South-East Finland – Russia
ENPI CBC 2007 - 2013

SOUTH-EAST FINLAND - RUSSIA ENPI CBC PROGRAMME 2007-2013
Efficient use of natural stone in the Leningrad region and South-East Finland

Site Inspections

This project is co-funded by the European Union, the Russian Federation and the Republic of Finland

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METHODOLOGIES OF NON-DESTRUCTIVE TESTS ON SITE AND IN LABORATORY

Figure 1 Thermal camera, thermometer, Schmidt hammer, ground penetrating radar, radiation pulse meter.

Ultrasonic pulse velocity (UPV)

The evaluation of ultrasonic velocity in a stone material has been used in order to evaluate possible sign of weathering on site. The method according to EN 14579 (2005), is versatile but affected by uncertainties. Generally it was not available fresh material to be used as a comparison also because in most of the site it was not even known the origin of the material. GTK has been cooperating with the Polytechnic of Turin in performing the tests. The test procedure has also been described in the project “Kiviainekset ja luonnonkivet – materiaaliominaisuudet, uudet käyttösovellukset ja esiintymäinventoinnin kehittäminen”.

The measurements had been performed using a signal generator and receiver of a Pundit (Portable Ultrasonic Non-destructive Digital Indicating Tester) that is sending and receiving a wave, or train of impulses through the material to be tested. The Pundit is sending the analogical signal to a digitizer NI USB 5133 that sends the digital signal to an oscilloscope installed on a PC for visual evaluation of the waves.

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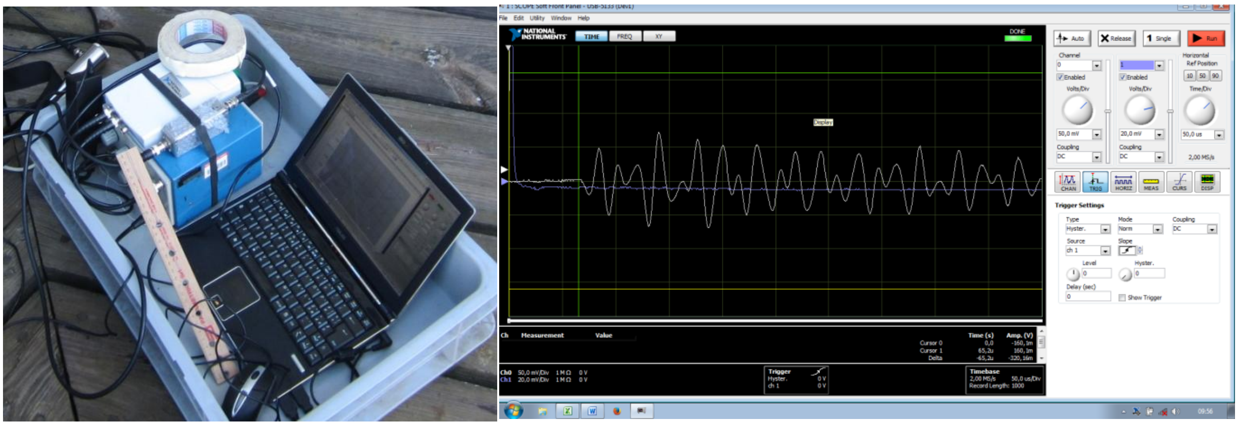

Figure2. Equipment used for UPV measurement on the left and wave form red from the oscilloscope on the right.

The tests had been performed as indirect method, drawing measuring points along a line at a distance of 20,40,80,120,160,200 mm from the dot where it is placed the transmitter transducer. In the marked points is then placed the receiver transducer (Rec) that is moved step by step. (Figure 3) At each measuring position is evaluated the wave form, most often it is taken as reference a point in the arrival wave times and it is followed that point from measure to measure.

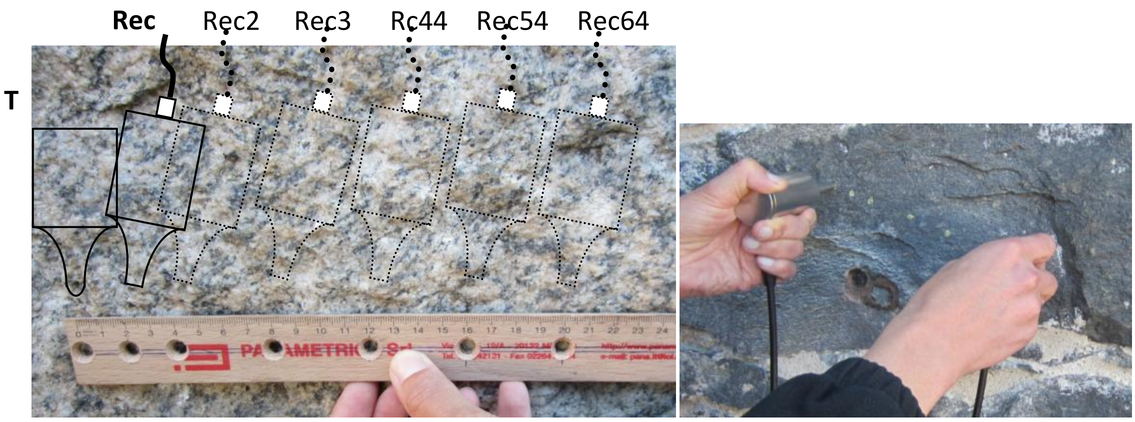

Figure 3. Representation of the movement of the receiver, compared to the transmitter, that is kept fix for performing measurements on site.

The transducers used had been exponential in order to assure contact on rough surface and their nominal frequency had been 50 kHz while effective frequency 33kHz. They had been positioned perpendicular to the surface as visible from Figure 3.

The collected arrival times (µs) had been plotted against the distances (mm) of receiver-transmitter transducers positions, often excluding the first measuring point from the calculation because of higher uncertainties given by reciprocal inclination of the transducers. /Bellopede,2006/ From the measurements it is evaluated the velocity and if the curve had deviated from the linear regression line. In Figure4 it is shown an example of data in which there is a deviation from the linear regression line in correspondence of

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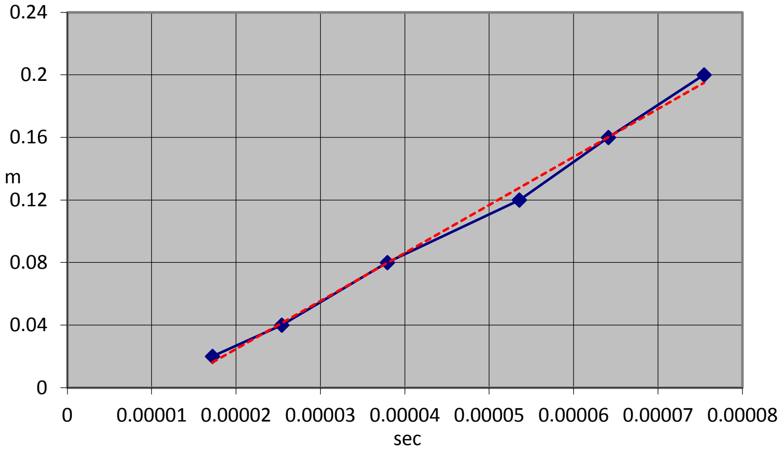
the 4th measurement that could be caused by a fracture by material heterogeneity or weathering level. Uncertainty in measurements includes also influence of humidity and temperature.

sec	m
1.72E-05	0.02
2.54E-05	0.04
3.79E-05	0.08
5.36E-05	0.12
6.41E-05	0.16
7.55E-05	0.2



Velocity: 3083 m/s

Figure 4. Evaluation of the average velocity: on the left the table of measurements collected, on the right the plotted diagram from which it is calculated the velocity.

Ground penetrating radar (GPR)

GPR techniques works in a similar way as UPV, sending a signal that is reflected and refracted back to the antenna. The signal is affected by material's weathering level e.g. higher porosity, cracks, presence of water and surface coatings. The equipment consisted of a SIR-3000 data acquisition unit with 900 and 1600MHz antennae. (Figure 5) The data collected with 900 MHz antennae penetrated in detail to deeper layers of the walls and could show the full depth of the structure. In fact this kind of antennae could penetrate up to 6 meters even if the needed thickness had mostly be under 3 m. The higher frequencies had better resolution and a more detailed picture of the top 2 meters of the structure. The depth and precision obtained were also affected by the dielectric constant of the materials (Ranalli et al. 2004, Moropoulou et al. 2013) that is why it had been measured for each kind of tested material, when possible, selecting single, well- defined site blocks. The calculation of ER value and the evaluation of the radargrams had been done onsite. GeoDoctor 2.491 software had been used for the analysis.

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Figure 5. On the left SIR-3000 data acquisition unit with 1600MHz antennae, on the right evaluation of the results

Measuring lines had been selected on the sites in order to understand the capacity of the instrument to evaluate the typology of structure and possible defects. GPR should had been able to detect interfaces, open cavities, presence of water, anchoring... but has to be considered also that results had been affected by uncertainties in the cases where the material and the structure had been highly heterogeneous.

Schmidt hammer

Schmidt hammer tests have been performed using a SADT Model HT225A hammer choosing specific blocks and performing 4 set of measurements. (Figure 6) Each set of measurement had been composed by 3 rebounds per point, evaluating the average on the block. It had been decided to perform only 3 rebounds on each spot because the aim was to assess the surface weathering, also possible surface cracks, chipping or rusting of the minerals.

Figure 6 In the figure are shown a moment of the measurement on Niirala school on the left and the instrument on the right.

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The test had been performed keeping the instrument perpendicular to the façade, so, horizontal. For concrete measurements it is possible to get a correlation with the strength of the material from tabulated values, but the values normally got from hard rock testing have rebound values higher than those tabulated. The analysis had then concentrated using the rebound values measured.

Thermal images

Thermal images had been taken from all the sites with a Fluke Thermal Imager Ti20, trying to evaluate a possible correlation of temperature and humidity with deterioration effects. Analysis of the thermal image results were done under the guidelines defined in RESNET Interim Guidelines for Thermographic Inspections of Buildings (2012). The results in detail and procedures are shown in the report of Kiviainekset ja luonnonkivet – materiaaliominaisuudet, uudet käyttösovellukset ja esiintymäinventoinnin kehittäminen

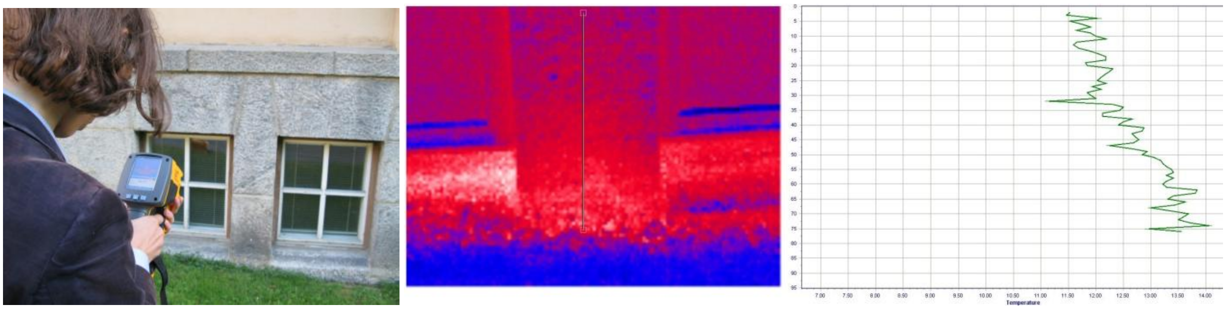

Figure 7. Measuring process of Thermal camera is shown on the left, an example of results is shown in the centre and on the right.

Sampling

Samples had been collected from sites in different periods along the project and of different kind:

- drill cores with different diameters: 17mm for those collected in 2012 with depth reaching few cm presenting often breaking of the core and 20mm for those sampled in 2013, longer intact cores

Figure 8. Drill cores on the left, hand samples on the right.

- hand samples: fragment loosen from the surface of small dimension had been used to assess the weathering condition on Russian sites since sampling had not been possible otherwise;
- dust collection explained in the report “Evaluation of the condition of granite in architectural monuments”, Guide 61, edited during the project.

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The drill cores had been collected with a battery hand drill, connected to a water tank as visible from figure 9 on the left. The drill core had been collected and put in a marked plastic bag left open to allow drying of the sample. The hole had been later filled according to the requests of the National Bureaux of Antiquities. In order to maintain the strength of the blocks and to minimize material heterogeneity the holes had been filled with a similar material, drilled from fresh material blocks, as visible from the third photo from the left in Figure 9. The substitutive drill core had been connected with a soft cement, but best finishing results had been those given by substitution with drill cores fitting perfectly in the hole's size, minimizing the use of cement as visible from figure 9, 4th and 5th photo.

Problems had derived by the fact that the material could had been affected by deposition and fixation of dust, and the new drill core, even being of the same material, have been showing differences compared to the site ones. Also contact between cement and lichens had cause oxidation of lichens not used to a basic environment as visible from Figure 9, 5th picture.

Figure 9. Collecting the drill cores on the first and second picture from the left, on the third one the preparation of substitutive drill cores, that are then places on site as visible in the 4th and 5th picture (on the right)

Laboratory tests

Water absorption, open porosity and apparent density had been measured following the procedures described by the European standards EN 1936 and EN 13755 (2001). The number and dimensions of the specimens had deviated from the standard, since it had been available only drill cores collected from the building sites and not used for other testing. Image of the testing is visible in Figure 10. The instrument used had been a balance able to measure the hydrostatic weight (immersed weight), a vacuum system according to the standard, an oven able to maintain a temperature up to 70°C. In the water absorption specimens had been dried to constant mass measuring the dried weight (m_d),then had been immersed gradually in water and measured after the saturated weight, after 48 hours, m_s. The water absorption had been calculated according to formula 1.

$$A_b = \frac{m_s - m_d}{m_d} 100 \qquad [1]$$

Figure 10. Testing of the drill cores for water absorption and density.

The open porosity and density had been measured drying the specimens at constant mass, measuring their dry weight, m_d. Placing the specimens into a vacuum system and leaving them under vacuum for 2 hours, immersing gradually into water and releasing the vacuum, leaving them immersed for 24h. The specimens had then been weighted immersed in water, m_h, and as saturated weight in air, m_s. The apparent density and open porosity had then been calculated according to formula 2 and 3 reciprocally.

ρ_b (kg/m^3) = ρ_{rh}*m_d/(m_s-m_h) [2]

p_o (%) = 100* (m_s-m_d)/(m_s-m_h) [3]

The measurement had been affected by uncertainties given mainly by the small amount of specimens and their dimension.

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Kiviainekset ja luonnonkivet – materiaaliominaisuudet, uudet käyttösovellukset ja esiintymäinventoinnin kehittäminen

NIIRALA SCHOOL

Documentation and research methods

Historical information have been collected from the report of GTK: Kivi Kuopion kaupunkirakentamisessa by Heikki Lukkarinen /1/.

Description of the building

Number	36
Name of building	School of Niirala
Architect	Armas Lindgren, Bertel Liljequist
Address	Huuhankatu 2 kuopio
Lat	62,89314304900
Lon	27,66312631510
Built (year)	1926
Use 1	Stone foundation
Rock type 1	Granite-Granodiorite, gray, chiseled

The building, situated in Huuhankatu 2- Kuopio, had been built in 1926 by the architects Armas Lindgren and Bertel Liljequist. Its position is visible on the map in Figure 1. It has a rectangular shape and its longer façades face East and West, while the shorter face North and South.

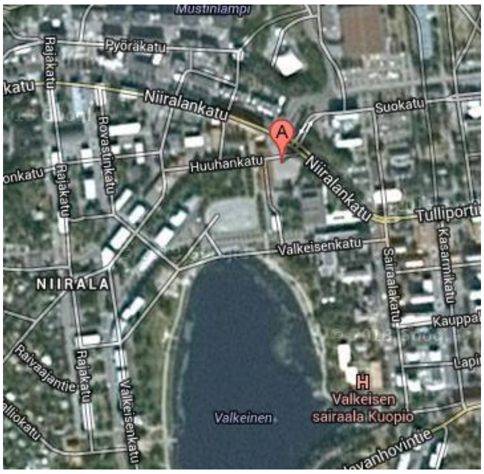


Figure 1. Map of the area where the school is located. (Googlemap)

The façade, visible in Figure 2, presents window openings and small details that make lighter an otherwise massive structure. The building is organized into three blocks: a large central one, visually vertically divided into five sectors by rain pipes and two side blocks, lower, shorter and in the East side forwarded respect the central façade of approx. a couple of meters. The East and West façades are different. In fact the central West façade has 15 windows in row in the upper floors while has only 9 in the East side towards the yard. The East façade moreover has in its middle the main entrance and massive granitic stairs. The building central facades and structure are symmetric compared to the main door but the facade design on the side wings differ.

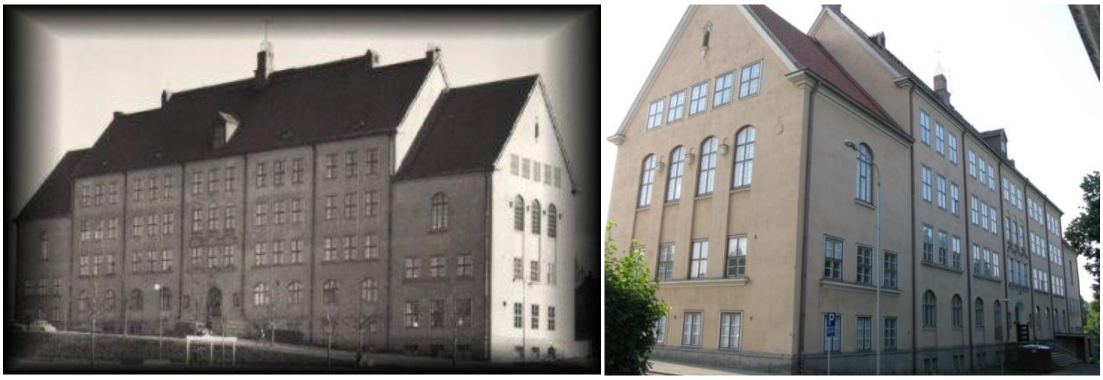


Figure 2. Historical picture of the West side compared to one taken in 2013. (Photo N. Luodes, GTK)

The roofs are steep and covered with red tiles presenting in the middle of the central section a main dormer surrounded by each side by small semicircular dormers. Along the ridge of the roof in the central part of the building a metal wall pumps up a couple of meters presenting openings on its upper part and possibly functioning as chimneys or ventilation exhaustions. In its centre, being the centre of the hole building a pillar holds a light wire onion and a vane.

The building's walls stand over a stone basement, and are plastered on a uniform light colour not showing chromatic motives. The harmony is given instead by the window organization, shape and small architectonical and decorative details as visible in Figure 3.

Figure 3. Roof detail from East side. Are visible the dormers, the wall over the ridge of the roof and the architectonic decorative details (on the right). (Photo N. Luodes, GTK)

The structure has been renewed as visible from comparison with old photos with the addition of a porch in the façade facing the yard reaching about 3m height. The façade facing the park on the West presents a light concrete structure, functioning as storage and an entrance had been created from a window opening splitting on site the stone blocks as visible from Figure 4.

Figure 4. Particular of the door created from a window. (photo N.Luodes, GTK)

The stone material used in the building is grey granit/granodiorite, showing in some block a gneiss structure. The building presents a basement in massive rock blocks probably derived by the same quarry affected by different weathering levels and presenting visible veins. The material has been squared to form regular shaped blocks and its surface roughly textured with chisels. The division between the basement and the upper wall is delineated by a stone sill.

The wall inspected has been the one facing West that is free from coverings, existing instead on the opposite side, and that has in its middle section a stair built with massive stone (pictured with Gigapan ref 1.3.1). The stairs has high architectonic value because of its construction technology; in fact it is build of massive blocks both placed to form the parapet and the steps. The same wall had been tested with non destructive tests and had been sampled through drill cores.

Characterization of the environment

Local environment (architecture etc.)

It stands on the surroundings of the lake Valkeisenlampi, around which several other historical buildings are located. The lake area has undergone recently an environmental reshaping, increasing the value of the site and its accessibility as visible from Figure 5.

Figure 5. Views of Niirala School from the lake side (today and in the past)

On the East the façade faces a fenced inner yard and the façade is partially covered by a porch at the ground level. The opposite side faces a public garden from which is separated by unpaved road. The short sides are facing the main road on the North and a part of the park on the South. The building has large space around it and is not in direct contact with other buildings. The building pumps up from the neighbor environment for its height and massiveness as visible from Figure 5.

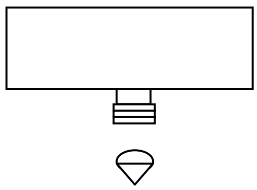
Climatic conditions, microclimate, etc.

Kuopio is located in Central East Finland on the lake Kallavesi. Its climate is characterized by an average of approximately 82% of humidity along the year, diminishing to about 60% in spring-summer time, from March to August. Kuopio's climate presents dry seasons, generally during the spring months and a rainy season during the autumn time. Generally from November to March the temperatures do not rise over the zero during the day and as an average the minimum temperature reached could be considered around -22°C /2/.

Photographic documentation

The site has been documented photographically in detail by Gigapan photos, normal camera photos of the complex and of the architectonic elements, of the deterioration problems and of the materials and finally by high definition photos of the samples. The processes of sampling and testing have also been recorded.

Gigapan photos



A gigapan photo of the exterior of the stair has been taken as visible from the map in Figure 6. A gigapan image is visible at www.gigapan.com under the "enpi-tiedä" image collection.

Figure 6. Schematic map of the school

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Visual inspection

The visual inspections and further measurements focus mainly on the basement and stairs since it is the part of the building built with stones. The blocks are regularly shaped and present a rough surface worked by chisels. Mortar has been used in the sealing between the blocks that has possibly been renovated after the original construction. The visual inspection has considered the element listed below and the results had been pictured over a detailed panoramic image as visible in Figure 7. In this case a base image has been created connecting consequent pictures in such a way that the resulting picture would look ortonormal. Over it had been noted the main elements found from visual inspection.

Figure 7 . Example of Map of the damages

Color coding:

Light blue-changes of color both from anthropogenic origin and natural weathering;

Yellow – Orange: soiling, from light deposition (light yellow) to crust (orange).

Dark orange lines: cracks

Overall the wall present only limited elements of deterioration but some of them are diffused along the whole basements, as atmospheric particles deposition and fixation.

Detection of weathering types

Peeling and exfoliation

Not recognized on the basement

Rudd surfaces

Not recognized on the basement

Deepenings and cavities

The material is a granite kind and has a roughly worked chiselled surface over which are not recognized opening of cavities, but are noticed de-cohesion effects, as visible from point 1.4.5.

Hollows and chipping

Hollows are not recognized but chipping it is noticed, as form of de-cohesion of some parts of the surface, more than single crystals or mineral grains. An example is shown in Figure 8.

Figure 8 Decohesion of some element of the surface, chips or pieces of about 5mm have tendecy to detach when the surface is touched.

Stone flaking-off

Flaking has not been recognized over the granitic basement of the school.

Granular disintegration , decohesion of single crystals or mineral grains

Not seen on the material of the school.

Fractures and fissuring

The stone elements of the façade show some cracks attributed to anthropogenic actions derived by possible impacts against the structure over a window on the left of the entrance stair and over the corner of the stair (Figure 9).

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Figure 9. Missing part over a window, stair parapet's block moved by an impact action.(Nike Luodes, GTK)

Cracks along 2 blocks, visible from the map of deterioration in Figure 7, are instead caused by structural movements as well as cracks along a window corner on the same façade. (Figure 10)

Figure 10 Cracks given by structural deformation. Fracture in the middle of a block, successively measured with UPV, on the left (photo by Nike Luodes GTK). Crack in correspondence of the upper corner of a block over a window, on the right (photo by Joonas Toivanen GTK).

Deformations

Not high deformations of the structures that would represent a risk for stability of the building have been recognized but some fractures had been caused by structural movements as visible from Figure 10. Impact against the structure has been relevant in deforming the stair structure as visible from Figure 9 and Figure 11 where a block of the stair has been dislocated.

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Fungus

Not evaluated its presence (Not tested)

Seaweed

Not evaluated presence (Not tested)

Lichens

Lichens can be seen mainly on the stair's wall facing North on its inner-outer and upper surface (Figure 11). Samples had been taken in correspondence of the lichens on this wall (Section 1.4.1).

Figure 11. On the left: Stair's wall facing North showing presence of lichens and biofilm. On the stairs, on the right, is visible presence of higher plants (and dislocation of steps by anthropogenic origin)

Mosses and higher plants

The part of the stair presents also high amount of biological colonization where higher plants are growing on the steps and on the entrance floor as visible from Figure 11 on the right and Figure 27.

Bio-films of different composition

On the wall facing north on the stairs can be a diffused biofilm even if its composition has not been studied (Figure 12 is an enlargement of Figure 11).

Figure 12. Biofilm and biological colonization on stairs parapet facing North.

Dung of birds

It is seen only in few areas and sparsely that cannot be considered a problem for the facade.

Atmospheric particle depositions and fixation

On the lower part of the basement in contact with the soil is visible an area with loosen atmospheric dust deposition (light brown). On the basement are visible also areas where deposition has turned into black crust as near the corners and in more protected areas as behind the rain pipes, on the window sills and on the wall between the windows (Figure 13).

Figure 13. Atmospheric particle deposition and fixation

Crusts

Fixation of dust into crust is shown in 1.4.15. Being a granite it does not undergo the limestone's crust formation and dissolution problem even if some level of washing and crusting is noticeable as visible from figure 13.

Loss/change of colour

Changes of color determined by weathering of the material are visible on some blocks. Especially one shows rusting of minerals along a fracture of the material given by some sulphuric iron minerals (Figure 14), probably pyrrhotite. While changes of color attributed to anthropogenic origin in correspondence of joints filled with mortar are mainly visible on the stone sill between the basement and the upper wall (Figure15).

Figure 14 Changes of colour given by original weathering of the block on the left, and by weathering of sulphuric iron minerals on the building site, on the right.

Figure 15. Changes of colour determined by migration of the salts of the mortar.

Ovoid weathering

It is not visible since the material has not tendency to this kind of weathering

SAMPLES

Samples that have been further analysed had been taken from the facade facing West and on the stair in correspondence of large lichens colonies. Extra specimens have been collected that have not been further analysed and the samples have mainly been drill cores.

Sampling methods

In Niirala school sampling has been performed drilling cores using two different drill edges. The samples collected in 2012 have a diameter of 17mm and their depth reaches few cm presenting often breaking of the core. In 2013 a larger drill core has been collected, with a diameter of 20mm and it has been possible to collect longer intact cores compared to the previous year. In Figure 16 are shown the two sampling drills edges.

Figure 16 On the left the drill edge of 17 mm and on the right that of 20 mm. The drill is the same but the difference of diameter allowed collecting longer intact cores.

Sampling locations

The locations have been chosen in order to find the surfaces that showed weathering actions but that would not comprise the sight of the building.

Description of the environment

The samples have been taken mainly from the facade facing West, that is facing a garden and it is not protected by covering or roofs. The samples collected by the stairs are in an environment more protected and contained than those collected from the basement, since they were on the inner side of the north wall parapet, facing south; a couple of meter from the main facade and less than 50 cm from the other parapet wall of the stair facing West. The sample is not in contact with soil humidity and is generally positioned on a dry surface, exposed anyhow to atmospheric actions.

Location of the sampling sites

On a map is possible to schematise the sampling areas (Figure17). The photos of the sampling are then visible in Figure 18,19,20.

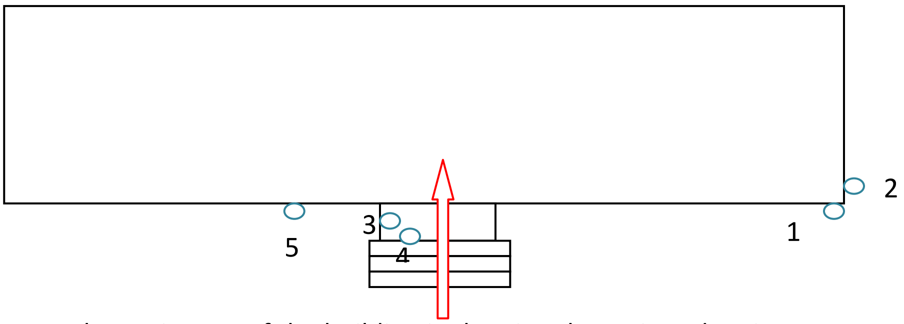

Figure 17. Schematic map of the building is showing the stair and main entrance on the West facade, the sampling points and their numberings. Sample number 3 has then been tested and renamed HAP$2012-25

Figure 18. Drilling of sample Niiralan school 1 (on the left) - on the West façade on the corner with Valkeisenlampi- Not weathered material. Drilling of sample Niiralan school 2 (on the right)- it is on the South façade on the corner with the park. The surface is affected by atmospheric particle fixation. Material sampled on 17.8.2012. (Photo Heikki Pirinen)

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Figure 19. Drilling of sample Niiralan school 3 (on the right) and 4 (on the left) on the inner walls of the stairs parapet. On the surface of sample 3 was growing lichen, on that of sample 4 there was presence of dust fixation. Material sampled on 17.8.2012 and 2013. Photo Joonas Toivanen, GTK

Figure 20 Drilling of sample Niiralan school 5 on the West basement façade on a stone not presenting weathering affects.

Sample types

Thin sections

One thin section has been cut from drill core sample collected in 2013: HAP$2012-25_3. It presented a lichen on the surface.

Chemical analyses

Drill cores

Chemical analysis has been performed on drill core sample collected in 2012: HAP$2012-25_1-2. It presented lichen on the surface.

Surface samples

No other surface samples have been collected from the site.

Biological analysis

Surface sections from collected samples and drill cores. The samples had been drilled and top part had been used.

Mechanical and physical tests

Three samples are used to perform the tests: Niirala 1, HAP$-2012-25 and Niirala 4 covered with a black crust.

Photos of Samples

Normal photos

The sample collected from the stair during 2012 and tested for chemical analysis HAP$2012-25.1-2 is shown in Figure 21. The sample was a drill core of 20mm diameter taken over lichen.

Figure 21 Normal photo of the specimen from Niirala school chosen for chemical analysis.

