceramic finds (Diagram 2). The basic relatively dated data set consists of 61 cliffs on 47 sites.

34

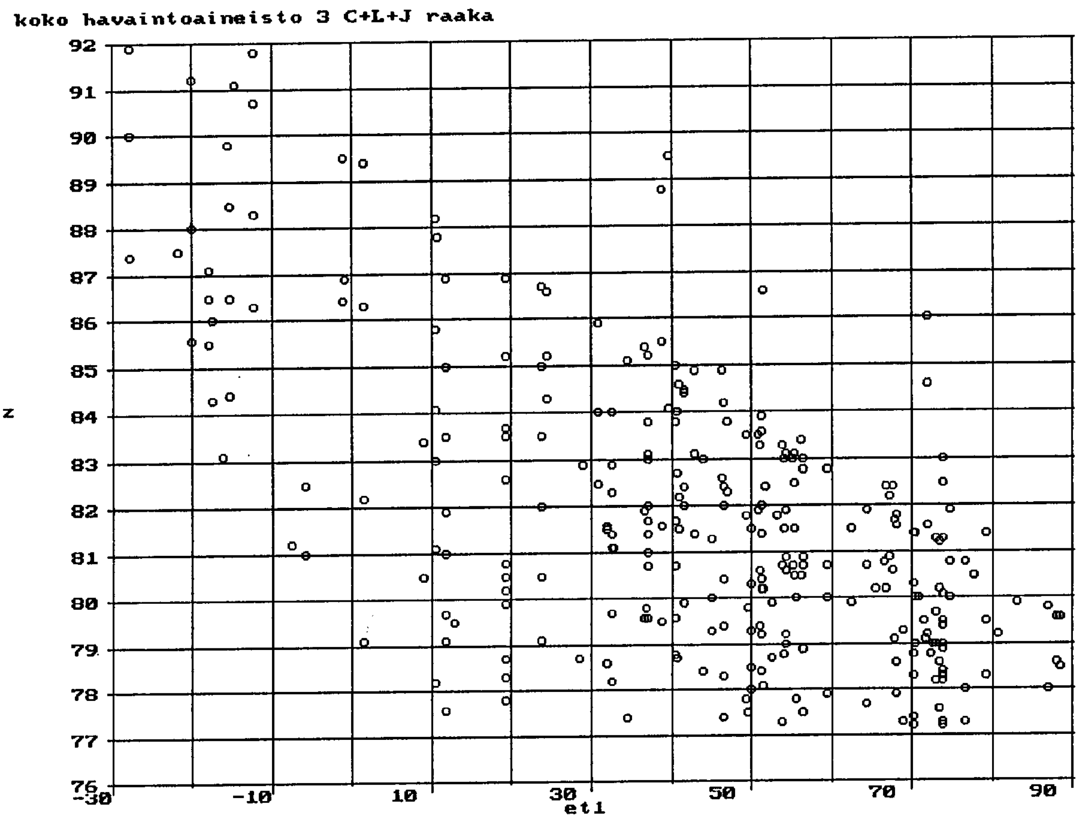


Diagram 1. All raw shore observations, bases of cliffs.

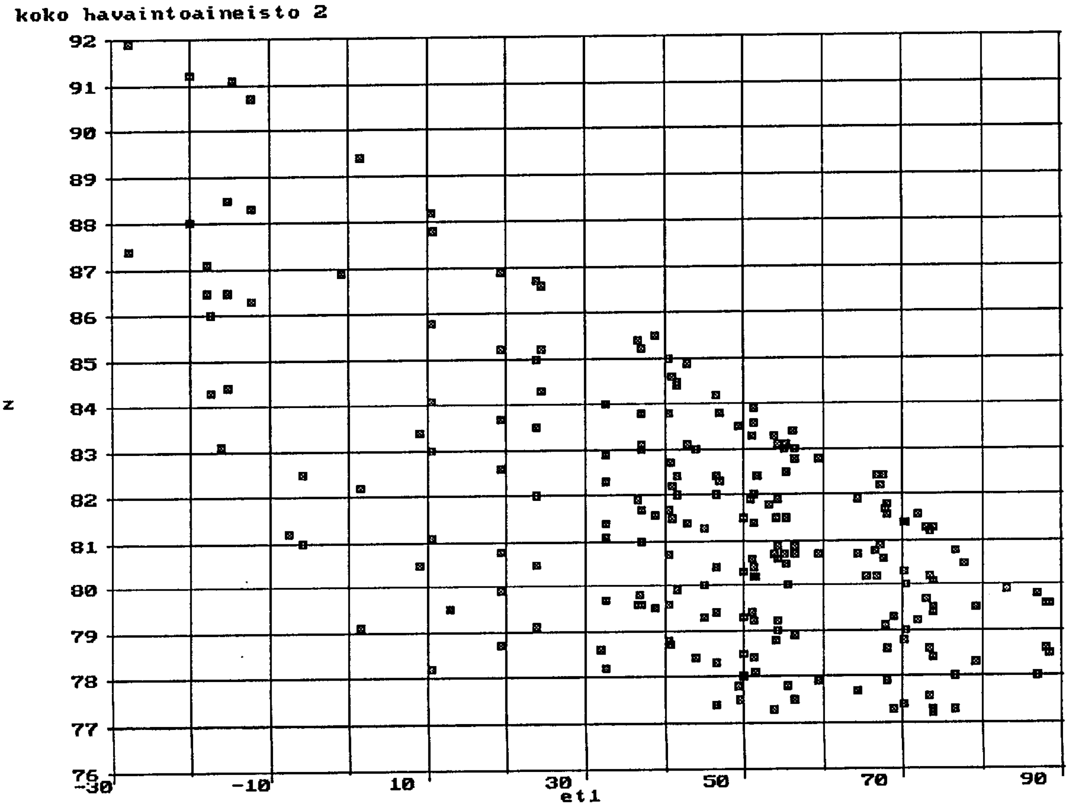


Diagram 2. Modified observation set used in the calculations of shore lines. Cliff bases.

6.3.2. Leveled and dated sites and cliffs

The lists of observation points used in determining the synchronous basic shorelines.

Middle Neolithic, Early Asbestos Ceramics (Diagram 3): 9

Commune	nro	Village	Name	Water basin	Dist. km	Base z	Top z	X co-ord.	Y co-ord.
KERIMÄKI	127	Raikuu	Martinniemi 1	4 18	51.2	83.6	84.0	6881 70	4472 70
KERIMÄKI	87	Paasniemi	Pikarniemi	4 31	42.9	83.1	85.1	6887 94	4467 10
KITEE	10	Niinikumpu	Hiekanpää I	4 39	67.9	81.8	85.2	6881 78	4496 58
KITEE	12	Niinikumpu	Hiekanpää III	4 39	67.2	82.2	84.2	6881 36	4495 13
PUNKAHARJU	3	Vaara	Pahatso	4 18	73.8	81.3		6858 00	4480 80
RÄÄKKYLÄ	6	Täitimänniemi	Mehonlahti	4 31	54.2	80.9	82.2	6898 80	4494 39
RÄÄKKYLÄ	7	Täitimänniemi	Pörrinmökki	4 31	55.3	80.5	82.0	6898 09	4495 12
RÄÄKKYLÄ	7	Täitimänniemi	Pörrinmökki	4 31	55.3	82.5	84.0	6898 09	4495 12
RÄÄKKYLÄ	9	Täitimänniemi	Lappalaissuo 1	4 31	56.1	83.4	86.2	6897 54	4495 78
RÄÄKKYLÄ	15	Jaama	Kivilammensuo	4 31	51.5	80.2	82.5	6901 10	4492 86

Middle Neolithic, Typical Comb Ceramics (Diagram 3): 31

Commune	nro	Village	Name	Water basin	Dist. km	Base z	Top z	X coord	Y coord.
ENONKOSKI	39	Ihamaniemi	Pöytälahti c	4 22	23.9	83.5	85.0	6895 68	4447 86
IMATRA	1	Imatra	Lammassaari	4 11	88.1	78.6	79.8	6789 52	4431 30
KERIMÄKI	59	Jouhenniemi	Kaitasuo	4 18	53.1	81.8	83.7	6869 83	4463 29
KERIMÄKI	76	Raikuu	Raikuunkangas	4 18	50.8	81.9	83.0	6882 80	4473 19
KERIMÄKI	103	Jouhenniemi	Hälvä	4 18	59.5	80.7	82.3	6865 82	4468 33
KESÄLAHTI	2	Purujärvi	Sirnihta	4 18	70.4	79.3	80.0	6864 40	4482 36
KITEE	4	Niinikumpu	Koivikko	4 39	66.5	80.8	81.9	6886 08	4499 00
KITEE	17	Muljula	Sarvisuo	4 31	56.5	80.7	82.2	6897 53	4496 32
PUNKAHARJU	3	Vaara	Pahatso	4 18	73.8	81.3		6858 00	4480 80
PUNKAHARJU	45	Turtianniemi	Lamminniemenlampi b	4 18	73.7	81.3	83.4	6850 08	4472 56
PUUMALA	16	Liimattala	Kotkatlahti A	4 11	45.1	81.3	82.8	6820 43	3562 10
PUUMALA	19	Niinisaari	Syrjäluhta	4 11	50.0	81.5	84.0	6813 83	3562 62
PUUMALA	45	Luukkola	Karkianiemi I	4 11	56.4	80.9	82.2	6813 45	3571 08
PUUMALA	74	Luukkola	Karsikkolahti	4 11	55.4	81.5	82.6	6810 46	3566 88
RANTASALMI	1	Hiismäki	Suoranta	4 21	10.7	87.8	91.5	6877 76	3568 48
RISTIINA	32	Huttula	Hietaniemenkangas	4 11	19.3	83.7	85.0	6821 86	3528 28
RISTIINA	32	Huttula	Hietaniemenk.	4 11	19.3	85.2	86.4	6821 86	3528 28
RUOKOLAHTI	3	Rautiala	Haukpohja	4 11	86.9	78.0	79.2	6797 55	4437 97
RUOKOLAHTI	10	Syyspohja	Anttila	4 11	70.4	81.4	82.4	6809 86	4427 09
RUOKOLAHTI	17	Terävälä	Korosniemi	4 11	77.7	80.5	81.5	6797 00	4424 40
RÄÄKKYLÄ	5	Täitimänniemi	Anninkangas	4 31	55.1	80.7	82.5	6898 75	4495 62
RÄÄKKYLÄ	6	Täitimänniemi	Mehonlahti	4 31	54.2	80.9	82.2	6898 80	4494 39
RÄÄKKYLÄ	7	Täitimänniemi	Pörrinmökki	4 31	55.3	80.5	82.0	6898 09	4495 12

RÄÄKKYLÄ	9	Täitimänniemi	Lappalaissuo 1	4 31	56.1	83.4	86.2	6897 54	4495 78
RÄÄKKYLÄ	11	Jaama	Mikinsuo 1+2	4 31	51.3	82.0	83.0	6900 89	4492 34
SAVONLINNA	45	Tolvanniemi	Porrassalmi b	4 21	36.7	81.9	83.1	6869 98	4439 94
SAVONLINNA	54	Pellossalo	Povenlahti	4 12	66.7	80.2	81.6	6840 76	4453 07
TAIPALSAARI	5	Jauhiala	Konstunkangas	4 11	68.8	79.3	82.1	6781 05	3557 93
TAIPALSAARI	6	Jauhiala	Vaateranta	4 11	70.2	80.3	80.3	6780 70	3559 46
TAIPALSAARI	30	Laukniemi	Syrjälä 2	4 11	64.3	80.7	81.6	6789 82	3559 92

Late Neolithic, Late Comb Ceramics (diagram 5) 11

Commune	nro	Village	Name	Wat. basin	Dist. km	Base z	Top z	X co-ord.	Y co-ord.
KERIMÄKI	127	Raikuu	Martinniemi	4 18	51.2	81.4	82.0	6881 70	4472 70
LAPPEENRANTA	15	Rutola	Hietaranta	4 11	73.4	78.6	79.9	6771 93	3555 67
PUUMALA	13	Rokansalo	Käärmelahti	4 11	41.5	82.0	83.5	6820 64	3557 42
PUUMALA	74	Luukkola	Karsikkolahti	4 11	55.4	81.5	82.6	6810 46	3566 88
PUUMALA	77	Rokansalo	Martikkala 2	4 11	37.0	83.1	84.2	6824 25	3554 66
PUUMALA	79	Lintusalo	Lahdenluhta	4 11	46.6	80.4	81.5	6811 05	3555 49
PUUMALA	85	Huhtimaa	Pistohiekka C	4 11	32.7	81.4	82.2	6829 03	3553 11
RÄÄKKYLÄ	7	Täitimännie.	Pörrinmökki	4 31	55.3	80.5	82.0	6898 09	4495 12
RÄÄKKYLÄ	13	Jaama	Läävälahdensuo	4 31	50.9	80.6	82.7	6901 19	4492 12
TAIPALSAARI	11	Kilpiänsaari	Ketvele	4 11	76.6	78.0	79.0	6784 63	3571 80
TAIPALSAARI	29	Jauhiala	Taipaleenranta 2	4 11	67.8	79.1	80.8	6783 93	3559 16

Late Neolithic, Kierikki Ceramics (diagram 4): 3

Commune	nro	Village	Name	Water basin	Dist. km	Base z	Top z	X co-ord.	Y co-ord.
JUVA	7	Risulahti	Otamo	4 11	24.4	85.2	86.2	6839 18	3551 24
PUNKAHARJU	3	Vaara	Pahatso	4 18	73.8	80.1	82.0	6858 00	4480 80
TAIPALSAARI	11	Kilpiänsaari	Ketvele	4 11	76.6	78.0	79.0	6784 63	3571 80

Late Neolithic, Pöljä Ceramics (diagram 4): 7

Commune	nro	Village	Name	Water basin	Dist. km	Base z	Top z	X co-ord.	Y co-ord.
KESÄLAHTI	2	Purujärvi	Sirnihta	4 18	70.4	78.3	80.0	6864 40	4482 36
KESÄLAHTI	2	Purujärvi	Sirnihta	4 18	70.4	79.3	80.0	6864 40	4482 36
KERIMÄKI	127	Raikuu	Martinniemi	4 18	51.2	81.4	82.0	6881 70	4472 70
PUNKAHARJU	3	Vaara	Pahatso	4 18	73.8	79.4		6858 00	4480 80
RISTIINA	32	Huttula	Hietaniemenkangas	4 11	19.3	82.6	83.7	6821 86	3528 28
RÄÄKKYLÄ	7	Täitimänn.	Pörrinmökki 1+2	4 31	55.3	80.5	82.0	6898 09	4495 12
SAVONLINNA	47	Niittylahti	Niittyranta	4 21	32.6	81.1	82.2	6873 88	4438 06

Early Metal Period, textile ceramics,Sarsa-Tomitsa (Diagram 6): 10

Commune	nro	Village	Name	Water basin	Dist. km	Base z	Top z	X co-ord.	Y coord.
KERIMÄKI	57	Jouhenniemi	Kokkomäki	4 18	54.2	79.2	81.5	6868 37	4463 37
KERIMÄKI	127	Raikuu	Martinniemi	4 18	51.2	79.2	80.3	6881 70	4472 70
KERIMÄKI	127	Raikuu	Martinniemi	4 18	51.2	80.4	81.0	6881 70	4472 70
KESÄLAHTI	2	Purujärvi	Sirnihta	4 18	70.4	78.3	79.0	6864 40	4482 36
PUUMALA	16	Liimattala	Kotkatlahti A	4 11	45.1	80.0	80.9	6820 43	3562 10
RISTIINA	26	Laasola	Kitulansuo d	4 11	12.8	79.5	81.0	6822 28	3519 78
RUOKOLAHTI	11	Utula	Alatalo	4 11	68.0	77.9	78.4	6803 32	3577 43
RÄÄKKYLÄ	20	Täitimänniemi	Huotinniemi	4 31	55.6	77.8	78.7	6897 35	4494 85
TAIPALSAARI	6	Jauhiala	Vaateranta	4 11	70.2	77.4	78.4	6780 70	3559 46
TAIPALSAARI	30	Laukniemi	Syrjälä 2	4 11	64.3	77.7	79.1	6789 82	3559 92

Early Metal Period, Sär. 2 asbestos ware (Diagram 6): 10

Commune	nro	Village	Name	Water basin	Dist. km	Base z	Top z	X co-ord.	Y co-ord.
JOROINEN	11	Kotkatlahti	Rydänniemi	4 21	-16.1	83.1	85.0	6896 66	3549 40
KERIMÄKI	57	Jouhenniemi	Kokkomäki	4 18	54.2	79.2	81.5	6868 37	4463 37
KERIMÄKI	127	Raikuu	Martinniemi	4 18	51.2	79.2	80.3	6881 70	4472 70
KESÄLAHTI	2	Purujärvi	Sirnihta	4 18	70.4	78.3	78.7	6864 40	4482 36
LIPERI	6	Taipale	Hylkylä	4 31	-7.5	81.2	82.0	6949 46	4457 88
MIKKELIN MLK	11	Väänälä	Konnunlahti	4 11	9.1	83.4	84.0	6835 40	3526 82
PYHÄSELKÄ	2	Niva	Nivansalo Porolahti	4 37	38.8	79.5	81.5	6921 12	4495 08
RÄÄKKYLÄ	6	Täitimänniemi	Mehonlahti	4 31	54.2	79.0	80.4	6898 80	4494 39
RÄÄKKYLÄ	19	Täitimänniemi	Rantala	4 31	49.6	77.5	79.5	6902 15	4491 25
RÄÄKKYLÄ	20	Täitimänniemi	Huotinniemi	4 31	55.6	77.8	78.7	6897 35	4494 85

Early Metal Period, "epineolithic" and Morby like, single fragments (Diagram 6): 2

Commune	nro	Village	Name	Water basin	Dist. km	Base z	Top z	X co-ord.	Y co-ord.
PUUMALA	9	Huhtimaa	Pistohiekka B	4 11	32.6	79.7	81.1	6829 06	3553 03
PYHÄSELKÄ	2	Niva	Nivansalo Porolahti	4 37	38.8	79.5	81.5	6921 12	4495 08

The deviation of elevations inside periodical groups might be partly explained due to differences in the height of cliffs. In distance diagrams is plotted the base of a cliff. Vertical distance from the dwelling site to the base of the cliff, must be examined during the dating process later.

In diagram 2, where is plotted all accepted observations, is seen that observations are stressed to greater distances. The distance zone between -30 to +30 km has fewer observations. This situation comes simply from the fact that the deviation of known sites with dateable ceramics is stressed the same way (in 1992).

From basic data lists comes in to sight that same ceramic group will exist in some sites on two separate cliffs of different elevation. From these observations we can draw preliminary conclusions:

- Early asbestos ware exists at least on two shore levels (Rääkkylä [7]).
- Typical comb ceramics exist at least on two shore levels (Ristiina [32]).
- Textile ceramics exist at least on two shore levels (Kerimäki [127]).