In Niirala school photos with normal camera of the sample collected during 2013 have not been taken.

Stacking photos

In Figure 22 and 23 are visible the high definition photo of the samples collected during 2012 and 2013. On the left can be seen the sample HAP$2012-25.3 used to cut a thin section , on the right, three samples not used for further testings named Niirala Koulu 1,2, 4.

Figure 22. Weathered surface of the sampled collected from Niirala school, on the left the sample used for cutting the thin section. On the right three samples collected during 2012. (Photo by Jouko Ranua GTK)

Figure 23. Back part of the drill cores collected, same as in figure 22, to evaluate the un-weathered surface of the material. (Photo by Jouko Ranua GTK)

The high definition pictures allow to zoom and see in detail the surface of the material (Figure 24).

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Figure 24 Detail of the surface of sample HAP$2012-25.3 cut over lichen on the stair parapet. The sample diameter in its section is 20mm. (Photo by Jouko Ranua GTK)

PETROGRAPHIC AND CHEMICAL PROPERTIES

HAP$-2012-25.1 has been the top part of the drill core, the one with the surface of the stone HAP$-2012-25.2 has been the bottom part of the drill core, the one considered relatively fresh and possibly not yet affected by biological activity. In Table 1 in Annex 1 is shown the list of the results obtained. Al, Ca,Fe,K,Mg,Na are the main elements of the bottom and top and their amount is shown into a visual form in the graphic of Figure 25.

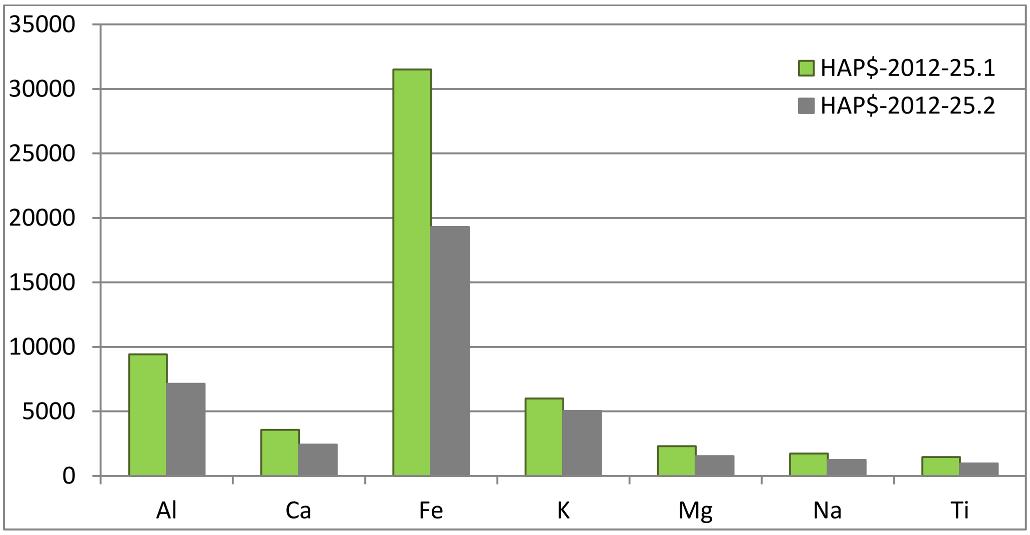

Figure 25. Main chemical elements of the material from top and bottom part of a single drill core.

Minor elements are instead visualized in the graphic of figure 26.

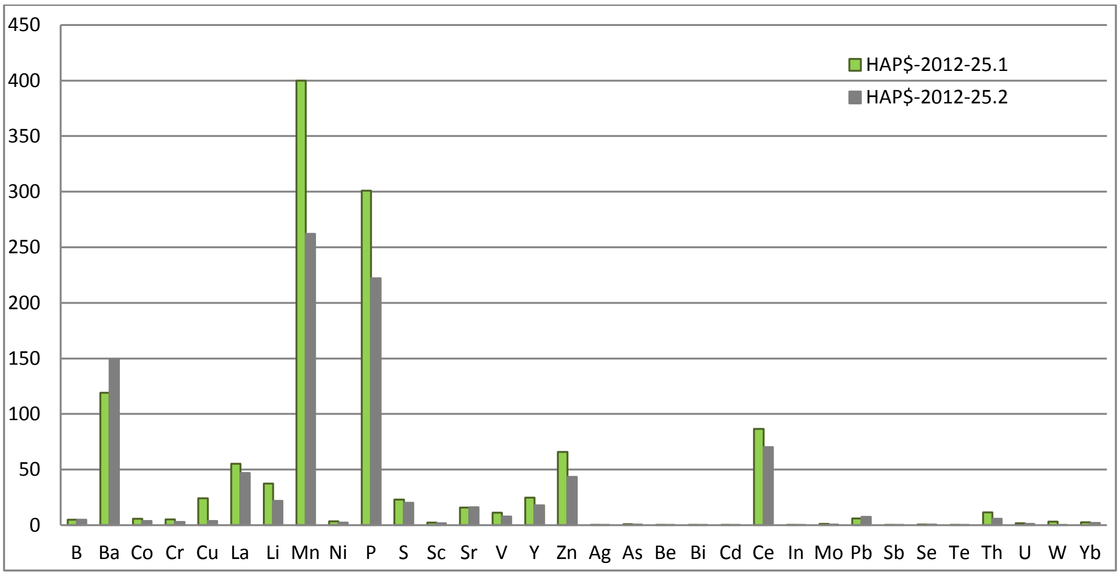

Figure 26. Minor chemical elements of the material from top and bottom part of a single drill core.

The units and amounts are those defined in Table 1, Annex 1. The total chemical analysis has not been done since the sample was too little, therefore has not possible to calculate the weathering indexes for Niirala school. From the chemical results of the chemical analysis can be compared which had been the chemical lost or enrichment of the surface layers compared to the bottom layers of the drill core. From Figure 27 and 28 it is possible to visualize the chemical composition changes between the top and the bottom of the sample.

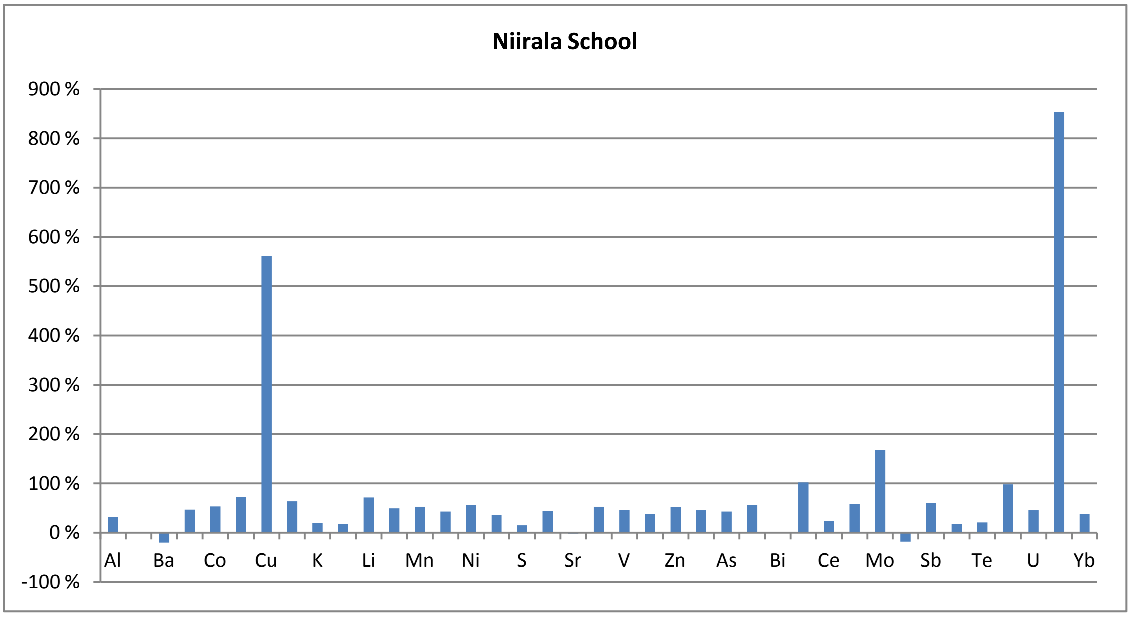

Figure 27 Changes in percentages of the chemical elements of the top respect the bottom of the drill core

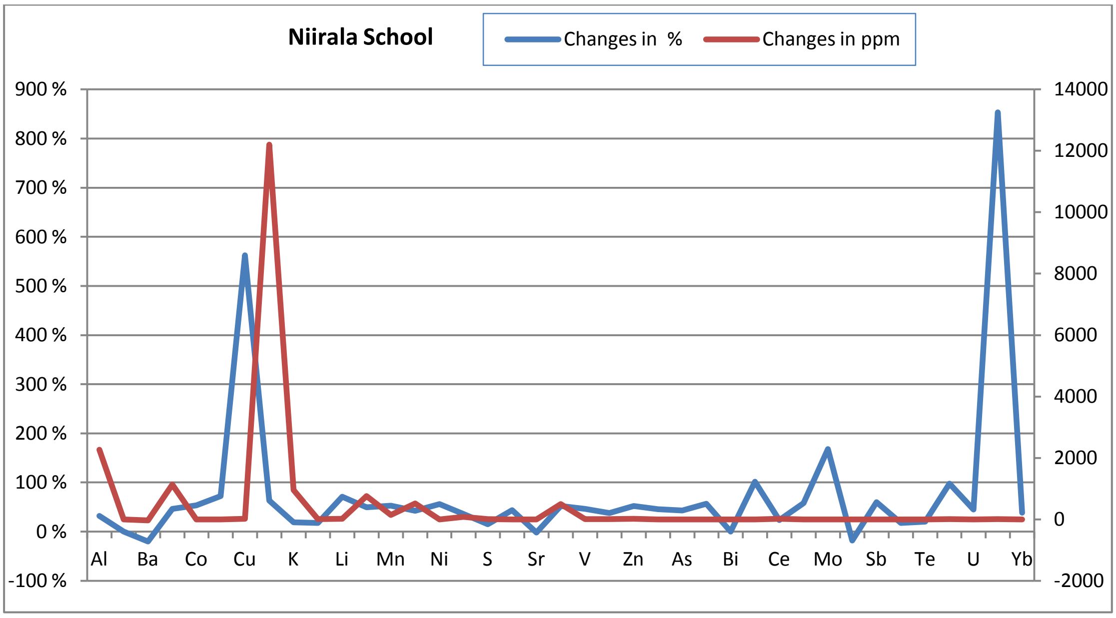

Figure 28 Changes in percentages and in ppm of the chemical elements of the top respect the bottom of the drill core.

The specimens have been collected in correspondence of a lichen and from the analysis is visible that the surface has increased levels of Cu and W, as peaks, even if generally most of the elements are richer on the surface.

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Non-destructive research methods

Non destructive research methods have included Ground penetrating radar and Schmidt hammer hardness test performed by the Geological Survey of Finland. Ultra Pulse velocity on specific blocks has been performed in cooperation with the Polytechnic of Turin-Italy while thermal camera measurements have been performed in cooperation with Mikkeli University of Applied sciences.

Ground penetrating radar

GPR has been performed on the walls on the basement, along the whole West façade until the stairs as shown on the map F5 in Figure 29 Performing the line had been noticed some differences in the thickness of the blocks compared to that of the wall, expecting to have massive basement. In order to establish a more precise measurement has been evaluated the ER on the corner block of the parapet of the stairs, being a single block of known thickness. While measuring the parapet had been noticed differences in the depth of the blocks. A shorter line has then been taken, F2, and another one F3, to show the differences in thickness of the structure. The measurements have been performed in July 2013.

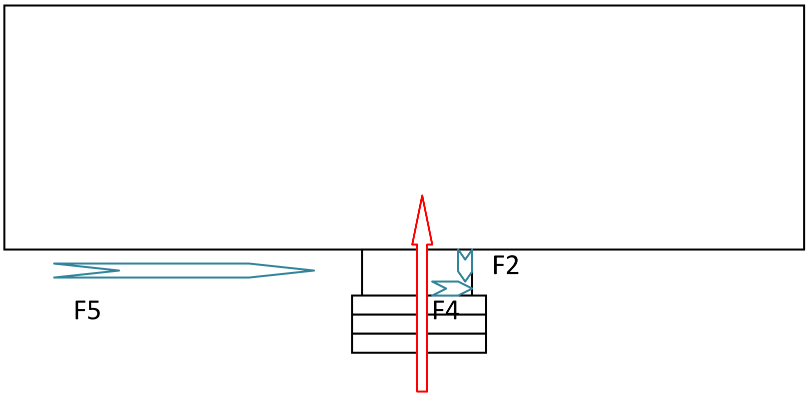

Figure 29 Map of the GPR measurements performed on the school.

The parapet of the stair is composed by a three layer wall: a stone block of approximately 200mm in the inner side of the parapet, a part filled with loosen material and air and an external wall with block thick 200-300mm as visible from the radardgrams of Figure 30. The top of the radargram represent the surface of the wall over which the antennae has been placed.

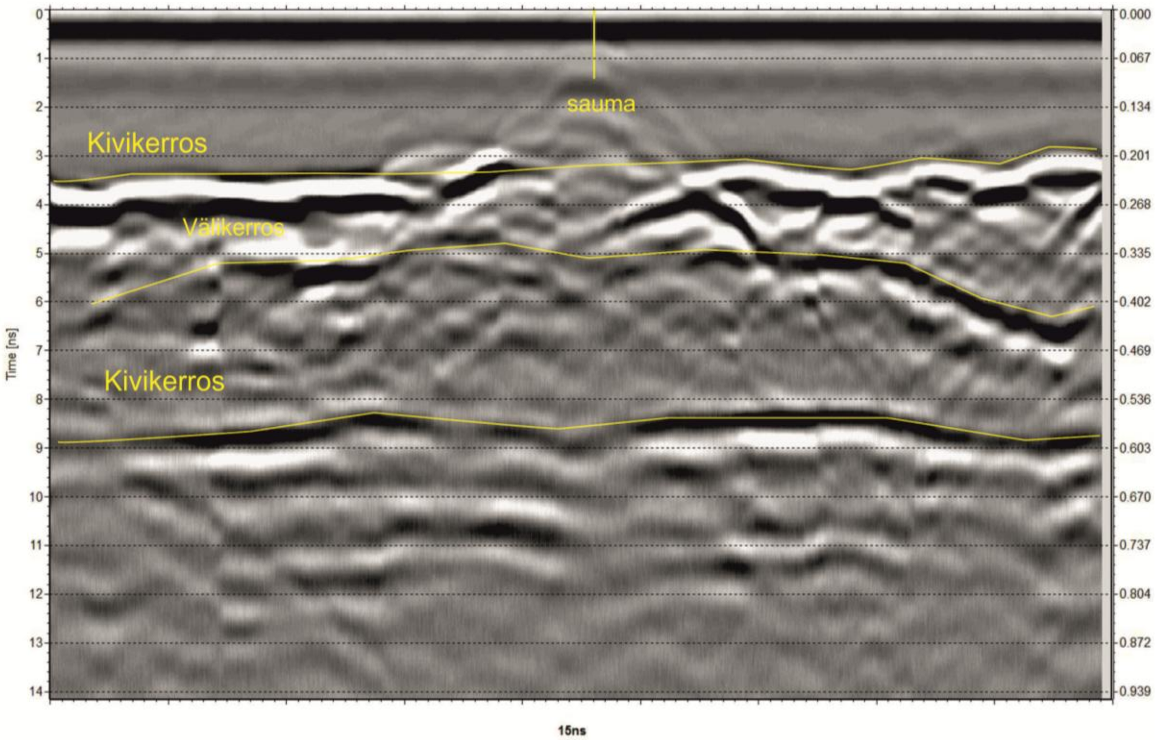

Figure 30. Processed radargram of Line F2, showing in yellow the wall layers. Kivikerros meaning Stone layer and välikerros meaning a middle layer that is in between the two stone blocks. The radardgram has been taken according to Figure 31

Figure 31. Inner parapet wall on the stairs, showing the line F2 where GPR measurement using an antenna of 1600 MHz has been performed.

On the inner wall it has also been taken a measurement line on the entrance wall, to see the difference in structure of the corner block compared to the back wall structure. The line, named F4 has been taken according to Figure32.

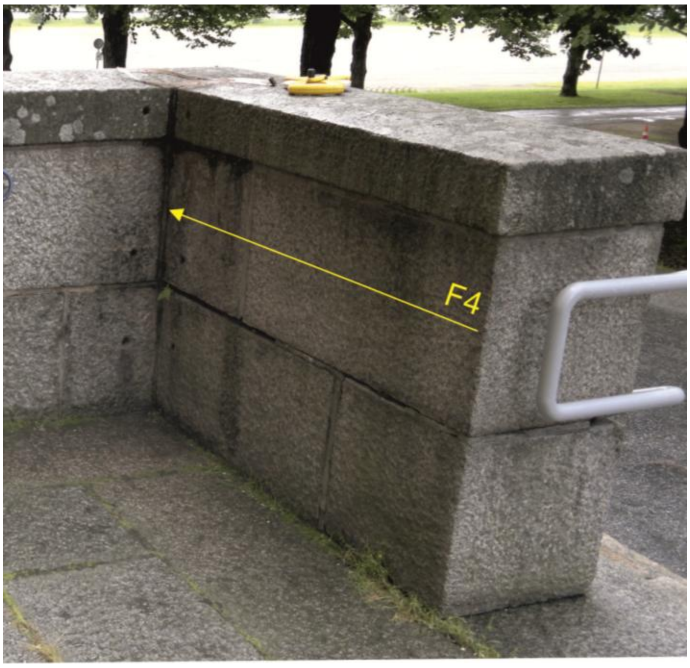

Figure 32. F4 is representing the line measured with GPR using an antenna of 1600 MHz

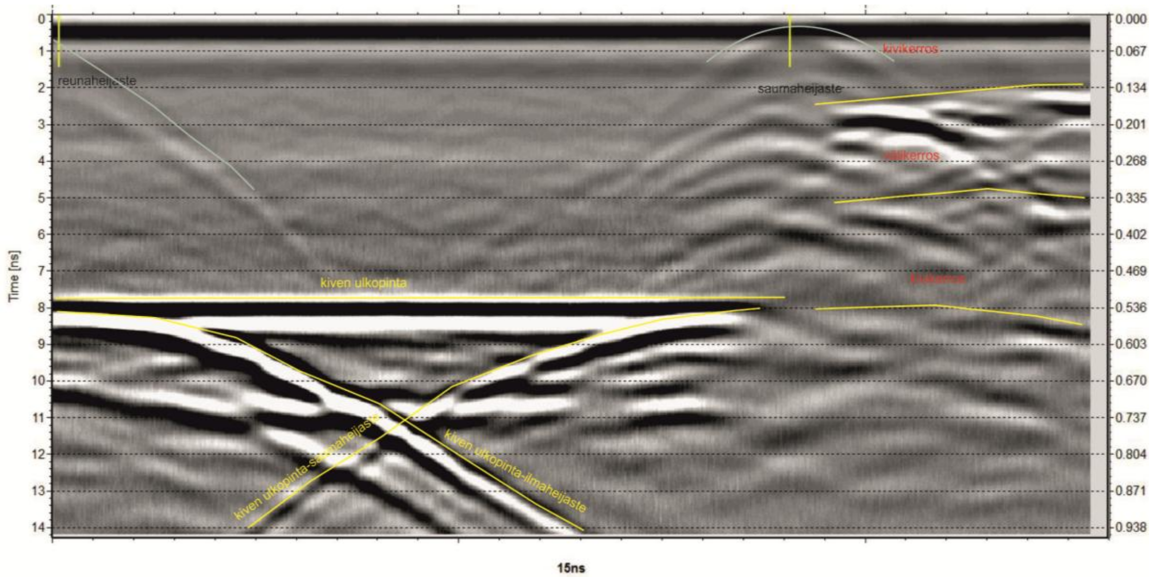

Figure33. Processed radargram of line F4.

From Figure 33 it is visible the initial massive corner block, thick approx.500 mm, and after it, three layer wall structure as the previous wall. The same layered structure has been found also in the basement performing a long measurement on the basement of the West façade.

The line has been coded F 5 and its direction is visible in Figure 34.

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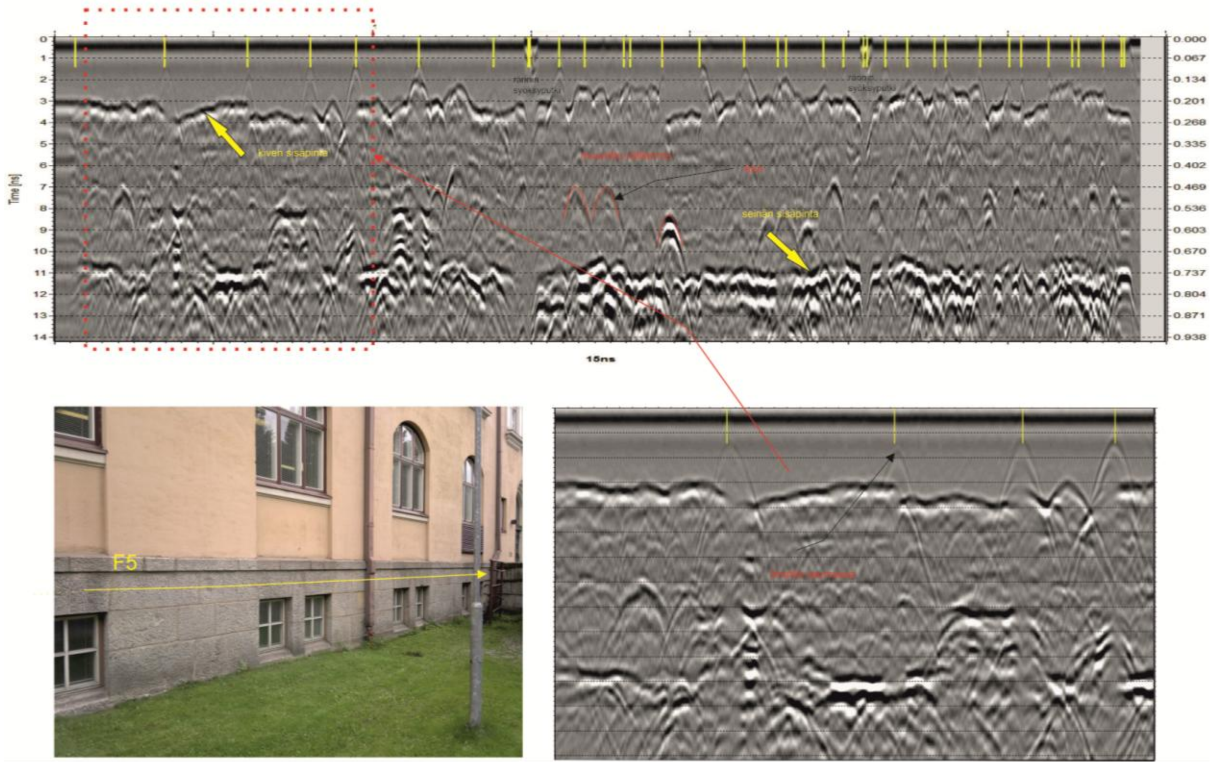

Figure 34. Processed radardgram showing the “Kiven sisapinta”back side of the stone basement, “muurattu välikerros”, laid and compacted filling material in the hollow, “seinän sisäpinta” inside surface of the whole wall-possibly 73cm thick. In the lower frame is enlarged a detail of the full radargram

The line has been taken from all the façade. The antenna had been taken out from the wall in correspondence of the rain waste pipes and in correspondence of the detachment is visible a high anomaly on the surface of the radargram, marked with double vertical yellow lines. Each vertical line of the surface means a seam between the blocks. An anomaly given by the discontinuity is generally visible in the shape of a parabolic curve in correspondence of the lines (=joints).

From the radardgram is visible that the stone blocks are of irregular thickness and shape from their inner side, ranging from 130 to 260 mm. Behind the blocks there is a thick layer of mixed compacted material, since high reflections show presence of rocks but not of homogeneous rock wall as those seen in the parapet. The back wall outside surface is situated at 730 mm depth and it is possibly built by an inner brick wall.

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Ultrasonic measurements (UPV)

The measurements have been performed in an indirect way according to the report "Methodology UPV" , choosing on the basement the blocks that presented surface anomalies, as block 6, possibly weathered from the quarry, block 10, presenting a fracture, block 11 presenting dust fixation and black crust. On the facade has then been also measured direct velocity of block 11 to evaluate the elastic modulus of the material and has been performed the velocity in indirect measurement on a block that had been protected by weathering actions, near a door protected by a shelter.

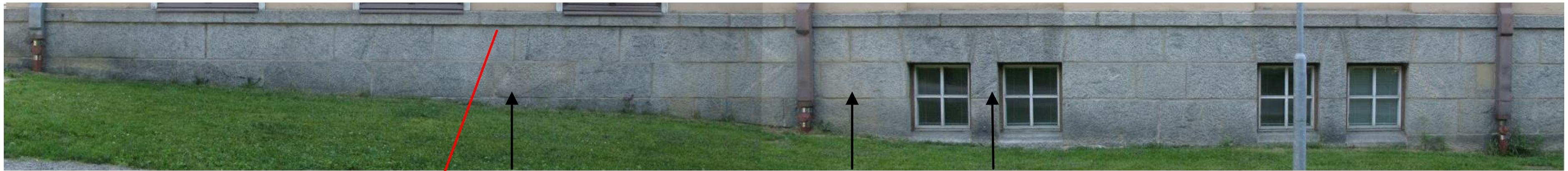

Figure 35. Blocks tested with UPV. 6th 10th 11th

Blocks shown in the picture had been tested with UPV, while a block in a more protected area on the right of the façade had been chosen as visible from the pictures below.

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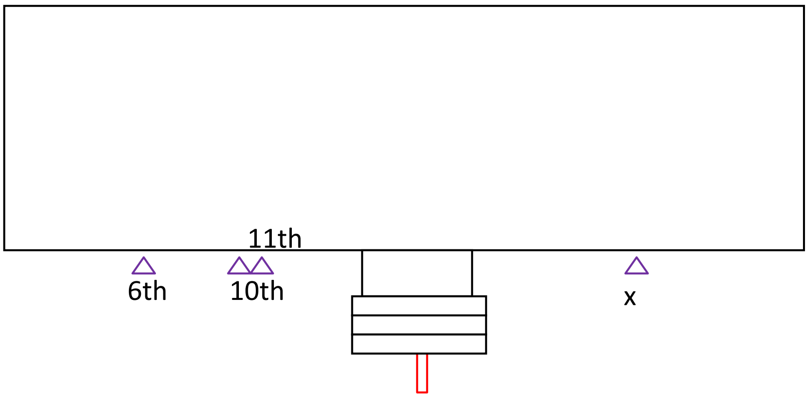

Figure 36. Map of the school showing the positions of the blocks tested with UPV.

Block 6th (figure 37) presented a change in colour of the stone, more yellow than other blocks. Even thought the weathering sign is diffused to the whole block and some parts of neighbour block it is reasonable to think that it is due to an original increased weathered area in the quarry. Velocity= 2549,01 m/s

Figure 37 Block 6th on the basement, placing of the rule to mark the measuring points and performing the measurements.

Block 10th presents a fracture and its average velocity= 2178,48 m/s. Reading after the third point was not possible due to the interference of the crack, so the velocity had been measured only from interpolation of the first three points.

Figure 38. On the right, block 10 on the basement of the school.

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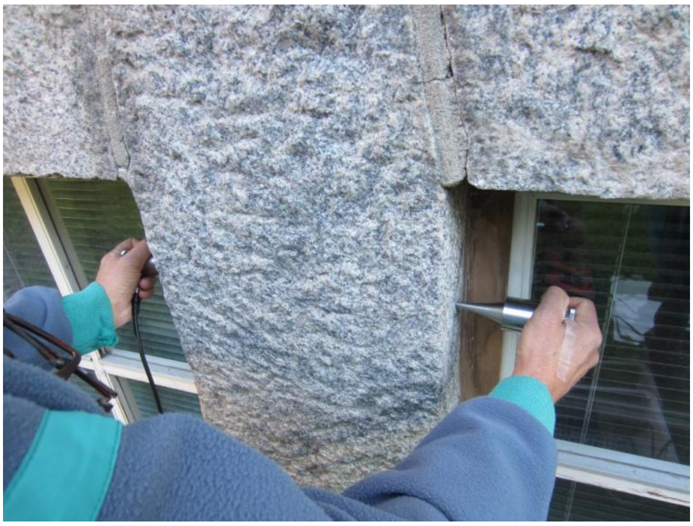

Figure 39. Measuring block 11th

Block 11th (Figure 39) presents fixed dust deposition-black crust. The UPV measurements had been performed as indirect measurements over the black crust and its velocity=2619,074m/s,
and as direct measurements on the column between two windows, with velocity=4456,27m/s in the measuring points crossing a vein of biotite,
while velocity=3998,24 m/s in the measuring points located on an homogenous area of the stone.

The wave forms of the measurements with the transducers positioned at 200 mm have been collected in the report of UPV Niirala.

A measurement has been performed on a protected area of the building, drier compared to other more exposed, near the door on the West façade under a roof shelter (Figure 40). The indirect measurement of Velocity= 2533,419 m/s

Figure 40. On the right, measuring block near the door under the shelter.

Schmidt hammer

The Schmidt Hammer has been used perpendicular to the surface to be tested, according to the methodology described in “Methods Schmidt Hammer”. The blocks tested are shown in Figure 41

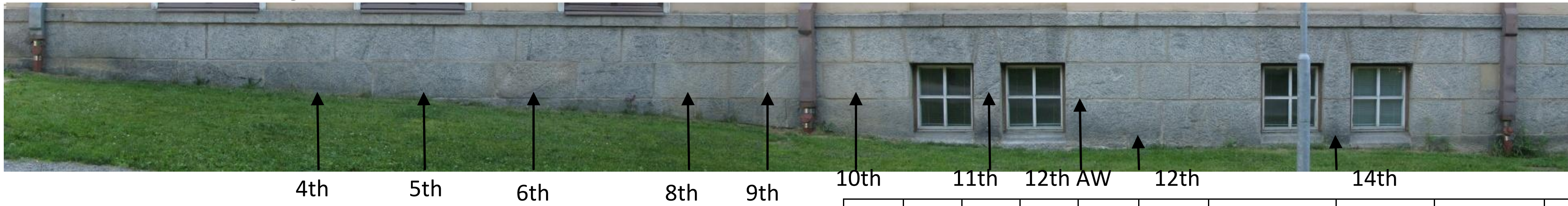

Figure 41. West facing basement and position of the blocks tested

Three rebounds for each spot. Totally 4 spots for slab (from right to left)

Block 6th presented a change in color of the stone

Block 9th: the values highlighted had been collected testing over the vein of potassium feldspar.