6.3.3. First test

The regression lines of all **Ka2** sites were calculated (average shore of all Ka2 sites). R.m.s and CoD were much too large, as excepted. Then i extracted all points that deviated more than +0.9 m from that line and calculated a regression line for these points. The resulting line is reasonable and it was stated as "Ka2 Upper Shore". It corresponds well to known GLS-shore. Next step is to extract all points that deviates more than -0.6 m below first line and to calculate a regression line for these points. The resulting line is good and it was stated as "Ka2 Down Shore". Finally i calculated a regression line for those Ka2 points that were left between Up and Down -lines. Resulting line is fairly reasonable, but not good enough to be a final shoreline. This line was stated as "Ka2 Middle Shore" (Diagram 3). Early asbestos ceramic finds were so sparse that it is not worth to calculate an own regression line for them. Then i plotted **Vasb** sites on Ka2 scatter. Vasb points are all near the Ka2 shores.

Then i plotted late Neolithic points on top of Ka2 lines. From scatter diagram it come out clearly that most late Neolithic sites are near Ka2 shores (or near enough in this phase of the study). Seven late Neolithic points were clearly under the lowest Ka2+Vasb shore. For these **Ka3** and **Pöljä** points were then calculated a regression line. Resulting line was excellent (Diagrams 4 and 5).

Early Metal period points are all deviated so disassociatedly, that there is no sound method to calculate them straight any regression line. It has to be done entirely manually. Some sites are clearly connected to the previous late Neolithic line (diagram 6). Several alternatives exist to settle a regression line for the rest of points. Some fairly evident selections will give however unlogic and bad looking results. It is very difficult to state arguments for any selection. This pure calculation ("dummy") method will not work so far.

Diagram 3

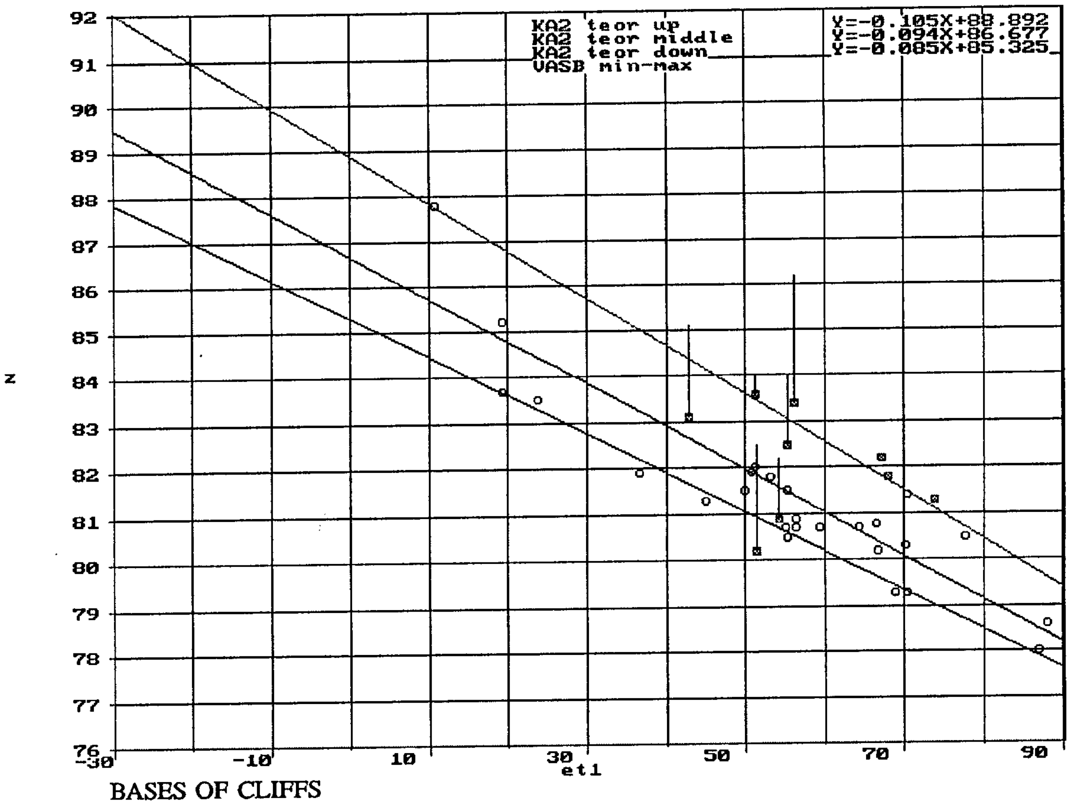


Diagram 4. PÖLJÄ AND KIERIKKI SITES AND NEOLITHIC "DUMMY" GRADIENTS

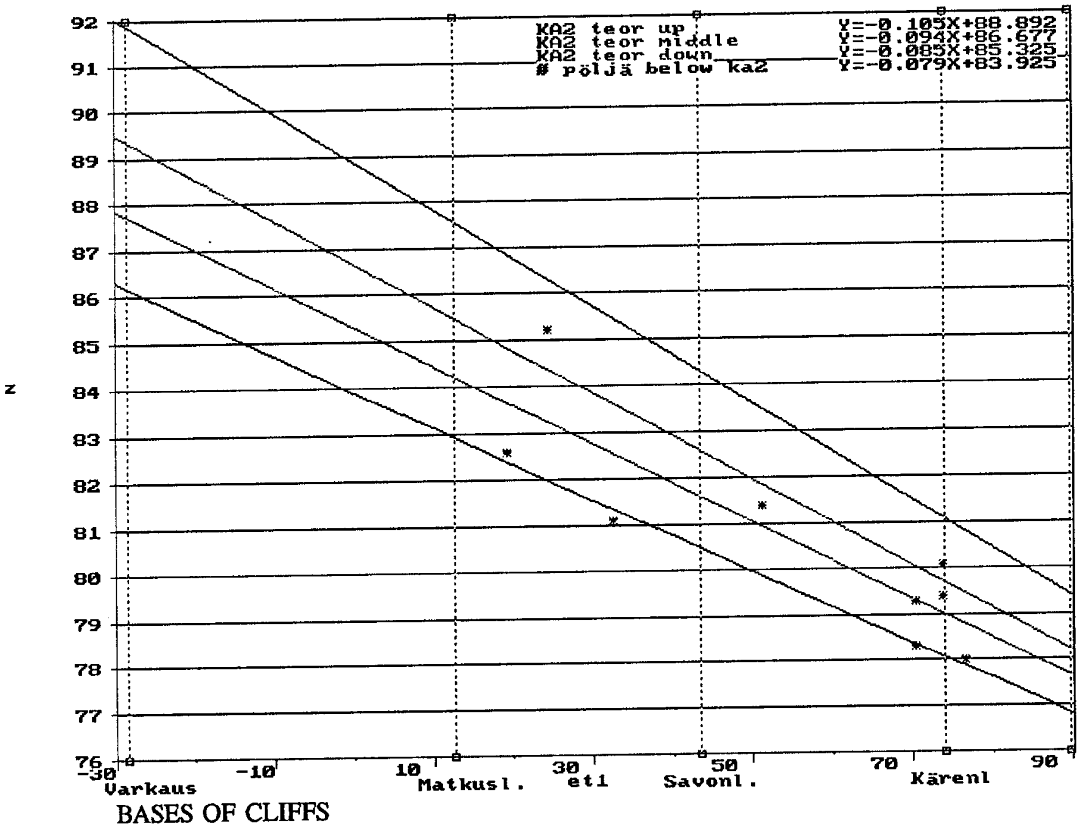
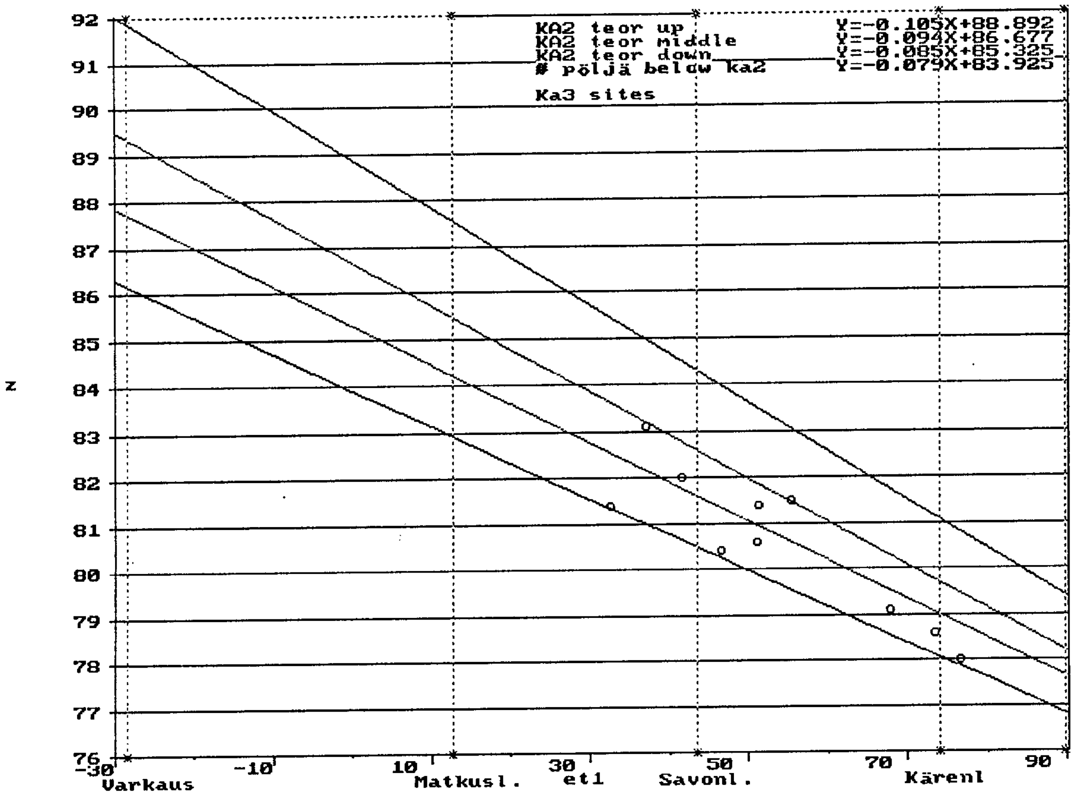
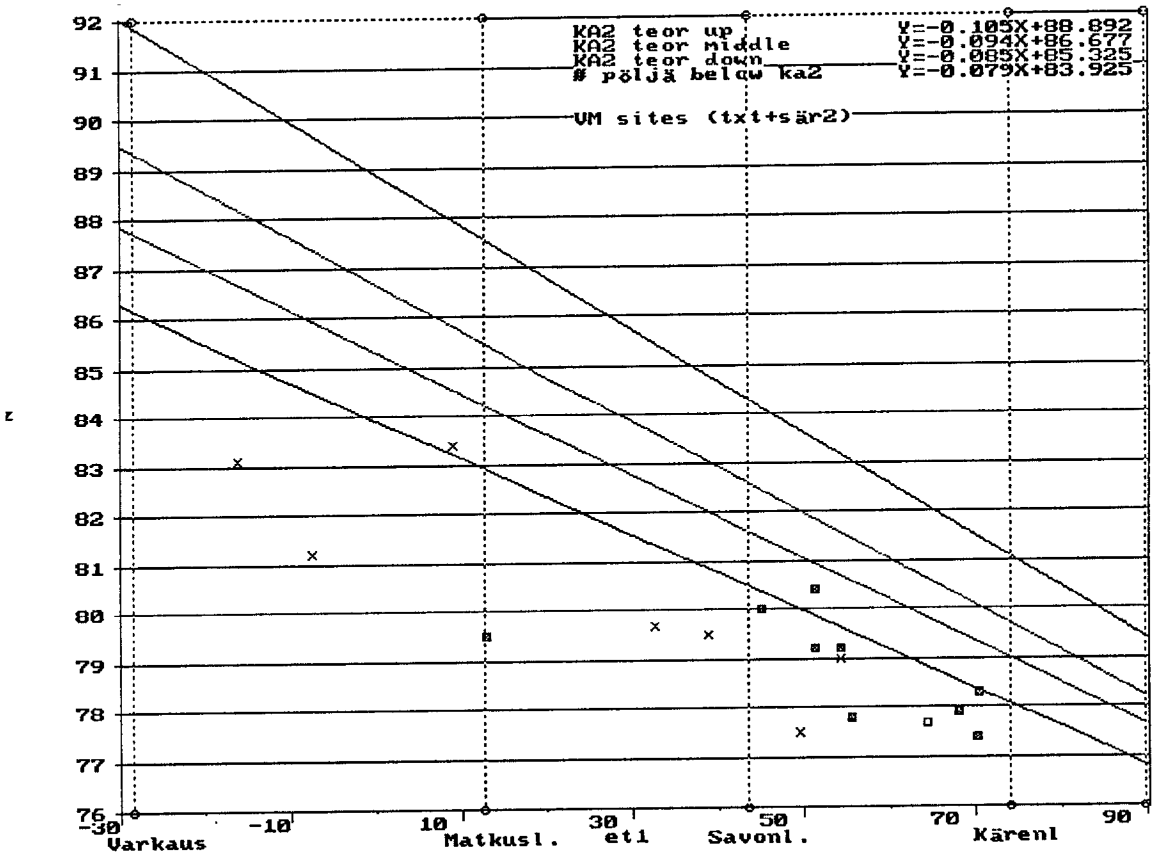


Diagram 4

Diagram 5





BASES OF CLIFFS

Diagram 6

Then was recalculated rather well looking Neolithic lines and took with the calculations all shore observations within deviation of +-40 cm from each line. The resulting lines are not better than original lines. Too many unlogic situations exist: to same shore line is connected two clearly different cliffs from the same site. This situation is certainly not desirable. Too many points were left entirely outside lines. Post Neolithic lines stays almost indefinite. This first calculation was done with minimum human aid by "stupid" computer. Evidently this kind of "idiot run" will not give permanent and exact results, at least with this amount of points. The intercept value of a regression line will be too accidental. One significant inconvenience is the accumulation of sites in SE part of diagram. However results concerning Ka2 sites are interesting. It is also noticeable how easily the known GLS-shore came out of the material. The results of this first test are only advisable. Some preliminary conclusions can be draw according to first test:

Table 2, results of the first test

Period	Regression m/km	r.m.s m	CoD %
Ka2 up	-0.105	0.32	98
Ka2 middle	-0.094	0.29	96
Ka2 down	-0.085	0.17	99
Late Neolithic	-0.079	0.20	99

- Early asbestos ceramics are on the same shore levels than Ka2 sites, or slightly higher on average.
- Ka2 sites are locating on at least three shore levels, between gradient values 0.105 and 0.085 m/km.
- Pöljä ware and Ka3 features are generally on the same shore levels.
- There might be distinguished at least four Neolithic shore levels.

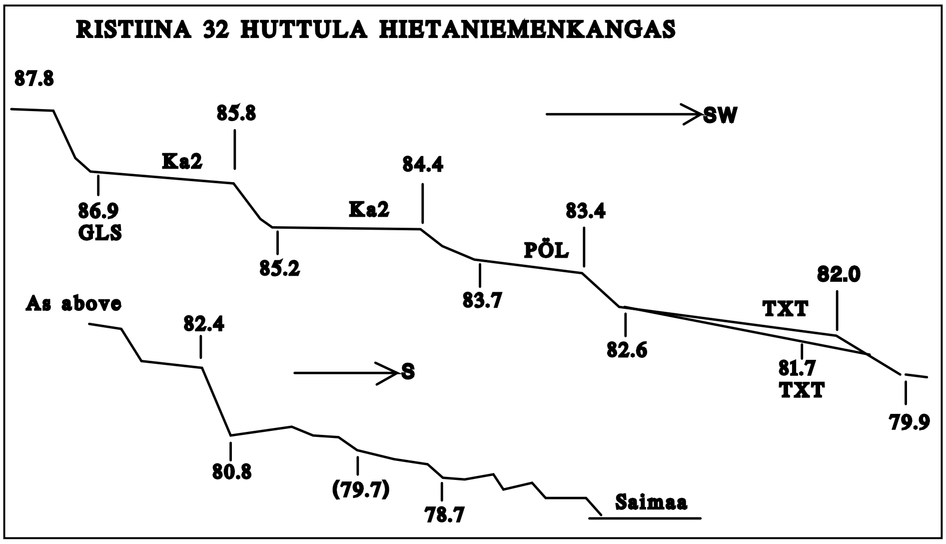
6.3.4. Second test

It is obvious that regression lines must be fixed with reliable arguments to the y-axis of distance diagram. This was tried to achieve by exploring rational individual observations and then joining synchronous cliffs to hypothetical basic shorelines, which will then be adjusted further with all observations. First we have to select a basic set of well and safely dated clear cliffs or cliff serieses from the opposite edges of the distance diagram. We try to find cliffs that are clearly separated vertically from each other in the same district (at about the same distance). Two basic shore-sets were formed: one for the southern Saimaa area (west from the Puumala Strait), and other for northeastern Saimaa (Puruvesi-Orivesi area).

6.3.4.1. Basic shores at S-Saimaa

In the NW-edge of distance diagram is an excellent site where is continuous series of cliffs: Ristiina [32] Huttula Hietaniemenkangas. On almost every cliff there is a dwelling site with identified ceramics. However the identification of textile ceramics is based on very sparse and fragmentary material and it is rather an assumption than a fact.

Fig. 13



There is seven clearly different metachronous cliffs in Ristiina [32]. This site is a good starting point in NW edge of the diagram. In most southern Saimaa there is not such a clear site as Ristiina [32] is. From Taipalsaari, Lappeenranta, Imatra and Ruokolahti area, close to the mouth of Vuoksi, several sites were choosed to conform basic shores. The leveled cliffs (i.e. their bases) and their period datings are in table 3. All GLS elevation values were not leveled by this project. Some GLS elevations are taken straight from Hellaakoski (1922). Many leveling sites of Hellaakoski locates near our leveling points. All these comparable GLS elevations of Hellaakoski were inspected. GLS elevations of Hellaakoski are in the whole investigation area of this study almost exactly the same than we leveled during this research project.

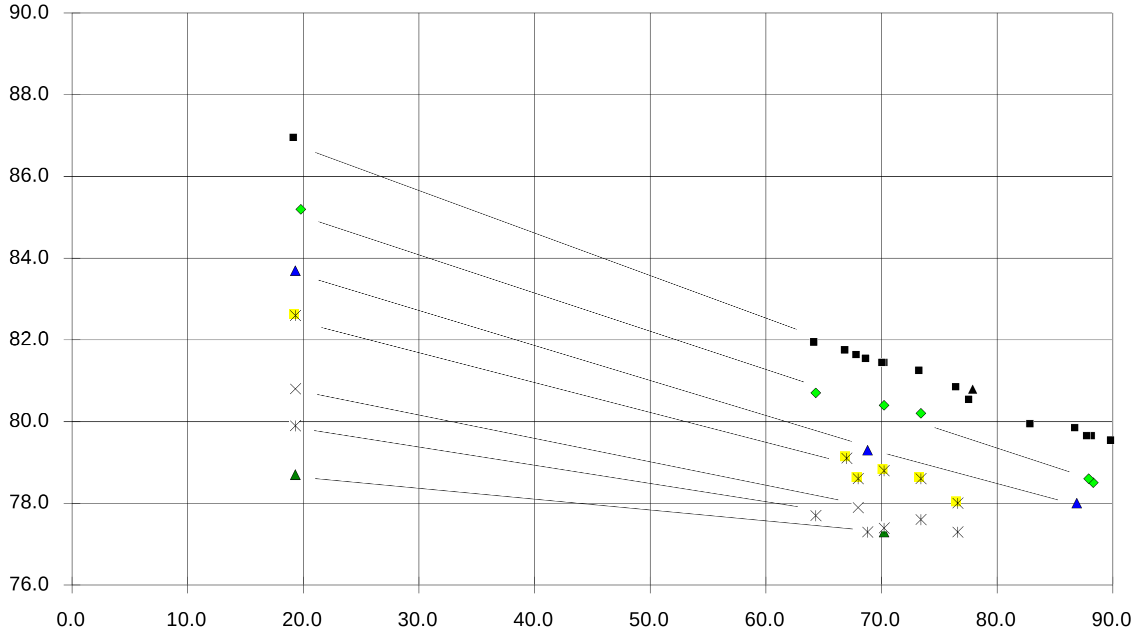
From table 3 and diagram 7 it comes out that the number of separate shores increases to NW, towards greater land uplift. In Ristiina we can differentiate seven separate cliffs, each of different age (metachronous to some extent, that we do not exactly know). As we go to SE, to the area of smaller land uplift, these eight shores began to mix with each other. In Taipalsaari and northern Ruokolahti we can distinguish accumulations of shore scarps on four different elevation levels. Near Vuoksi outlet we can distinguish clearly only two shore levels. The lowest accumulation of shore marks is near or almost inside the modern beach formations.