Block 10 presents a crack: the values on spot 4 had been over a detached part, a flake. The values on point 5 had been over the fracture

Block12: highlighted values are taken over a potassium area

R: Rebound value

	4th	5th	6th	8th	9th	10th	11th-MW	12-AW	12th low	14th
	R	R	R	R	R	R	R	R	R	R
Spot 1	49	59	59	58	49	58	52	60	58	62
	59	60	60	62	68	62	50	60	58	62
	59	60	60	58	62	60	52	60	58	62
Spot 2	59	58	50	58	58	58	52	62	62	60
	58	60	52	62	62	60	56	62	62	60
	59	56	52	59	58	62	52	60	60	58
Spot 3	59	60	48	58	48	58	50	62	62	58
	60	61	50	58	52	58	56	60	62	60
	59	60	50	60	48	58	50	60	62	60
Spot 4	61	49	52	58	58	52	58	48	60	58
	60	50	60	60	62	52	58	50	60	58
	60	50	62	61	62	52	58	50	60	60
Spot 5						58				
						52				
						52				

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Three rebounds for each spot. Totally 4 spots for slab (from right to left)

	St	2C
	R	R
Spot 1	48	48
	52	52
	52	52
Spot 2	58	48
	58	48
	60	50
Spot 3	60	52
	60	52
	60	52
Spot 4	54	48
	54	50
	54	50

The block St. (Figure 41, St stands of stairs) has been taken over the stair parapet near the drill core after the drill core had been extracted. The values might have been affected by the high content of water absorbed during the drilling operation.

The Block 2C is a block that presented two colours: a part more red and a part less weathered. The weathering is assumed to be originating from quarry.

Figure 41. On the right, block St.

The results for each spot and those on each block had been averaged in order to evaluate the medium condition of the material on site. The result is illustrated on the graph of figure 42 in which on X axes are the block numbers and on Y axes are positioned the averaged rebound values R.

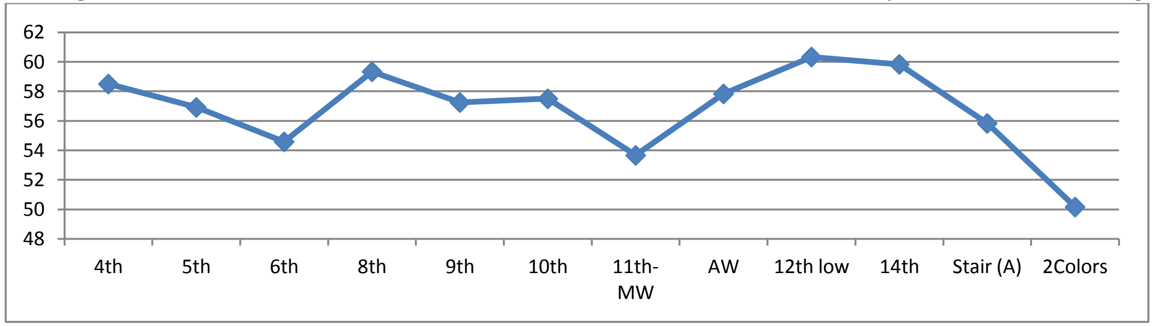

Figure42. Schmidt hammer averaged results along the stone basement facing West.

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Thermal camera

The measurements have been performed on morning, protected by direct insulation, with air temperature of 17degrees.

The façade overall show that the basement has higher temperature compared to the upper wall and this could be caused both by different thermal properties of the stone compared to bricks wall: the brick wall would be dissipating faster the heat gathered during insulating hours in the day time compared to the basement, and could also be cause by different insulation characteristics of the walls, since in the basement have probably not been used insulating materials, benefiting of the thickness of the layered structure. Figure 43 show this thermal difference.

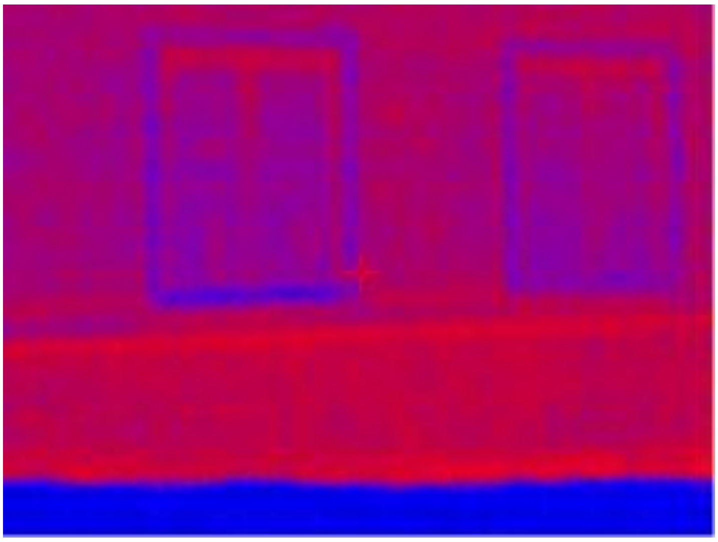

Figure 43 Thermal image of a segment of the façade facing West. (Thermal photo by Aleksei Shkurin)

Some elements of the basement had been checked with thermal camera: the block n. 6, that present two colors, the stone affected by black crust between the windows, the oxidized mineral fracture on the West façade (Figure 44,45,46)

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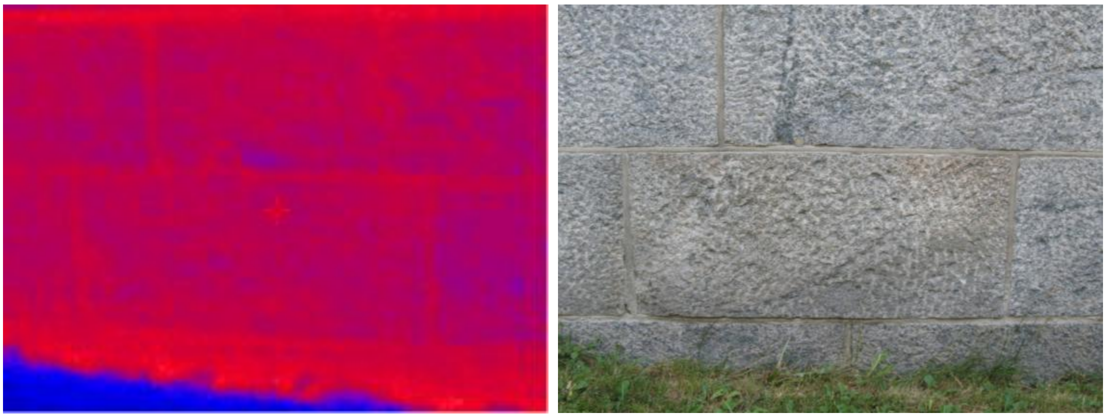

Figure 44. Thermal image and photo of the block that presents change of color given by original weathering- block 6. (Thermal photo by Aleksei Shkurin, Photo by Nike Luodes, GTK)

It is not visible a connection between changes of color given by different weathering and changes of surface temperature of the block. A black vein is visible as warmer compared to hollow areas of the same block.

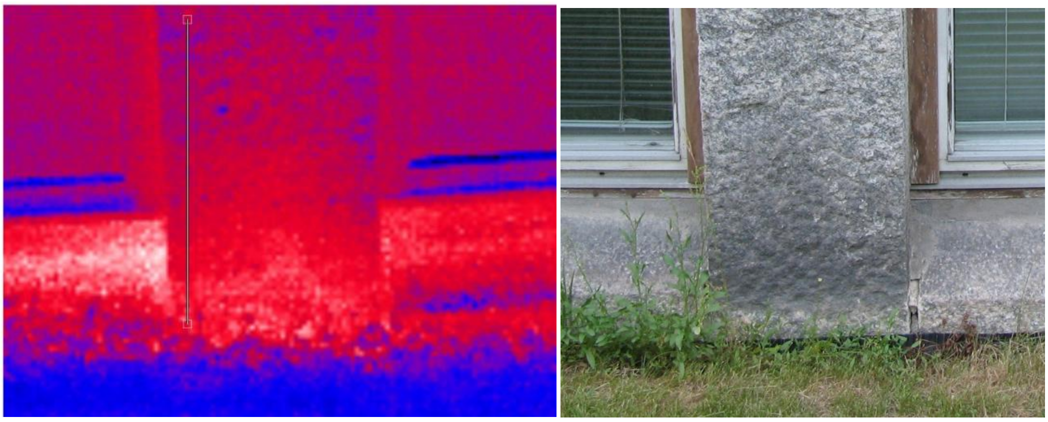

Figure 45. Thermal image and photo of the black crust between the windows. (Thermal photo by Aleksei Shkurin, Photo by Nike Luodes, GTK)

Higher temperature has been noticed over the black crust, probably caused by different thermal properties of covered and uncovered material or be influence of windows shape on air circulation.

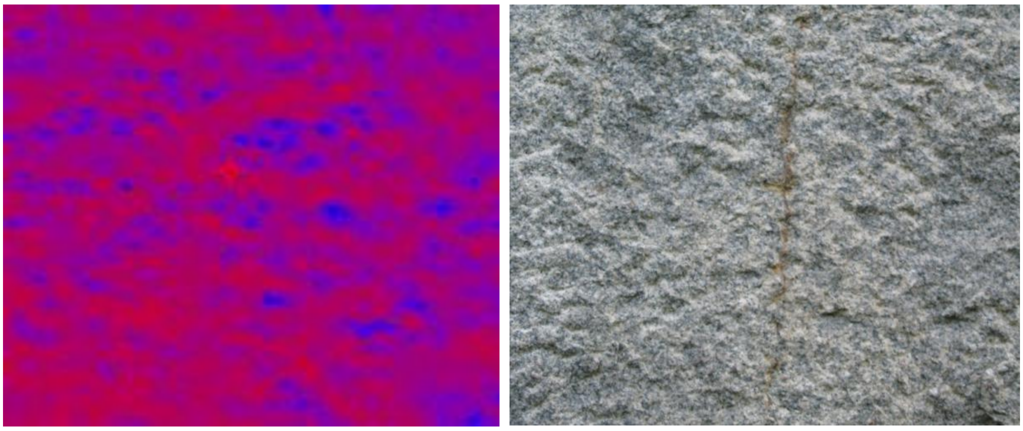

Figure 46. Thermal image and photo of the block presenting an oxidized mineral vein. (Thermal photo by Aleksei Shkurin, Photo by Nike Luodes, GTK)

It is not visible a strong change in thermal properties to allow the individuation of the vein, even thought a change in mineral composition and structure could also imply a change in thermal behaviour of the material.

One of the hottest spot found on the building has been in correspondence of the corner over the stairs between the parapet and the brick wall of the building visible in Figure 47. The average temperature of the basement surface was around 13 ˚C while the average temperature of the basement near the stairs was around 16 ˚C especially in the corners, where the temperature was around 17 ˚C.

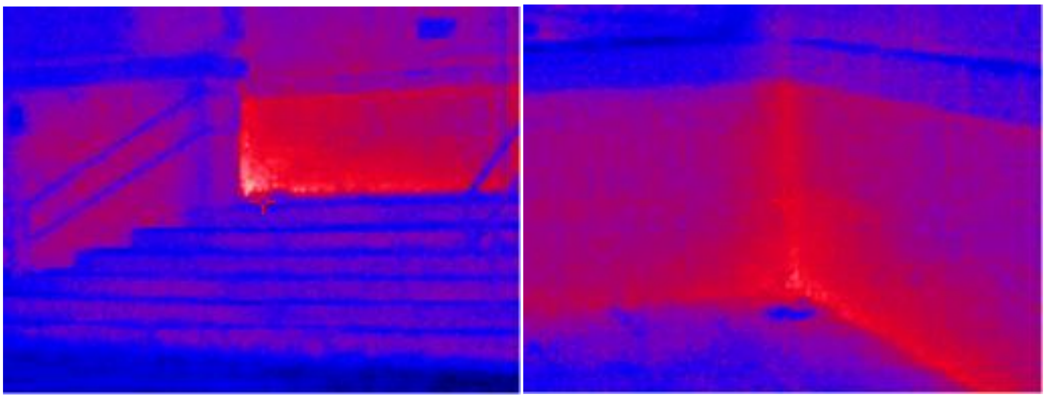

Figure 47. Thermal image of the stair and of the inner the corner between the brick wall and the parapet. (Thermal photo by Aleksei Shkurin)

The reason could be given by the fact that the area is protected from circulation of the air that otherwise would dissipate faster the heat emitted by the wall.

Mechanical and physical properties

Three specimens have been tested, Niirala 1 and Niirala 4, drill cores of smaller dimensions sampled in 2012 presenting the surface part, and HAP$-2012-25.3, bottom part of the drill core used for petrographic analysis, sampled in 2013. A photo of the samples is shown again in Figure 48.

Figure 48. Samples used to evaluate the open porosity: HAP$ -2012-25.3 (on the left), Niirala 1 (in the center) and Niirala 4 (on the right)

In Table 2 are shown the results for density and open porosity while in Table 3 are shown those of water absorption.

Table 2. Results of apparent density and porosity

	DRY WEIGHT (g)	UNDER WATER (g)	SATURATED WEIGHT (g)	Apparent density (kg/m3)	Open porosity (%)
Niirala 1	25,27	15,72	25,32	2627	0,52
HAP$-2012-25.3 (bottom)	57,57	35,95	57,69	2643	0,55
Niirala 4	20,63	12,78	20,69	2603	0,76

Table 3. Results of water absorption

	DRY WEIGHT (g)	WET (g)	Water absorption (%)
Niirala 1Top	25.26	25.31	0.20
HAP$-2012-25.3 (bottom)	57.55	57.64	0.16
Niirala 4 (Black crust)	20.62	20.67	0.24

The sample Niirala 4 showed presence of biofilm and black crust over a pink colour granite. The drill cores presented different density probably due to the heterogeneity of composition and the texture of the material that had given high impact on the small dimensions of the specimens. The open porosity has probably been affected more by surface deterioration. The sample Niirala 4 had shown much higher porosity and higher water absorption compared to the other samples but the sample is also showing a different level of weathering of the feldspars compared to the other samples. The extension of the weathered feldspar, that changed colour into pinkish, could be attributed to an original higher weathering level in the quarry more than deterioration actions during construction life. This has been also visible in other blocks while making the visual inspection.

REFERENCES

/1/ Itä-Suomen yksikkö K21.7/2010/61 Kuopio- KIVI KUOPION KAUPUNKIRAKENTAMISESSA Tuomiokirkon ympäristö- 4.8.2010 Heikki Lukkarinen

/2/ World weathered and travel information, web site: http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,kuopio,Finland

Annex 1

Table 1. Chemical composition of the top (HAP$-2012-25.1) and bottom (HAP$-2012-25.2) part of the drill core examined for Niirala school

			HAP$-2012-25.1	HAP$-2012-25.2
Al	mg/kg	+ 511P	9420	7150
B	mg/kg	+ 511P	5	5
Ba	mg/kg	+ 511P	119	149
Ca	mg/kg	+ 511P	3560	2430
Co	mg/kg	+ 511P	5,8	3,8
Cr	mg/kg	+ 511P	5	3
Cu	mg/kg	+ 511P	24	4
Fe	mg/kg	+ 511P	31500	19300
K	mg/kg	+ 511P	5990	5030
La	mg/kg	+ 511P	55	47
Li	mg/kg	+ 511P	38	22
Mg	mg/kg	+ 511P	2300	1540
Mn	mg/kg	+ 511P	400	262
Na	mg/kg	+ 511P	1740	1220
Ni	mg/kg	+ 511P	3	2
P	mg/kg	+ 511P	301	222
S	mg/kg	+ 511P	23	20
Sc	mg/kg	+ 511P	2,3	1,6
Sr	mg/kg	+ 511P	15,9	16,2
Ti	mg/kg	+ 511P	1460	958
V	mg/kg	+ 511P	11	8
Y	mg/kg	+ 511P	24,7	17,9
Zn	mg/kg	+ 511P	66	43
Ag	mg/kg	+ 511M	0,10	0,07
As	mg/kg	+ 511M	0,84	0,59
Be	mg/kg	+ 511M	0,40	0,26
Bi	mg/kg	+ 511M	0,01	0,01
Cd	mg/kg	+ 511M	0,22	0,11
Ce	mg/kg	+ 511M	86,56	70,10
In	mg/kg	+ 511M	0,04	0,02
Mo	mg/kg	+ 511M	1,24	0,46
Pb	mg/kg	+ 511M	6,00	7,33
Sb	mg/kg	+ 511M	0,09	0,06
Se	mg/kg	+ 511M	0,61	0,52
Te	mg/kg	+ 511M	0,020	0,017
Th	mg/kg	+ 511M	11,43	5,77
U	mg/kg	+ 511M	1,60	1,10
W	mg/kg	+ 511M	3,24	0,34
Yb	mg/kg	+ 511M	2,61	1,89

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KUOPIO LYCEUM

Documentation and research methods

Historical information about the building has been collected from the report of GTK: Kivi Kuopion kaupunkirakentamisessa by Heikki Lukkarinen /1/.

Description of the building

Number	14
Name of building	Lyceum of Kuopio
Architect	Carl Ludvig Engel
Address	Puijonkatu 18
Built (year)	1826
Modifications 1	1875
Remark_mod 1	Ferdinand Öhman
Modifications 2	1885
Remark_mod 2	Georg Wilenius
Modifications 3	1914
Remark_mod 3	Sigismund von Nadelstadh
Modifications 4	1940
Remark_mod 4	Väinö Vähäkallio
Use 1	Stone foundation
Rock type 1	Different stone types, split surface
Use 2	Stone foundation 1875
Rock type 2	Different stone types, split surface
Use 3	Stone foundation 1885
Rock type 3	Granodiorite, partly gneissic, gray, chiseled or bush hammered

A schematic map of the evolution of the building can be seen from Figure 1.

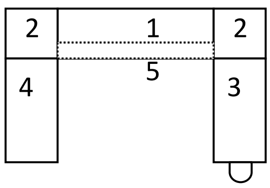

Figure 1. Schematic map of the enlargements of the Lyceum. Numbering means:

1: Original building from 1826. 2: enlargements of additional three windows done in 1874. 3: wing facing Pujionkatu built in 1885. 4: wing facing Hallinkatu built in 1914. 5: extension of the court yard and increasing of the height done in 1940.

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It has been built by Carl Ludwig Engel in 1826 and has been used as a school from 1844 to 1872, it was composed by the central wing+ three windows at both sides. During 1874-1875 the building was enlarged by the architect Ferdinand Öhmannin on the façade facing the Kauppakatu, adding other three windows on both sides. Between 1884-1885 was added the left wing by Georg Wilenius facing Puijonkatu and in 1914 the wing facing Hallinkatu by Sigismund von Nandelstadh. In 1940 Väinö Vähäkallio planned a further enlargement and an extension of the courtyard with the addiction of 1 floor to the top, visible from the fact that the height between floors is different between the old ones and the top one.

From the oldest part to the newest has been seen a change on the use of the material, from more rough structure, presenting heterogeneous boulders and natural cleavage splitted materials coupled with large mortar joints, to more fine structure and homogeneous material showing good example of the construction style of the area. The material used in 1885 and in 1914 had been chiseled and is formed by homogeneus material, possibly gneiss banded granodiorite. Inner court basement walls are constructed by several grey stone types that makes the wall look heterogeneous.

Figure 2. Kauppakatu - basement from the part built in 1826

Figure 3a. Kauppakatu - basement from the part built in 1874 towards Hallinkatu- enlargement n.2

Figure 3b.Hallikatu- basement from the part built in 1875 – enlargement n.2

Figure 4. Puijonkatu- basement from the part possibly built in 1875 (on the right) and that constructed in 1885 (on the left) – enlargement n.2 and 3

On Figure 4 is visible that the old part constructed in 1875 (on the right) is much different from those constructed in the same years on the other sides (figure 3 and 2) and as material choice and finishing is more similar to the enlargement constructed in 1885. Different construction styles visible in Figure 4 are probably determined by the different uses of the basement (cold basement vs worm basement) but the material is the same.

Figure 5. Hallikatu - basement of the enlargement done to build the gym hall in 1914 –enlargement n.4

Figure 6.Inner yard enlargement dated 1940, showing heterogeneous material.

The building is in Neoclassical style, a style used in many forms by the original architect also in other buildings in south Finland. The enlargements had maintained a similar style playing later with the volumes and maintaining an harmonic balance of the facades. The main façade facing Kauppakatu is symmetrical in all its elements: constructive and decorative, vertically and horizontally as visible from Figure 7.

The façade is divided in two orders, a lower floor , functioning as a “basement floor” more simple, with bossy surface, with a clear rhythm given by the squared windows, and an upper one, “the noble floor” more decorated and lively, in which the windows of the central wing are covered by a circular tympanum and the windows in the side wings are alternated between simple frame and roofed frames. The sides of the building recall the sides of the main façade while the courtyard façade are more modernists with unframed squared window openings and undecorated walls , as visible from Figure 8.

Figure 7. Main façade towards the Kauppakatu.

Figure 8. Image of the façade facing the inner yard of the building.

Different volumes had been used during the enlargements of the sides of the school. On the one done on Hallikatu, since it had to be done a gym hall, it is just one floor height with a basement underground floor, while the sidefacing Puijonkatu reaches two floors height and presents also a basement underground floor.

The wings facing Puijonkatu presents in the basement round top windows, also in the facades facing the inner yard, while the wing facing Hallikatu presents squared windows in the basement floor, also in the side facing the inner yard.

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The inner yard façade presents 4 orders of windows, that means 4 floors, against the two floors visible from the main façade on Kauppakatu, this has been possible from the addition of a top floor in inner court and a deepening of the yard paving level, considering that the building is placed over a hill area. In Figure 6 is visible that the regular worked stone basement had been placed over more irregular one that possibly was before under ground.

Characterization of the environment

Local environment (architecture etc.)

The building is located in the centre of Kuopio on the side of the main square in front of the Kauppahalli. The building has a U shaped form presenting the main facade and main old entrance on Kauppakatu, one of the main roads of the centre nowadays characterized by limited traffic access. The successively built side wings form an inner open courtyard where a car park has been located.

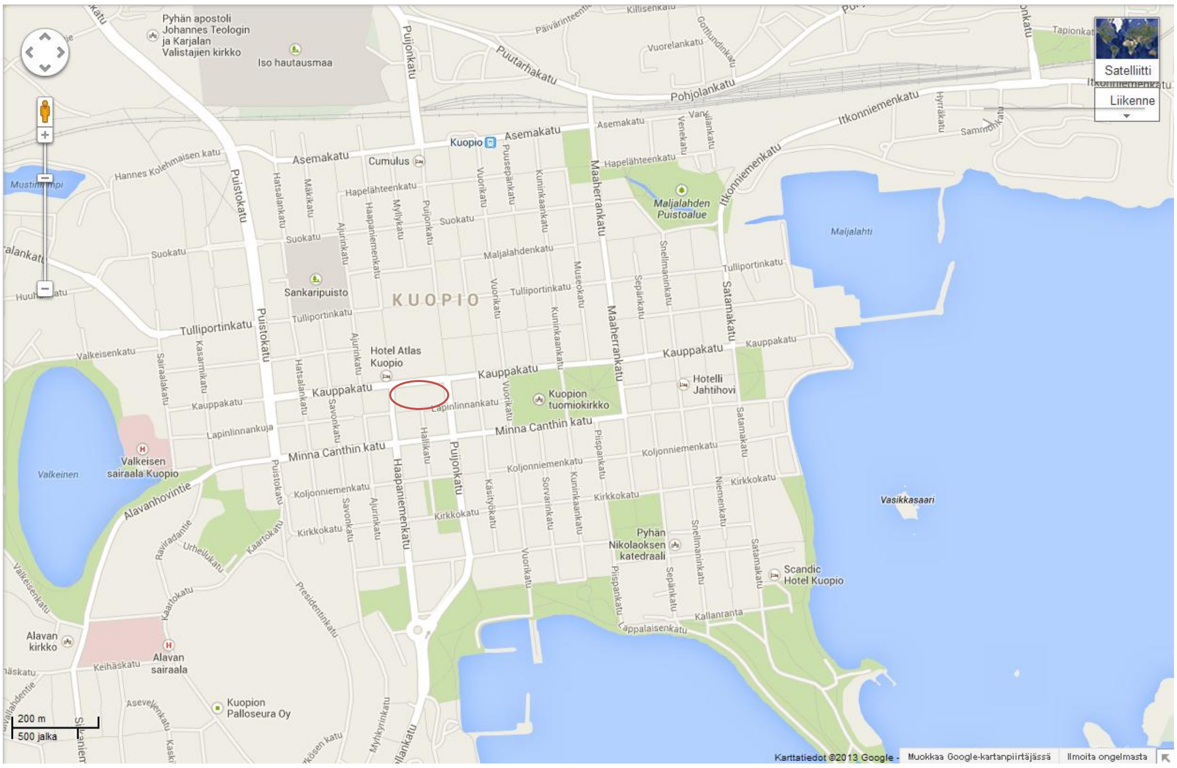

Figure 9. Area where the building is located (Google Maps)

Climatic conditions, microclimate, etc.

Kuopio is located in Central East Finland on the lake Kallavesi. Its climate is characterized by an average of approximately 82% of humidity along the year, diminishing to about 60% in spring-summer time, from March to August. Kuopio's climate presents dry seasons, generally during the spring months and a rainy season during the autumn time. Generally from November to March the temperatures do not rise over the zero during the day and as an average the minimum temperature reached could be considered around -22°C. /2/.

Photographic documentation

The site has been documented photographically in detail by Gigapan photos, normal camera photos of the complex and of the architectonic elements, of the deterioration problems and of the materials and finally by high definition photos of the samples. The processes of sampling and testing have also been recorded.

Gigapan photos

A gigapan photo has been taken from the yard side of the building, so from the youngest reconstruction. It is visible on gigapan.com under the name of Kuopio Lyseo HLuodes

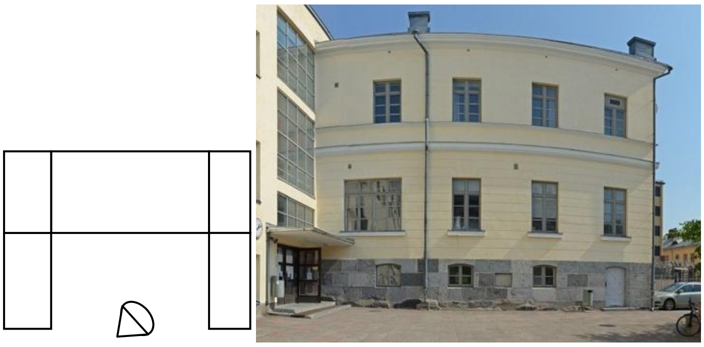

Figure 10. Schematic map of the school and the gigapan image collected

Visual inspection

No mapping had been done for this building in 2013.

Detection of weathering types

The basement has been probably cleaned with some mechanical tools, as air pressure or water-jet, since the surface of the stone is clean and in some areas looks abraded. It is assumed that the visible mechanical weathering (sharp grains, lost of chiselling patters, hollows...) is not occurred by normal deterioration mechanisms connected with climate and length of exposition and is not original of the quarry or of the construction time, but has been caused by successive actions: anthropogenic actions, as for example cleaning operations.

Peeling and exfoliation

Not recognized on the basement

Rude surfaces

The original surface was either split or chiselled. On the stones used in the extension done in 1874 could be noticed that the harder minerals have been weathered off less than the softer minerals, as visible from Figure 11, leaving a more rough surface compared to the fresh material.

Figure 11. Routhening of the surface on the blocks of the basement facing Hallinkatu done in 1874.

Also the surface of the blocks used in the latest enlargement in the courtyard have shown similar trend, as visible from Figure 12, where the chiseling marks are not visile anymore. The level of weathering has been lower than the one that affected the older part of the building and can be assumed that the weathering action has happened on site but probably has been due to cleaning operations, that gave a different impact on material that already presented different level of deterioration.

Figure 12. Block used on the inner yard and showing roughening of the surface.

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Deepenings and cavities

Some of the old basement blocks have shown higher degree of surface degradation as the block shown in Figure 13 from the enlargement done in 1874 facing Hallikatu. It is possible that the blocks used had already been originally weathered, since the material has been not quarried but picked as erratic blocks. The material is also a kind that has higher tendency to deterioration and that last less than a sound granite the local environmental condition, moreover, if mechanical cleaning operations have been used, the surface could have been abraded also by those.

Figure 13. Block on the side constructed in 1874 facing Hallikatu, the material is showing deepening and cavities

Hollows and chipping

Hollows are recognized on the entire basement and in different forms depending on the stone kind. The newest part of the basement built as Ashlar masonry, used a granitic gneiss that showed in all the parts where has been used (inner yard, left and right wing) cavities of large dimensions that appeared to be detached according to splitting faces, as visible from Figure 14 and 15.