The GLS-shore is clear and independent formation in the whole area of the distance diagram. GLS-shore is the same than first Ka2 shore. Also the second Ka2 shore level, just below GLS, is still unmixed at the neighborhood of Vuoksi, where it begins to mix with later shores. The third shore level begins to mix with fourth (late Neolithic) shore level at the distance of +70 km. Early Metal Period fifth and sixth shores begins to mix before the distance of +70 km. The lowest shore level of Ristiina is still quite artificial. It is supposed to come out from the recent "noise" farther in NW. The gradient values of the basic Neolithic shores are almost the same than values of the First Test. Now these shore levels are fixed accurately to elevation levels. The intercept value of the equation of the regression line is argued. R.m.s values are naturally better than in first test, since the material is sparser, selected and more accurate. Post-Neolithic shores were identified and the exactness of these basic shores is good enough for using them as a hypotethical basis.

Table 3. Basic cliffs in Southern Saimaa: bold values means that there is a dwelling site on top of that cliff

	Dist. km	GLS-0	GLS-1	GLS-2	GLS-3	GLS-4	GLS-5	GLS-6	date & misc.
Vuoksenniska	90.0	79.5							(by Hellaakoski)
Imatra 2	88.3	79.6	78.5	x					(site at 78,1)
Imatra 1	87.9	79.6	**78.6**						ka2
Ruokolahti 3	86.9	79.8		**78.0**					ka2
Ruokolahti 1	83.0	79.9	x						(site at 79.5 ka2+ka3)
Ruokolahti 17	77.7	**80.5**		x					ka2, (ka2 at 79.7)
Taipalsaari 11	76.6	80.8			**78.0**		77.3		ka3+kie, (ka2 at 80)
Lappeenranta 22	73.4	81.2	80.2		**78.6**		77.6		ka3
Ruokolahti 10	70.4	**81.4**							ka2
Taipalsaari 6	70.2	81.4	**80.4**		**78.8**		**77.4**	77.3	ka2, ?, txt
Taipalsaari 5	68.8	81.5		**79.3**			77.3		?
Ruokolahti 11	68.0	81.6			78.6	**77.9**			txt
Taipalsaari 29	67.0	81.7			**79.1**	+			ka3 (or ka2), ?
Taipalsaari 30	64.3	81.9	**80.7**				**77.7**		ka2, (txt)
Ristiina 32	19.3	86.9	**85.2**	**83.7**	**82.6**	**80.8**	**79.9**	78.7	ka2, ka2, pöl, txt, txt
Date summary		ka2	ka2 (ka3)	ka2	ka3 kie/pöl	txt	txt	?	Period dates of bolded values
Basic Gradient -		0.106	0.096	0.085	0.077	0.060	0.047	0.028	
intercept elevation		88.9	87.1	85.0	84.1	82.0	80.8	79.2	at the zero distance
r.m.s		0.102	0.121	0.124	0.198	0.000	0.177	0.00	
nr. of points		13	6	3	6	2	6	2	
First to last grad.		0.105	0.097	0.084	0.080	0.060	0.045	0.028	

Diagram 7, Distance diagram of basic shores in S-Saimaa, data from table 3 above.



Lines in the diagram above are only for guiding, they are not real regression lines.

From diagram 7, we can draw a preliminary conclusion of the shore formation process. The mixing of shore marks begins when the vertical distance of shorelines diminishes to less than about 80 cm. The vertical difference between two distinguishable and different shore levels, and as well the difference between subsequent well-formed shore scarps, is at a minimum of about one meter. This means that when the water level drops 70-100 cm it is potential for a new cliff to begin to develop. On the contrary it means also that when water level drops the mentioned amount it is possible for the previous cliff to survive. These observations fits well to Varjo's investigation results and to scenarios of shore formation processes in figures 5-8.

The drop rate of water level is connected to the time. In the SE-edge of the distance diagram the time when water drops one meter is considerably longer than on the areas of greater land uplift. The formation process of a new cliff takes longer time in SE than in NW. Also the cliffs have been at shoreline a longer period in SE than in NW. **The shore line displacement dating is thus more accurate in the areas of greater land uplift and quite rough in the most SE parts of Lake Saimaa. The synchrony of a shore level diminishes to SE and the time span between shore observations of different altitudes is shorter in NW than in SE.**
We can assume, that the resulting distance diagram ought to appear as a fan-like figure. If a "fillet of the fan" is parallel to another it means fast sudden drop in water level **and** otherwise steady slower regression. We have to accept the situation that two vertically separate cliffs from the same site might belong to the same calculated shoreline in SE, where shorelines begins to mix with each other.

According to previous observations the cliffs in SE ought to be generally better formed, higher and terraces wider than cliffs in NW. In theory it might be possible to determine a relative rate of regression during different times by comparing and ranking dimensions of shore formations.
The formation of a new cliff depends on the slope of the whole shore and on the shore material. On sheer slopes the shoreline retreats relatively slower than on gently sloping shores; or vice versa, on sheer shore water drops relatively faster than on gentle shore. The erosion forces of regressive water level are able to cut shoreline relatively longer time on steep slopes. A step-like continuous cliff series, like in Ristiina [32], had formed probably due to the ideal slope of the hillside with homogenous shore material in relation to land uplift rate.

The +-40 cm error range of elevations, demonstrated before, must be kept strictly as the maximum deviation of elevations inside "synchronous" shores, that will be discovered in next phase of this work. It might be good idea to use in first calculations smaller deviation values, and then when searching final result to use greater deviation value.

6.3.4.2. Shores at South-Saimaa

Previously determined basic gradients were then used with all shore observations from South-Saimaa. First was searched all those points that deviates less than +-25 cm from a certain basic line. A new regression value was calculated for all those values found within the range of +-25 cm. Then i searched all those points that deviates less than +-31 cm from this new first line. A new, second regression line was calculated including all found points. Finally the last gradient was calculated. During each step some points were dropped out and new points were connected in to the line. The points of final line were examined with residual plot, and most deviating points were dropped manually out of that line.

Nearly all 90 cliffs were constrained into regression lines (diagram 9). Ten percent of points were left entirely out of lines. These line-out shores might represent intermediate shores that are beginning to shape between well formed calculated shores. The material in South-Saimaa is heavily stressed to SW part of the diagram. That is why the intermediate shaping shores will not come out in calculation. They do not have yet observation pairs in the NW part of the diagram. Estimation of cermic periods according to resulted diagram appeared to be very good.

Table 4. South-Saimaa, calculated from all leveled cliffs:

Date summary	GLS Ka2	Ka2 (Ka3)	Ka2	Ka3 Kie/Pöl	Txt	Txt	?	
South-Saimaa Gr. -	0.109	0.091	0.085	0.074	0.061	0.047	0.024	
intercept elevation	89.1	86.6	85.3	83.9	82.1	80.8	79.1	at the zero distance
r.m.s	0.140	0.170	0.190	0.195	0.160	0.185	0.150	
nr. of points	21	13	8	12	9	11	8	
Basic Gradient -	0.106	0.096	0.085	0.077	0.060	0.047	0.028	
intercept elevation	88.9	87.1	85.0	84.1	82.0	80.8	79.2	at the zero distance

During the calculation process it emerged that the GLS-shore is slightly curved. The regression value of the GLS-shore marks between distance's +70 to +90 is about -0.093 cm/km. This is almost the same value than regression calculated by Lappalainen for the same area and slightly less than value that Saarnisto calculated by trend-surface analysis. The regression value becomes gradually greater when moving SE. However, differences of regression values are fairly small and distances short. With all error margins these observations of sheering gradient could be considered only as rough and perspicacious. Curving of gradients can not anymore be observed below the GLS-shore. Slight curving disappears to the noise of measurement errors when gradients are more gentle than GLS-gradient.

The differences between upper gradients of basic-gradient-set and upper gradients of South-Saimaa set might be explained by the curving character of the shoreline. The elements that causes curving are not affecting to that amount in basic gradients, which relies on sparser amount of observations. The straight GLS-shoreline represented in the distance diagram is a generalization of different local gradient values.

6.3.4.3. Basic shores at Northeast-Saimaa

The same procedure was committed with the data of NE-Saimaa, Puruvesi-Orivesi area, than on S-Saimaa. However there is not as good site in NE-Saimaa as was Ristiina [32] in S-Saimaa. Enonkoski [39] site has a continuous series of cliffs, but the slope is still fairly sheer and the terraces are narrow. The dwelling sites are farther away from leveled cliffs. Enonkoski [38] site is also fairly sheer sloping with narrow terraces. The dwelling site in Enonkoski [38] is farther away than leveled cliff series.

Table 5. NE-Saimaa:

	distance	GLS-0	GLS-1	GLS-2	GLS-3	GLS-4	GLS-5	
Kesälahti 4	73.9	81.3						
Punkaharju 3	73.9	**81.3**	**80.1**	**79.4**		78.4	77.3	Ka2, Kie, Pöl
Punkaharju 45	73.7	**81.3**		**79.5**	78.9			Ka2, ?
Punkaharju 22	72.9	81.3		**79.7**				?
Punkaharju 48	71.9	81.6			**79.3**			(Pöl+Ka3)
Kerimäki 127	51.2	**83.6**		**81.4**	**80.3**	**79.2**	**78.4**	Vasb, Ka3+Pöl, Txt, Sär2, ?
Enonkoski 39	23.8	86.7	85.0	**83.5**	82.0	**80.5**	79.1	Ka2, ?
Enonkoski 38	10.3	88.2	85.7	84.1	83.0			
Periods		Vasb Ka2	Ka2 Kie	Ka2 Ka3 Pöl	Txt	Sär2	?	
Gradient		0.109	0.091	0.075	0.061	0.043	0.038	
intercept		89.3	86.9	85.1	83.6	81.5	80.1	elevation at zero distance
r.m.s		0.080	0.221	0.017	0.080	0.080	0.161	
nro of points		8	3	6	4	4	4	

South-Saimaa Basic Gradients:

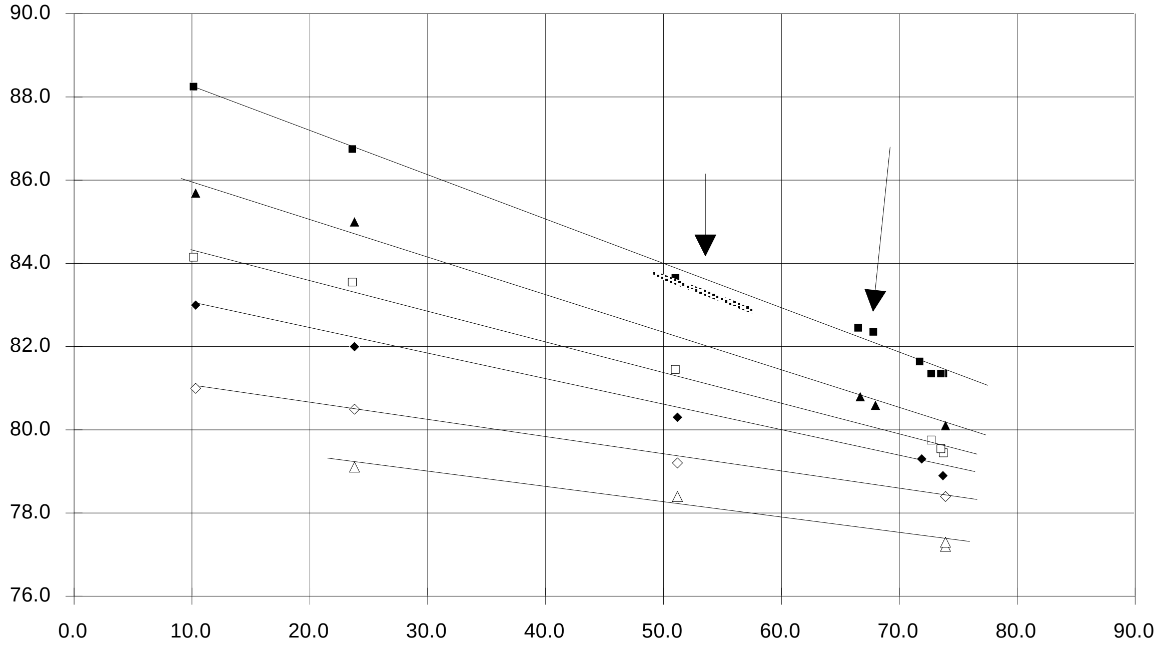
Basic Gradient -		0.106	0.096	0.077	0.060	0.047		0.028	
Intercept		88.9	87.1	84.1	82.0	80.8		79.2	
Date summary		Vasb Ka2	Ka2 (Ka3)	Ka3 Kie/pöl	Txt	Txt		?	
		GLS-0	GLS-1	GLS-3	GLS-4	GLS-5		GLS-6	

0.085
85.0
Ka2
GLS-2

When comparing the basic gradients of S-Saimaa to gradients of NE-Saimaa (table 5), the greatest difference is the lack of GLS-2 shore of S-Saimaa in NE-Saimaa. GLS-5 shores of NE-Saimaa do not appear in S-Saimaa gradient series. Gradient values are almost the same for the rest of shores, but zero elevations are definitely different below the GLS-2 shore. All lower gradients are settled differently in NE-Saimaa than in S-Saimaa. The GLS shore and the shore below it are the same in both areas. If we look at the Diagram 8, where the basic cliffs of NE-Saimaa are plotted, it looks bit more confused than corresponding diagram from S-Saimaa. After further calculations and adjusting of regression lines, 39 cliffs out of total 128 were out of lines (30%).

After brutal manual adjusting, still more than 20 cliffs were out. (20%). Period estimations according to results were not as good as excepted.

Diagram 8, basic cliffs in NE-Saimaa.



Lines are only for guiding, they are not actual regression lines.

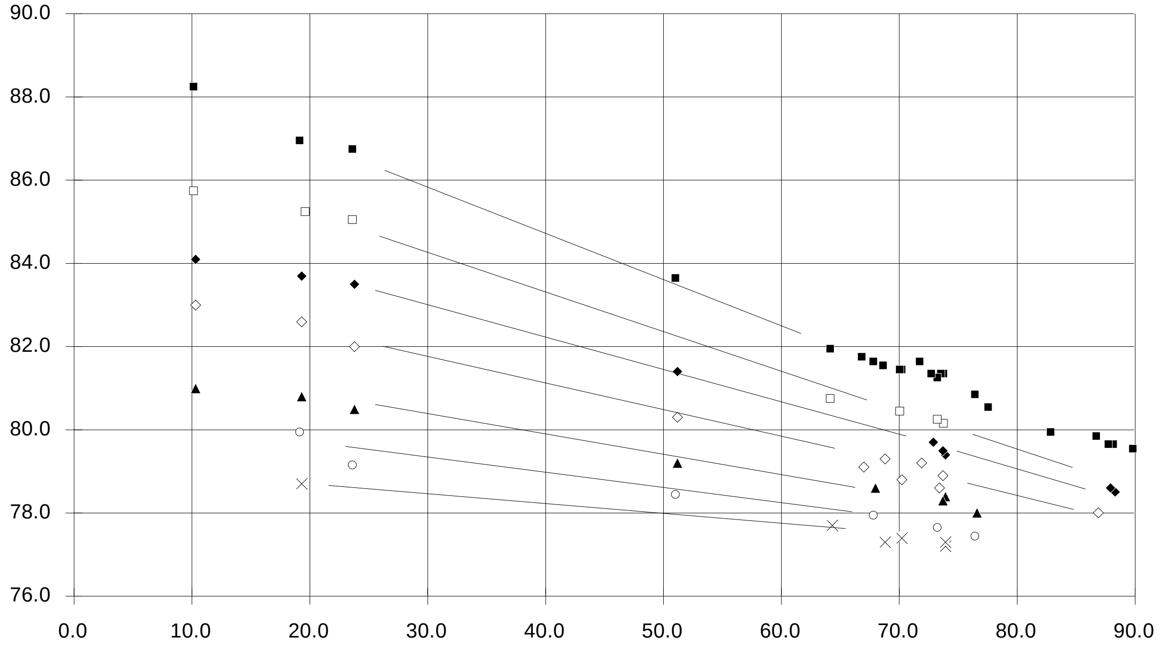
The **left arrow** points to Rääkkylä Jaamankangas esker, where all leveled GLS-cliffs are at slightly lower elevations than elsewhere. **Right arrow** points to Kitee Hiekanpää and Kovikko sites that are not included in calculations. Their effect to gradient values is however minimal.

An intresting phenomenon exists between distances of 48 - 57 km. GLS-shore marks of six sites that are all locating on the slopes of the same esker between Kitee and Rääkkylä (Rääkkylä 5, 6, 7, 13, 23 and Kitee 18) are systematically at lower elevation than elsewhere. In final gradients it was clearly seen that something went wrong in the determination process. The main features are the same than in S-Saimaa. Shores will mix in the same manner than in S-Saimaa. Two lowest gradient lines look out fairly unlogic. The fundamental reason of bad results is that selected basic points were not good. The determination of basic points failed. There is a possibility that the irregularities in land uplift isobases in the area might affect to results. That question is left to future examinations, since the development of the method is now the main question. These possible local difficulties must be kept in mind, while seeking universal solution to the whole investigation area.

If we look at the diagram 8, where are combined the basic sites of both S-Saimaa and NE-Saimaa, we can see that the differences between these two areas do not necessarily really exist.

The basic solution of South Saimaa will work also in NE-Saimaa. It is argued to use the regression lines of South Saimaa as a base for the whole investigation area.

Diagram 9. The combination of basic sites of South and NE Saimaa.



Lines in the diagram above are only for guiding, they are not real regression lines.

Sites from left: Enonkoski [38], Ristiina [32], Enonkoski [39], Kerimäki [127]...

6.3.5. Final Test

The basic starting gradient set consists of regression lines calculated for S-Saimaa. To all cliffs was first calculated a deviation value from the regression lines of S-Saimaa. Every basic regression line (i.e. S-Saimaa line) was named with numerical code. The highest regression line is 100, second line is 101 and so on. Every cliff has an own card in the database. Computer program calculated to all cliffs a deviation value from the highest regression line. This value was stored to cliff-cards as also the name of the basic line to what the deviation value is pointing. Then, to every point was calculated a deviation value from the second basic regression line. If the absolute value of deviation was smaller than the value stored before, then the smaller value was stored instead the previous value. The name of the current basic line replaced the previous one. This procedure was repeated until all basic regression lines were used. Every cliff was now connected to the nearest basic shore line (to one line only).

Then cliff-cards were listed in the order: za - *basic_cliff_name, az - deviation*.

First was listed those cliffs that are connected to the highest regression line and they are ordered according to the deviation from that line. The list begins from uppermost and ends to lowest cliff counted from the line. The deviation value tells how much (in meters) above or below the cliff is from the regression line. The resulting list of cliffs is in the hypothetical order of the age of cliffs.

Listed sites were divided into groups according to their deviation values, which must be in the range of +-40 cm from the regression line. The resulting shore series was named as *series -**T*** (it i just a pure name with no abbreviative meaning). Those groups that includes cliffs from several (two) different basic lines or groups that do not fit to their neighboring group were stated as intermediate shorelines. An intermediate shoreline is expected to be a shore level that is not yet well seen at the distance range of this study. They are "shaping" shores, that are expected to come up at smaller distance values farther in NW.

preliminary division of sites to synchronous shore levels.

Commune	nro	Dist.	Z	**Grad1**	**Dev1**	Period	Shore name
KITEE	16	67.6	82.4	100	0.665		
PYHÄSELKÄ	2	38.8	85.5	100	0.622		
SAVONLINNA	54	66.7	82.4	100	0.572		
KERIMÄKI	87	42.9	84.9	100	0.468		
KANGASLAMPI	10	1.5	89.4	100	0.459		
KITEE	12	67.2	82.2	100	0.421	vasb kn	**T0, MAIN SHORE**
RÄÄKKYLÄ	9	56.1	83.4	100	0.411	ka2 kn vasb	
OUTOKUMPU	6	-14.6	91.1	100	0.400		
RÄÄKKYLÄ	11	51.3	83.9	100	0.388		
PUNKAHARJU	48	71.8	81.6	100	0.323		
PUUMALA	36	40.5	85.0	100	0.310		
SAVONLINNA	45	36.7	85.4	100	0.291		
HEINÄVESI	1	-12.3	90.7	100	0.255		
KESÄLAHTI	4	73.9	81.3	100	0.247		
PUNKAHARJU	3	73.8	81.3	100	0.244	ka2 kn vasb	
ENONKOSKI	38	10.5	88.2	100	0.237		
PUNKAHARJU	45	73.7	81.3	100	0.231	ka2 kn	
ENONKOSKI	39	23.9	86.7	100	0.196		
KERIMÄKI	103	59.5	82.8	100	0.183		
KERIMÄKI	4	46.6	84.2	100	0.173		
RUOKOLAHTI	3	86.9	79.8	100	0.168		
JUVA	70	24.4	86.6	100	0.150		
PUNKAHARJU	22	72.9	81.3	100	0.146		
PUUMALA	76	37.1	85.2	100	0.140		
IMATRA	2	88.5	79.6	100	0.126		
KITEE	10	67.9	81.8	100	0.099	vasb kn ss	
LAPPEENRANTA	15	73.4	81.2	100	0.098		
KERIMÄKI	127	51.2	83.6	100	0.081	vasb	
IMATRA	1	88.1	79.6	100	0.081		
PUUMALA	57	53.8	83.3	100	0.061		
PUUMALA	45	56.4	83.0	100	0.046		
TAIPALSAARI	11	76.6	80.8	100	0.043		
PUUMALA	74	55.4	83.1	100	0.032		
TAIPALSAARI	29	67.8	81.7	100	-0.015		

RUOKOLAHTI	10	70.4	81.4	**100**	**-0.027**	ka2 kn	
KERIMÄKI	1	41.0	84.6	**100**	**-0.032**		
TAIPALSAARI	6	70.2	81.4	**100**	**-0.051**		
PUUMALA	13	41.5	84.5	**100**	**-0.079**		
JOROINEN	1	-20.0	91.2	**100**	**-0.090**		
RÄÄKKYLÄ	6	54.2	83.1	**100**	**-0.093**		
RUOKOLAHTI	11	68.0	81.6	**100**	**-0.095**		
RÄÄKKYLÄ	5	55.1	83.0	**100**	**-0.095**		
RISTIINA	32	19.3	86.9	**100**	**-0.097**		
RUOKOLAHTI	17	77.7	80.5	**100**	**-0.132**	ka2 kn	
RANTASALMI	1	10.7	87.8	**100**	**-0.137**	ka2 kn	
KITEE	17	56.5	82.8	**100**	**-0.147**		
RUOKOLAHTI	1	83.0	79.9	**100**	**-0.153**		
PUUMALA	14	41.5	84.4	**100**	**-0.177**		
PUUMALA	80	47.0	83.8	**100**	**-0.180**		
TAIPALSAARI	30	64.3	81.9	**100**	**-0.191**		
RÄÄKKYLÄ	18	49.3	83.5	**100**	**-0.228**		**T0, MAIN SHORE**
JOROINEN	15	-27.8	91.9	**100**	**-0.237**		
RÄÄKKYLÄ	13	50.9	83.3	**100**	**-0.252**		

RÄÄKKYLÄ	7	55.3	82.5	**100**	**-0.582**	ka2 kn vasb	
PUUMALA	36	40.5	83.8	**101**	**0.885**		
JUVA	7	24.4	85.2	**101**	**0.826**	kie mn asb	
POLVIJÄRVI	1	-12.4	88.3	**101**	**0.605**		**T1, INTERMEDIATE SHORE**
ENONKOSKI	39	23.9	85.0	**101**	**0.581**		
SAVONLINNA	17	37.1	83.8	**101**	**0.575**		
OUTOKUMPU	7	-15.4	88.5	**101**	**0.531**		
PUUMALA	20	51.8	82.4	**101**	**0.504**		

KITEE	12	67.2	80.9	**101**	**0.400**		
KERIMÄKI	87	42.9	83.1	**101**	**0.399**		
RÄÄKKYLÄ	2	44.0	83.0	**101**	**0.398**		**T2, MAIN SHORE**
RISTIINA	32	19.3	85.2	**101**	**0.372**	ka2 kn	
SAVONLINNA	47	32.6	84.0	**101**	**0.367**		
LAPPEENRANTA	15	73.4	80.2	**101**	**0.261**		
KITEE	4	66.5	80.8	**101**	**0.240**	ka2 kn	
HEINÄVESI	4	-1.0	86.9	**101**	**0.234**		
KERIMÄKI	57	54.2	81.9	**101**	**0.226**		
PUNKAHARJU	3	73.8	80.1	**101**	**0.199**	kie mn asb	
ENONKOSKI	38	10.5	85.8	**101**	**0.171**		
KITEE	16	67.6	80.6	**101**	**0.136**		
LAPPEENRANTA	9	79.2	79.5	**101**	**0.086**		
TAIPALSAARI	6	70.2	80.3	**101**	**0.072**	ka2 kn	
RÄÄKKYLÄ	11	51.3	82.0	**101**	**0.062**	ka2 kn	
KERIMÄKI	4	46.6	82.4	**101**	**0.035**		
KERIMÄKI	59	53.1	81.8	**101**	**0.027**	ka2 kn	
IMATRA	1	88.1	78.6	**101**	**-0.013**	ka2 kn	
PUUMALA	80	47.0	82.3	**101**	**-0.026**		
TAIPALSAARI	30	64.3	80.7	**101**	**-0.059**	ka2 kn	
PUUMALA	74	55.4	81.5	**101**	**-0.069**	ka2 ka3 kn mn	
JUVA	7	24.4	84.3	**101**	**-0.071**		
IMATRA	2	88.5	78.5	**101**	**-0.075**		
KERIMÄKI	76	50.8	81.9	**101**	**-0.083**	ka2 kn	
PUUMALA	76	37.1	83.1	**101**	**-0.121**		
PUUMALA	77	37.0	83.1	**101**	**-0.128**	ka3 mn	
KERIMÄKI	58	54.0	81.5	**101**	**-0.197**		
PUUMALA	4	40.7	82.7	**101**	**-0.201**		
KESÄLAHTI	2	70.4	78.3	**101**	**-0.215**	pöl txt sir luu mn vm	
SAVONLINNA	17	37.1	83.0	**101**	**-0.225**		
PUNKAHARJU	22	72.9	79.7	**101**	**-0.282**	asb	
SAVONLINNA	54	66.7	80.2	**101**	**-0.341**	ka2 kn	**T2, MAIN SHORE**

PUUMALA	79	46.6	82.0	**101**	**-0.360**		
JOROINEN	1	-20.0	88.0	**101**	**-0.388**		

PUNKAHARJU	45	73.7	79.5	**101**	**-0.412**		
PUUMALA	14	41.5	82.4	**101**	**-0.421**		
SAVONLINNA	51	65.5	80.2	**101**	**-0.455**		**T3, INTERMEDIATE SHORE**
KERIMÄKI	103	59.5	80.7	**101**	**-0.495**	ka2 kn	
KERIMÄKI	127	51.2	81.4	**102**	**0.531**	mn pöl ka3	
PUUMALA	19	50.0	81.5	**102**	**0.521**	ka2 kn	
PUUMALA	45	56.4	80.9	**102**	**0.476**	ka2 kn	
PUNKAHARJU	3	73.8	79.4	**102**	**0.471**	pöl mn ??	
KERIMÄKI	1	41.0	82.2	**102**	**0.454**		
SAVONLINNA	47	32.6	82.9	**102**	**0.427**		

PUUMALA	13	41.5	82.0	**102**	**0.296**	ka3 ? mn	
JOROINEN	8	-17.9	87.1	**102**	**0.293**		
RÄÄKKYLÄ	6	54.2	80.9	**102**	**0.288**	ka2 kn vasb	**T4, MAIN SHORE**
KITEE	17	56.5	80.7	**102**	**0.282**	ka2 kn	
ENONKOSKI	39	23.9	83.5	**102**	**0.280**	ka2 kn	
RUOKOLAHTI	3	86.9	78.0	**102**	**0.192**	ka2 kn	
RÄÄKKYLÄ	5	55.1	80.7	**102**	**0.165**	ka2 kn	
PUNKAHARJU	48	71.8	79.2	**102**	**0.096**	mn ?	
RISTIINA	32	19.3	83.7	**102**	**0.092**	ka2 kn	
PUUMALA	57	53.8	80.7	**102**	**0.052**		
KERIMÄKI	57	54.2	80.6	**102**	**-0.013**		
HEINÄVESI	1	-12.3	86.3	**102**	**-0.023**		
RÄÄKKYLÄ	7	55.3	80.5	**102**	**-0.025**	ka2 kn vasb pöl ka2	
TAIPALSAARI	5	68.8	79.3	**102**	**-0.057**	ka2 kn	
PUUMALA	36	40.5	81.7	**102**	**-0.092**		
PUUMALA	16	45.1	81.3	**102**	**-0.097**	ka2 kn	
PUUMALA	85	32.7	82.3	**102**	**-0.166**		
LAPPEENRANTA	9	79.2	78.3	**102**	**-0.168**		
KERIMÄKI	87	42.9	81.4	**102**	**-0.188**		
SAVONLINNA	45	36.7	81.9	**102**	**-0.221**	ka2 kn	
KESÄLAHTI	2	70.4	79.3	**102**	**-0.228**	ka2 pöl kn mn	
KERIMÄKI	1	41.0	81.5	**102**	**-0.246**		
JOROINEN	15	-27.8	87.4	**102**	**-0.256**		
ENONKOSKI	38	10.5	84.1	**102**	**-0.269**		
RÄÄKKYLÄ	13	50.9	80.6	**102**	**-0.295**	ka3 mn (kn)	
JOROINEN	8	-17.9	86.5	**102**	**-0.307**		**T4, MAIN SHORE**
PYHÄSELKÄ	2	38.8	81.6	**102**	**-0.339**		
SAVONLINNA	17	37.1	81.7	**102**	**-0.386**		

JOROINEN	9	-17.4	86.0	**103**	**0.755**		**?**

KERIMÄKI	127	51.2	80.4	**103**	**0.269**	txt VM	
TAIPALSAARI	29	67.8	79.1	**103**	**0.201**	ka3 mn	
RÄÄKKYLÄ	20	55.6	80.0	**103**	**0.193**		**T5, MAIN SHORE**
MIKKELIN MLK	11	9.1	83.4	**103**	**0.128**	asb (vm ?)	
LAPPEENRANTA	15	73.4	78.6	**103**	**0.119**	ka3 mn	
RISTIINA	32	19.3	82.6	**103**	**0.094**	pöl mn asb	
RÄÄKKYLÄ	15	51.5	80.2	**103**	**0.090**	vasb kn	
TAIPALSAARI	6	70.2	78.8	**103**	**0.081**		
PUUMALA	19	50.0	80.3	**103**	**0.074**		
RÄÄKKYLÄ	11	51.3	80.2	**103**	**0.074**		
PUNKAHARJU	3	73.8	78.4	**103**	**-0.049**		
PUUMALA	79	46.6	80.4	**103**	**-0.074**	ka3 mn	
PUUMALA	85	32.7	81.4	**103**	**-0.115**	ka3 mn	
ENONKOSKI	38	10.5	83.0	**103**	**-0.165**		
ENONKOSKI	39	23.9	82.0	**103**	**-0.169**		
SAVONLINNA	17	37.1	81.0	**103**	**-0.186**		
PUUMALA	36	40.5	80.7	**103**	**-0.231**		**T5, MAIN SHORE**

TAIPALSAARI	11	76.6	78.0	**103**	**-0.245**	ka3 kie kn mn asb	
RUOKOLAHTI	11	68.0	78.6	**103**	**-0.285**		
SAVONLINNA	47	32.6	81.1	**103**	**-0.422**	pöl mn asb	
PUUMALA	16	45.1	80.0	**103**	**-0.589**	tom txt vm	**T6,INTERMEDIATE SHORE**
OUTOKUMPU	7	-15.4	84.4	**103**	**-0.591**		
JOROINEN	9	-17.4	84.3	**103**	**-0.945**		
KERIMÄKI	57	54.2	79.2	**104**	**0.382**	txt tom asb vm	
RÄÄKKYLÄ	13	50.9	79.4	**104**	**0.381**	asb	
PUUMALA	13	41.5	79.9	**104**	**0.306**		**T7, MAIN SHORE**
PUUMALA	19	50.0	79.3	**104**	**0.222**		
PUUMALA	45	56.4	78.9	**104**	**0.217**		
KERIMÄKI	127	51.2	79.2	**104**	**0.200**	vm luu txt tom	
RÄÄKKYLÄ	6	54.2	79.0	**104**	**0.183**	vm asb	
KANGASLAMPI	10	1.5	82.2	**104**	**0.161**		
PUUMALA	79	46.6	79.4	**104**	**0.118**		
LIPERI	2	-5.8	82.5	**104**	**0.011**		
JOROINEN	11	-16.1	83.1	**104**	**-0.017**	vm	
KERIMÄKI	58	54.0	78.8	**104**	**-0.034**	asb	
LAPPEENRANTA	15	73.4	77.6	**104**	**-0.045**		
PUUMALA	36	40.5	79.6	**104**	**-0.057**		
SAVONLINNA	71	37.0	79.8	**104**	**-0.073**		
PUUMALA	16	45.1	79.3	**104**	**-0.076**		
RUOKOLAHTI	11	68.0	77.9	**104**	**-0.078**	tom txt vm	
RISTIINA	32	19.3	80.8	**104**	**-0.150**		
ENONKOSKI	39	23.9	80.5	**104**	**-0.173**		
PYHÄSELKÄ	2	38.8	79.5	**104**	**-0.262**	mn (vm?) (morby?) asb	
SAVONLINNA	17	37.1	79.6	**104**	**-0.266**		**T7, MAIN SHORE**
SAVONLINNA	45	36.7	79.6	**104**	**-0.291**		
ENONKOSKI	38	10.5	81.1	**104**	**-0.391**		
PUUMALA	9	32.6	79.7	**104**	**-0.441**	vm epineol	**?**
MIKKELIN MLK	11	9.1	80.5	**105**	**0.164**		
PUUMALA	19	50.0	78.5	**105**	**0.094**		
LIPERI	6	-7.5	81.2	**105**	**0.083**	vm	**T8, MAIN SHORE**
KERIMÄKI	127	51.2	78.4	**105**	**0.054**	rautak.	
RISTIINA	32	19.3	79.9	**105**	**0.049**		
TAIPALSAARI	30	64.3	77.7	**105**	**-0.028**	txt	
LIPERI	2	-5.8	81.0	**105**	**-0.038**		
PUUMALA	36	40.5	78.8	**105**	**-0.053**		
KERIMÄKI	103	59.5	77.9	**105**	**-0.056**		
KESÄLAHTI	4	73.9	77.2	**105**	**-0.079**		
PUUMALA	4	40.7	78.7	**105**	**-0.145**		
RÄÄKKYLÄ	15	51.5	78.1	**105**	**-0.233**		
PUUMALA	79	46.6	78.3	**105**	**-0.263**		
RÄÄKKYLÄ	2	44.0	78.4	**105**	**-0.289**		
ENONKOSKI	39	23.9	79.1	**105**	**-0.537**		**?**
RISTIINA	26	12.8	79.5	**105**	**-0.658**	tom txt vm	
SAVONRANTA	6	31.9	78.6	**106**	**0.282**		
PUUMALA	19	50.0	78.0	**106**	**0.121**		
RISTIINA	32	19.3	78.7	**106**	**0.079**		**T9, MAIN SHORE**
TAIPALSAARI	11	76.6	77.3	**106**	**0.065**		
RÄÄKKYLÄ	20	55.6	77.8	**106**	**0.057**	txt tom asb vm	
KANGASLAMPI	10	1.5	79.1	**106**	**0.047**		
TAIPALSAARI	6	70.2	77.4	**106**	**0.011**	txt vm	
PUNKAHARJU	3	73.8	77.3	**106**	**-0.001**		
RÄÄKKYLÄ	18	49.3	77.8	**106**	**-0.095**		
PUUMALA	9	32.6	78.2	**106**	**-0.101**		
TAIPALSAARI	5	68.8	77.3	**106**	**-0.122**		
PUUMALA	45	56.4	77.5	**106**	**-0.223**		

```
RÄÄKKYLÄ      19   49.6  77.5  106 -0.387 vm
```

T10, INTERMEDIATE SHORE

```
PUUMALA       57   53.8  77.3  106 -0.486
PUUMALA       79   46.6  77.4  106 -0.560
ENONKOSKI     38   10.5  78.2  106 -0.636
```