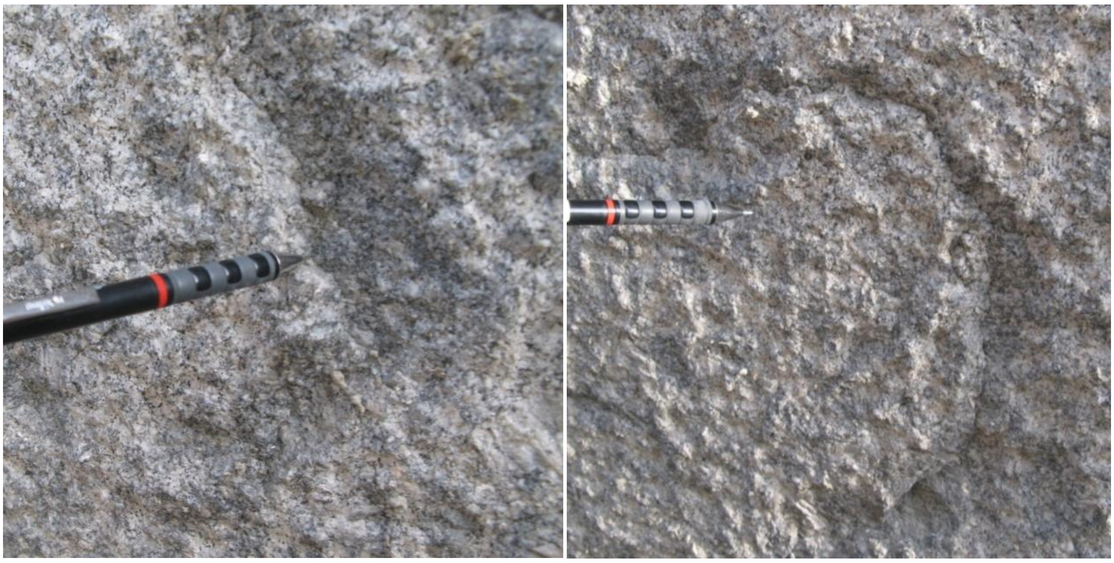

Figure 14. Two examples of formation of deepenings from the basement facing Hallikatu.

Figure 15. Two examples of formation of deepenings from the basement facing West in the courtyard.

Both of the example shown in Figure 14 and 15 are on walls oriented to West, but same behaviour has been noticed also towords others orientations.

Stone flaking-off

Flaking has not been recognized over the granitic basement of the school.

Granular disintegration , decohesion of single crystals or mineral grains

The material at a touch had always given the impression to be well attached even if some cases, as the block in Figure 13 could give the impression of being affected also by granular disintegration. The material used in the original building and in the extension of 1874, being more heterogeneous, and composed by erratic boulders, could also present some blocks that have higher tendency to granular

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disintegration, but generally the blocks had been of granitic material not showing these characteristics.

Fractures and fissuring

Fractured material has been noticed on some blocks used in the inner yard. The fractures are original of the deposit and have probably opened later on site, thanks also to the oxidation of some minerals, as visible from Figure 16.

Figure 16. Fracture original from the deposit where the block has been extracted and that has opened on site. Photo of a block used on the basement facing East in the inner yard.

A crack probably given by anthropogenic actions is the one shown in Figure 17, in this case the stone has probably been subjected to an impact. The corner is also showing a natural plane over which a fracture has opened.

Figure 17. Fracture and scaling, probably given by a combination of actions: an impact and own tendency to fracture on a natural cleavage.

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Deformations

One deformation has been noticed over a window on the basement facing Puijonkatu. The central block has been dislocated probably because of the vibrations caused by the works of reconstruction of the main square and repaving of the roads (Figure 18)

Figure 18. Windows on the side facing Puijonkatu over which a block has been dislocated.

Another fracture visible is on a block on the basement facing Hallikatu and built in 1874, shown in Figure 19. The corner has cracked, probably to vibrations or movement of the structure.

Figure 19. Corner cracked on a block in the old basement built in 1874 facing Hallikatu.

Fungus

Not evaluated its presence (Not tested)

Seaweed

Not evaluated presence (Not tested)

Lichens

Lichens have not been found to affect the stone.

Mosses and higher plants

Higher plants have been growing on the soil near the basements but have not grown over the stones, as visible from Figure 18.

Bio-films of different composition

Biofilm has been recognized in correspondence of the draining pipes, probably because of the higher humidity given by the rain flush. Examples from the facade facing Puijonkatu and Kauppakatu are shown in Figure 20.

Figure 20. Example of the biofilms formed over the stones in correspondence of the drain pipes. On the left the facade facing Puijonkatu and on the right that facing Kauppakatu.

Dung of birds

It is not seen in any part of the basement.

Atmospheric particle depositions and fixation

Atmospheric particle deposition has been seen mainly as dust deposition caused by the reconstruction works done in the area.

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Crusts

Fixation of dust into crust is visible only on some parts of the buildings, as those near the drain parts (Figure 20), probably because humidity capture dust and enhance the deposition and later the fixation, also considering that the buildings has been probably cleaned in recent years.

Loss/change of colour

Changes of colour determined by weathering of the material are visible over the building and mainly on the newer enlargements since those have been constructed by homogeneous quarried material. Difference in colour of the whole block is shown in Figure 21, on a block of the part built in 1914 facing Hallikatu.The block looks more yellow than the others even if the material should be similar and coming from the same quarry.

Figure 21. basement facing Hallikatu built in 1914, a block has been affected by higher level of weathering compared to the others used on the same wing. Probably has been taken from a higher part of the crop.

Weathering of minerals has been noticed mainly on the stone used in the inner yard, but both on the wing built in 1914 and in that built in 1885. In the one built in 1885 have been clear spots given by oxidating minerals as visible from Figure 22 and 23 and have been characteristics of a single stone type. The inner yard basement is in fact composed by different stone types and not all are showing the problem. The material used on the wing built in 1914 has shown veins of oxidating minerals as visible from figure 16 and 24.

Figure 22. Oxidation of minerals on the inner yard basement on the wing on Puijonkatu built in 1885

Figure 23. Oxidation of minerals on the inner yard basement on the wing on Pujionkatu built in 1885.

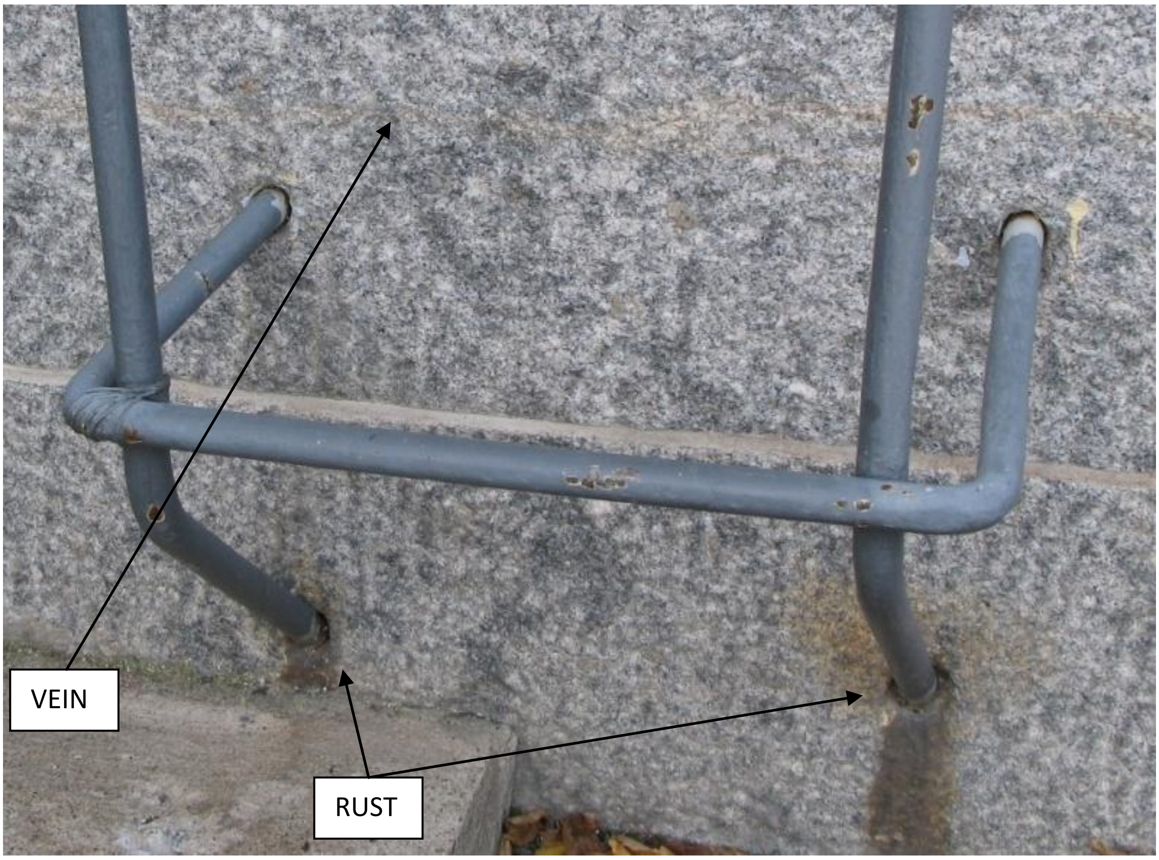

Figure 24. Vein showing oxidation of minerals on the inner yard basement on the wing on Hallikatu, facing south, built in 1914. In the figure is also visible rusting given by interaction with the metal stairs.

Ovoid weathering

It is not visible since the material has not tendency to this kind of weathering

Samples

Samples that have been further analysed had been taken from the facade facing West and North.

Sampling methods

In the Kuopio Lyceum, as has been for Niirala school, sampling has been performed in 2012. Cores have diameter of 17mm and their depth reaches few cm (in 2013 a larger drill core has been collected, with a diameter of 20mm and it has been possible to collect longer intact cores compared to the previous year).

Sampling locations

The building is characterized by three different expansion periods and drilling had been taken from all of them. The oldest basement is formed by heterogeneous material and some blocks had been collected that would look the most affected by deterioration actions.

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Description of the environment

The samples have been taken on the facades facing North and West. Those taken from the facade facing North have been at about 20 centimetres from the paving. The basement had been probably restored and cleaned recently therefore have not been recorded high deterioration problems. The drill core had been near a drain pipe and showed presence of biofilm.

Location of the sampling sites

On a map is possible to schematise the sampling areas (Figure25). The photos of the sampling are then visible in Figure 26,27,28,29,30.

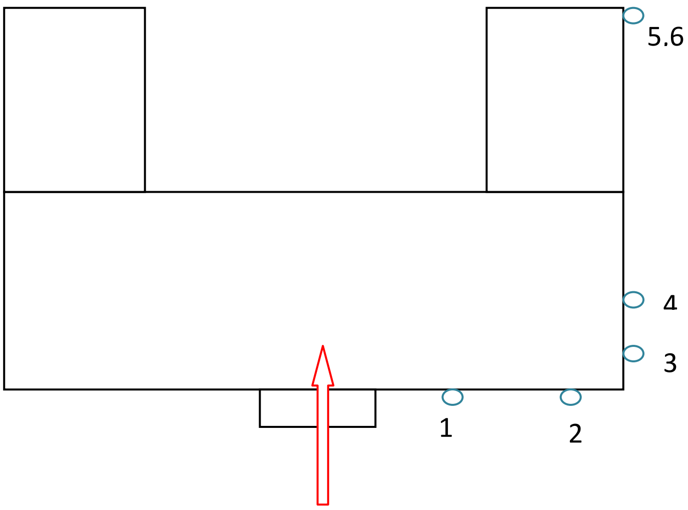

Figure 25. Schematic map of the building. In the figure is shown the main entrance from Kauppakatu.

Figure 26 Sampling of ”Lyseo 1” core taken from the old basement on the right of the main entrance door on Kauppakatu. It has been chosen a rock near a drain pipe, showing presence of biofilm (taken on 15.8.2012, photo Heikki Pirinen)

Figure 27 Sampling of ”Lyseo 2” core taken from the old basement on the right of the main entrance door on Kauppakatu. The rock does not present deterioration problems (taken on 15.8.2012, photo Heikki Pirinen).

Figure 28 Sampling of ”Lyseo 3” core taken from the basement dated 1874 on Hallikatu near the cross with Kauppakatu. The rock does not present deterioration problems (taken on 15.8.2012, photo Heikki Pirinen).

The sample has also been re-coded HAP$2012-24 (1-2-3 depending on the analysis for which had been used).

Figure 29 Sampling of ”Lyseo 4” core taken from the basement dated 1874 on Hallikatu. The rock does not present deterioration problems (taken on 15.8.2012, photo Heikki Pirinen).

Figure 30 Sampling of ”Lyseo 5” and “Lyseo 6” cores. Both have been taken from the newest part of the basement built in 1914 facing Hallikatu towards Kuopionlahti and constructed by homogeneous rock. Lyseo 5 has been taken from the top part and Lyseo 6 near the paving. (Samples taken on 15.8.2012, photo Heikki Pirinen).

Sample types

From the building sample Lyseo 3 has been prepared for further analysis, all the other have been spared and prepared for physical testings. Lyseo 3 has been sampled in 2012, coded HAP$2012-24.

Thin sections

HAP$2012-24 rock has been sampled again 2013 collecting drill cores with diameter of 20 mm. The sample has been coded HAP$2012-24_3 and of it has been cut few cm from the top part of the core to prepare thin sections.

Chemical analyses

Drill cores

Chemical analysis has been performed on drill core sample collected in 2012 and coded HAP$2012-24-1 and HAP$2012-24-2 distinguishing the top and bottom part of the drill core.

Surface samples

No other surface samples have been collected from the site.

Biological analysis

Surface sections from collected samples and drill cores

Not Performed

Mechanical and physical tests

Samples for water absorption and compression tests

In October 2013 have been performed density and open porosity and for it have been used the part of samples collected in 2012, small drill cores, and the bottom part of sample HAP$2012-24_3 . The material has been the same pictured in Figure 32 and is better described in the section of the results of the tests.

Photos of Samples

Normal photos

From Kuopio Lyceum has only been taken a normal photo from the sample chosen for chemical analysis in 2012 (Figure 31), those drilled in 2012 and not chosen and that drilled in 2013 have not been pictured with normal camera but with stacking technique and are visible in Figure 32 - 33.

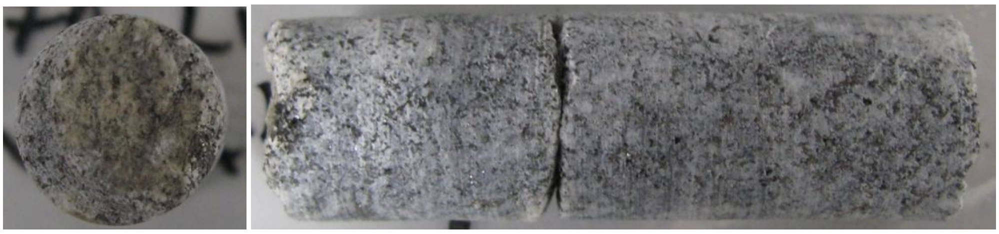

Figure31 Normal photo of the specimen from the Lyceum chosen for chemical analysis.(Sampled in 2012. Photo: Heikki Pirinen)

Stacking photos

The high definition photo of the drill cores collected during 2012 and 2013 do not show the one used for chemical analysis. In Figures 32 and 33 are shown the samples, in order from left to right: HAP$2012-24_3 Lyseo 1, 2,4,5,6

Figure 32 Weathered surface of the drill cores from Kuopio Lyceum . (Photo by Jouko Ranua GTK)

Figure 33 Back part of the drill cores collected, same as in figure 32, to evaluate the un-weathered surface of the material. (Photo by Jouko Ranua GTK)

The high definition pictures allow to zoom and see in detail the surface of the material as visible from Figure 34.

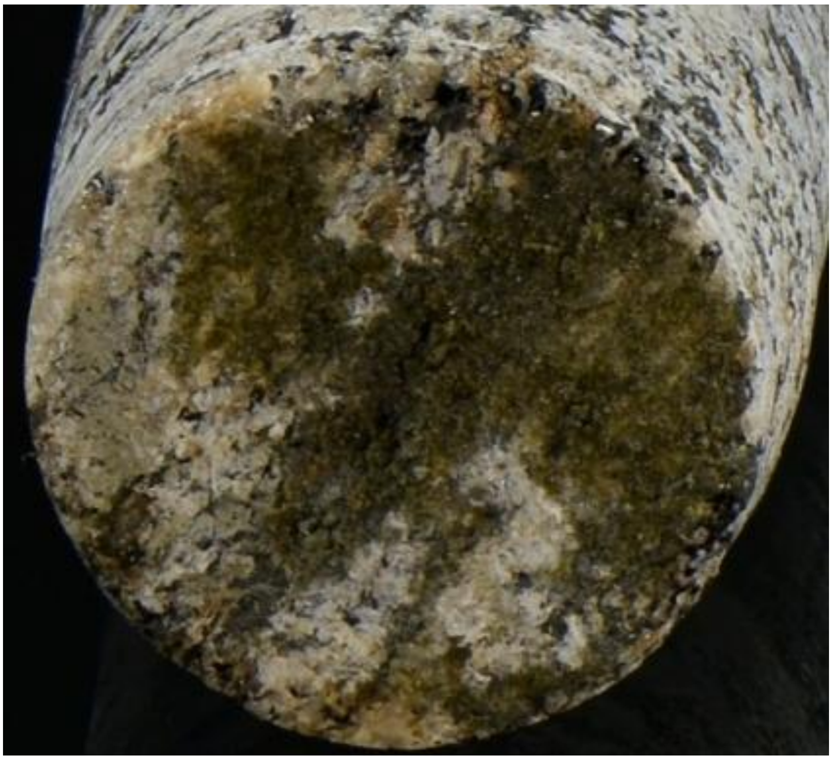

Figure 34 Detail of the surface of the sample Lyseo 1 collected in proximity of a drain pipe on the main facade. The sample diameter in its section is 17mm. (Photo by Jouko Ranua GTK)

Petrographic and chemical properties

The sample from surface was too small and it has not been performed the total chemical analysis, but the sample from the bottom had been analysed. HAP$-2012-24.1 has been the top part of the drill core, the one with the surface of the stone HAP$-2012-24.2 has been the bottom part of the drill core, the one considered relatively fresh and possibly not yet affected by biological activity. In Annex 1 Table 2 is shown the list of the results obtained. Al, Ca,Fe,K,Mg are the main elements of the bottom and top and their amount is shown into a visual form in the graphic of Figure 35. Ti, P and S are also having higher percentages.

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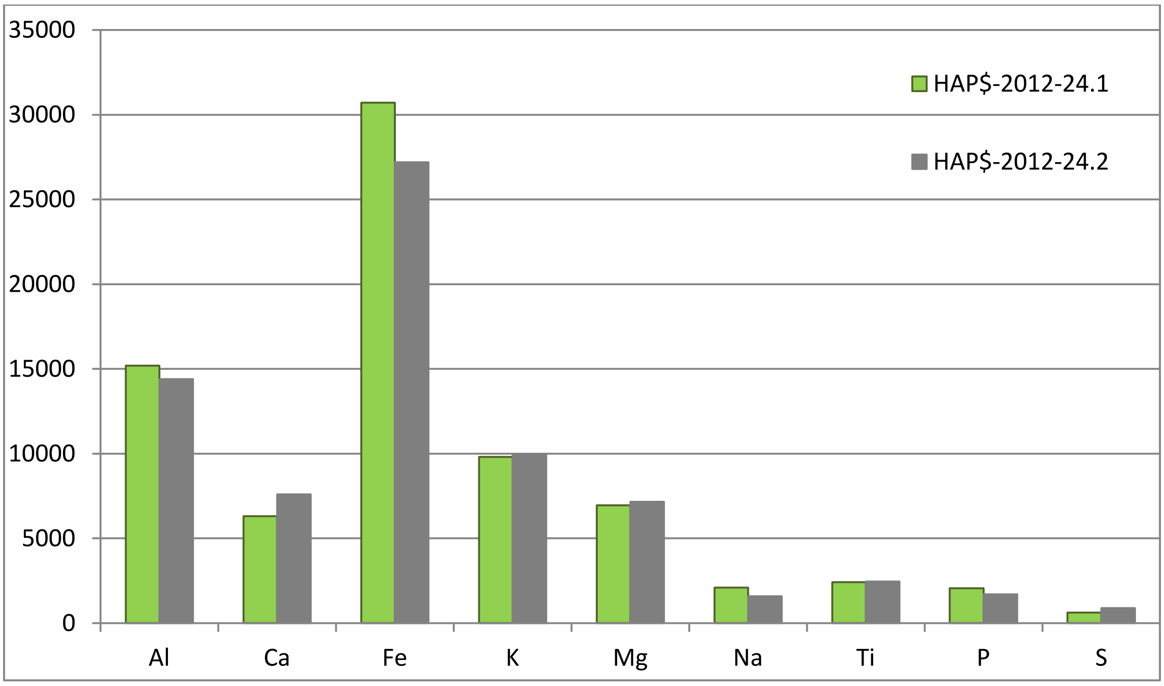

Figure 35. Main chemical elements of the material from top and bottom part of a single drill core.

Minor elements are instead visualized in graphic 2.

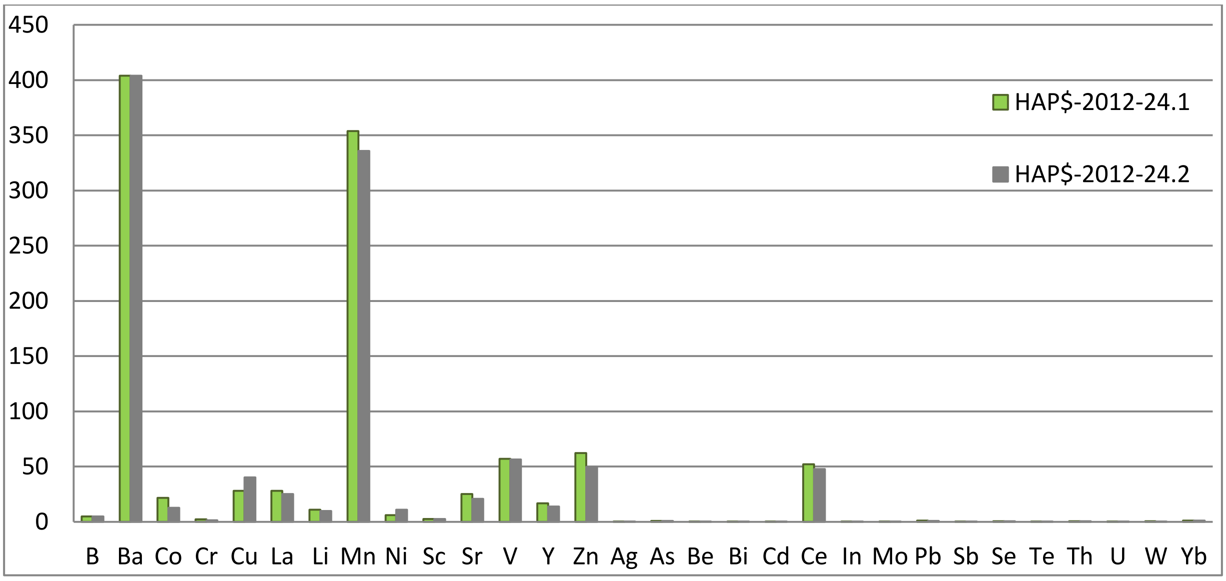

Figure 36. Minor chemical elements of the material from top and bottom part of a single drill core.

The units and amounts are those defined in Table 1 in Annex 1. Chemical weathering indexes had been calculated using the total chemical analysis of the bottom part of the drill core. From the chemical results of the chemical analysis can be compared which had been the chemical lost or enrichment of the surface

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layers compared to the bottom layers of the drill core. From the graphs of Figure 37 and 38 it is possible to visualize the chemical composition changes between the top and the bottom of the sample.

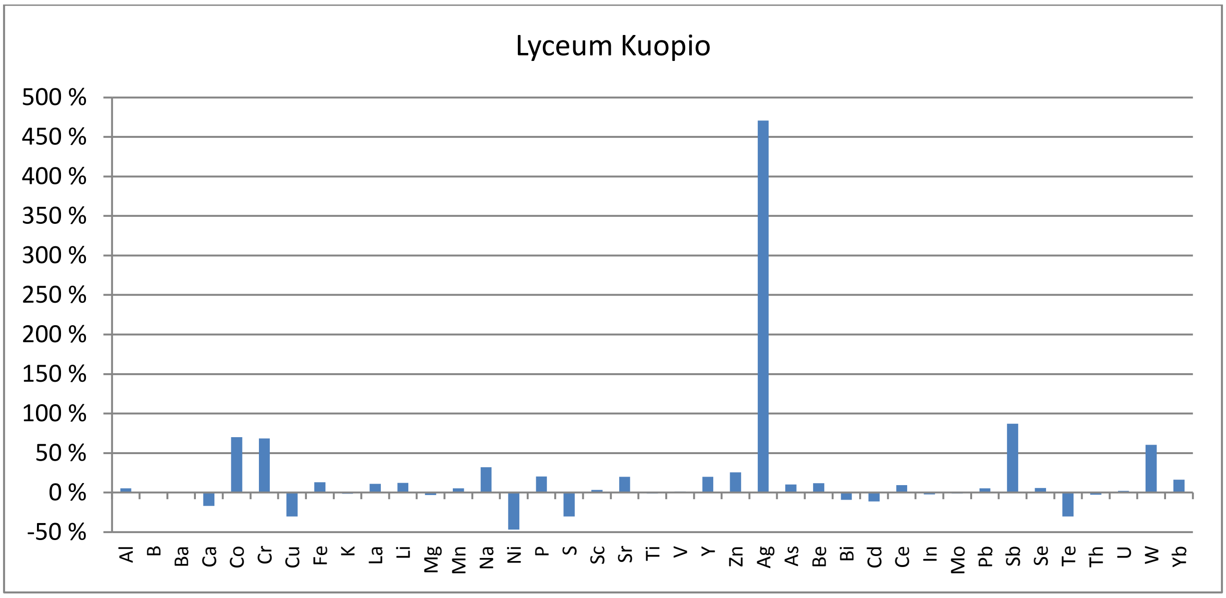

Figure 37 Changes in percentages of the chemical elements of the top respect the bottom of the drill core

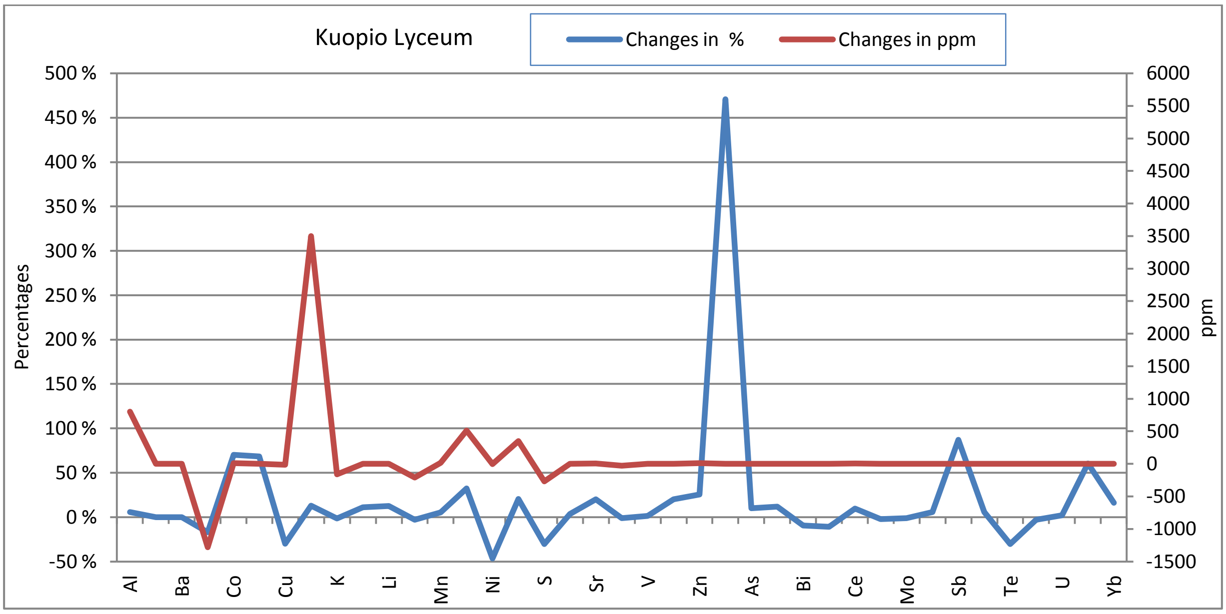

Figure 38 Changes in percentages and in ppm of the chemical elements of the top respect the bottom of the drill core.

The specimens have been collected on a stone that didn't present visible deterioration factors either presence of biofilm, still is visible an increased accumulation of silver on its surface, besides Cobalt, Chrome, Sb and W.

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Non-destructive research methods

Non destructive research methods have included Ground penetrating radar and Schmidt hammer hardness test performed by the Geological Survey of Finland. Ultra Pulse velocity on specific blocks has been performed in cooperation with the Polytechnic of Turin-Italy while thermal camera measurements have been performed in cooperation with Mikkeli University of Applied sciences.

Ground penetrating radar

Measurements have been performed along the Lyceum on the basement facing Hallikatu (F1,F2,F3,F4) and on that facing Kauppakatu (F5, F6) as visible from Figure 39.

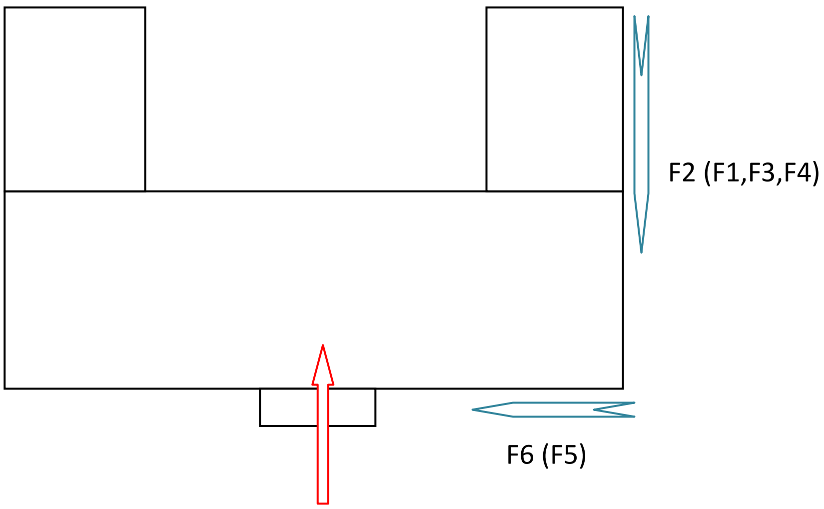

Figure 39 Map of the GPR measurements performed on the Lyceum.