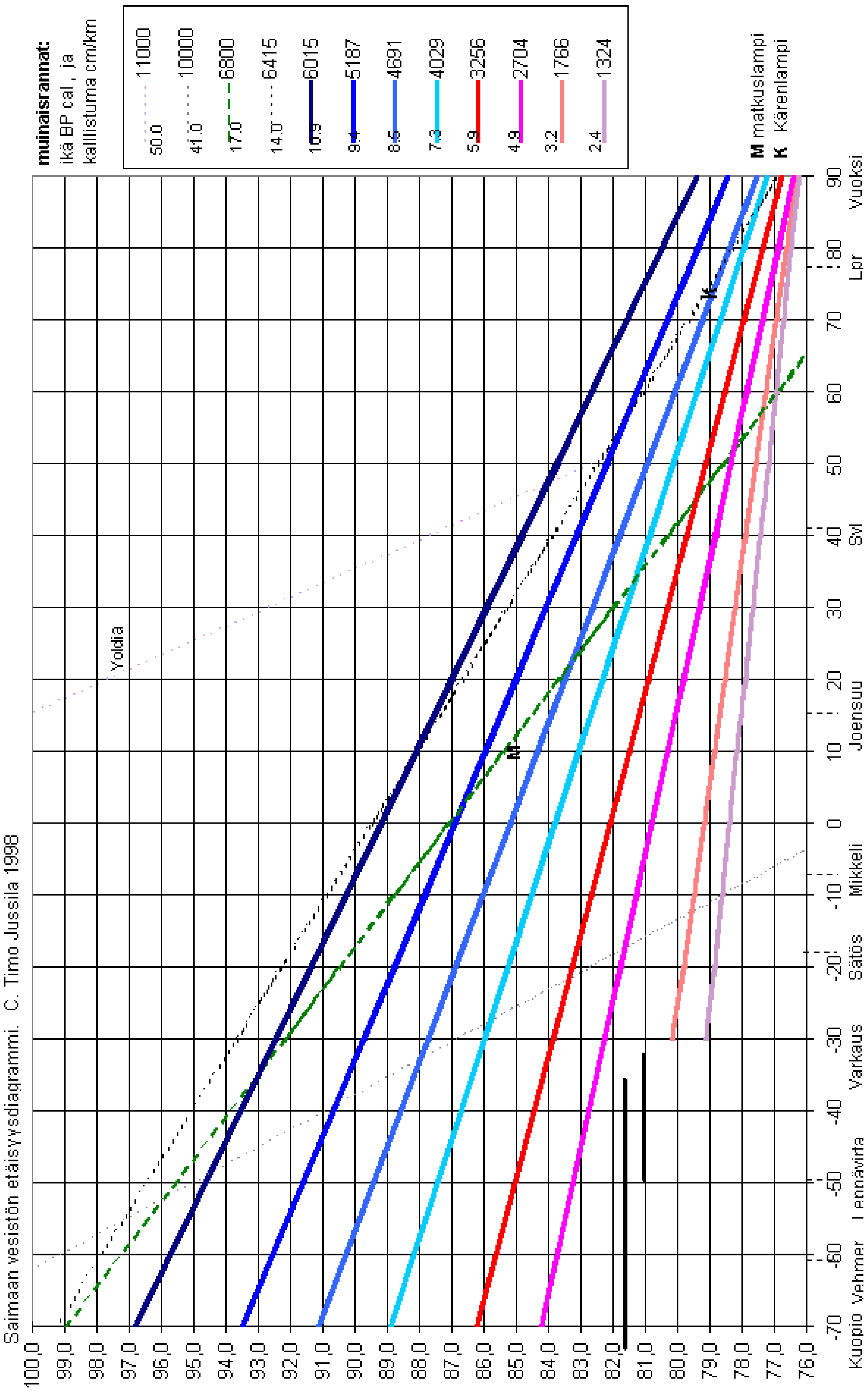
This list is not yet the result! Now we have 11 shoreline candidates waiting for further adjustments. It was not allowed two different cliffs from the same site (or leveled line) to exist in the same shore group. Names of the shores (T0 - T10) were marked to cliff-cards. To every shore was then calculated a regression line. Regressions were examined by residual plots and cliffs that are out of allowed range were dropped out from the shore. In this phase the allowed range was lowered to +-0.31 m. The program seek then all those cliffs that were out of shores but which were nearer (deviates less) than +-40 cm from each shoreline and connected these oprhan cliffs to "parent shores".

The resulting shoreline series appeared to be good and solid, except the intermediate shores. They are so far too sparse of observations that it is not useful to give them a status of regression line and gradient value. Their mass is not yet big enough to calculate them sensible regression line. We do not indeed know if these intermediate shores are real "shaping" shores. They might as well be, at least partly, "shades of errors", especially ghosts of measurement failures. In greater distances, where mixing of shores begin to effect strongly, many shore marks now stated to belonging to an intermediate shore might better represent errors or even better occasional local formations in the area of slow land uplift (especially T3 shores). Totally 178 cliffs were connected to main shore lines. GLS-shores of Rääkkylä Jaamannkangas which were in NE-Saimaa test diagram systematically slightly below the highest line are now inside error margins and their absolute deviation do not differ considerably from other points.

Table 6. Shore levels of Iso Saimaa

Shore nro	Shore name	Gradient m/km	zero elev. m asl.	r.m.s	CoD	nr. of points	Ceramic Periods purely according to the **base** of the cliffs
300	**T0**	**-0.109**	**89.2**	**0.204**	**99.00**	**50**	Ka2, Vasb, GLS
301	**T1**						
302	**T2**	**-0.094**	**86.9**	**0.215**	**99.00**	**32**	Ka2, Vasb
303	**T3**						
304	**T4**	**-0.085**	**85.2**	**0.205**	**99.00**	**27**	Ka2, Ka3, Pöl
305	**T5**	**-0.073**	**83.8**	**0.192**	**98.00**	**20**	Ka3, Pöl, (Txt)
306	**T6**						
307	**T7**	**-0.059**	**82.1**	**0.205**	**97.00**	**22**	Txt, Sär2
308	**T8**	**-0.048**	**80.8**	**0.140**	**99.00**	**20**	Txt, Sär2
309	**T9**	**-0.033**	**79.2**	**0.165**	**93.00**	**7**	(Txt), Sär2, Iron age

Diagram 10. The Distance diagram of Ancient Shores in Iso-Saimaa. See also Diagram 11 and 12 on page 75

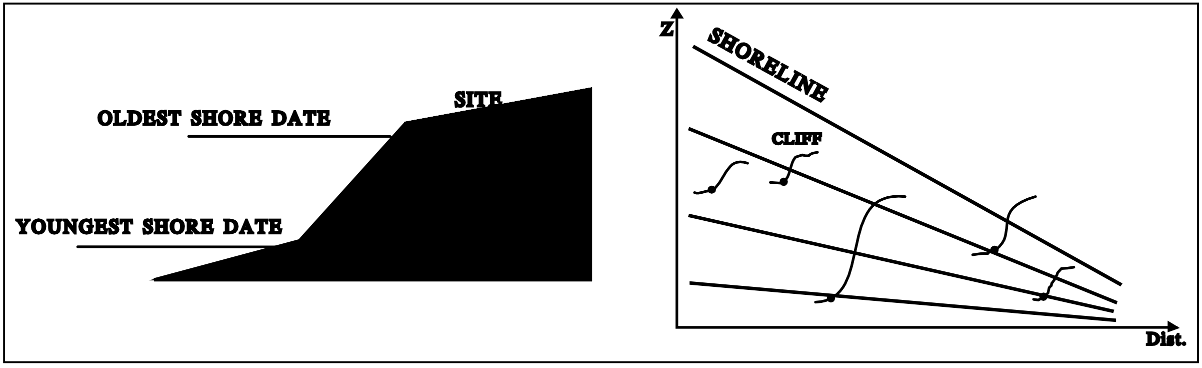


Ei alkuperäinen kuva

7. Relative dating of shorelines

Shores are now fixed to distance diagram and they are determined according to bases of cliffs. Fixing operation was done by using well known reference sites in areas where cliffs of different age (i.e locating under each other) are clearly visible. Further adjustement of regression values were then calculated from the whole accepted cliff material. The periodical dating of cliffs is at this phase suggested according to the bases of cliffs. Cliffs have lived their own life and ancient people their own. A top of a cliff was born after the waterlevel dropped below it. The base of a cliff has eroded downwards from the beginning of the formation process of a single cliff. The top of a cliff become suitable for a dwelling site soon after it has revealed, often well before the final beach scarp is formed. The base of a cliff tells the end of the formation process. After that the waterlevel has moved away from a cliff and the top of a cliff is no more at the shore. The elevation of the top of a cliff represents in distance diagram the oldest possible date for a site on it. The base of a cliff tells the youngest possible date for a shore-bound site on the cliff.

fig 14



In several cases the top of a cliff reaches well above older shorelines than the shoreline represented by the base. Sometimes a cliff is high enough to cross several shore lines, especially in SE. To connect ceramic periods to shorelines we have to examine which regression lines will cross the cliff boundaries in distance diagram. We will then obtain the youngest and the oldest date for a certain ceramic period that is represented in the material found on the top of a cliff. For this purpose i have created a shore-date index.

7.1. Shore-date index

Every determined ancient shore line has a number code, a number from 300 to 310. As mentioned before all elevation, distance and period information of leveled cliffs is stored in a computer database. A specific program seeks the first shorelevel that is below the base of the cliff (or below the lowest finds from the site etc..). The program starts seeking from highest shore (smallest shore name number) to which it calculates a deviation of the elevation of the top from that shoreline (=regression line). If the deviation is negative then the program takes next shoreline **below**, until the deviation of the top-elevation from a shore line is positive. The base number of the index is then the number code of this shoreline. Then program returns to the previous shoreline above and calculates also the deviation to that line. These absolute values of two deviation values are counted together. The resulting value is the distance between the shorelines between which the top is situated. This distance is transformed to number one and the deviation from shore line below is computed to this scale. At this way the vertical distance between shore lines is always one, regardless of the true diffrence. A site that is just in the middle of two shore lines will always have an index-deviation of 0.5.

For instance a cliff which top is at the elevation of 86.2 m asl. At that elevation is a comb ceramic site on a cliff. Program calculates the distance (if not yet calculated) of the site from the baseline. Then it seeks the first shoreline, starting from the highest shore nr. 300, that at this distance is about 87.1 m. In this case the first shoreline below top is shore nr. 302. The deviation of the top is +1.17 m from the shoreline 302. The deviation from the shore line above (nr. 300) is -0.90. The vertical difference of shores 301 and 300 is at site 2.07. This value is divided with two (because there is no regression line for shore 301, the relative distance will then be double instead of one). The deviation value from the shore below is then divided with that. Resulting number is the relative deviation value that is then subtracted from shore number of the shore below the top:

top_index := 302 - (1.17 / ((0.90 + 1.17) / (302 -300))) = 302 - 1.13 = 300.87

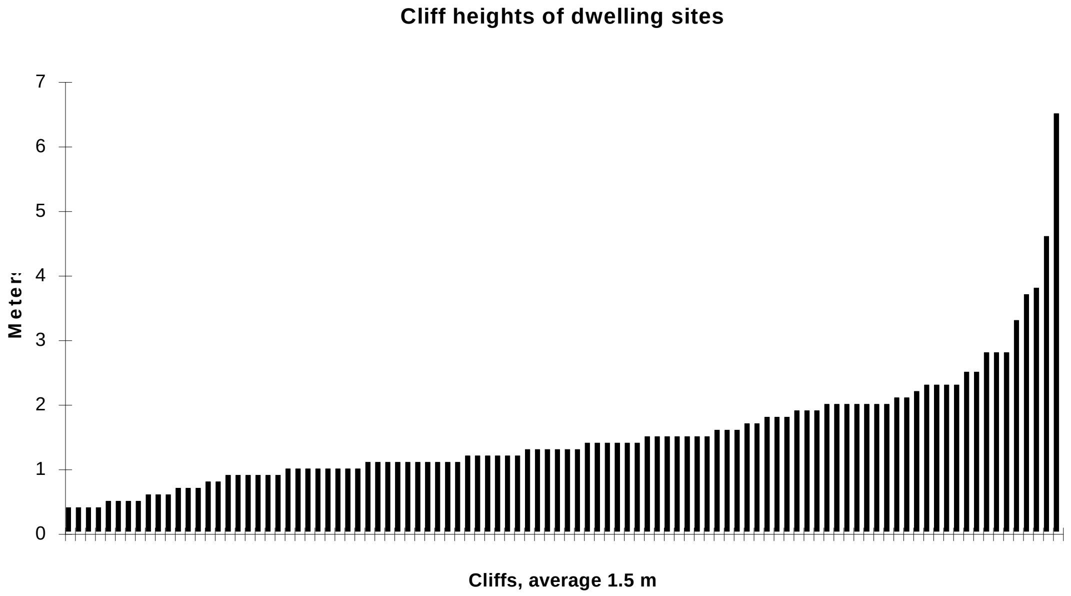
This index of oldest possible date is then stored in database. From that index we can now see that this site has exposed under water little earlier than the time of shoreline 301.

Second index is then calculated according to the base of the cliff. Program seeks, starting from the lowest shoreline, first line that is same or **above** the elevation of the base of the cliff at the current distance. The base-index value is then calculated at the same way than top-index value. Now we have the index number of youngest possible date for the site on top of the cliff.

The time span, or rather "shore-span", for a site might become very wide if the cliff below site is high. It is questionable if the site has been used all the living time of a high cliff. If a cliff is several meters high it has not been comfort shore dwelling site since the vertical distance to waterlevel had grown to several meters. If a cliff is both deep an high then it is obvious that the site on it has become useless far before the formation of the cliff is terminated. To diminish the time span of shoreline dating, it is useful to try to find a maximum height of a cliff suitable for shore-bound dwelling site. What is then the typical height of a comfort cliff? How high is too high cliff?

The average cliff height of all leveled dwelling sites is 1.6 m (sdv is 0.9 m). The highest cliff on which is a dwelling site is 6.50 m and lowest cliffs are 0.4 meters high. If we assume with common sense that a cliff over 2.5 meters high is certainly not comfort for dwelling on it, then the average cliff height is 1.3 meters (sdv is 0.5 m). The average height of cliffs that are well below the GLS-shore is 1.4 m (sdv is 0.6).

fig. 15



In regard to cliff-height data i constructed third index, a "probable age index". It is calculated in the same manner than oldest age, the top-index, but from the elevation of the top of the cliff is subtracted 60 cm. Then we get the age estimation of the situation when waterlevel was 60 cm below top of the cliff, and the site was at assumed most comfort stage. The value subtracted from elevation might be other as well. In this case i thought that subtracted value ought to be half of the average height of dwelling cliffs.

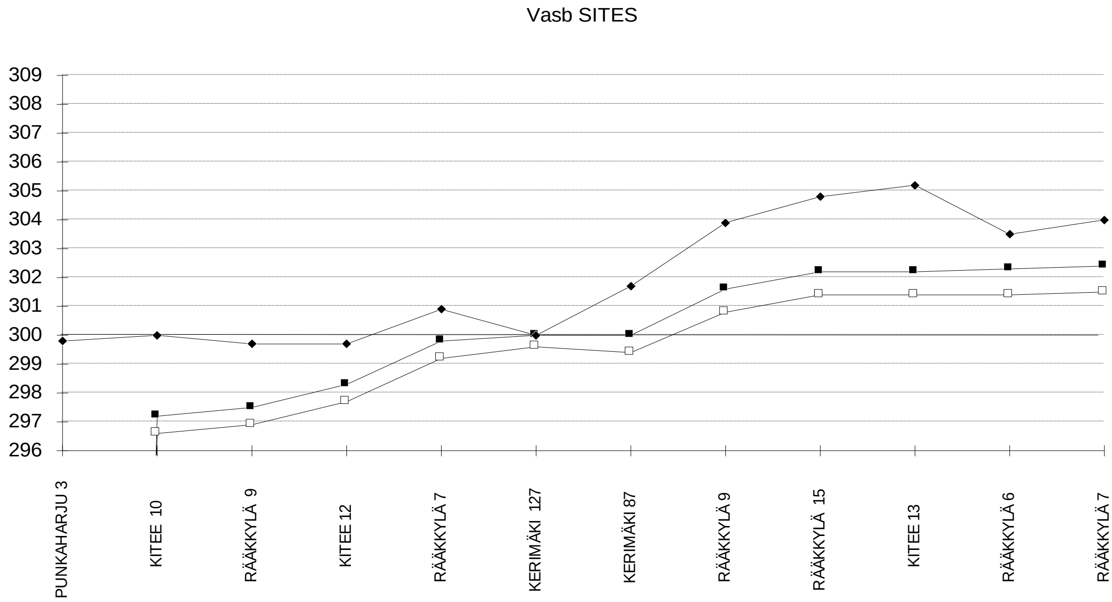
To all dwelling site cliffs were calculated these three indexes. In lists below sites are grouped according to their ceramic finds. Every ceramic group is further ordered by "propable-index". The site lists below are thus in theoretical order of age, from oldest to youngest. When ceramic periods are compared to index numbers we can estimate the relative period dating for shore lines. Bolded values in the middle column are propable-index numbers. In diagrams the propable index values are in the middle line, top-index values below it and base-index values above. In following lists are included also sites that were not used in the determination calcula-tions of shorelines.

Early Asbestos Ceramics

Commune	nr	name	**Shore index**	Ceramic Periods	S-ind. Top	S-ind. Base
OUTOKUMPU	3	Antinkangas		vasb kn		300.9
PUNKAHARJU	3	Pahatso		ka2 kn vasb		299.8

KITEE	10	Hiekanpää I	**297.2**	vasb kn ss	296.6	300.0
RÄÄKKYLÄ	9	Lappalaissuo 1	**297.5**	ka2 kn vasb	296.9	299.7
KITEE	12	Hiekanpää III	**298.3**	vasb kn	297.7	299.7
RÄÄKKYLÄ	7	Pörrinmökki 1+2	**299.8**	kn vasb	299.2	300.9
KERIMÄKI	127	Martinniemi	**300.0**	vasb	299.6	300.0
KERIMÄKI	87	Pikarniemi	**300.0**	vasb kn	299.4	301.7
RÄÄKKYLÄ	9	Lappalaissuo 1	**301.6**	vasb txt tom kn vm	300.8	303.9
RÄÄKKYLÄ	15	Kivilammensuo	**302.2**	vasb kn	301.4	304.8
KITEE	13	Lopola	**302.2**	ka2 kn vasb	301.4	305.2
RÄÄKKYLÄ	6	Mehonlahti	**302.3**	ka2 kn vasb	301.4	303.5
RÄÄKKYLÄ	7	Pörrinmökki 1+2	**302.4**	ka2 kn vasb pöl ka	301.5	304.0
Average			**300.3**		299.6	301.6

Fig 16



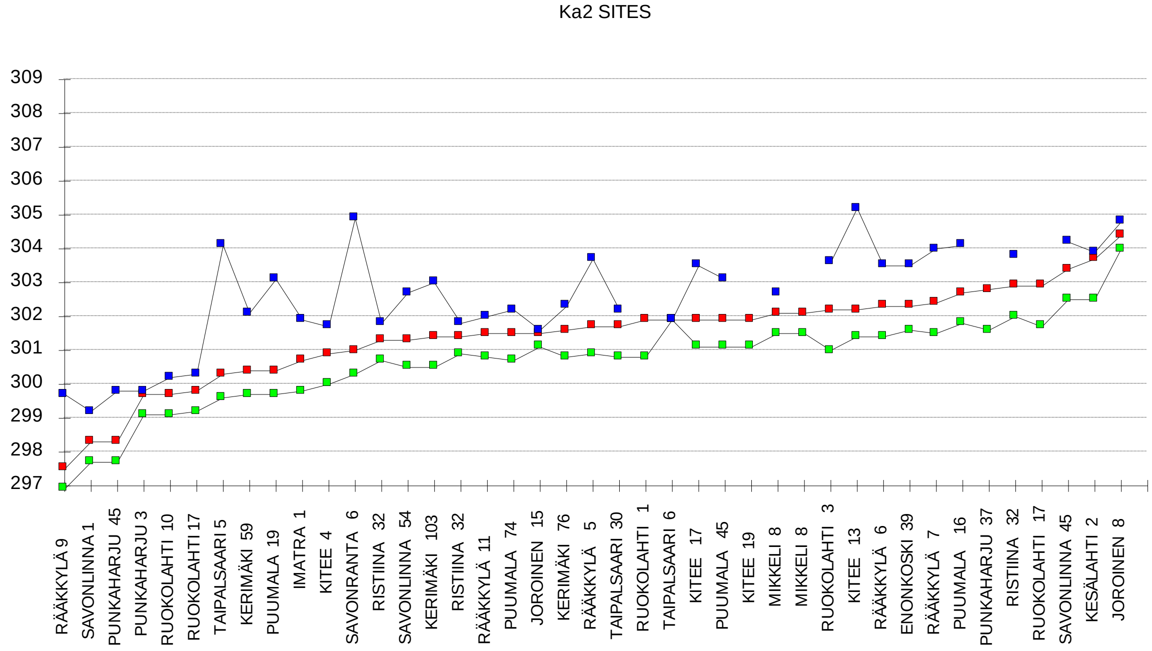
Vasb sites are clearly consentrated to oldest shores. Three sites are well above GLS-level. The height of the cliff is in Kitee [10] over three meters. In Rääkkylä [9] and Kitee [12] the cliff heihght is two meters above GLS-shorelevel. It is obvious that these sites have not anymore been shore-sites during the formation of the GLS-shore scarp. The waterlevel have had to be a longer period at clearly higher elevation than GLS-shore formation suggests.

Typical Comb Ceramics

Commune	nr	name	S-index	Periods	Top	Base
LAPPEENRANTA	10	Utransaari		kn kie ka2		302.1
MIKKELI	8	Konnunsuo a		ka2 asb kn		302.7
PUNKAHARJU	3	Pahatso		ka2 kn vasb		299.8
RANTASALMI	1	Suoranta	**297.1**	ka2 kn	296.5	300.2
RÄÄKKYLÄ	9	Lappalaissuo 1	**297.5**	ka2 kn vasb	296.9	299.7
SAVONLINNA	1	Pääskylahti	**298.3**	kn ka2	297.7	299.2
PUNKAHARJU	45	Lamminniemenl.	**298.3**	ka2 kn	297.7	299.8
RUOKOLAHTI	10	Anttila	**299.7**	ka2 kn	299.1	300.2
RUOKOLAHTI	17	Korosniemi	**299.8**	ka2 kn	299.2	300.3
TAIPALSAARI	5	Konstunkangas	**300.3**	ka2 kn	299.6	304.1
KERIMÄKI	59	Kaitasuo	**300.4**	ka2 kn	299.7	302.1
PUUMALA	19	Syrjäluhta	**300.4**	ka2 kn	299.7	303.1
IMATRA	1	Lammassaari	**300.7**	ka2 kn	299.8	301.9
KITEE	4	Koivikko	**300.9**	ka2 kn	300.0	301.7
SAVONRANTA	6	Kaatiolahti	**301.0**	ka2 kn	300.3	304.9
RISTIINA	32	Hietaniemenkang	**301.3**	ka2 kn	300.7	301.8
SAVONLINNA	54	Povenlahti	**301.3**	ka2 kn	300.5	302.7
KERIMÄKI	103	Hälvä	**301.4**	ka2 kn	300.5	303.0
RISTIINA	32	Hietaniemenkang	**301.4**	ka2 kn	300.9	301.8
RÄÄKKYLÄ	11	Mikinsuo 1+2	**301.5**	ka2 kn	300.8	302.0
PUUMALA	74	Karsikkolahti	**301.5**	ka2 ka3 kn mn	300.7	302.2
JOROINEN	15	Kolman kansakou	**301.5**	ka2 kn	301.1	301.6
KERIMÄKI	76	Raikuunkangas	**301.6**	ka2 kn	300.8	302.3
RÄÄKKYLÄ	5	Anninkangas	**301.7**	ka2 kn	300.9	303.7
TAIPALSAARI	30	Syrjälä 2	**301.7**	ka2 kn	300.8	302.2
RUOKOLAHTI	1	Satamoinniemi	**301.9**	ka2 asb (ka3) kn (	300.8	
TAIPALSAARI	6	Vaateranta	**301.9**	ka2 kn	301.9	301.9
KITEE	17	Sarvisuo	**301.9**	ka2 kn	301.1	303.5
PUUMALA	45	Karkianiemi I	**301.9**	ka2 kn	301.1	303.1
KITEE	19	Kyöpelinvuori	**301.9**	ka2 kn	301.1	
MIKKELI	8	Konnunsuo a	**302.1**	ka2 kn	301.5	
RUOKOLAHTI	3	Haukpohja	**302.2**	ka2 kn	301.0	303.6
KITEE	13	Lopola	**302.2**	ka2 kn vasb	301.4	305.2
RÄÄKKYLÄ	6	Mehonlahti	**302.3**	ka2 kn vasb	301.4	303.5
ENONKOSKI	39	Pöytälahti c	**302.3**	ka2 kn	301.6	303.5
RÄÄKKYLÄ	7	Pörrinmökki 1+2	**302.4**	ka2 kn vasb pöl ka	301.5	304.0
PUUMALA	16	Kotkatlahti A	**302.7**	ka2 kn	301.8	304.1
PUNKAHARJU	37	Kärensalmi	**302.8**	ka2 kn	301.6	
RISTIINA	32	Hietaniemenkang	**302.9**	ka2 kn	302.0	303.8
RUOKOLAHTI	17	Korosniemi	**302.9**	ka2 kn	301.7	
SAVONLINNA	45	Porrassalmi b	**303.4**	ka2 kn	302.5	304.2

KESÄLAHTI	2	Sirnihta	**303.7**	ka2 pöl kn mn	302.5	303.9
JOROINEN	8	Kyrönmäki	**304.4**	ka2 kn	304.0	304.8
Average			**301.4**		300.6	302.5

Fig. 17



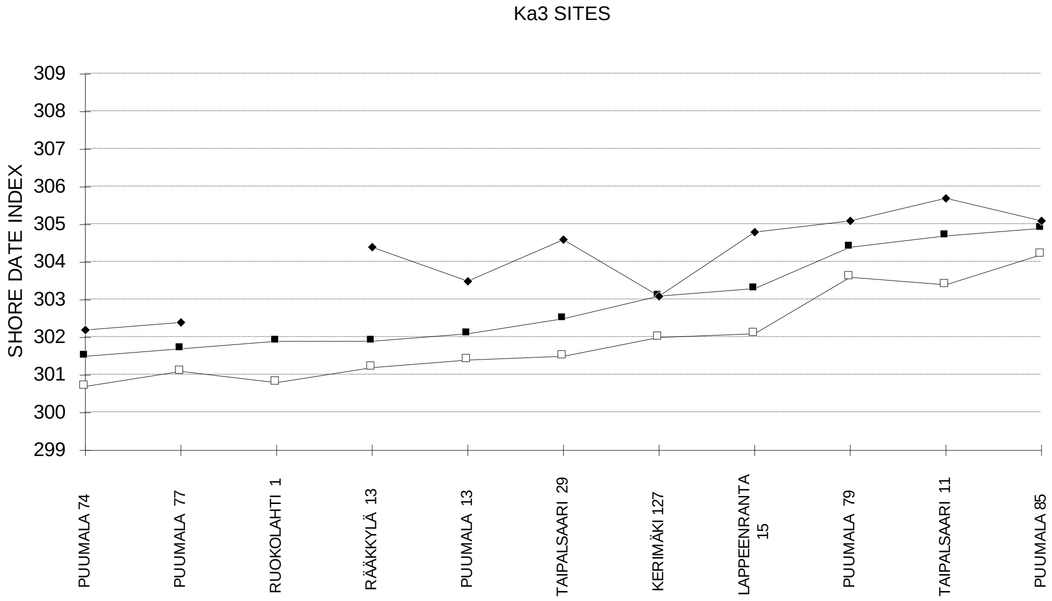
Typical comb ceramic sites are deviating to three oldest shores. Most sites are at the shorelevel T2 (302). Only about five sites are near the GLS-shore. Somewhat more sites are at the intermediate shore T1 (301). This might indicate the realtive duration of these shore-phases. The regression probably slows down during the T2 phase. Like some Vasb sites also some Ka2 sites are located well above GLS-shorelevel. Rääkkylä [9] is the same site than in Vasb list. Punkaharju [45] site is two meters above GLS-shore scarp. Savonlinna [1] site is on the top of about 1.5 m cliff. Joroinen [8] site is clearly "alone" at younger shore level than other Ka2 sites. The period of Joroinen site is based on a single four gram fragment of ceramics (km 26718:1) decorated with comb stamps.

Late Comb Ceramics:

Commune	nr	name	**Shore index**	Periods	S-ind. Top	S-ind. Base
PUUMALA	74	Karsikkolahti	**301.5**	ka2 ka3 kn mn	300.7	302.2
PUUMALA	77	Martikkala 2	**301.7**	ka3 mn	301.1	302.4
RUOKOLAHTI	1	Satamoinniemi	**301.9**	ka2 asb (ka3) kn (	300.8	
RÄÄKKYLÄ	13	Läävälahdensuo	**301.9**	ka3 mn (kn)	301.2	304.4
PUUMALA	13	Käärmelahti	**302.1**	ka3 ? mn	301.4	303.5
TAIPALSAARI	29	Taipaleenranta	**302.5**	ka3 mn	301.5	304.6
KERIMÄKI	127	Martinniemi	**303.1**	mn pöl ka3	302.0	303.1
LAPPEENRANTA	15	Hietaranta	**303.3**	ka3 mn	302.1	304.8
PUUMALA	79	Lahdenluhta	**304.4**	ka3 mn	303.6	305.1

TAIPALSAARI	11	Ketvele	**304.7**	ka3 kie kn mn asb	303.4	305.7
PUUMALA	85	Pistohiekka C	**304.9**	ka3 mn	304.2	305.1
Average			**302.9**		302.0	304.1

Fig. 18

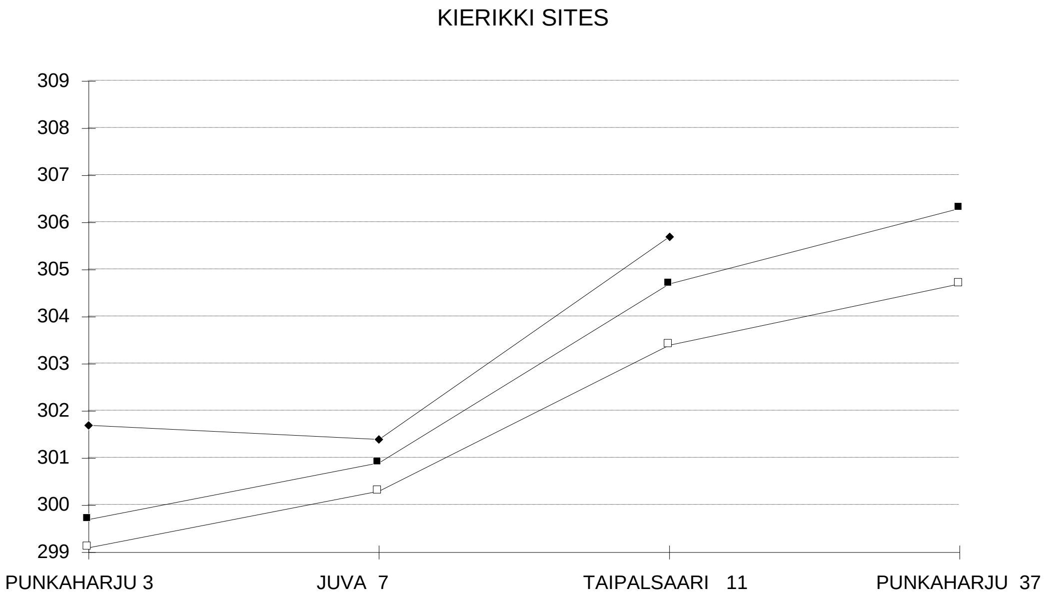


Few sites with ceramics which have **features** of late comb ceramics are generally at younger shores than Ka2. Some fragments that are identified as Ka3 ceramics might as well be degenerated typical comb ceramics Ka2:2. Ceramics from Puumala [85] (km 27563:1) and Taipalsaari [29] (km 27587:1) are exactly equal, mixed with crushed bone and some other organic splintered material that have vanished. It must be rememberd that most SE sites, at Lappeenranta, Ruokolahti and Taipalsaari, are in the area of slow land uplift, where the vertical elevation differs only slightly between shore levels. The shore date index of sites in these communes are not so accurate than in other areas more NW.

Kierikki Ceramics

Commune	nr	name	**Shore index**	Periods	S-ind. Top	S-ind. Base
LAPPEENRANTA	10	Utransaari		kn kie ka2		302.1
PUNKAHARJU	3	Pahatso	**299.7**	kie mn asb	299.1	301.7
JUVA	7	Otamo	**300.9**	kie mn asb	300.3	301.4
TAIPALSAARI	11	Ketvele	**304.7**	ka3 kie kn mn asb	303.4	305.7
PUNKAHARJU	37	Kärensalmi	**306.3**	kie mn asb	304.7	
Average			**302.9**		301.9	302.7

Fig. 19



Kierikki sites are so few, that it is impossible to get final datings from this material. Ceramics of these sites are however clear Kierikki ware. It is possible that fragmentary material identified as Pöljä ceramics might include also Kierikki ware.

Pöljä Ceramics

Commune	nr	name	**Shore index**	Periods	S-ind. Top	S-ind. Base
LAPPEENRANTA	3	Ahvensaari		asb pöl mn		303.9
RÄÄKKYLÄ	18	Mikinsärkkä	**301.3**	asb jys pöl mn	300.5	302.7
PUNKAHARJU	3	Pahatso	**301.5**	pöl mn	300.5	303.0
RÄÄKKYLÄ	7	Pörrinmökki 1+2	**302.4**	ka2 kn vasb pöl ka	301.5	304.0
KERIMÄKI	127	Martinniemi	**303.1**	mn pöl ka3	302.0	303.1
KESÄLAHTI	2	Sirnihta	**303.7**	ka2 pöl kn mn	302.5	303.9
LIPERI	7	Hylkylä 2	**304.2**	mn asb (pöl?)	303.6	
HEINÄVESI	4	Kalettomankanga	**304.5**	mn asb (pöl)	304.1	
SAVONLINNA	47	Niittyranta	**304.9**	pöl mn asb	304.2	305.6
SAVONLINNA	72	Niittyranta 2	**305.1**	asb mn (pöl?)	304.4	305.6
KESÄLAHTI	2	Sirnihta	**306.0**	pöl txt sir luu mn	305.0	306.0
Average			**303.7**		302.8	304.2

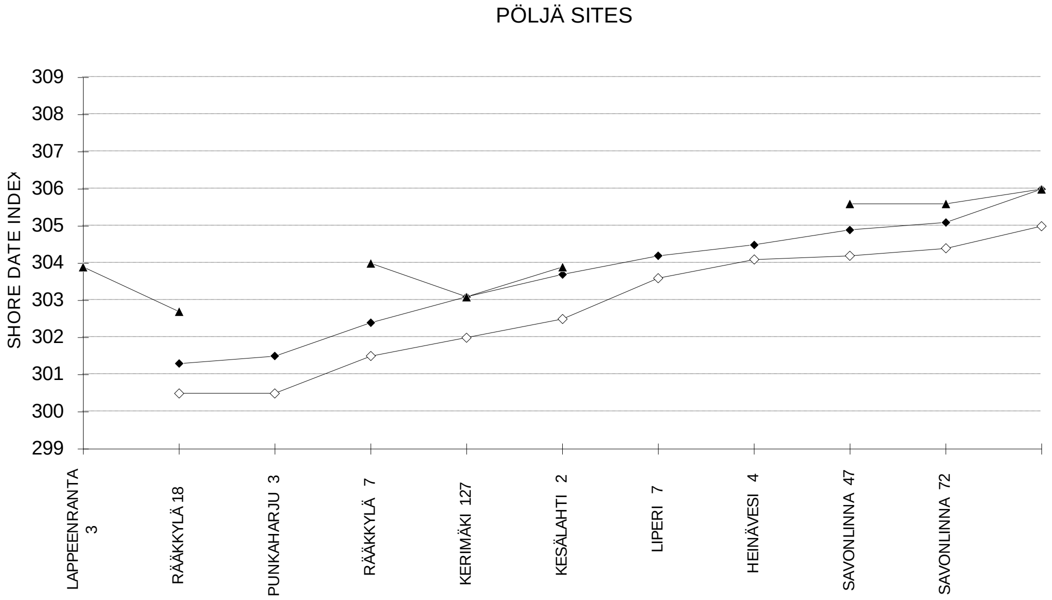


Fig 20

From Punkaharju [3] Pahatso site has been found Pöljä ware according to memos of Carpelan. The elevation and the exact location of Pöljä ware in Pahatso is however uncertain. The identification of ceramics from Rääkkylä [18] is based on a single three gram fragment. Other sites are quite clear Pöljä dwellings (often mixed with other ceramic types).