F1 and F2 have been taken with the same antenna on the whole newest part of the basement as visible from Figure 40 - on the same path have also been done F3 and F4 measurements using the 900MHz antenna. Only the results got from 1600 MHz are shown in Figure 41, since it has been noticed that the wall has three layers of which the one visible from outside of stone has no deeper thickness than approx. 400 mm.

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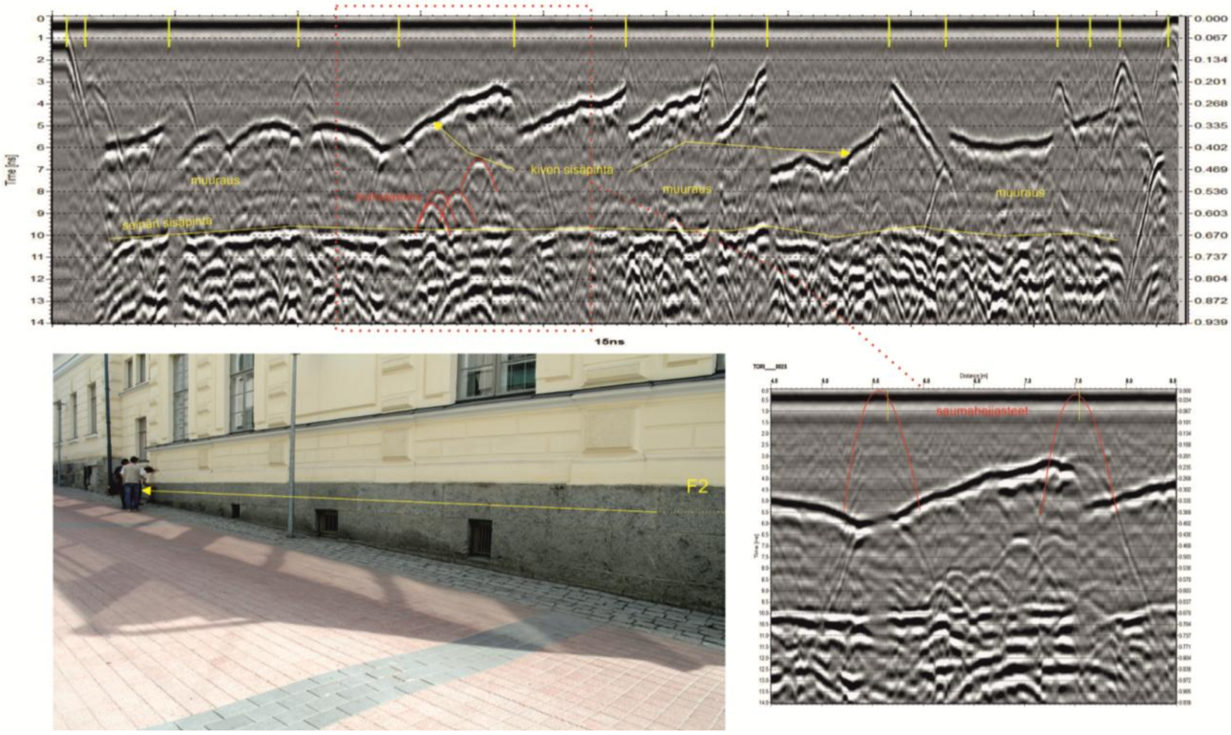

Figure 40. It is shown the radargram of the whole new basement (1914) facing Hallikatu. The antennae had never been taken out from the wall even in correspondence of the light pole standing in front of it. In the figure the joints between the blocks are shown in yellow. (Radardgram and photo: Heikki Sutinen)

From the radargram is visible that the thickness of the blocks varies between blocks and can be understood that the inner face is not squared since the back reflection lines in the radargram are not horizontal even within the same block. The joint's reflections are highlighted in the right lower radargram picture in red.

In this case the construction typology is with Ashlar masonry. The wall is formed by three layers, the inner side of bricks, most possibly, the outside one of stone blocks and the middle one that is not left empty but it is filled with fine grained and compact material that presents some higher reflections maybe in correspondence of some irons or bigger stones.

A measurement has been performed on the facade facing Kauppakatu as shown in Figure 41. In this case is visible that there less regular surface cladding material, as the construction typology is different from the previous one. There is not clear back wall neither of the surface stone cladding neither of the back side of the wall, probably unshaped blocks had been placed and cemented together, larger block with smaller in between for the depth needed to create the fundaments.

In Figure 41 is shown an enlargement of the starting of the radargram, taken over the newer part of the wall. On it are shown some higher peaks that could be also caused by metal anchors to keep the wall connected, or by bigger bolders. The typologies of construction look similar since there is not high difference between the radargrams. In some parts of the walls, mainly in the newer part have been used bigger stones, while in the older one have been used smaller ones, since on the right of the radardgram is visible a much higher density of refractions.

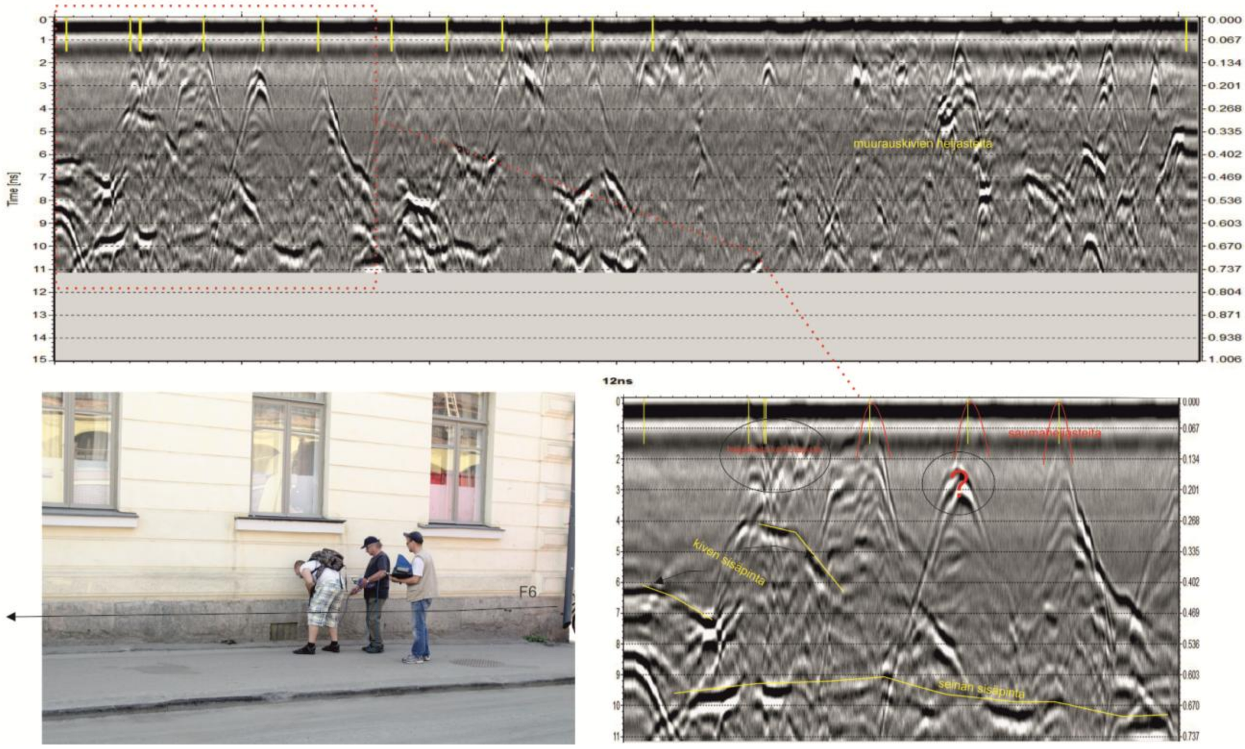

Figure 41 It is shown the radargram of the basement facing Kauppakatu, taken from the side built in 1874 to the one built in 1820.(Radardgram and photo: Heikki Sutinen)

A view of the inner wall has been attempted looking inside an opening on the basement facing Puijonkatu as visible from Figure 42. The walls are built of stones and bricks and are cemented.

Figure 42 Photos taken from an aeration hole of the basement on the side built on Puijonkatu. On the left the upper-left side of the hole, on the right the right-bottom side of it.

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Ultrasonic measurements (UPV)

The measurements have been performed in an indirect way according to the report "Methodology UPV". The blocks tested had been those from which had been taken samples from the older part of the building constructed in 1874-75 (samples 2 and 3) and one that had been tested with GPR from the newer part of the basement built in 1914, sample 1. A map of the samples is shown in Figure 43 and a photo of the wall facing Hallikatu showing the sampled block is visible in Figure 44.

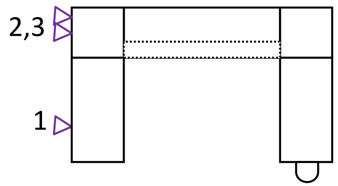

Figure 43. Schematic map of the blocks tested for UPV.

Figure 44. Basement facing Hallikatu and indication of the blocks tested for UPV.

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Block *Kuopio Lyceo1* that is the block over the window shown in Figure 45. The material didn't show any particular deterioration problem and the velocity of the material has been of 3010,87 m/s having an interpolating curve linear, not showing problems or weathering phenomena in any point measured.

Figure 45.On the left image of the Block 1, the block over window. On the right image of the measuring area on the block.

Block *Kuopio Lyceo2* is a Diabase block, an erratic boulder used in the basement part built in 1874-75. On the block is still visible the splitting core. The velocity has been measured being of 3314,07 m/s but the measurement is affected by high uncertainty since the single punctual values have not been showing a constant velocity. The variations could be given by deterioration level of the material, by problems in positioning the transducers over the surface or by the presence of the drill hole created during sampling. In figure 46 is visible the block and in red is marked the position of the measured line.

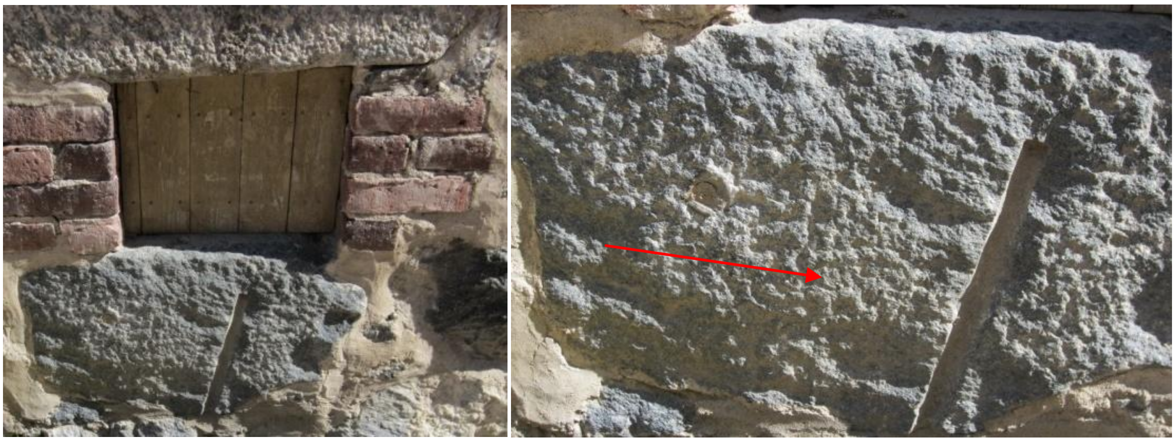

Figure 46.On the left image of the Block 2, the block under window. On the right image of the measuring area on the block marked with a red line.

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Block *Kuopio Lyceo3* gave more uniform and reliable measurements of velocity, deviating slightly by the expected values in the 2nd point, recording slight faster velocity and in the 4th point, recording slight lower velocity. The mean velocity has been of 2892,97m/s. The velocity has been probably lowered compared to a similar fresh material - affected by the weathering level of the block, being an erratic boulder. In Figure 47 is shown the block and the measuring activity.

Figure 47. On the left image of the Block 3. On the right image of the measuring activity on the block.

Schmidt hammer

The Schmidt Hammer has been used perpendicular to the surface to be tested, according to the methodology described in "Methods Schmidt Hammer" and has been performed on the same on which has been done the GPR measurements. The blocks tested are shown in Figure 48.

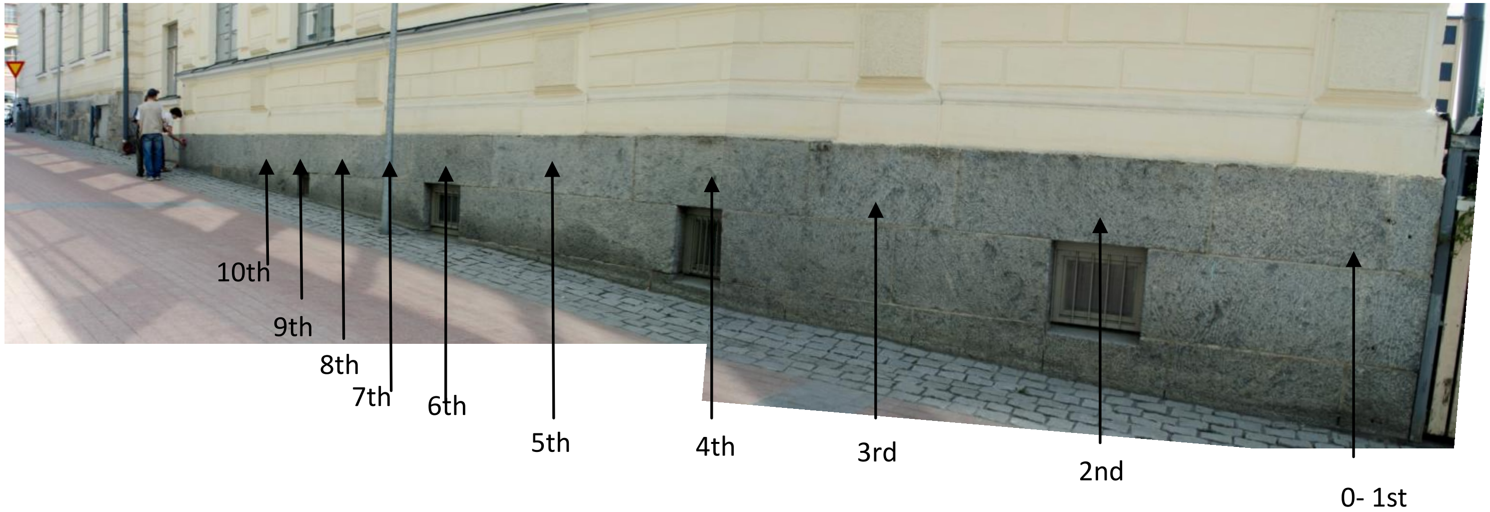

Figure 48. Basement wall on Hallikatu on which are indicated the blocks tested with Schmidt Hammer and their numbering.

In Table 1 are shown the results of Schmidt rebound test of the measurement performed over the blocks.

Table 1. Rebound values of the tests performed over the basement and their average over each block.

	Block number										
	0th	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
R values averaged for each spot	51	50	47	56	56	51	41	52	52	49	58
	60	51	51	50	55	59	58	58	52	49	58
	51	50	54	52	54	51	58	60	40	51	54
		55	53	39	51	55	45	55	53	43	45
Average over the block	54	51	52	49	54	54	51	56	49	48	54

On the 5th block the third test rebound tests have been performed over a part more weathered and looking red. The value is in line with the others obtained from the same block and is not lower than others from the basement. The visualization as graphic form of the results is visible in the graph of Figure 49.

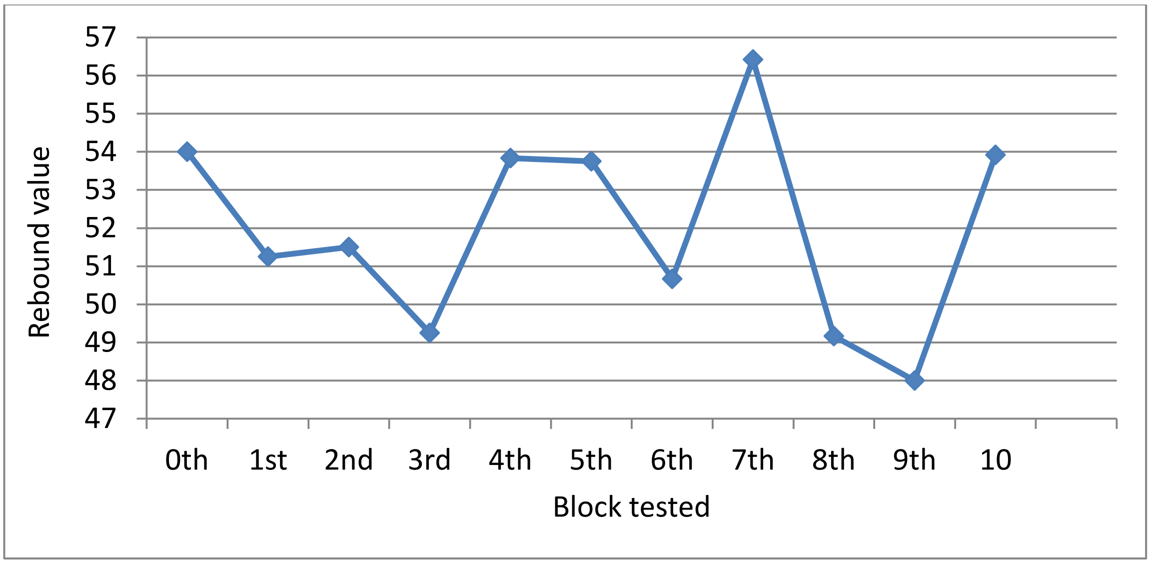

Figure 49. Schmidt rebound average values of individual blocks of the basement towards Hallikatu.

Block 3, 8 and 9 show much lower results compared to others. From a visual inspection it is not visible any deterioration effect and the lower values could be given by the minerals over which has been placed the hammer or by the surface finishing, presenting higher irregularities and increased breakability compared to previous blocks.

Thermal camera

The measurements have been performed on morning, protected by direct insulation, with air temperature of 17degrees.

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Basement of the Lyceum of Kuopio was as cold as the temperature of the ground and temperature of the air only the areas near the windows had been irradiating more, probably because of lower thermal insulation capacity of the glass. Moreover the images collected had been affected by the higher reflectance of the metal that flattened the temperature of the stone.

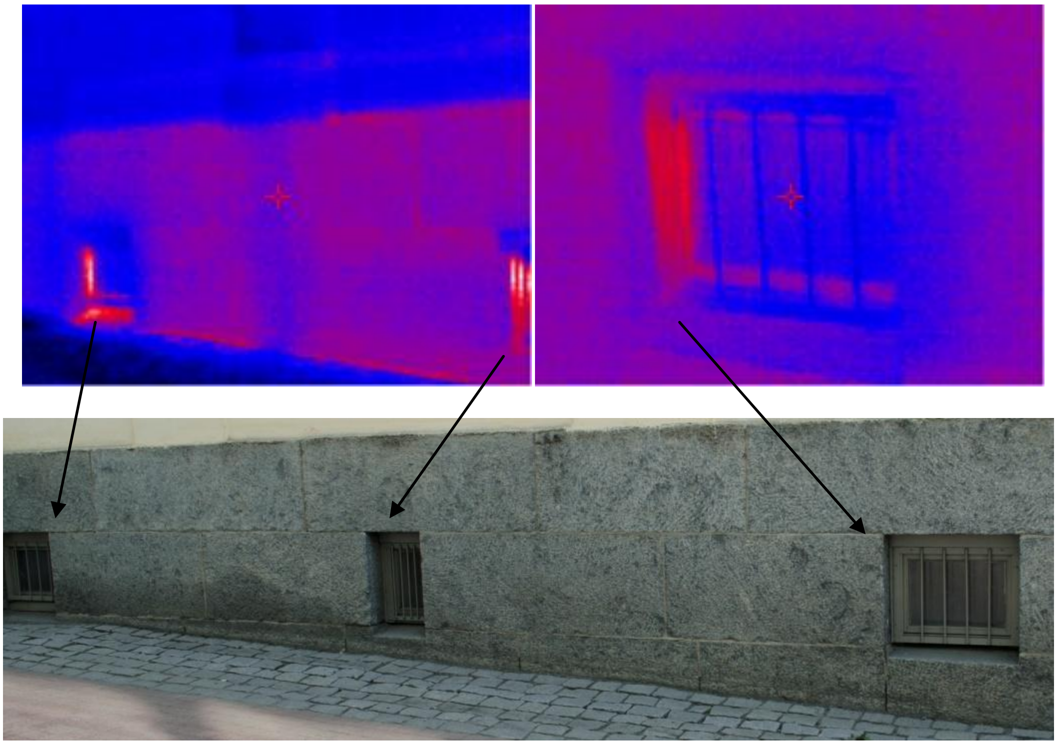

Figure 50 Thermal image and photo of the wall facing Hallikatu. (Thermal photo by Aleksei Shkurin, Photo by Joonas Toivanen, GTK)

Since the wall didn't present visible cracks or deterioration points, its surface had not been checked thoroughly. In this case even if it is visible some dust deposition and fixation on the photo of Figure 50, it is not detected change of surface temperature by the thermal camera. The neat difference between the top part in mortar and the basement part in stone is instead clear as visible from the first thermal image of Figure 50.

Mechanical and physical properties

Totally 8 samples had been tested. The bottom of the drill core HAP$-2012-24.3, and the ones sampled in 2012 with the small drilling machine, cut in half to evaluate the differences between top- weathered surface and bottom un-weathered surface. The samples are shown in Table2 while the results of density and open porosity are shown in table 3.

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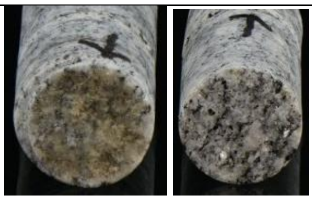
Table 2. Samples used to perform physical tests, photos and codes and date of construction of the basement from which they had been sampled.

Sample photo	Sample number	Sample photo	Sample number
	LYC1 (year 1826)		LYC4Top LYC 4Bottom (year 1874)
	LYC 2Top LYC 2Bottom (year 1826 or 1874)		LYC 5 (year 1914)
	HAP$-2012-24.3Bottom (year 1874)		LYC 6 (year 1914)

From the photos is visible that the specimen LYC 1 has a top surface affected by presence of biofilm while the specimens LYC 4 and 6 are affected by dust deposition.

Table 3. Results of density and open porosity.

	DRY WEIGHT (g)	UNDER WATER (g)	SATURATED WEIGHT (g)	Apparent density (kg/m3)	Open porosity (%)
LYC1	24,43	15,58	24,5	2733	0,78
LYC 2Top	9,91	6,17	9,93	2630	0,53
LYC 2Bottom	15,26	9,49	15,29	2626	0,52
HAP$-2012-24.3Bottom	64,48	40,66	64,58	2690	0,42
LYC4Top	15,02	9,98	15,04	2962	0,40
LYC 4Bottom	17,55	11,68	17,57	2974	0,34
LYC 5	12,09	7,58	12,11	2664	0,44
LYC 6	8,66	5,43	8,68	2659	0,62

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The materials sampled had been very heterogeneous, since the original basement had been built using erratic boulders but differences in density had been found also on the Top and Bottom part of the same drill core. This could have been caused by mineral composition, deterioration or deposition and fixation mechanisms. In the graph of figure 51 are shown in a figurative way the results of density and open porosity. On the X axes are listed the samples as in Table 3, and on the diagram are circles those specimens who belongs to the same drill core as Top and Bottom part.

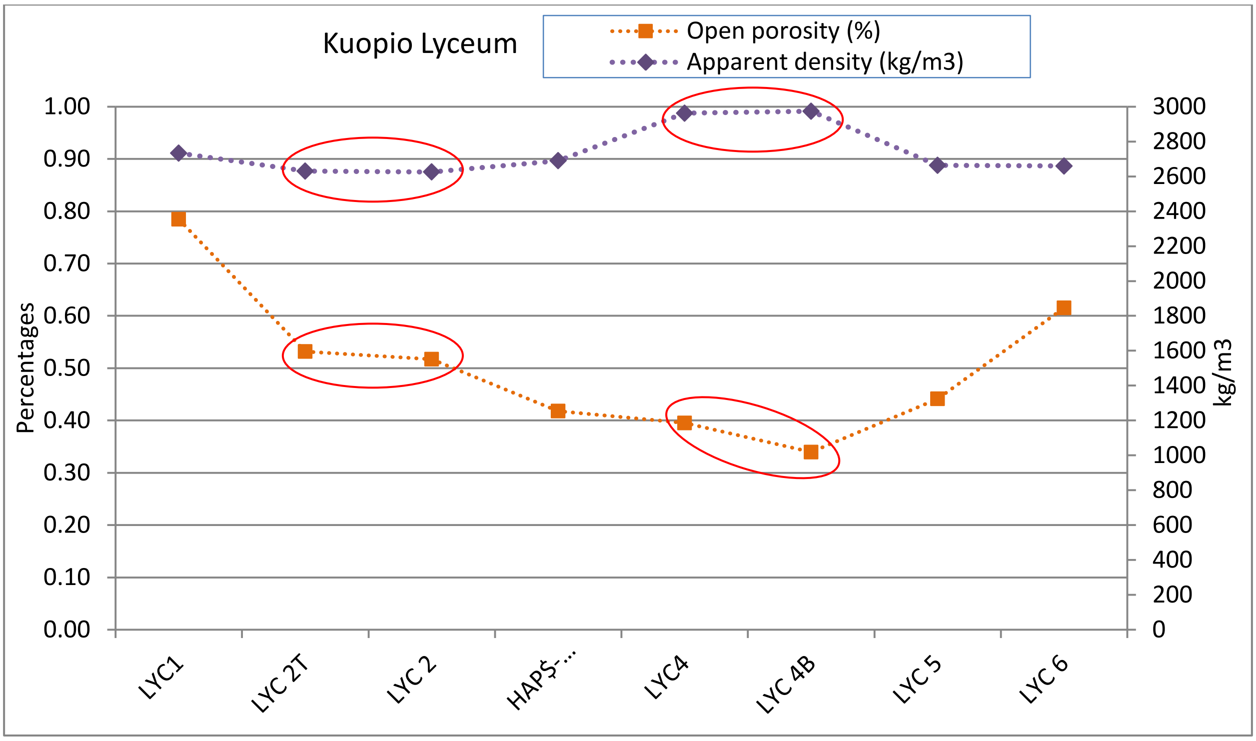

Figure 51. Density and open porosity of the material tested from Kuopio Lyceum.

REFERENCES

/1/ Itä-Suomen yksikkö K21.7/2010/61 Kuopio- KIVI KUOPION KAUPUNKIRAKENTAMISESSA Tuomiokirkon ympäristö- 4.8.2010 Heikki Lukkarinen

/2/ World weather ad climate information. Available online http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,kuopio,Finland

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Annex 1

Table 1. Chemical composition of the top (HAP$-2012-24.1) and bottom (HAP$-2012-24.2) part of the drill core examined for Kuopio Lyceum.

			HAP$-2012-25.1	HAP$-2012-25.2
Al	mg/kg	+ 511P	15200	14400
B	mg/kg	+ 511P	5	5
Ba	mg/kg	+ 511P	404	404
Ca	mg/kg	+ 511P	6310	7590
Co	mg/kg	+ 511P	21,6	12,7
Cr	mg/kg	+ 511P	2	1
Cu	mg/kg	+ 511P	28	40
Fe	mg/kg	+ 511P	30700	27200
K	mg/kg	+ 511P	9800	9960
La	mg/kg	+ 511P	28	25
Li	mg/kg	+ 511P	11	10
Mg	mg/kg	+ 511P	6950	7160
Mn	mg/kg	+ 511P	354	336
Na	mg/kg	+ 511P	2090	1580
Ni	mg/kg	+ 511P	6	11
P	mg/kg	+ 511P	2060	1710
S	mg/kg	+ 511P	621	890
Sc	mg/kg	+ 511P	2,7	2,6
Sr	mg/kg	+ 511P	25,1	20,9
Ti	mg/kg	+ 511P	2420	2450
V	mg/kg	+ 511P	57	56
Y	mg/kg	+ 511P	16,7	13,9
Zn	mg/kg	+ 511P	62	50
Ag	mg/kg	+ 511M	0,24	0,04
As	mg/kg	+ 511M	0,90	0,82
Be	mg/kg	+ 511M	0,06	0,06
Bi	mg/kg	+ 511M	0,02	0,02
Cd	mg/kg	+ 511M	0,03	0,04
Ce	mg/kg	+ 511M	52,23	47,67
In	mg/kg	+ 511M	0,02	0,02
Mo	mg/kg	+ 511M	0,32	0,32
Pb	mg/kg	+ 511M	0,98	0,92
Sb	mg/kg	+ 511M	0,06	0,03
Se	mg/kg	+ 511M	0,42	0,39
Te	mg/kg	+ 511M	0,014	0,020
Th	mg/kg	+ 511M	0,64	0,66
U	mg/kg	+ 511M	0,20	0,19
W	mg/kg	+ 511M	0,54	0,34
Yb	mg/kg	+ 511M	1,23	1,06

KUOPIO ART MUSEUM

Documentation and research methods

Historical information about the building has been collected from the web pages of the Museum /1/ and the report of historical stone monument in Kuopio done by GTK /2/.

Description of the building

Name of building	Kuopio Art Museum
Architect	Vilho Penttilä
Address	Kauppakatu 35, Kuopio
Built (year)	1904
Modifications 1	1924–1925
Remark_mod 1	Modified the corner tower into a wall, an extended wing of the building by architect Kauno S. Kallion
Modifications 2	1958, 1969 ja 1980
Remark_mod 2	When the building had been turned into museum
Rock type	Grey granite, black granite, Kuru diorite

The building had been built in 1904. Had been used as Bank and by regional authority before 1954 and from images of 1920 (Figure 1) it is visible that the museum had one section less, the one shown in Figure2.

Figure 1. Historical image of the art museum in 1920 on the left and from 1959 on the right. /1/

Only in 1980 had opened as an art museum. In Figure 2 and 3 are shown part of the original wall and of the decorative elements.

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Figure 2a. The West side of the building, facing the road. (Photo: N.Luodes)

Figure 2b. The West side of the building facing the road, is the same façade of Figure 1.