Textile Ceramics

Commune	nr	name	**Shore index**	Periods	S-ind. Top	S-ind. Base
RÄÄKKYLÄ	9	Lappalaissuo 1	**301.6**	vasb txt tom kn vm	300.8	303.9
KERIMÄKI	57	Kokkomäki	**303.5**	txt tom asb vm	302.4	306.4
KERIMÄKI	127	Martinniemi	**304.6**	txt VM	303.8	304.6
PUUMALA	16	Kotkatlahti A	**305.4**	tom txt vm	304.6	306.0
RISTIINA	32	Hietaniemenkang	**305.7**	tom txt vm	304.9	307.7
KERIMÄKI	127	Martinniemi	**305.8**	vm luu txt tom	304.7	306.7
TAIPALSAARI	29	Taipaleenranta	**306.0**	txt vm	304.6	
KESÄLAHTI	2	Sirnihta	**306.0**	pöl txt sir luu mn	305.0	306.0
TAIPALSAARI	30	Syrjälä 2	**306.5**	txt	305.1	307.9
RISTIINA	32	Hietaniemenkang	**306.9**	txt ? vm	306.1	307.7
RISTIINA	22	Pulmionlampi	**307.0**	vm luu sarsa txt a	306.2	307.3
TAIPALSAARI	6	Vaateranta	**307.2**	txt vm	305.8	307.9
RUOKOLAHTI	11	Alatalo	**307.3**	tom txt vm	306.2	307.3
RISTIINA	26	Kitulansuo d	**307.8**	tom txt vm ss+4	307.3	308.5
RÄÄKKYLÄ	20	Huotinniemi	**308.0**	txt tom asb vm Sär	307.1	308.4
SAVONLINNA	71	Haukilahden poh	**308.1**	tom txt vm	307.4	
Average			**306.4**		305.4	307.1

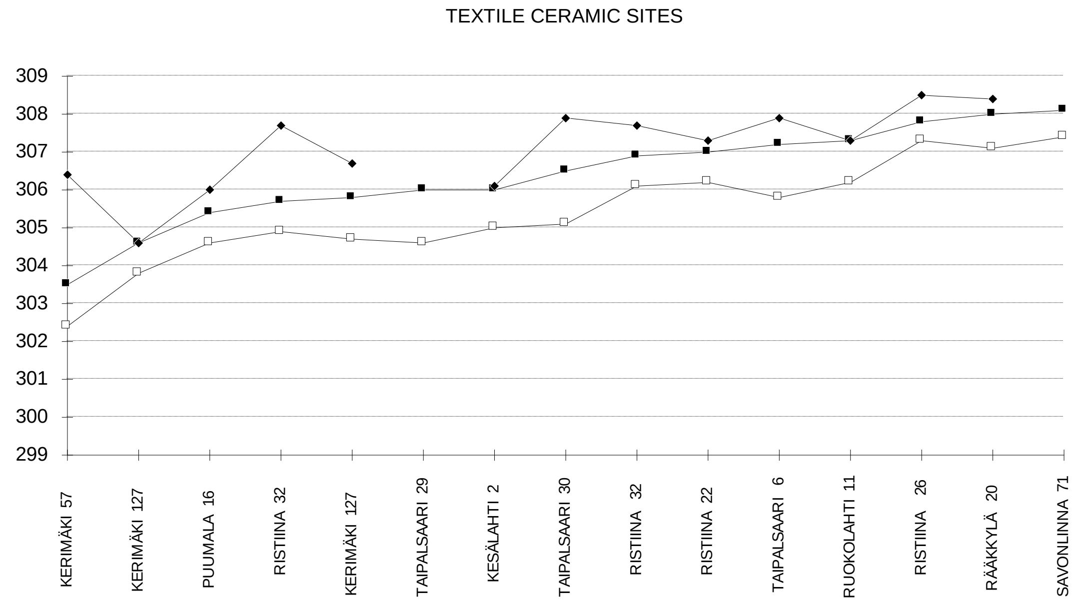


Fig. 21

Rääkkylä [9] site was certainly not a shore-bound dwelling during the textile ceramic phase. Ceramic material from Kerimäki [57] site is very sparse and fragmentary. The ware identified as textile ceramics might also be late Neolithic ware. The site is located on the 2.3 m high cliff. Ceramics from upper shore of Kerimäki [127] are found on a narrow terrace, not far from bronze age shore. Sparse ceramics from this shore of Kerimäki [127] site are unusual and strange and they are not very typical Tomitsa or Sarsa ware.

Sär-2 Ceramics

Commune	nr	name	**Shore index**	Periods	S-ind. Top	S-ind. Base
JOROINEN	11	Rydänniemi	**305.6**	vm sär2	305.0	306.9
KERIMÄKI	127	Martinniemi	**305.8**	vm luu txt tom	304.7	306.7
KESÄLAHTI	2	Sirnihta	**306.0**	pöl txt sir luu mn	305.0	306.0
PUUMALA	9	Pistohiekka B	**306.5**	vm epineol	305.6	307.5
RISTIINA	22	Pulmionlampi	**307.0**	vm luu sarsa txt	306.2	307.3
LIPERI	6	Hylkylä	**307.8**	vm sär2	307.4	307.9
RÄÄKKYLÄ	20	Huotinniemi	**308.0**	txt tom asb vm Sär	307.1	308.4
Average			**306.7**		305.9	307.2

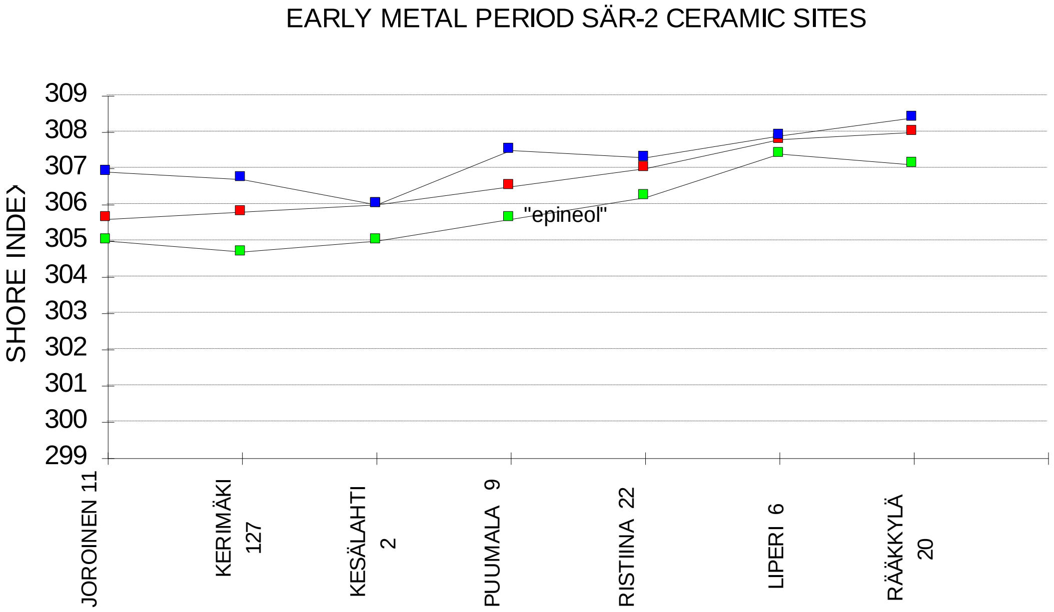


Fig. 22

From Puumala [9] site is found a single tiny piece of well burned scraped ware that resembles bronze age ceramics of SW-Finland. Other sites in the list are clear Sär2-sites with fine thin walled asbestos ceramics, either Luukonsaari or Sirnihta ware.

From above lists we can examine occurences of different ceramic types near certain shore levels. We can examine the first shore, the last shore and the most propable shore level on which ceramic types exists. Following table is based on probable shore index values:

Table 7.

Period	Min. Shore		Max. Shore		**Aver. Shore**	
Vasb	298	T0-	303	T3	**300.3**	T0
Ka2	298	T0-	304	T4	**301.4**	T1
Ka3	302	T2	305	T5	**302.9**	T3
Kie	300	T1	306	T5	**302.9**	T3
Pöl	303	T2	306	T5	**303.7**	T4
Txt	305+	T5			**306.4**	T6
Sär2	305+	T6			**306.7**	T7

Table 8.The final shoreline displacement dating table. Shores are connected with ceramic periods. A rough deviation of ceramic groups among shore lines.

Shore nro	Shore name	Gradient m/km	zero elev. m	Vasb	Ka2	Ka3	Kie ?	Pöl	Txt	Sär2
300	**T0**	**-0.109**	**89.2**	**XXX**	XX		x			
301	**T1**	**x**		XXX	**XXX**		x			
302	**T2**	**-0.094**	**86.9**	XXX	XXX	XXX	x	x		
303	**T3**	**x**		x	XX	**XXX**	**x**	XX		
304	**T4**	**-0.085**	**85.2**		x	XX	x	**XXX**		
305	**T5**	**-0.073**	**83.8**			X	X?	XXX	X	X
306	**T6**	**x**						x	**XXX**	XXX
307	**T7**	**-0.059**	**82.1**						XXX	XXX
308	**T8**	**-0.049**	**80.8**						XXX	XX
309	**T9**	**-0.032**	**79.2**						?	?

Stone-age / bronze age border is bolded line, between T5 and T6.

7.2. Comments of relative dating

From the table above and figures 16-21 comes out fairly sharp and clear transition from Neolithic ceramic types to Early Metal period Sär2 and Textile ceramics after the shore phase T6. With textile ceramics comes also a new style of dwelling on the shores of Lake Saimaa. Textile ceramics is an indicator of the beginning of the bronze age in Finnish lake area (Carpelan 1979). While Neolithic sites have followed strictly retreating shoreline, textile ceramic sites have not allways done so. Original hunter-gatherer sites have located just at the shore line, where the clearing of forest was unnecessary. Bronze age users of textile ceramics did not avoid clearing work when settling their dwellings. Have they been used to forest clearing in other meanings? Some textile ceramic sites are located on a top of very high cliff, some times together with older neolithic material. In the Table above such kind of site is Rääkkylä [9] Lappalaissuo. Most clear non-shore textile ceramic (some with Sär2 ceramics) sites were dismissed from the material before calculations.

Table 9. Shoreline gradients compared to other investigations:

period	Jussila Iso-Saimaa	Carpelan Saimaa	Matiskainen 1979 Päijänne	Siiriäinen, Baltic coast
Vasb	(0.110) - 0.093	0.133 - 0.118		
Ka2	(0.110) - 0.090	0.120 - 0.113	0.125 lowest	0.120
ka3	0.094 - 0.073			0.110
Kie	0.110 - 0.073	0.110		
Pöl	0.090 - 0.070	0.090 - 0.080		
Txt	0.073 - (0.032)		(txt, kiukais) 0.070	kiukais cer. 0.070
Sär2	0.073 - (0.032)	0.041		

Values of Carpelan are from his unpublished notes and diagrams from 1970:ies. Capelan' s gradients are for the whole Saimaa area. Siiriäinen's values are for baltic Coast (1974).

8. Absolute Dating

With the help of C14 or other absolute dating methods it is possible to create a time gradient curve. Siiriäinen has constructed a time-gredient curve for Baltic Shores according to distance diagram based on archaeological data (1974). Lappalainen constructed for the southest Saimaa area a time gradient curve, but he did not have absolute C14 datings as a basis.

In order to fix gradient values of shores to a time-gradient curve we have to estimate their ages BP. We can do it by calculating the amount of land uplift between two distance points of the distance diagram. If we can estimate the annual differences of landuplift between these points, we can then calculate how long a time it has taken to erect the differences in elevations of each shores between these points.
From landuplif isobases (map. 2 and 3) we can estimate that the difference in annual land uplift between the base line (at zero distance) and Vuoksi (at +90 km distance) is about 1.5 mm/yr. For example: the difference of elevations of these two points in distance diagram at the synchronous GLS shorelevel T0 is 9.7 meters. The difference in annual land uplift between these points is 1.5 mm. The calculated time for the period of formation of the elevation difference of 9.7 m is then 9700 / 1.5 = 6467 years.
However, the scale of used landuplift contour maps (map 2 and 3) is rather big and thus the determination of the difference of landuplit is not exact. There is also regional variances, or better sayed zonal variations of landuplif difference between baseline and +90 km distance. In table 9 is calculated also an estimated error margin in landuplift difference determination: 1.44 mm/yr. and 1.56 mm/yr. This determination error of dates grows (naturally) in older dates but it is still tolerable. Minor changes in gradient values do not cause notable differences in datings. Major error source of the calculated absolute datings is the determination of the landuplift difference value.

Table 10. Calculated datings

shore	grad.	BP calc. 1.5 mm yr.	BP calc 1.44 mm yr.	BP calc 1.56 mm yr.	Z at zero (base-line)	Z at +90 Vuoksi	diff.. of elev.	diff. of years (1.5) between shores	diff. of years (1.44)	diff. of years (1.56)	reg.rate m. per yr. at zero (1.5)	shore inclina-tion per year mm/km (1.5)
T0	0.109	6540	6813	6288	89.2	79.4	9.8	↓	↓	↓	↓	↓
T2	0.094	5640	5875	5423	86.9	78.4	8.5	900	938	865	0.0026	0.0167
T4	0.085	5100	5313	4904	85.2	77.6	7.7	540	563	519	0.0031	0.0167
T5	0.073	4380	4563	4212	83.8	77.2	6.6	720	750	692	0.0019	0.0167
T7	0.059	3540	3688	3404	82.1	76.8	5.3	840	875	808	0.0020	0.0167
T8	0.049	2940	3063	2827	80.8	76.4	4.4	600	625	577	0.0022	0.0167
T9	0.032	1920	2000	1846	79.2	76.3	2.9	1020	1063	981	0.0016	0.0167
T10	0.024	1440	1500	1385	78.4	76.2	2.2	480	500	462	0.0017	0.0167
Tres	0.000	0	0	0	76.0	76.0	0	1440	1500	1385	0.0017	0.0167

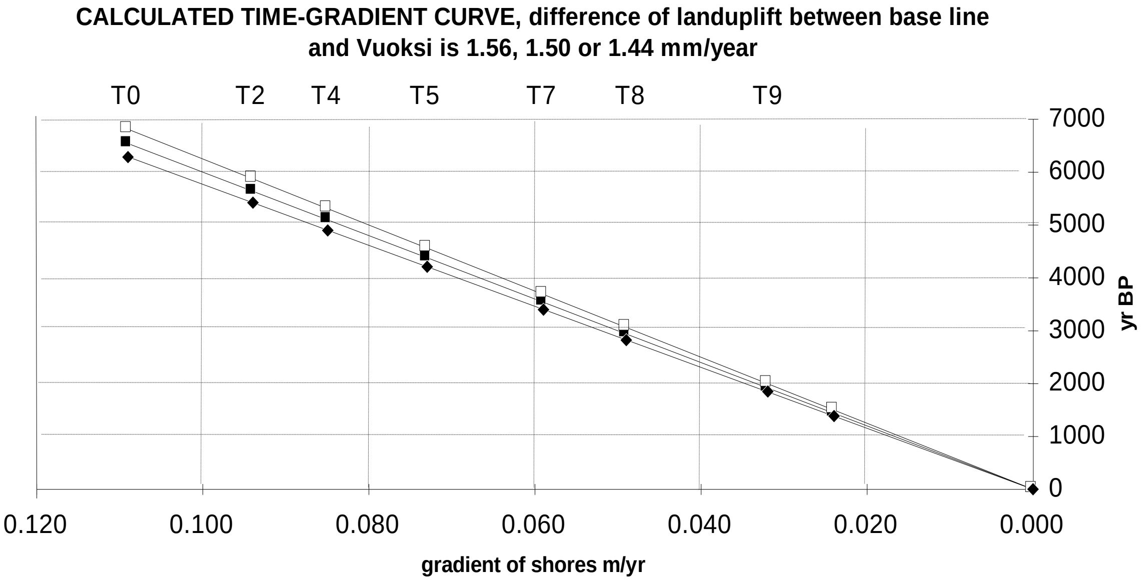


Fig. 23

Calculated datings do not take on account any sudden or temporal eustathical changes in water-level. Constant eustathical effect will impress the diagram. This effect comes primarily from the used distance diagram. The eustathical effect can be seen in diagram 11 at column "regression rate per year". There has existed a constant but decrasing water pressure in downstreams, that had caused shore gradients to be less inclined than without it.

We can and we should correct the calculated datings with C14 datings, to reveal incidents in waterlevel change which will not come out in calculated datings. From the area of this study its available (in 1993) only few C14 datings that can be connected to shore observations of this study. These datings are:

- Rääkkylä [7] Pörrinmökki, charcoal from a fire place, at 84 m asl. It is about 30-50 cm above the GLS (T0) shoreline. Dating index is 299.8. Gradient of the shore is 0.109.

5090+-100 (Hel 3223) , 5270+-100 (Hel 3222)
and charcoal from a pit at the same level than fire place:
5640+-100 (Hel 3224) (P.Pesonen, pers.comm.)

- Kerimäki Puntusensuo, a dating from equisetum layer from a bog. According to Saarnisto (1970) dating represents the waterlevel when bog basin isolated from Saimaa. Treshold at about 79 m asl. Distance 54 Km. In distance diagram it fells right on to shoreline T7 (307), Gradient 0.059. 3635+-150
- Varkaus Sarkalahti, a dating from bog tells the isolation of lake Unnukka from Iso-Saimaa (Saarnisto 1970). At about 81 m asl, Distance -29 km, between shores T8 and T9 and gradients 0.049 - 0. 033 = 0.41. 2460+-150

The datings of the GLS of Saarnisto are about the same than datings of Pörrinmöki fire place. The dating of the pit in Pörrinmökki is about the same than Saarnisto's dating connected to GLS from Puntusensuo (Saarnisto 1970: 61). Is this dating representing the habitation before the highest waterlevel during the fast transgression period?

In time-gradient curve we have to use C14 ages that are calibrated to solar years. Datings were calibrated with Groningen version 1988 based on Stuivier & Pearson 1986.

Table 11. C14 datings used in time-gradient curve.

shore	site	C14	94%	BC	aver.	BP cal.
T0	Pörrinmökki	5090+-100	4220	3690		
		5270+-100	4350	3820	4020	**5970**
T7-	Puntsensuo	3635+-150	2310	1740	2025	**3975**
T8-T9	Sarkalahti	2460+-150	900	200	550	**2500**

Calibrated C14 dating of Sarkalahti will fit extremely well in calculated diagram. According to C14 dates the only clear difference is in the dating of the GLS-shore, in which is connected a clear and well known eustathical change: the Vuoksi catastrophe. Also the younger Puntusensuo dating fells bit younger than the calculated date. Hovever the diffrence is fairly small since the dating is from the bog and is connected roughly to the treshold altitude of that bog. In basic calculated Time Gradient Curve we must then substitute calculated ages of T0 shore and T7 shores with calibrated C14 datings and add the T8-9 intermediate dating of Sarkalahti.

Table 12.. C14 BP cal. time span per gradients.

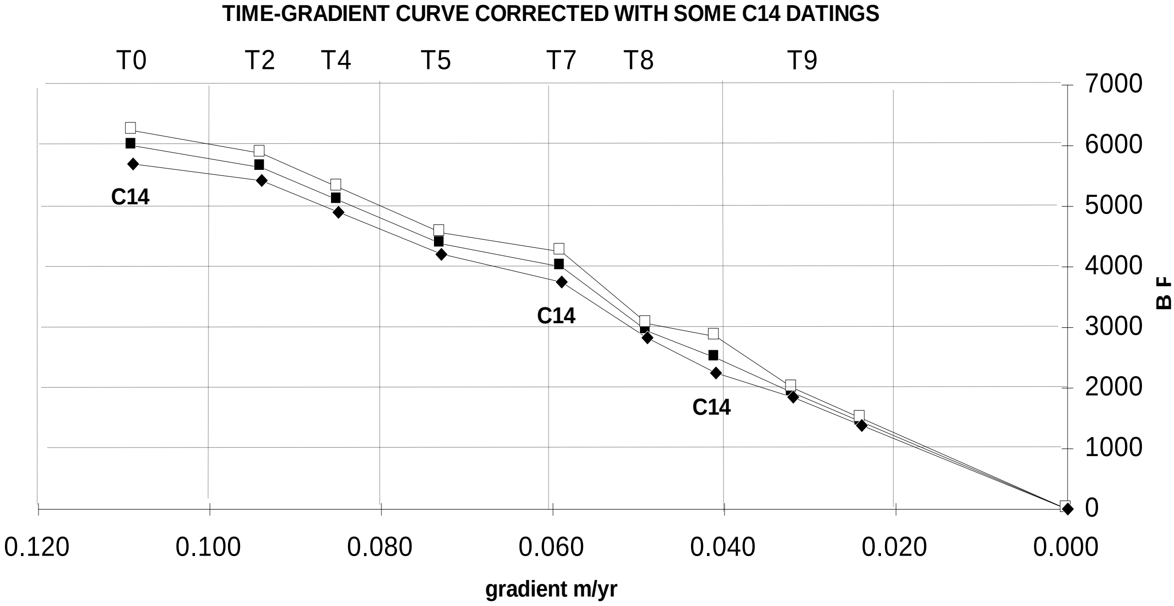
min. 6300	0.110
max. 5650	0.110
min. 4300	0.059
max. 3700	0.059
min. 2900	0.040
max. 2200	0.040

The resulting time-gradient curve is based only on three C14 datings (figs. 24 and 26). This result is, at least in its details, a preliminary curve to show possibilities that can be achieved with a well constructed time-gradient (or time-shore) curve. The error margin in corrected curve is among non C14 dates based on the determination error of landuplift difference and among C14 corrected dates straight from the C14 analyses themself (from calibrated sigma values).