Figure 3. (On the right in detail). Decorative element (Photo: N.Luodes)

The style is Jugend and it has been maintained also during enlargement works. The basement has a bossy finishing, while the upper raw has chiseled finishing. The contact to the ground is formed by a base of different granite with bossy surface. During late works the windows had been enlarged and the entrance had been reconstructed using black granite instead of the original Kuru diorite, that is instead still visible as stair's slabs.

Characterization of the environment

Local environment (architecture etc.)

The building is located in the centre of Kuopio facing two main streets and affected by moderate traffic.

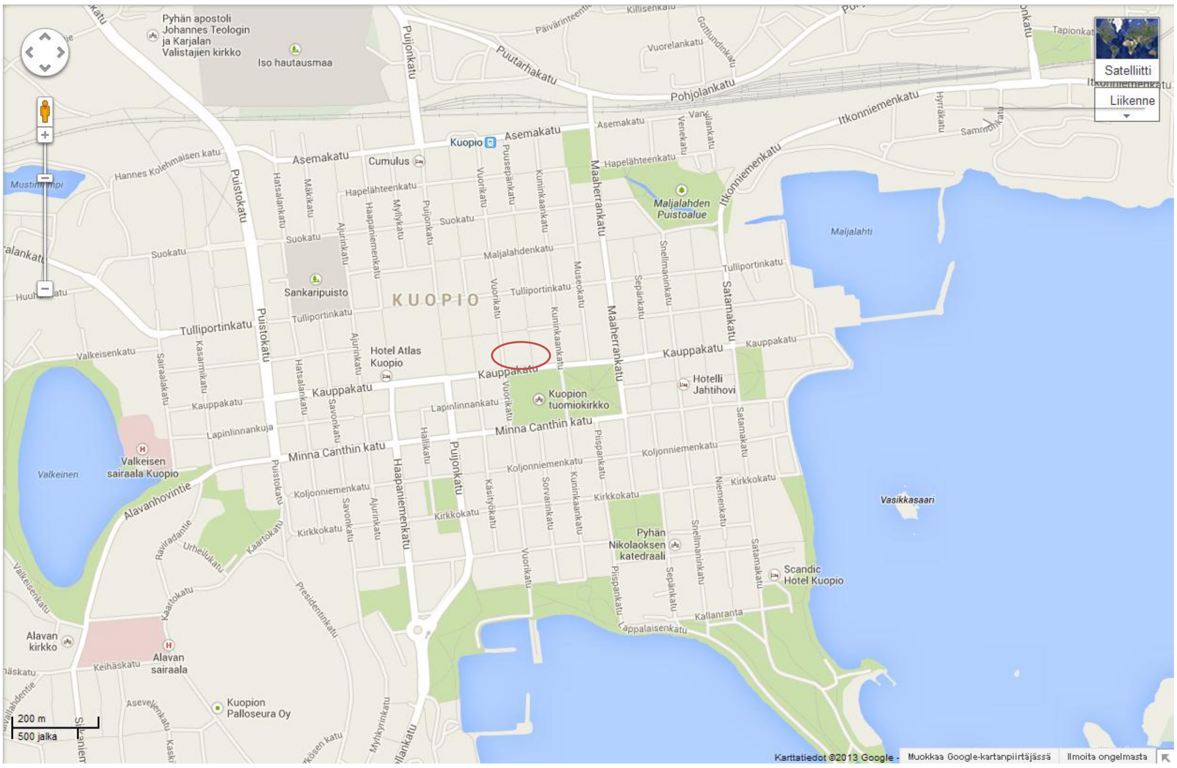

Figure 4. Area where the building is located (Google Maps)

Climatic conditions, microclimate, etc.

Kuopio is located in Central East Finland on the lake Kallavesi. Its climate is characterized by an average of approximately 82% of humidity along the year, diminishing to about 60% in spring-summer time, from March to August. Kuopio's climate presents dry seasons, generally during the spring months and a rainy season during the autumn time. Generally from November to March the temperatures do not rise over the zero during the day and as an average the minimum temperature reached could be considered around -22°C. /3/.

Photographic documentation

The site has been documented photographically in detail by Gigapan photos, normal camera photos of the complex and of the architectonic elements, of the deterioration problems and of the materials and finally by high definition photos of the samples. The processes of sampling and testing have also been recorded.

Gigapan photos

A gigapan photo has been taken as well as one of the museum of Kuopio.

Visual inspection

No mapping of the damages in detail had been done for this building. The building presents some effects given by the weathering, as changes of colours or growth of organic material, but the weathering level in not such to be visible by common eye.

Detection of weathering types

Different weathering forms had been noticed, even if the facade is not showing up high deterioration problems.

Peeling and exfoliation

Not recognized on the materials.

Rude surfaces

Not seen on the materials.

Deepenings and cavities

Some cavities had been notices in correspondence of flacking or spalling phenomenon, as see afterwards.

Hollows and chipping

Not seen in the materials

Stone flaking-off

On some blocks could be noticed that there has been fracturing, probably caused by different rate of weathering of the minerals in correspondence of a vein, as shown in figure5.

Figure5. Fracturing in large flackes, caused probably by weathering of certain minerals, or by original fractures. (photo Joonas Toivanen)

Granular disintegration, decohesion of single crystals or mineral grains

Not seen on the materials

Fractures and fissuring

The blocks are by themselves not presenting fractures, neither fissuring, meaning that their stability had been good and had not been undergoing too high stresses, even if the structure had in some been moving, creating structural fractures, as seen hereby.

Deformations

A mechanical deformation has interested the stair in the main facade, as visible from Figure 6 on the left, where a crack had affected the whole height of the structure. On the right instead is visible fracturing of the mortar in correspondence of two blocks, probably cause by their different response to thermal and moisture changes.

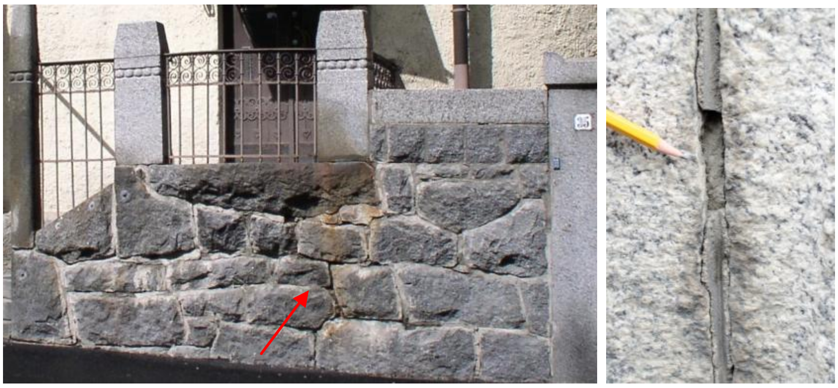

Figure6 Crack running on the parapet of the stair, showing that the structure has been moving. On the right the mortar had been cracking because of the natural movement of the blocks.(photo Heikki Pirinen and Joonas Toivanen)

Fungus

Not evaluated its presence (Not tested)

Seaweed

Not evaluated presence (Not tested)

Lichens

Lichens have started to colonize the material (Figure7) even if the facade had probably been cleaned in recent times or had been subjected to traffic or is too young to present elevated diffusion of lichens.

Figure 7. Initial colony of lichen. (photo Joonas Toivanen)

Mosses and higher plants

Higher plants have not been growing nearby also because the area had been kept clean, neither could be seen over the facade itself.

Bio-films of different composition

Biofilm has been recognized mainly in correspondence of drain pipes as in the sampling block in the courtyard. Other drain parts areas in the main facade didn't show the problem to such an extent.

Figure 8. Biofilm visible near a drain pipe in the courtyard area. (photo Joonas Toivanen)

Dung of birds

It is not seen over the blocks of the main facade and even if rarely could occur, as in the block facing the inner yard, its extent does not constitute a problem on this site.

Atmospheric particle depositions and fixation

Atmospheric particle deposition has been seen mainly as dust deposition and fixation on the basement blocks. The basements are facing main traffic roads, even if traffic moderate, being a small town.

Crusts

Fixation of dust has happened on the basement, as shown in Figure 9, in the areas not protected by running waters.

Figure 9. Atmospheric dust deposition and fixation. (Photo Nike Luodes)

Loss/change of colour

Changes of colour caused by mineral oxidation could be seen in some blocks. Several spots diffused on the surface can be seen in Figure 10 and 11.

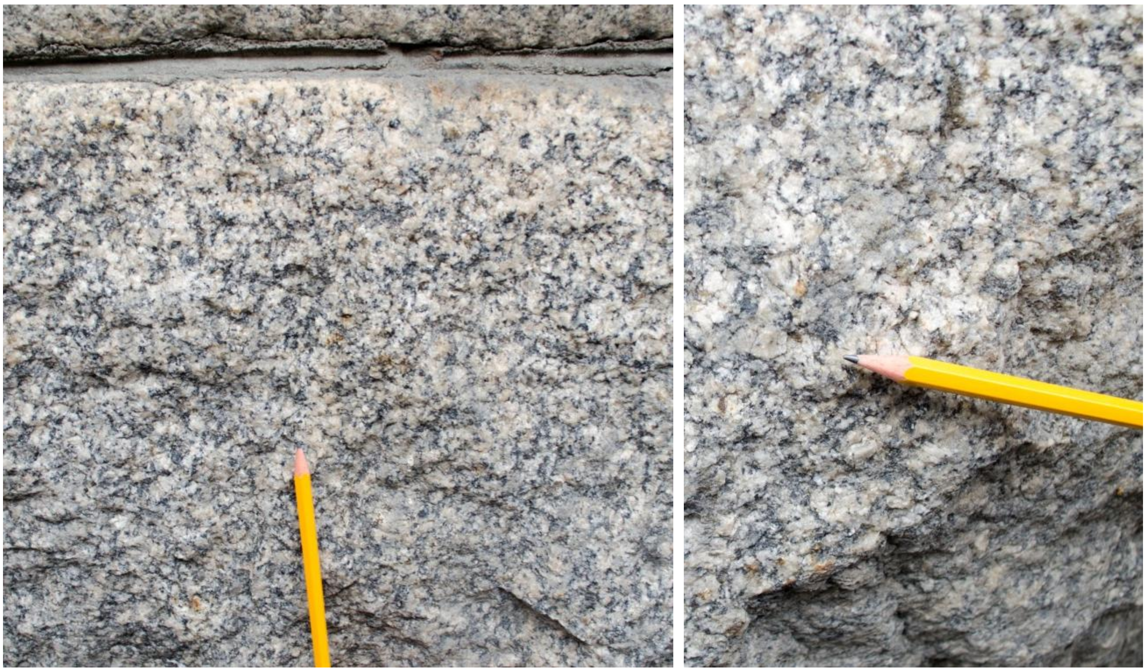

Figure10.Example of oxidation of elements in the material itself. (photo Joonas Toivanen)

Figure 11.Examples of oxidation of elements in the material itself. (photo Joonas Toivanen)

Changes of colour determined by leaching of material in contact with the stone could be noticed in the stair parapet as visible from Figure 12.

Figure 12. (On the left) Basement of the stairs showing surface colour change caused by rustiness of metal elements of the stairs. In this case has been a metal deposition more than a natural internal oxidation of the minerals. (Photo Heikki Pirinen)

Samples

Samples that have been further analysed had been taken from the inner yard side and from the facade facing west.

Sampling methods

In the Kuopio Museum, as has been for Niirala school, sampling has been performed in 2012. Cores have diameter of 17mm and their depth reaches few cm (in 2013 a larger drill core has been collected, with a diameter of 20mm and it has been possible to collect longer intact cores compared to the previous year).

Sampling locations

The samples that had been tested had been collected on the new wing of the building and from internal courtyard.

Description of the environment

The samples have been taken on the facades facing the main street and affected to traffic, even if the material had been newer, while the one sampled from the courtyard had been affected by biofilm and humid environment.

Location of the sampling sites

On a map is possible to schematise the sampling areas (Figure13). The photos of the sampling are then visible in Figure 14,15.

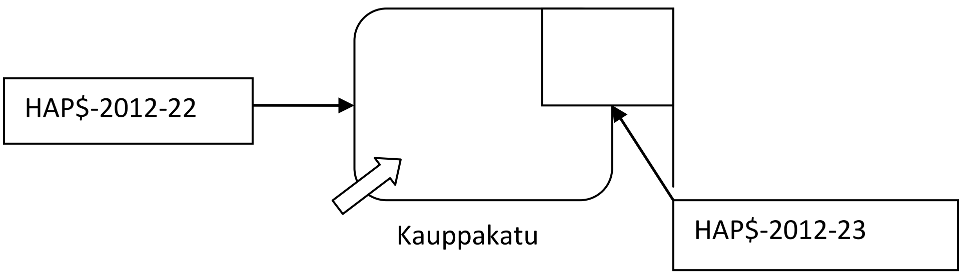

Figure 13. Schematic map of the building. In the figure is shown the main entrance from

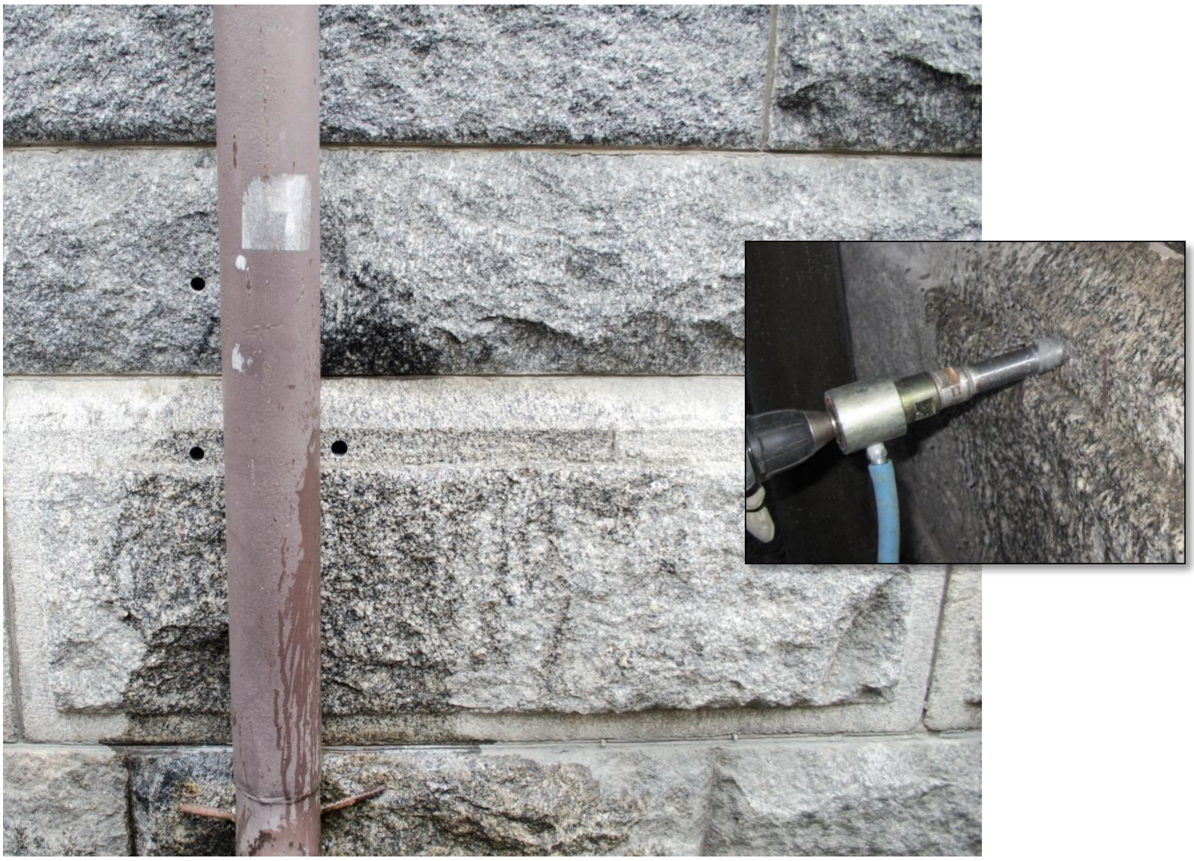

Figure 14 Sampling of HAP$-2012-22 (photo Joonas Toivanen)

Figure 15 Sampling of HAP$-2012-23 (photo JoonasToivanen, Heikki Pirinen). On the right are visible the first samples collected on 2012, with different drill edges.

Sample types

From the building both samples had been collected and prepared for further testing. Several drill cores for each had been taken.

Thin sections

HAP$2012-22.3 had been used for petrographic analysis from a sample collected in 2013.

Chemical analyses

Drill cores

Chemical analysis has been performed on drill core sample collected in 2012, analysis had been possible on HAP$2012-22.2 (bottom) and HAP$2012-23.1-2 (top and bottom part of the drill core).

Surface samples

No other surface samples have been collected from the site.

Biological analysis

Surface sections from collected samples and drill cores

Not Performed

Mechanical and physical tests

Samples for water absorption and compression tests

In October 2013 have been performed water absorption, density and open porosity on HAP$2012-22.3B and on Taide museo B.

Photos of Samples

Normal photos

From Kuopio Art Museum had been taken normal photos of the two sampled blocks:HAP$-2012-22 and 23. The second one is affected by biological growth, as visible from both the pictures 16 and 17.

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Figure 16. First samples, collected in 2012, used for surface examinations. (Photo: Heikki Pirinen)

Figure 17 Samples collected in 2013 used for petrographic descriptions.(Photo. Nike Luodes)

Stacking photos

The material had not been photographed by high definition photos.

Petrographic and chemical properties

Results of chemical analysis

The sample from surface was too small and it has not been performed the total chemical analysis, but the sample from the bottom had been analysed.

ICP MS analyses Results

HAP$-2012-23 and HAP$-2012-22 had been split in two and coded HAP$-2012-23.1 and HAP$-2012-22.1 for the top parts of the drill cores, and HAP$-2012-23.2 and HAP$-2012-22.2 for the bottom part of the drill core, the one considered relatively fresh and possibly not yet affected by biological activity. In Table 1 in Annex 1 is shown the list

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of the results obtained. The main elements of the two samples are differing slightly as visible comparing the graphic of Figure 18 and Figure 20.

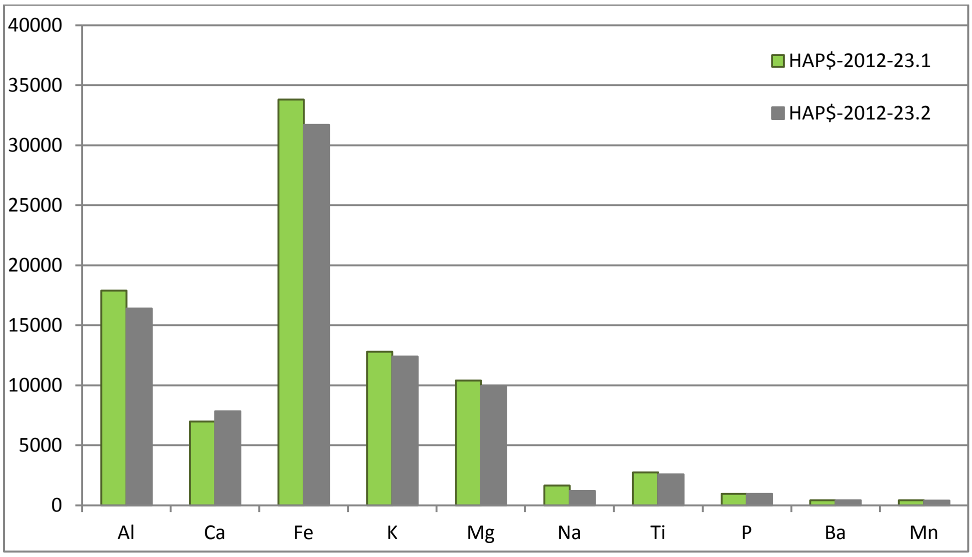

Figure 18. Main chemical elements of the material from top and bottom part of a single drill core.

Minor elements of the two samples are visualized in graphic 2 and 4.

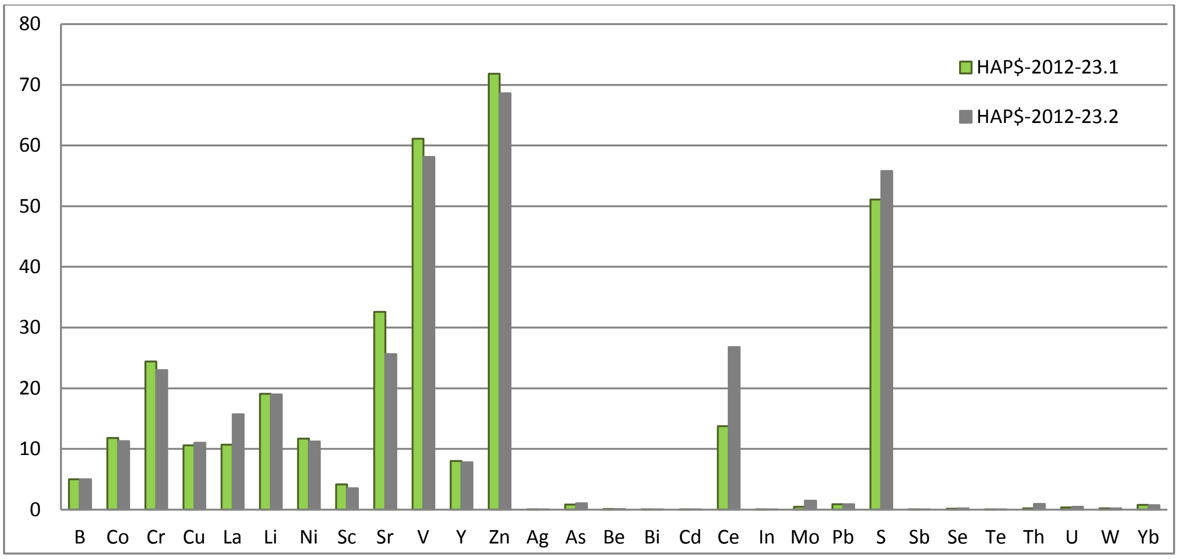

Figure 19. Minor chemical elements of the material from top and bottom part of a single drill core.

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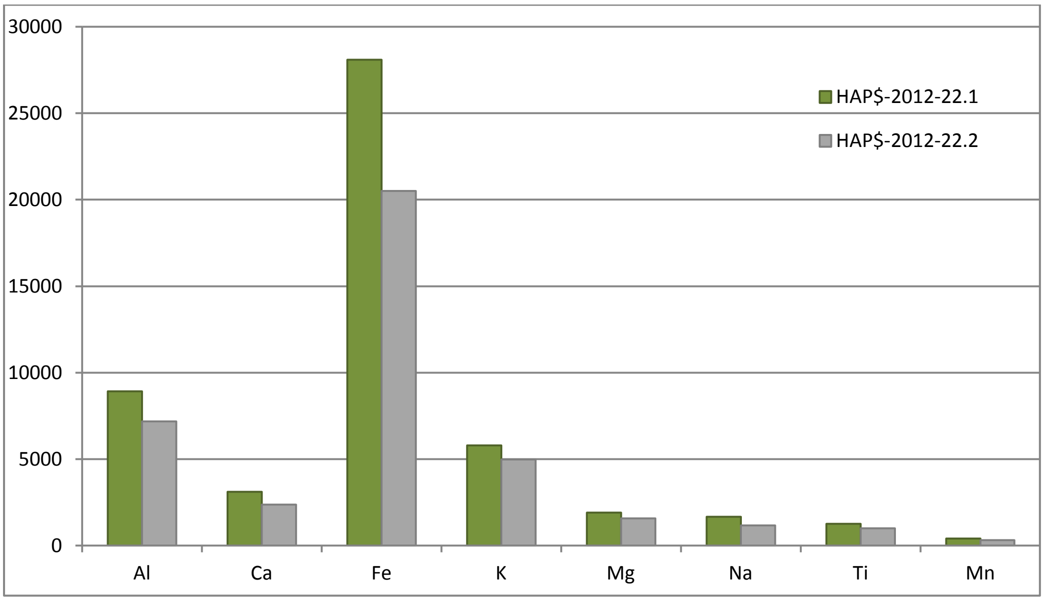

Figure 20 Main chemical elements of the material from top and bottom part of a single drill core

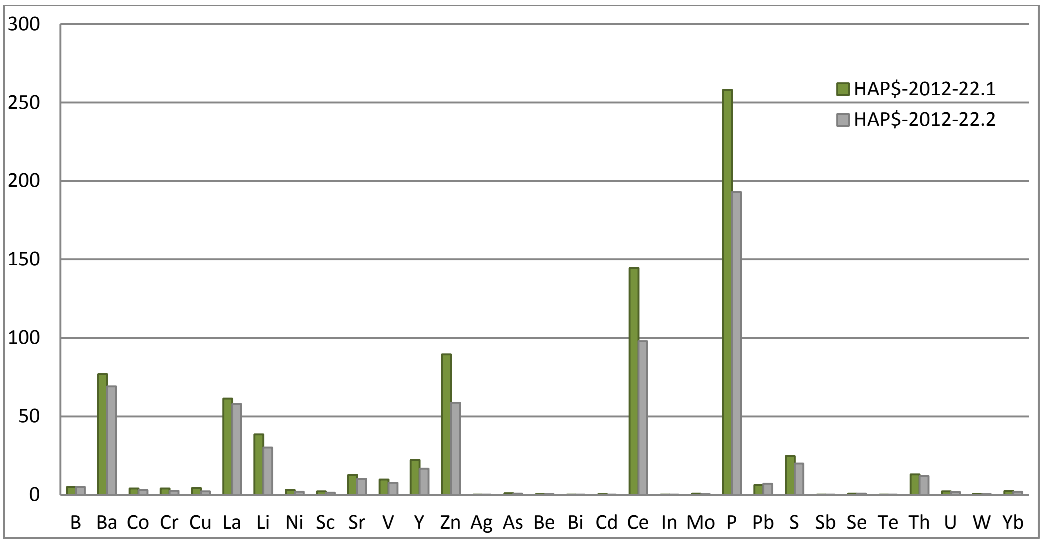

Figure 21. Minor chemical elements of the material from top and bottom part of a single drill core.

Leaching of the elements

From the chemical results of the chemical analysis can be compared which had been the chemical lost or enrichment of the surface layers compared to the bottom layers of the drill core. From graphic 3 and 4 is possible to visualize the chemical composition changes between the top and the bottom of the sample.

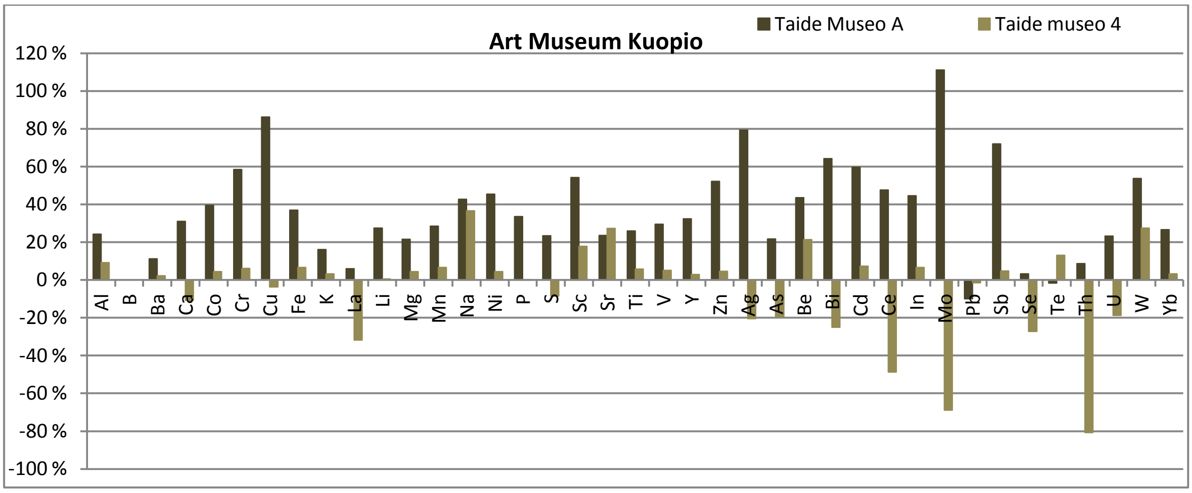

Figure22. Changes in percentages of the chemical elements of the top respect the bottom of the drill core for the specimens HAP$-2012-22.1 (Taide Museo A) and HAP$-2012-23.1 (Taide museo 4).

The two samples had behaved in very different way, that probably had been caused by the different kind of material. They do not show evident dispersion of element from the top part, instead some level of enrichment could be noticed, in Fe, Al,Cd,Be,Zn,Ti,Mn. HAP$-2012-23.1 should belong to the older part of the museum and it presents biological growth.

Non-destructive research methods

Non destructive research methods have included Ground penetrating radar and Schmidt hammer hardness test performed by the Geological Survey of Finland. Ultra Pulse velocity on specific blocks has been performed in cooperation with the Polytechnic of Turin-Italy while thermal camera measurements have been performed in cooperation with Mikkeli University of Applied sciences.

Ground penetrating radar

The rock was too bossy surface to allow to position the antennae assuring a good contact surface.

Ultrasonic measurements (UPV)

The measurements have been performed in an indirect way according to the report “Methodology UPV”. The blocks tested are shown in Figure 23 in the schematic map, and in Figure 24 and 25 in detail.

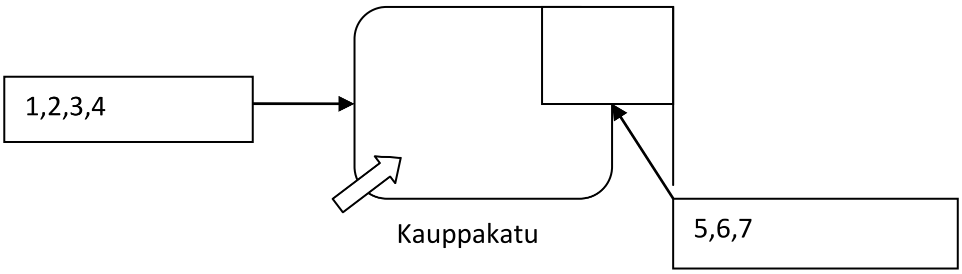

Figure 23. Schematic map of the blocks tested for UPV.

The measurements had been mainly performed over the drilled blocks, but had interested also blocks that presented changes in colors and surface depositions or biological growth.

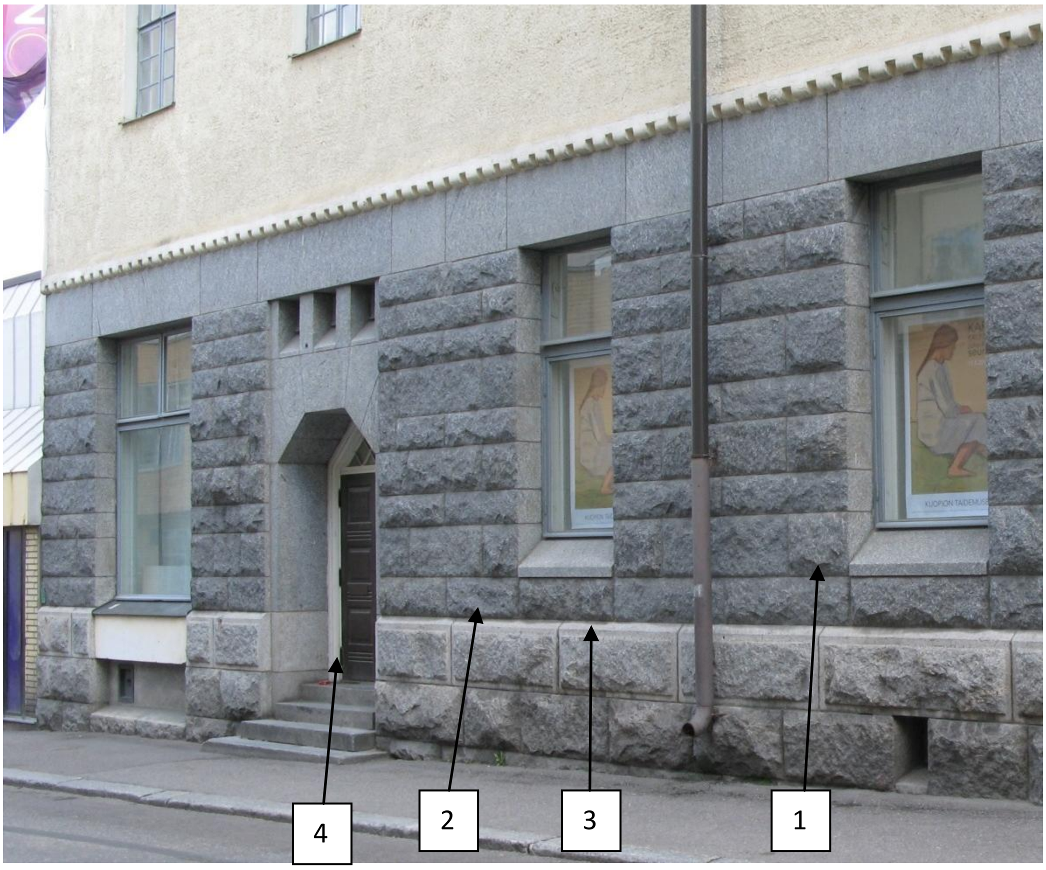

Figure 24Measurements performed over the West side of the building, on both kind of materials of the façade.

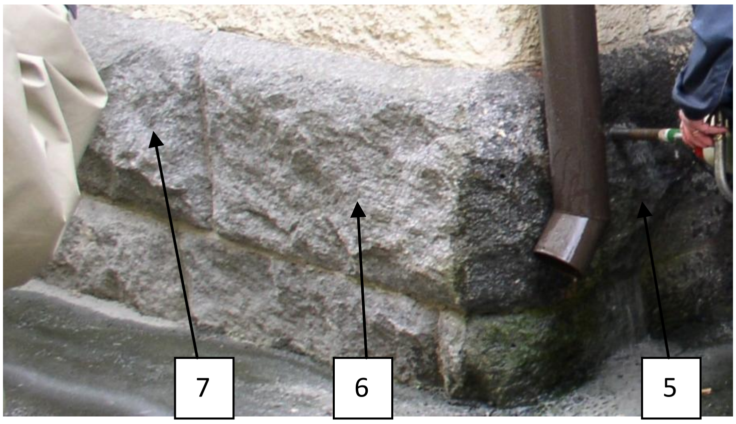

Figure 25Measurements performed in the inner yard.

Kuopio Taide Museo 1 (Kuopio TM1)

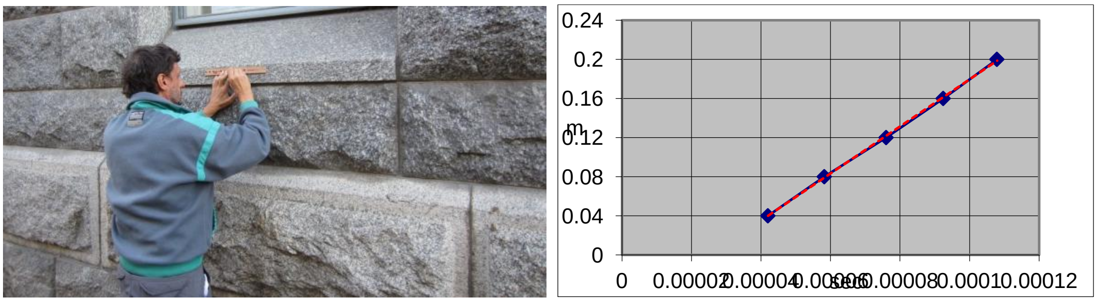

Figure 26. Measuring over the window sill, on dark tonalite, along the main façade. Diagrams of the measurements performed used to evaluate the velocity.

Velocity in the material: V=2409,9 m/s

Kuopio Taide Museo 2 (Kuopio TM2)

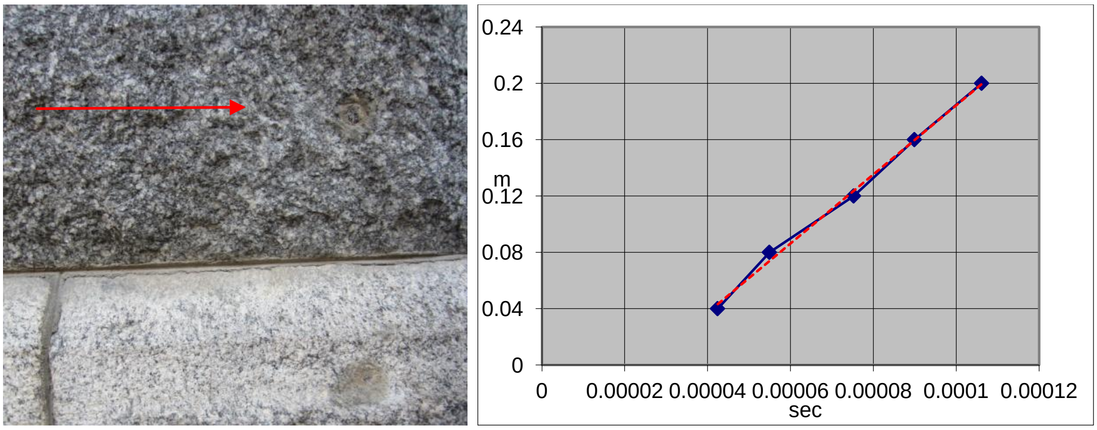

Figure 27. Measuring on the main façade, dark tonalite sampled for chemical analysis. Diagram of the measurements performed used to evaluate the velocity.

The test has been performed on the dark tonalite over which had also been done the sampling. The reading had not been carried over the hole, that, as visible from Figure 27, is on the right side of the measuring line.

Velocity V=2462,1 m/s

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Kuopio Taide Museo 3 (Kuopio TM3)

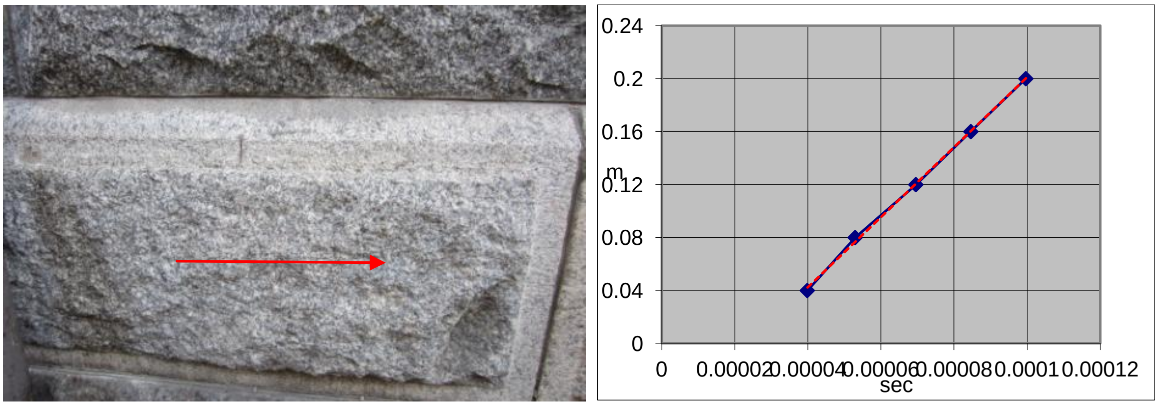

Figure 28. Measuring line on the main facade on light granite sampled for chemical analysis. Diagram of the measurements performed used to evaluate the velocity.

Velocity V=2643,4 m/s

As visible from the diagram of measurements (Figure 28) a faster wave speed has been recorded in correspondence of the 2nd point on the diagram (3rd measurement in practice). It is not clear the reason that has caused it, the block does not show evident surface weathering. Possible explanation could take into consideration that the surface is irregular and the transmitter could had been located at an angle between them, increasing the speed of reading, or the presence of rain during measurements could have affected the reading over a point more exposed.

Kuopio Taide Museo 4 (Kuopio TM 4)

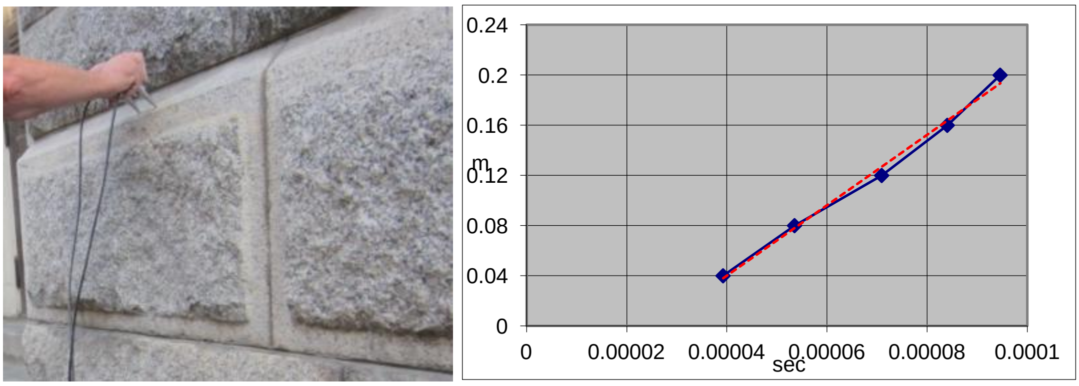

Figure 29. Measuring process on the main facade on light granite. Diagram of the measurements performed used to evaluate the velocity.

V=2833,78 m/s

The test has been performed on flat surface but the readings show a deviation from the linear regression line in correspondence of the 3rd point on the graph (4th reading in practice). The block in fact presents a yellow vein in

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correspondence of that point , showing a decrease in speed, this might be due to weathering effects or by the fact that the wave move in a different way along and trough the vein compared to a more homogeneous material.

Kuopio Taide Museo 5 (Kuopio TM5)

Ref pictures IMG 0994-0995

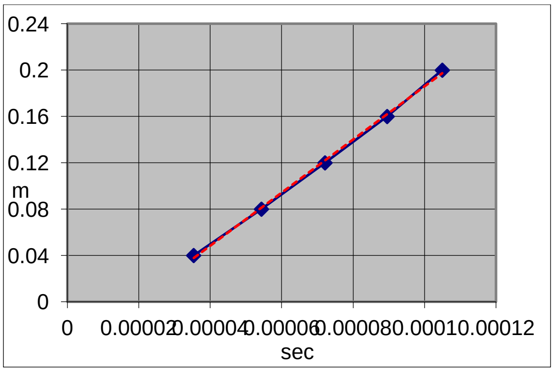
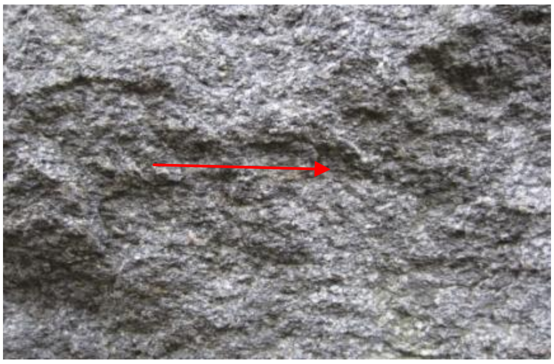


Figure 30. Measurements on the backyard block. Diagram of the measurements performed used to evaluate the velocity.

Velocity V= 2293,7 m/s

The block is located in the yard, on the corner of the wall, protected by direct rain, against the gate of entrance to the museum. The surface on that corner presents humidity brought by the rain pipe and a biofilm is visible over the block. Presence of bird’s dung is also visible.

Kuopio Taide Museo 6 (Kuopio TM6)



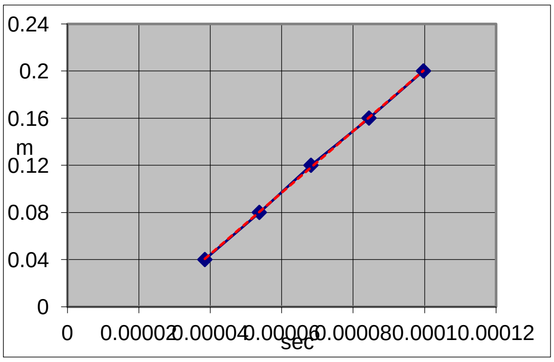


Figure 31. Backyard measurements along the side wall. Diagram of the measurements performed used to evaluate the velocity.

Velocity V=2613,0 m/s

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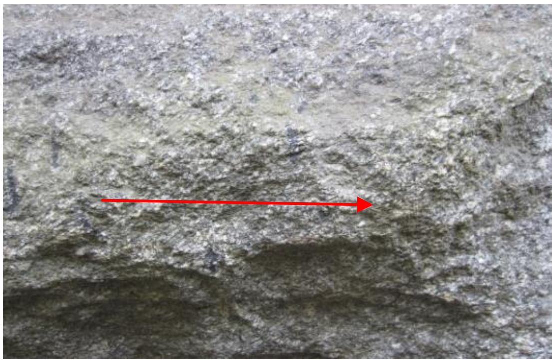
Kuopio Taide Museo 7 (Kuopio TM7)



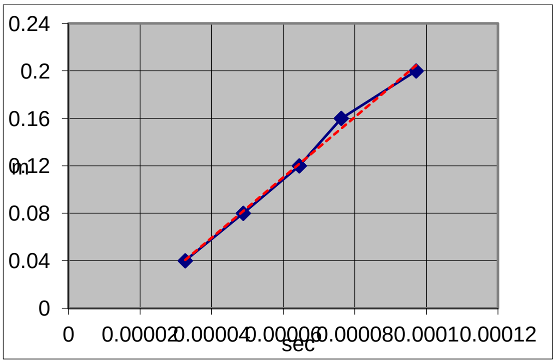


Figure 32. Backyard measurements along the side wall on block that show light presence of biofilm. Diagram of the measurements performed used to evaluate the velocity.

Velocity V=2557,4 m/s

The readings show a deviation from the linear regression line in correspondence of the 4th point of the graph in Figure 32 (5th reading in practice). A possible explanation is given by the presence of the biological film or presence of higher moisture that have increased the speed of the wave in that specific point, another possibility is given by wrong reciprocal position of the transducers.

Results of the UPV measurements

After have analyzed the results for each block it is possible to compare the results got from different materials. The different readings are compared in the following diagram and are divided per kind of material.

Kuopio TM1 and TM2 are performed on main façade on dark tonalite, Kuopio TM3 and TM4 are performed on main façade on light granite, Kuopio TM5,TM6,TM7 are performed on the backyard material on rainy day on dark granite.

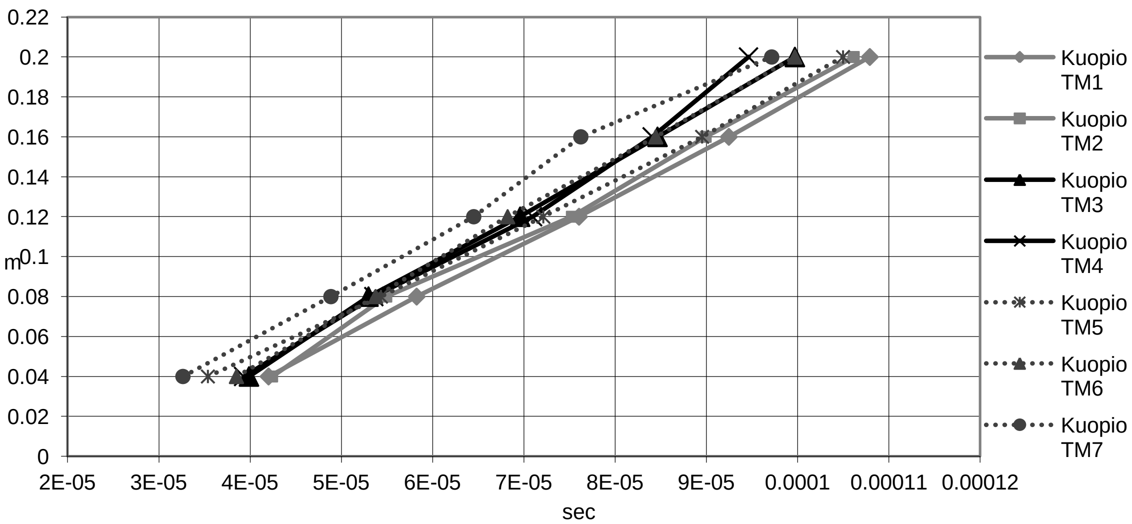


Figure 33. Graph of the measurements performed on the blocks of the museum.

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From Figure 33 is visible that the backyard material had fewer deviations from the theoretical values that run on the linear interpolating line compared to the façade material. Observing the velocities reached represented on the graph of Figure 34 are visible three group of velocities for the three kind of materials, and the effects of errors or surface deterioration.

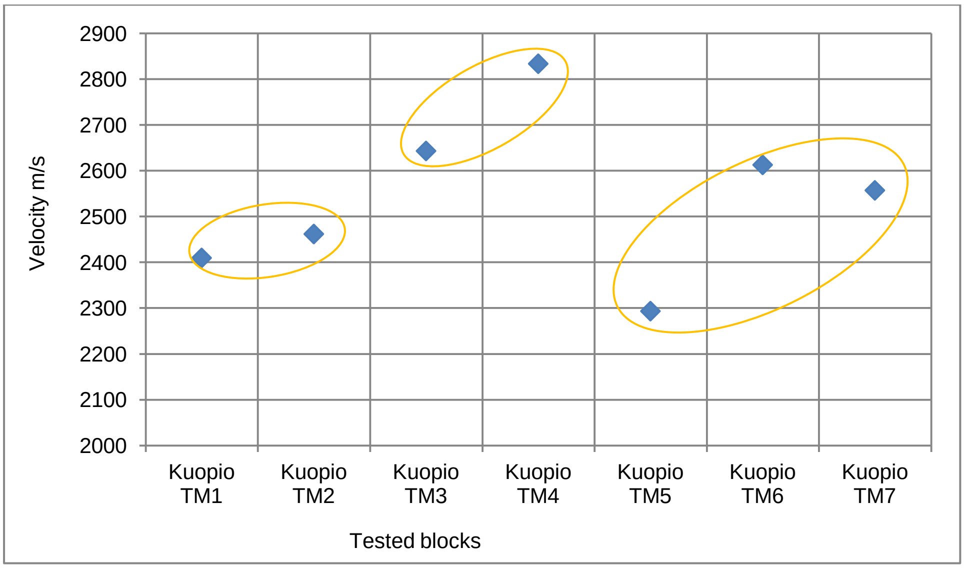

Figure 34. Velocities for each of the block measured on the Museum of Kuopio

Deviations of the readings of arrival time on the black tonalite blocks of the main façade (TM1 and TM2) didn't result in a strong change of velocity.

White granite showed a change of velocity between the two blocks examined, having higher speed in a block presenting a yellow vein. The change of velocity between the blocks can be caused by their different mineral composition, so it might be more related to natural heterogeneity of the material than to weathering effect.

The backyard presented the first block (TM5), that is the one more protected by the rain, with a lower velocity compared to the other two. The velocity of block TM5 is anyway also lower than the one of black granite of the main façade. The first block (TM5) had shown presence of biofilm by visual inspection and for this reason the velocity could had been lower, on the other side, the other back yard measurements could had been affected by surface humidity since the curve of arrival times of block TM5 is the most linear of this group.

From an analysis of the wave forms collected for some blocks it is not visible a reason for the changes in velocities observed making the measurements. The wave is migrating and maintaining quite regular shape. It is visible an attenuation of the wave moving the transducers at higher distances but not clear changes in its form. The attenuation can be given by absorption and by scattering phenomena. Besides errors given by reciprocal inclination of the transducers, given by irregular surface finishing, probably also errors of interpretation of the part of the wave to be followed had influenced the result.

Schmidt hammer

The Schmidt Hammer has been used perpendicular to the surface to be tested, according to the methodology described in "Methods Schmidt Hammer" and has been performed on the wall facing west, where also sampling had been done. In Table 1 are shown the results.

Table 1. Rebound values of the tests performed over the basement and their average over each block.

	Block number											
	1	2	3	4	5	6	1up	2up	3up	4up	5up	6up
R values averaged for each spot	47	57	47	61	48	55	51	50	51	53	56	56
	54	57	60	61	51	54	49	58	53	49	56	49
	50	55	60	57	60	56	38	58	59	50	55	51
		53	45	53	58	53	58	56	52	49	51	53
Average over the block	50	55	53	58	54	55	49	56	54	50	55	52

Block 1 presented rusty grains, that is probably the reason for a lower value of rebound,

Block 2 is presenting dust deposition and biofilm,

Block 3 over which the measurements had been performed is characterized by black crust in such an extent that the original stone kind is not recognizable.

As block 5 had been chosen the block over which has been performed the sampling. The lower rebound values could be caused by higher humidity originated by the drilling activity.

Block 6 presented a rusty zone.

In the upper row the last block (6up) has presence of old drilling and the lower values came in correspondence of flaking of the surface. It is not known why the block 1up had given so low result, neither have been noticed anomalies related to block 4up.

Results are visible in the graph of figure 35.

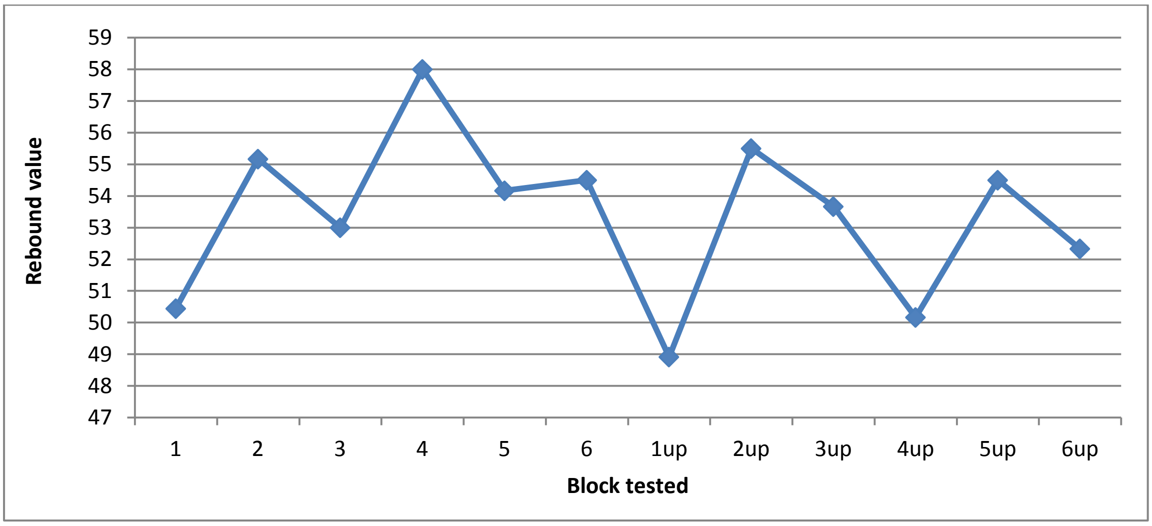

Figure 35. Schmidt rebound average values of individual blocks of Kuopio Art Museum.

Thermal camera

The measurements have been performed on late morning, in an area and time where the sun had already started to insulate the wall. Air temperature has been around 17 degrees while wall temperature had been between 14 and 16 degrees, in the wormer places. In Figure 36 is shown a moment of thermal analysis on site.

Figure 36. Collecting thermal images on site. (Photo: Nike Luodes)

The bossy surface reflects and refracts the light not allowing performing a clear analysis of the facade. A difference within stone and mortar replacement is visible in Figure 37 and 38 where the stone appears wormer, probably drier compared to the mortar block.

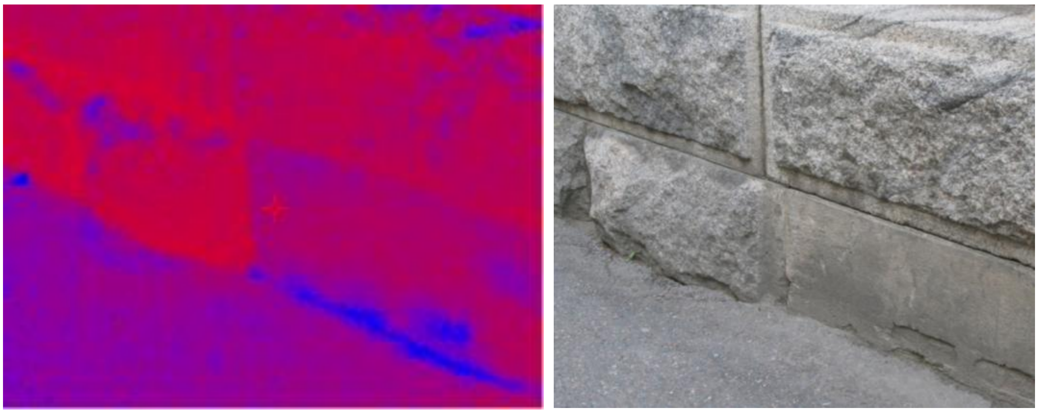

Figure37. Difference in heat radiation seen on a mortar replacement compared to the original stone blocks. (Thermal photo by Aleksei Shkurin, Photo by Nike Luodes, GTK)

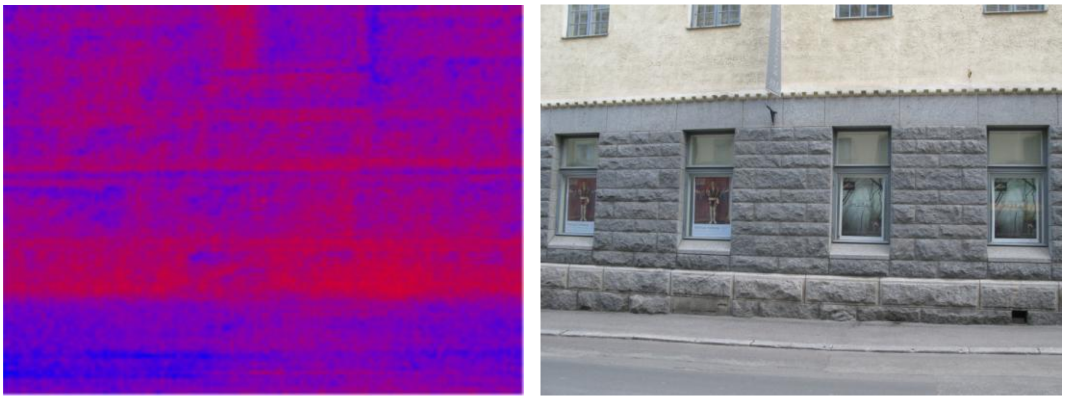

Figure 38.Heat image of the façade facing west. (Thermal photo by Aleksei Shkurin, Photo by Nike Luodes, GTK)

Mechanical and physical properties

Two samples had been tested TAIDE Museo B and HAP$-2012-22.3 Bottom and the results of water absorption are shown in Table 2, while those of density and open porosity are shown in table 3.TAIDE Museo B presents a surface a bit weathered with higher mica or higher scistosity, that is probably the reason for having higher Water absorption and Open Porosity.

Table 2- Results of water absorption

	DRY WEIGHT (g)	WET WEIGHT (g)	Water absorption (%)
TAIDE Museo B	19.95	19.98	0.15
HAP$-2012-22.3B	52.48	52.55	0.13

Table 3. Results of density and open porosity.

	DRY WEIGHT (g)	UNDER WATER (g)	SATURATED WEIGHT (g)	Apparent density (kg/m3)	Open porosity (%)
TAIDE Museo B	19,96	12,60	20,00	2692	0,54
HAP$-2012-22.3Bottom	52,50	32,65	52,59	2628	0,45

REFERENCES

1/ Web pages of the Art Museum of Kuopio http://taidemuseo.kuopio.fi/esihistoria

2/ Itä-Suomen yksikkö K21.7/2010/61 Kuopio- KIVI KUOPION KAUPUNKIRAKENTAMISESSA Tuomiokirkon ympäristö- 4.8.2010 Heikki Lukkarinen

3/ Meteorological information: http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,kuopio,Finland

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Annex 1

Table 1. Chemical composition of the top (HAP$-2012-23.1 and HAP$-2012-22.1) and bottom (HAP$-2012-23.2 and HAP$-2012-22.2) parts of the drill cores examined for Kuopio Museum.