Table 13. C-14 corrected datings

shore	grad.	BP C14 & calc 1.5 mm yr.	BP C14 & calc 1.44mm yr.	BP C14 & calc 1.56 mm yr.	z at zero (base-line)	Z at vuoksi	calc. diff. of elev.	diff. of years between shores (1.5)	diff. of years (1.44)	diff. of years (1.56)	reg.rate m. per year at zero distance (1.5)	shore inclination per yr. mm/km (1.5)
T0 **C14**	0.109	6000	6300	5650	89.2	79.4	9.8	↓	↓	↓	↓	↓
T2	0.094	5640	5875	5423	86.9	78.4	8.5	360	425	227	0.006	0.0417
T4	0.085	5100	5313	4904	85.2	77.6	7.7	540	563	519	0.003	0.0167
T5	0.073	4380	4563	4212	83.8	77.2	6.6	720	750	692	0.002	0.0167
T7 **C14**	0.059	4000	4300	3700	82.1	76.8	5.3	380	262	512	0.004	0.0368
T8	0.049	2940	3063	2827	80.8	76.4	4.4	1060	1238	873	0.001	0.0094
T8-9 **C14**	0.040	2400	2900	2200	80.0	76.4	3.6	540	163	627	0.001	0.0167
T9	0.032	1920	2000	1846	79.2	76.3	2.9	1020	1063	981	0.002	0.0167
T10	0.024	1440	1500	1385	78.4	76.2	2.2	480	500	462	0.002	0.0167
Tres	0.000	0	0	0	76.0	76.0	0.0	1440	1500	1385	0.002	0.0167

Fig.24



The time span beween T0 and T2 is quite short, only couple of hunred years. It is questionable if expected intermediate shore T1 will exist at all at the same mass of observations than other shores. Regression rate was after the Vuoksi catastrophe quite high. It gradually decreased during next shore phases (T2-T4).

According to this curve, we can see that there have existed at least two phases of faster regression. First fast regression is the formation of the Vuoksi. Second period of faster regression seems to be between shorelines T5 - T7, during the switch from neolithic ceramics to bronze age ceramics, at time period 4500 - 4000 BP cal.

Carpelan and Siiriäinen investigated a bog profile from Pökrönsuo at the SE shore of Puruvesi in seventies from which they observed two layers of sand. The dating of the profile just below lower sand layer was 4120+-170 bp (unpublished). Saarnisto (1970: 61) dated same kind of phenomena in Puntusensuo, at the NW shore of Puruvesi (not so far from Pökrönsuo) to 4155+-100. Calibrated age of Saarnisto's date is:

4400 - 4900 BP

68.3 % (1 sigma) confidence level yields the following ranges :

2890 cal BC ... 2850 cal BC

2830 cal BC ... 2610 cal BC

95.4 % (2 sigma) confidence level yields the following ranges :

2930 cal BC ... 2470 cal BC

These datings of Siiriäinen & Carpelan and Saarnisto indicates the second phase of accelerating regression during late Neolithic or Eary Bronze age, between shore phases T5 and T7. According to these bog profiles second fast regression showed by distance diagram and c14 corrected time-gradient curve, have been same kind of rough and sudden incident than the first Vuoksi catastrophe. C14-datings of Pökrönsuo and Puntusensuo suggests that this event happened at shore phase T5. Shore observations of the intermediate shore T6 are about half meter below the T5 shore (see circular plots between T5 and T7 in diagram 10 at page 54). The gradient value of these four T6 points is 0.071 m/km. It is practically the same than the gradient of T5. The intercept value of T6 is 83.2 m. It seems to be clear that at Late Neolithic a sudden half meter collapse of waterlevel occured at Lake Saimaa.

How is the great rate of inclination between T5 and T7 shores explained? The clear difference of the regression values between T5 and T7 suggests longer time period than 300-440 years between these shores. After the second collapse the waterlevel must have been stayed a longer period almost at the same level at the distance of the Vuoksi (figures 25-26 at page 76-77) and at the same time regression have continued in NW. In the collapse the waterpressure downstreams of the watershed was released for a short while. After the collapse water pressure increased for a period finally to achieve equilibrum. Same kind of movement from "temporal disorganization towards natrural order" must have happened during and after first collapse. If we accept sudden drop of half a meter, then abnormal inclination values in table 13 will be better understanded and they will be corrected in reality (figures 25 and 26).

Table 14. Preliminary absolute datings of shore levels and ceramics connected to shores. All datings are calibrated to solar years.

Abs. Grad.	Shore	BP max	BP min	Ceramic periods	BC max	BC min	Siiriäinen 1978	Nunez 1978	Carpelan 1979	bounda-ries
0.109	T0	6250	5750	Vasb, Ka2	4300	3700	max 4200	max 4300	max 3200	**Ka2 max**
	T1			Vasb , Ka2						
0.094	T2	5900	5450	Vasb, Ka2, Kie	3950	3500				
	T3			Ka2, Ka3, Kie, Pöl			3500	3800-3500	2700	**Ka2/Ka3**
0.085	T4	5300	4900	Ka3, Kie, Pöl	3350	2950	3300	3200	1800	**Ka3 min**
0.073	T5	4550	4200	Pöl	2600	2250				
	T6			Txt						
0.059	T7	4100	3900	Txt ,Sär 2	2150	1950			1300	Txt max.
0.049	T8	3050	2850	-"-	1100	900			1000	
0.033	T9	2000	1850	-"-	50	AD 100				
0.024	T10	1500	1400		AD 450	AD 550				

Datings in table 14 shows the years during which the waterlevel was at +-40 cm span from certain average shoreline. The dates of Siiriäinen and Nunez are absolute dates from Nunez's diagram in Iskos 2 1978, p. 45. Dates of Carpelan are from his picture (1979) that illustrates the relations and datings between Finnish ceramic groups. Group boundaries of this picture of Carpelan are calibrated to above table by author.

The dating of the arrival of textile ceramics to the Saimaa area is an interesting result. According to constructed time-gradient curve textile ceramics emerges to the shores of the Lake Saimaa about 2000 BC or even one or two hundred years before. If we do not accept this dating based on one C14 value, we can then estimate the arriving of textile ceramics by calculated datings according to which the first Textile ceramics shore (T6 or early T7) is dated to about 2100 - 1600 BC. Textile ceramics exist clearly and undoubtedly without Neolithic counterparts on the T7 shore. Arriving of textile ceramics had had to been happened before shore phase T7 and after shore phase T5. So far it is impossible to move the calculated datings of T5 and T7 shores any younger. There is no such a possibilities in sight. Instead the older dating of these shores is very possible and sensible alternative to calculated ones. Datings of early textile ceramics presented here fits well to the datings of Kiukais ceramics in SW Finland, which roots are partly at the baltic textile ceramics (Carpelan, lecture in 1993, Meinander 1954), and to the datings of Ruhtinaansalmi material at NE-Finland (Lavento 1993).

The hypothesis for future shoreline displacement investigation of northern Saimaa is that T1 and T6 shores should not emerge in an extent than other intermediate shores. The T6 shore, if it emanates, should have about the same gradient than T5 shore about half meters below it. There might also emerge a intermediate shore between T7 and T8 as well as between T8 and T9 farther in NW. However, the northern Saimaa have lived its own life, separate from Iso-Saimaa after shore phase T8.

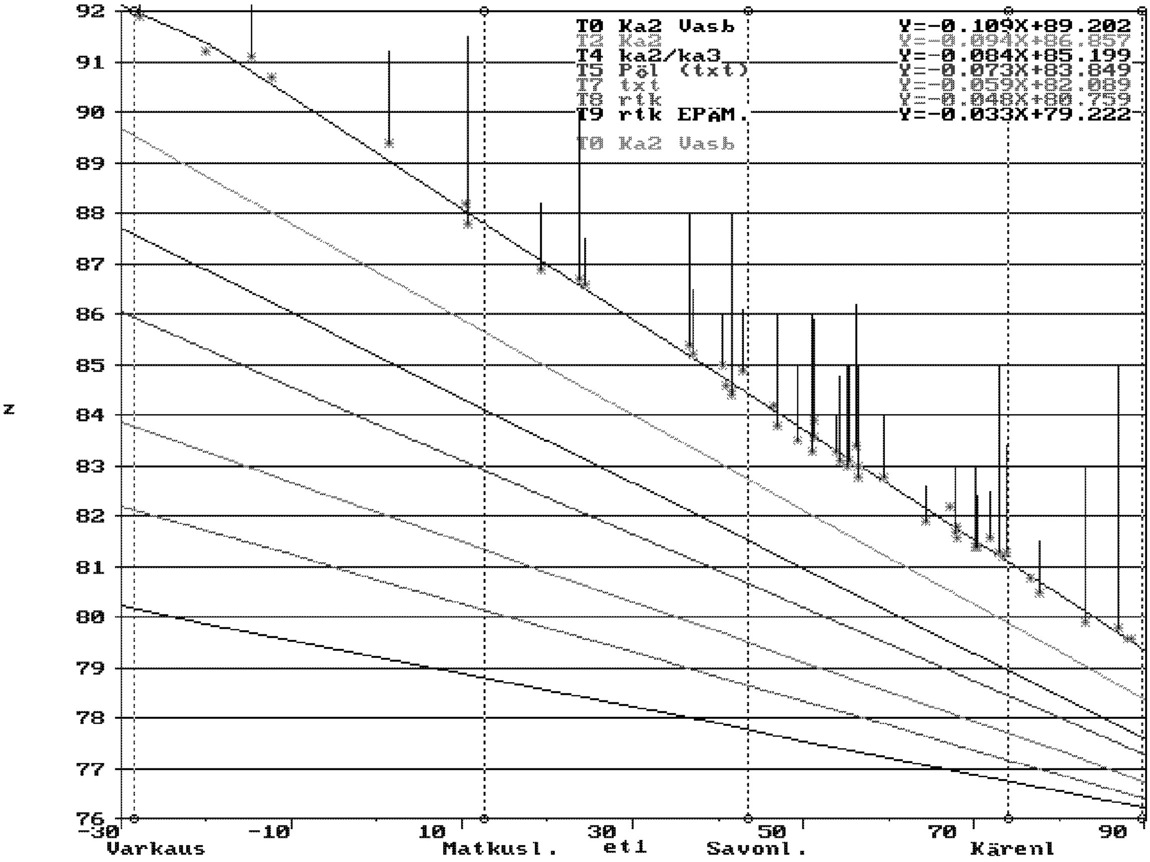
9. The highest Great Lake Saimaa Shore

The formation of Vuoksi occurred about 6000 years ago. It is fairly clear that there have **not** occurred a sudden collapse of two meters in waterlevel due to Vuoksi catasthrope from GLS-shore to below it. The drop between well adjusted shore lines T0 and T2 is in SE near Vuoksi about one meter. Two or three sites exist on the intermediate shore T1. These sites as well as three of these shore formations are clearly below GLS and above T2-shores. The regression have been moderate enough in the level of T1-shore that there have been formed shore marks and there have been enough time to live on these shores. However, the small amount of sites might indicate that the regression has been relatively fast (still only about six cm per year at the zero distance). On T2 shoreline exists then numerous dwelling sites. This shore level has been suitable for living for a longer period.
Six dwelling sites are locating on the top of the GLS shore formations (T0). This tells that water level has stayed for a period at that level. The amount of sites is still less than in younger shores, even though these altitudes of traditional GLS have been generally better investigated during surveying works than lower altitudes. This might again indicate the relatively short period of existence of the GLS-shoreline. Four sites are on the top of more than two meters high sheer cliff (Kitee 10, Kitee 12, Punkaharju 45 and Rääkkylä 9).
Around these sites is lot of lower and better shores to live vertically closer to the current shoreline. We can assume that these sites have been used when the water level was nearer the top of cliffs, at least about one meter below these sites. It is quite possible that the transgression have been just before the breaking of the Vuoksi very rapid. As stated before, the highest shoreline represents rather a shore line before or after the maximum level of transgression. The traditional highest shoreline, represented by the bases of cliffs, is representing the first delay in regression (a delay in relative meaning). There is sites on highest GLS-shore. Sites are on also on the top of low GLS cliffs (for instance Kerimäki 127, Ruokolahti 3 and 18). The traditional GLS cliffs must have been formed and existed **after** the transgression and **after** the Vuoksi catastrophe during the regression period.

Transgression rate before Vuoksi catastrophe have probably been contioniously increasing in southern Saimaa. When Pielavesi outlet dried the transgression must have been accelerated to very fast rate. This fast transgression have reached about two meters **above** the shore level of traditional GLS. Dwelling sites on the shores of Saimaa have gradually escaped to upper shores, in a way that there is always a comfortable vertical distance to the current waterlevel (0.4 - <2 m). Those uppermost four sites represents the end of the relatively fast regression. If we draw a regression line, slightly more sloping than GLS-shore, at about 1 meter below these sites, it will cross the Vuoksi at the elevation of 81 m (Diagram 11). The altitude of the treshold was according to Hellaakoski at about 81.5 m altitude. Couple of years of increasing transgression after that level, or just very normal spring flood, and the water rose naturally over the treshold. No extra high floods nor water pore pressure are needed to explain the breakthru of the treshold esker.

The traditional GLS shore formations indicates the shore level **after** the sudden drop of water level due to Vuoksi catasthrope. (It is otherwise hard to explain the well developed forms of high GLS cliffs.) The GLS-shore is the level from which, or above which, (still relatively quick) reggression continued at slower rate after violent collapse. The sudden collapse of about two meters in water level occurred **above** the GLS level. There is otherwise absolutely no indication of such a catastrophe at the GLS-level and at shore levels just below it. I call this highest **waterlevel** two meters above traditional GLS **shorelevel** as a GLS+ level.[3]

Diagram 11. The GLS+ shore



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[3] During the summer 1994 some new sites, well above GLS+ level have emerged as well as some shore formations indicating the real highest level of GLS+. These new observations will be dealt in next part of this study near future.

10. Summary of the regression period of Lake Saimaa

Transgression of the waterlevel accelerated to a very fast level before the Vuoksi catastrophe. Waterlevel rose to about two meters above the traditional GLS-shorelevel, finally over the treshold at Vuoksenniska 81.5 m asl. A sudden collapse of the waterlevel due to the opening of Vuoksi outlet occurred about 6000 years ago. After the catastrophe a period of decreasing steady transgression began and GLS-cliffs were formed.

After the sudden two meters collapse of the waterlevel regression continued at the rate of 6 cm per year[*] (during which the shores T0, T1 and T2 were formed). The regression was continious and steadily decreasing. It was during T2 and T4 shore phases 3-2 cm per year*. On these shores of relatively fast but decreasing regression are neolithic comb ceramic and Pöljä ceramic sites. After the shore phase T5 happened a half meters collapse of waterlevel about 4400 years ago. That was at the time of neolithic - bronze age transition. After that the speed of regression increased in NE but was vanished in most SE part of the watershed. During the bronze age the regression decreased to more moderate rate (2-1 cm per year*) and it continued steadily to recent times (regression rate values from table 13 column 12).

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[*] at the zero distance, i.e. near the baseline area.

Figure 25

figure 26

11. Epilogue

The shoreline displacement chronology of the lake Saimaa is possible to solve by seeking shore lines that are synchronous in reasonable accuracy and connecting these shores to archaeological ceramic periods. The examination of shore morphology and formation process will judge the range of synchronity among shore formations. This method needs a mass of observations of clear shore formations and prehistoric sites. A tailored graphic computer program is essential in calculating regression analyses from the numerous data.

This relative shoreline dating method based on distance diagram tells what artefact types and ceramic types exists on the same relative shore level. The artifact types of the same shore do not have have to been used exactly parallel in time, but they have existed at least closely at the same time. This method do not, yet, revive floods. There might have occurred floods that have durated several years, if not tens of years. In such cases younger ceramics "move" upwards on to cliffs of older ceramics and material from upper cliffs might erode to lower elevations. The casual occurence of younger types in upper levels might be explained by flood or temporal transgression. However, no evidences of later transgressions can not be seen in archaeological material. These kind of occurences will come into sight in time-gradient curve based on numerous C14 datings. More thorough investigation of morphology, ceramic material and excavation data will give more accurate information and details about shore levels and their datings. Especially detailed investigation of shore profiles, slopes and other local elements that affects on shore formation in micro scale might give very interesting information from waterlevel changes. An interesting example of dating shore formations is given by Hult (1968). He dated fossilized organic layers under the accumulation walls on the shores of a small lake in NW-Finland.

The achieved result of this study is the creation of method and calculation tools. The accuracy of created distance diagram and its relative and absolute datings are first results. Further investigations will calibrate the diagram. More observations, both leveling data and new sites and period detrerminations of the ceramic material will adjust the diagram. It is now essential to begin to collect systematically absolute datings from sites in the Saimaa area. It is possible to create a cheap and accurate absolute dating method by constructing a time-shorelevel curve based on mass of C14 datings. The investigation tools are now ready to use and the method is tested and qualified. It is now easy to extend this investigation to the whole Saimaa area. To achieve competent results from the northern Saimaa area new levelings and, before all, new prehistoric dwelling sites are needed from the area. The notes of Siiriäinen and Carpelan from their works in early seventies will serve as a good basis for the north Saimaa investigation.

The created shore series of eleven shores will have more shore lines when the investigation of northern Saimaa exposes shores that are invisible or only shaping out in the Iso-Saimaa area. It is clear that the naming and numbering system of the shores in this study is temporal. The datings of shores will probably become more accurate when the data of fast land uplift area is connected to the recent results.

A computer program that gives the relative and absolute dating of a site was created. Program needs the coordinates of site and one or two elevation values from which it calculates the position of the site in distance diagram. Program reads coordinate and elevation data from a database or asks them interactively. Program shows distance diagram where site is plotted. The dating results, shore indexes and absolute dating of a cliff or site are also given in words. Program runs on all MS-DOS machines. A version for hand held pocket computer is under construction.

To get more data to adjusting work of shore line dating method it is essential for archaeologists to document their field works in a way that their documents are usable for shore line displacement investigations and especially for the shoreline dating itself. During field work archaeologists ought to draw a clear schematic shore profile picture, where is clearly visible shapes of shore formations, their relative size and sloping. To that drawning is inserted exactly absolute elevation values of cliffs. An elevation of the base and the top of the cliff. Most important documentation is to mark exactly the location of the site whithin shore marks, in a way that other investigators are able to connect artefact material to certain shore formations.

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Diagram 12. Shore gradients of Iso-Saimaa with allowed error margin lines, below plain shores of Iso-Saimaa.

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Appendix I

List of all prehistoric sites ordered by theoretical age from oldest to younges. Accorfding to probable shore index.

Appendix 2

List of leveled cliffs.

Contents