			HAP$-2012-23.1	HAP$-2012-23.2	HAP$-2012-22.1	HAP$-2012-22.2
Al	mg/kg	+ 511P	17900	16400	8920	7180
B	mg/kg	+ 511P	5	5	5	5
Ba	mg/kg	+ 511P	439	429	77	69
Ca	mg/kg	+ 511P	6990	7830	3120	2380
Co	mg/kg	+ 511P	11,8	11,3	4,1	2,9
Cr	mg/kg	+ 511P	24	23	4	3
Cu	mg/kg	+ 511P	11	11	4	2
Fe	mg/kg	+ 511P	33800	31700	28100	20500
K	mg/kg	+ 511P	12800	12400	5800	4990
La	mg/kg	+ 511P	11	16	61	58
Li	mg/kg	+ 511P	19	19	38	30
Mg	mg/kg	+ 511P	10400	9950	1910	1570
Mn	mg/kg	+ 511P	428	401	419	326
Na	mg/kg	+ 511P	1640	1200	1670	1170
Ni	mg/kg	+ 511P	12	11	3	2
P	mg/kg	+ 511P	956	955	258	193
S	mg/kg	+ 511P	51	56	25	20
Sc	mg/kg	+ 511P	4,2	3,5	2,2	1,4
Sr	mg/kg	+ 511P	32,6	25,6	12,6	10,2
Ti	mg/kg	+ 511P	2740	2590	1260	1000
V	mg/kg	+ 511P	61	58	10	8
Y	mg/kg	+ 511P	8,0	7,8	22,1	16,7
Zn	mg/kg	+ 511P	72	69	89	59
Ag	mg/kg	+ 511M	0,02	0,02	0,15	0,09
As	mg/kg	+ 511M	0,84	1,04	0,99	0,82
Be	mg/kg	+ 511M	0,09	0,07	0,43	0,30
Bi	mg/kg	+ 511M	0,03	0,04	0,02	0,01
Cd	mg/kg	+ 511M	0,06	0,05	0,26	0,16
Ce	mg/kg	+ 511M	13,75	26,78	144,50	97,87
In	mg/kg	+ 511M	0,02	0,02	0,04	0,03
Mo	mg/kg	+ 511M	0,45	1,44	0,75	0,35
Pb	mg/kg	+ 511M	0,89	0,91	6,36	7,06
Sb	mg/kg	+ 511M	0,03	0,03	0,08	0,05
Se	mg/kg	+ 511M	0,14	0,19	0,71	0,69
Te	mg/kg	+ 511M	0,007	0,006	0,020	0,020
Th	mg/kg	+ 511M	0,18	0,93	13,02	11,98
U	mg/kg	+ 511M	0,38	0,47	2,18	1,77
W	mg/kg	+ 511M	0,22	0,18	0,60	0,39
Yb	mg/kg	+ 511M	0,77	0,75	2,41	1,90

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NATIONAL MUSEUM

Documentation and research methods

Historical information about the building has been collected from the official web pages of the National Board of Antiquities. /1/ Herman Gesellius, Armas Lindgren and Eliel Saarinen designed in national romantic style the building that was built between 1905 and 1910 and restructured between 1997-2000 and in 2013, cleaning and re-seaming part of the facades, and rendering with a new color tone the parts originally rendered.

Description of the building

Number	
Name of building	Kansallismuseo – National Museum
Architect	Herman Gesellius, Armas Lindgren and Eliel Saarinen
Address	Mannerheimintie 34, 00100 Helsinki
Built (year)	1905-1910
Modifications 1	1997-2000
Remark_mod 1	Replastered and façade cleaning, refurbished interior, cleaned the ventilation lines, rebuilt cellar
Use 1	Blocks of facade
Rock type 1	Uusikaupunki granite
Quarry 1	Uusikaupunki
Use 2	Ornaments, decorative elements
Rock type 2	Steatite – vuolukivi (most probably from Nunnanlahti)
Use 3	Roof
Rock type 3	Slate (Norway)

The building is organized according to the national romantic design, it has two inner courtyards. The shape is not regular, neither symmetrical, it plays on curved and linear surfaces and on different height and surface finishing. A base map of the building is shown in Figure 1.

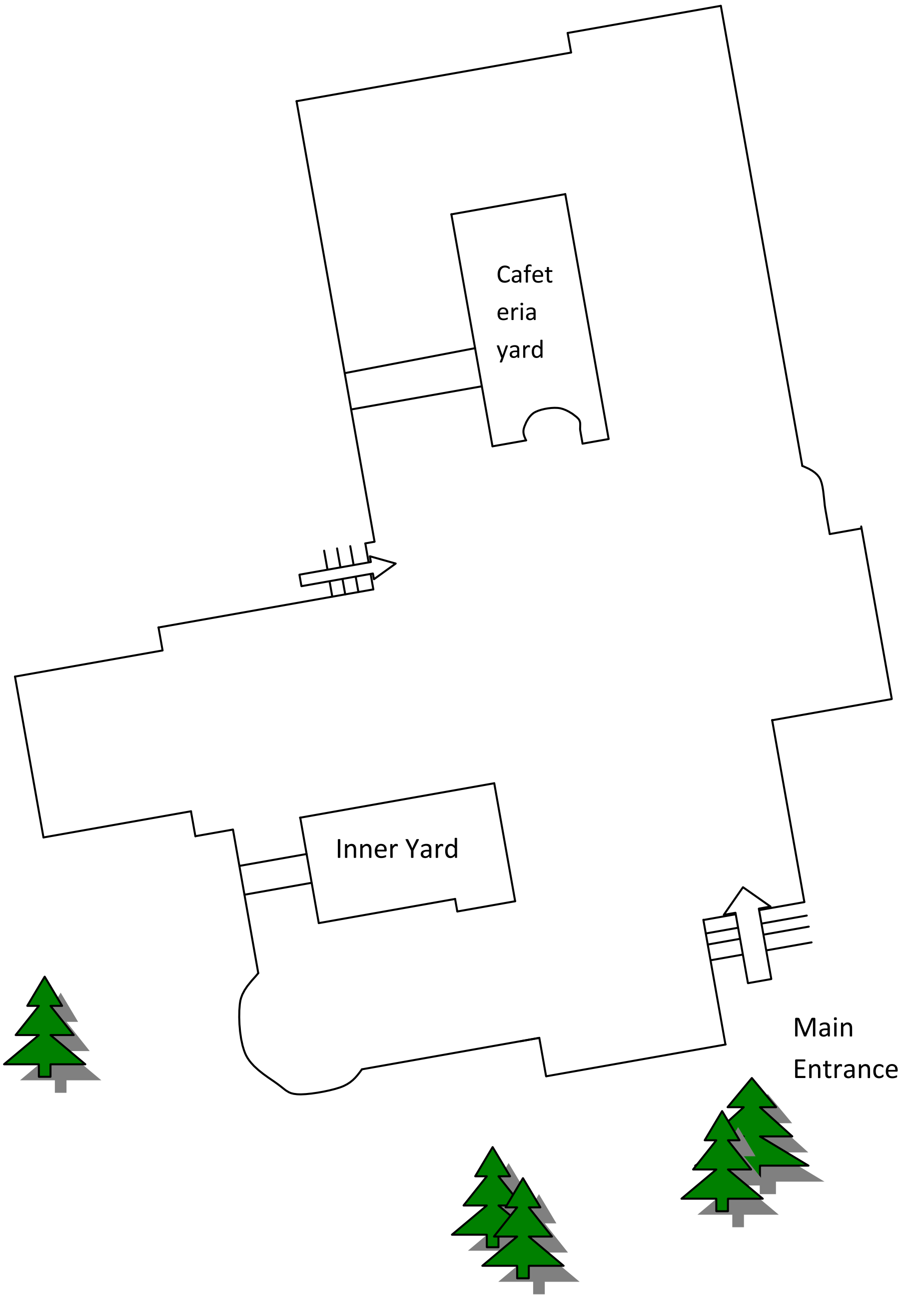

Figure 1. Map of the ground floor of the building.

The building is presenting bossy granitic facades joined to plastered ones and decorated with steatite ornaments (Figure 2). The main access ramp is characterized by bush hammered blocks that are visibly lighter compared to the bossy ones, but that still would belong to the same material, Uusikaupunki granit.


Figure 2. In the figure are shown: the bossy finishing on the main blocks of the façade, the rendered walls and the steatite decorations, and the slate roofs. (Photo: N.Luodes)

In Figure 3 are shown main views of the building from its back side. Gigapan pictures had been taken from this side in correspondence of the arc of entrance of Inner Yard 1.


Figure 3. Side facing the yard dedicated to park car on the West. On the right the cladding from which had been performed GPR measurements, that is facing North. (Photo: N.Luodes)

Figure 4 Part of the façade facing the park on the South. (Photo: N.Luodes)

A Gigapan picture of the side facing Mannerheimintie had been taken while a view from its north side is visible in figure 5.

Figure 5. The northern side of the building.(Photo: N.Luodes)

The inner yard from which had been taken drill samples and non destructive measurements is shown in figure 6.

Figure 6. Inner Yard A (Photo: N.Luodes)

The other inner yard where is located the cafeteria is shown in Figure 7. This inner yard had not been sampled also because the presence of stone material had been minimum compared to other parts of the building.

Figure 7. Inner yard that had not been sampled. (Photo: N.Luodes)

In Figure 8 and 9 are shown some examples of the decorative elements carved in soapstone.

Figure 8. Examples of the soapstone's decorative motives, on the left a part of the decoration over the arc facing West and of the capitals in the inner yard A. (Photo: N.Luodes)

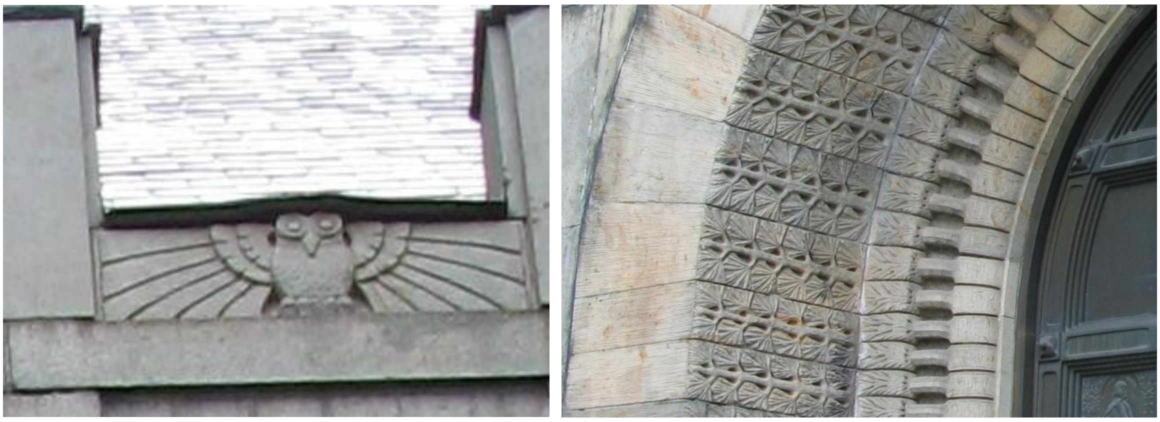

Figure 9. Examples of the soapstone's decorative motives on the façade of entrance, facing South. (Photo: N.Luodes)

Characterization of the environment

Local environment (architecture etc.)

The building is located near the Finlandia Talo and the Parliament house on Mannerheimintie, a main traffic line to access the city centre. On the other side the museum is facing inner parks, one organized as a garden and the second used as parking area for the personnel (Fig.5).

Generally looking at the climatic and air quality conditions the measuring cell located in Mannerheimintie shows higher pollution levels compared to other located out of the traffic area. (ref. ilmatietolaitos)

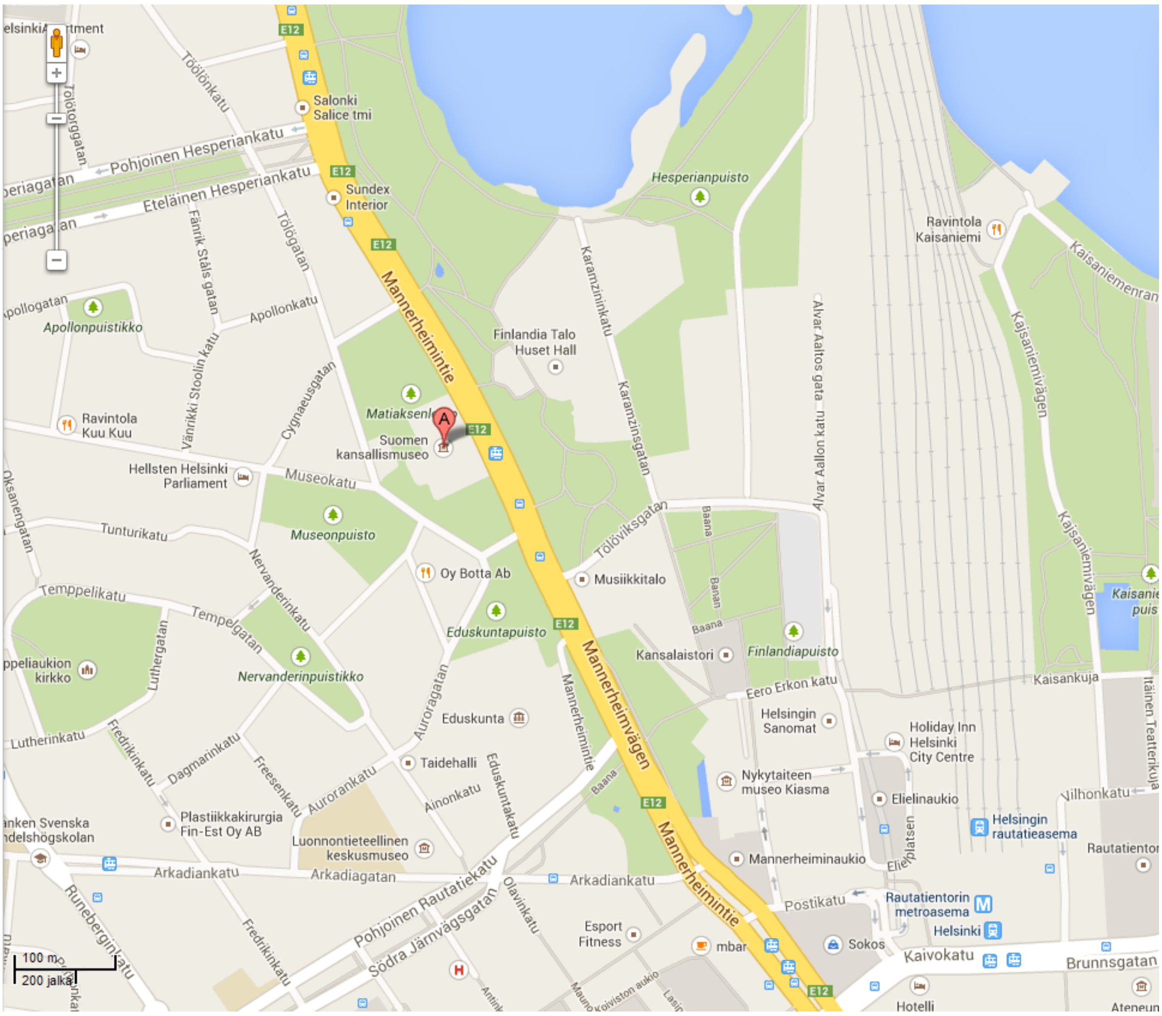

Figure 10. Area where the building is located (Google Maps)

Climatic conditions, microclimate, etc.

Helsinki is located in South Finland on the Baltic sea. Its climate is characterized by humidity over 80% from august to march, diminishing to about 60% from March to August. Being Helsinki a city that faces the sea, there is constant presence of wind and its intensity had been around 3-5 m/s. Helsinki's climate presents drier seasons during the spring-summer months (February-May) and rainier season during the late summer and winter time, but there is always presence of humidity. Generally from November to March the temperatures do not rise over the zero during the day and as an average the mean minimum temperature around -10°C even if had been recorded also temperatures around -30°C. /2/

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Photographic documentation

The site has been documented photographically in detail by Gigapan photos, normal camera photos of the complex and of the architectonic elements, of the deterioration problems and of the materials and finally by high definition photos of the samples. The processes of sampling and testing have also been recorded.

Gigapan photos

Gigapan photos have been taken from the West and East side of the building. The presence of trees on the other sides had not allowed having a free view over the full building sides. In Figure 11 are visible two samples of the high definition pictures. Their size is of 8 and 6 gigapixels.

Figure 11. Views of the Gigapan images collected, the first on the arc entering Inner Yard A facing West, and the second of the facade facing Mannerheimintie on the East

Visual inspection

During the performance of the site tests have been collected information on weathering but had not been drown a detailed map of the deterioration effects.

Detection of weathering types

The building had been undergoing cleaning of the facades and part of dust deposition had been removed. Some elements still show some deterioration and weathering effects. The West and North parts are more affected compared to those facing East (under maintenance during years 2013-2014) and South.

Peeling and exfoliation

Not recognized on the granites, neither on the soapstone.

Rude surfaces

Not seen on the materials.

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Deepenings and cavities

Some cavities had been notices on the soapstone elements, probably due to detachments or gradual weathering of some softer elements. (Fig.12)

Figure 12 Formation of cavities due to detachment of softer minerals from soapstone decorative elements over the arc of entrance to Inner Yard A, facing West.(Photo: N.Luodes)

Hollows and chipping

Not seen in the materials

Stone flaking-off

It is recognized on some granite blocks facing Mannerheimintie probably as a consequence of cleaning of the facade. It is not noticed elsewhere.

Granular disintegration, decohesion of single crystals or mineral grains

Not seen on the materials

Fractures and fissuring

It has been noticed on a block in the basement in the entrance to Inner Yard A as visible from figure 13. In this case the fractures seems to be due to natural properties of the material, probably have already been present from the quarry and have been enlarging during the years because of weathering actions. The compactness of the block had been studied with non destructive tests in a second moment.

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Figure 13. Fractures seen on the corner block in the entrance of Innseen on the corner block in the entrance of Inner Yard A. (Photo: N.Luodes)

Deformations

Presence of fractures induced by structural deformation could be noticed on the main entrance arc as visible from Figure 14.

Figure 14. Presence of two cracks probably due to mechanical actions or to structural deformation has been noticed on the main entrance arc. (Photo: N.luodes)

Fungus

Not evaluated its presence (Not tested)

Seaweed

Not evaluated presence (Not tested)

Lichens

Lichens have not been found to affect the stone.

Mosses and higher plants

Higher plants have been growing on the soil near the basements in rare areas but have not grown over the stones.

Bio-films of different composition

Susceptible areas as draining pipes had not shown presence of bio films as visible from Figure 15 where an area on the basement facing South had been pictured. But biofilm has been noticed on the wall near the main entrance, facing East, as visible from Figure 15. They have grown on the soapstone element and on the granite step. Their colour had been green.

Figure 15. Absence of visible biofilm in possible wet areas, on the left, and presence of biofilm on the walls near the main entrance, on the right. (Photo: N.Luodes)

Dung of birds

It is not seen also because had been taken measures to avoid their presence.

Atmospheric particle depositions and fixation

Atmospheric particle deposition could be seen on the bossy surfaces of the facade, since it shows a change of surface colour. The material used on the museum has been Uusikaupunki granite, and its original colour is more visible on the facade bush-hammered near the entrance stair, facing West, while on the bossy surface the colour is presently darker.

Crusts

Fixation of dust into crust is visible in some parts of the building, on some blocks near the joints, or near the ground, as visible from Figure 16. In the facade facing north its presence is stronger than on other facades, as visible from Figure 17.

Figure 16 Crust given by deposition of dust (Photo: N.Luodes)

Figure17 Dust fixation visible on the basement facing North. (Photo: N.Luodes)

In Figure17 is visible that the area of the facade covered by the terrace shows lower darkening compared to the one more exposed to rain.

Also deposition of metals given by leaching or by anthropogenic actions is visible in specific spots. Deposition of cupper, probably coming from original cupper draining elements, is shown in figure 18.

Figure18. Deposition of cupper forming a thick crust on the bottom most elements. The picture is taken from an element of the building facing South. On the left is shown the basement in dry conditions, on the right in a rainy day. (Photo: N.Luodes)

Deposition of iron given by anthropogenic activity is shown in Figure 19.

Figure19. Spots of rust on the facade facing the garden on the west. (Photo: N.Luodes)

A clear leaching pattern can be distinguished oven the stone surface in Figure 20 on the blocks of the basement facing West. The origin of the rustiness is difficult to be attributed clearly; it could have come from upper leaching of an architectonic element, probably from its roof. Rustiness is also visible on the mortar joints and all over that specific element of the building. It is only visible on the semicircular architectonical element that is covered by a roof and it is not seen on the adjacent blocks on the facade.

Figure 20. Presence of iron oxides over the surface of the blocks on the basement facing the car park on the West. (Photo: N.Luodes)

Loss/change of colour

The main bossy basement does not show an inner change of colour, meaning that the minerals had not changed their colour, so had not visibly weathered, but their surface had been affected by dust deposition. The Uusikaupunki granite though, has been studied in its natural outcrops and has been seen that has tendency to get reddish while weathering because of presence of fine grained potassium feldspate./3/ Change of colour could be mainly seen in the bush hammered blocks near the main entrance as visible from Figure 21. In this case it is not clear if it due to the feldspars or to other oxidizing minerals, but it surely attributed to mineral properties of the material.

Figure 21. Block near the main entrance, facing Mannerheimintie showing change of colour. (Photo: N.Luodes)

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The ornamental elements made by soapstone had instead shown a change of colour, given by the oxidation of the small amounts of iron present in the magnesite as visible from Figure 22.

Figure 22. Soapstone on the arc of entrance to Inner Yard A, showing changing of colour, from original grey to brown/yellow due to oxidation of iron minerals. (Photo: N.Luodes)

Ovoid weathering

It is not visible since the material has not tendency to this kind of weathering

Samples

Samples that have been further analysed had been taken from the facade facing the park on the South and at the basement of the wall of the park facing Mannerheimintie, moreover samples of a red granite used in Inner Yard A have been collected.

Sampling methods

In the National Museum sampling has been performed in summer 2013. Cores have diameter of 20mm and it has been possible to collect longer intact cores compared to the previous year.

Sampling locations

The building is characterized by a bossy basement of Uusikaupunki granite, a bush hammered facade of Uusikaupunki granite near the entrance, soapstone elements and red granite basement used in the inner yard A. Bossy granite had also been used as basement around the garden on the South of the building. Samples had been collected from bossy Uusikaupunki granite and from red granite.

Description of the environment

The samples taken on the facades facing South from the Uusikaupunki granite at about 1 m from ground and near a water draining pipe. This basement parts should had been presenting humidity effects. The drill core sampled from

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Mannerheimintie at the walls of the garden is sampled at about 50 cm from the ground and had been showing black crust, is the most affected by traffic and by salts used for melting the snow on the roads. The samples taken from the basement of Inner yard A are instead in a protected area and are sampled at about 30-40 cm from the ground. The inner yard is closed by a door so the material has been protected by traffic, moreover several samples had been taken in zone protected also from rain, since had been under the entrance hall.

Location of the sampling sites

On a map is possible to schematise the sampling areas (Figure23). The photos of the sampling are then visible in Figure 24,25,26,27,28.

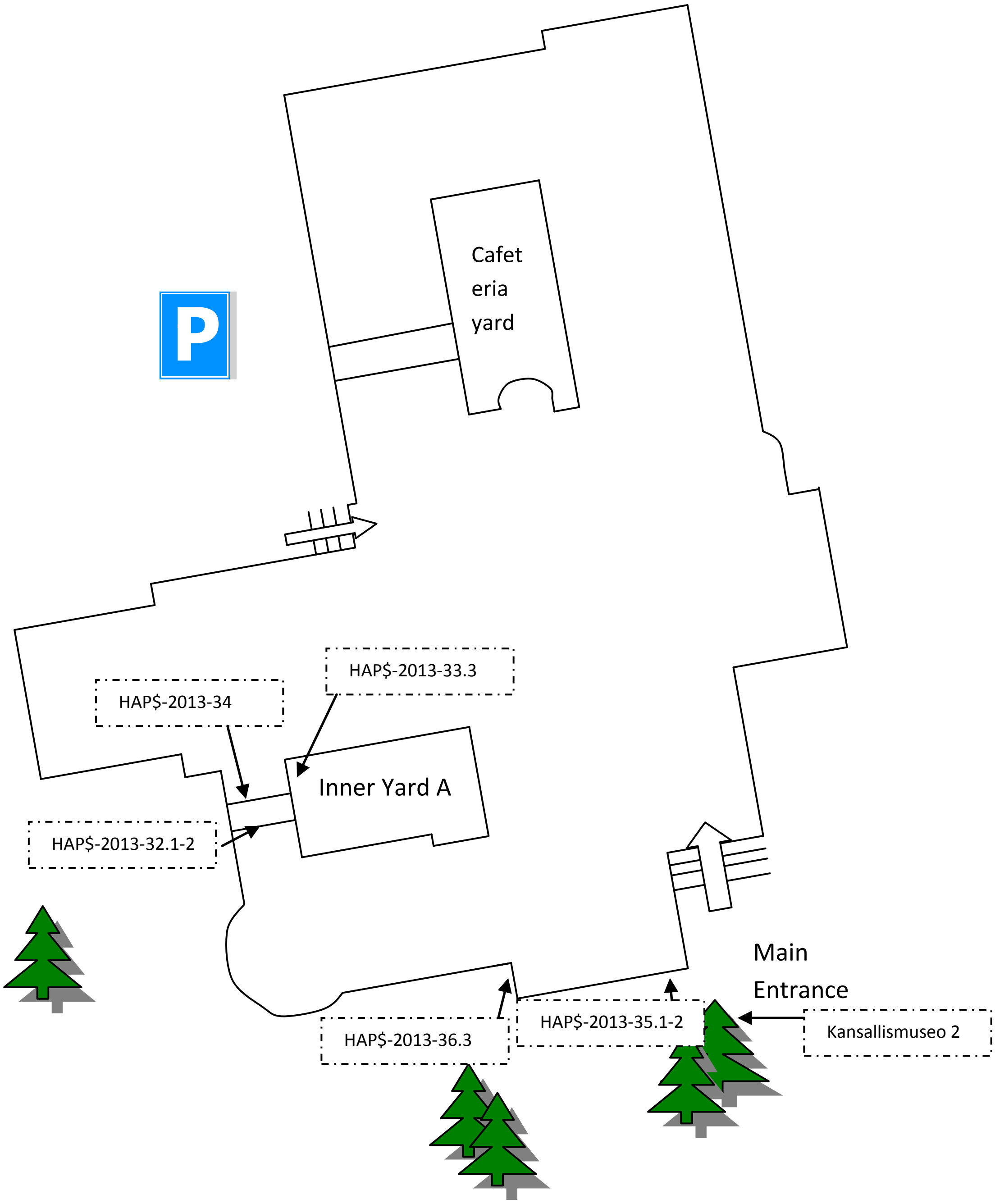

Figure 23. Schematic map of the building. In the figure is shown the main entrance from Mannerheimintie and in the boxes the samples collected.

Kansallismuseo 3 / HAP$-2013-36.3

Kansallismuseo 1 / HAP$-2013-35-1-2

Figure 24. Sample Kansallismuseum n.1 taken from a part that has usually been wet and has indoor problems of humidity while Kansallismuseum 3 have been taken on an area that could had been affected by humidity being near a draining pipe.

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Figure 25. Kansallismuseo 2 collected from a dirty part of the garden wall where black crust and dust deposition are visible.

Other samples had been collected from the Inner Yard A, where the material had been different compared to the one used on facade. The samples from the courtyard are shown in Figure 26, 27 and 28.

Figure 26. Kansallismuseo 4/ HAP$-2013-34, towards the inside yard on the left side of the door.

Figure 27. Kansallismuseo 5/HAP$-2013-33.3 in the courtyard near the water tab, on the left entering the yard

Figure 28. Kansallismuseo 6/ HAP$-2013-32.1-2 near the door on the right side (photo:N.Luodes)

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Sample types

Uusikaupunki granite (facade) and red granites (Inner yard A) have been tested for petrographic description and chemical analysis with specimens HAP$-2013-32.1-2 and HAP$-2013-33.3 for red granite, and HAP$-2013-36.3 and HAP$-2013-35.1-2 for Uusikaupunki granite. The samples have been collected in summer 2013.

Thin sections

Drill cores with diameter of 20 mm have been collected and coded HAP$-2013-36.3 and HAP$-2013-33.3 and of it has been cut few cm from the top part of the core to prepare thin sections.

Chemical analyses

Drill cores

Chemical analysis has been performed on drill core sample collected in 2013 and coded HAP$-2013-35.1-2and HAP$-2013-32.1-2 distinguishing the top and bottom part of the drill core.

Surface samples

No other surface samples have been collected from the site.

Biological analysis

Surface sections from collected samples and drill cores

Not Performed

Mechanical and physical tests

Samples for water absorption and compressive tests

In October 2013 have been performed density and open porosity and for it have been used specimens HAP$-2013-34 top and bottom parts.

Photos of Samples

Normal photos

From the National Museum have been taken photos of the samples collected for chemical analysis and chemical analysis.

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Figure 29. Normal photos of specimens from left to right HAP$-2013-31,36,33 gone to petrographic analysis and HAP$-2013-35,32 gone to chemical analysis. (photo:N.Luodes)

Stacking photos

The high definition photo of the drill cores are shown in Figure 30-33.

Figure 30 Weathered surface of the drill cores from the Uusikaupunki granite of the National Museum. (Photo by Jouko Ranua GTK). Samples from left to right: 31-35-36

Figure 31 Back part of the drill cores, same as in figure 30, to evaluate the un-weathered surface of the material. (Photo by Jouko Ranua GTK) Samples from left to right: 31-35-36

Figure 32 Weathered surface of the drill cores from the red granite of the National Museum (Inner Yard A). (Photo by Jouko Ranua GTK). Samples from left to right: 32-33-34

Figure 33 Back part of the drill cores, same as in figure 32, to evaluate the un-weathered surface of the material. (Photo by Jouko Ranua GTK) Samples from left to right: 32-33-34

The high definition pictures allow to zoom and see in detail the surface of the material as visible from Figure 34.

Figure 34 Detail of the surface of the sample HAP$-2013-31 (Photo by Jouko Ranua GTK)

Petrographic and chemical properties

Sample HAP$-2013-31 (Uusikaupunki granite) had been analysed at optical microscope with a magnification of 40x (Figure 35) It is visible that fractures evolved along the grains, and the minerals cracked in the top surface. The black crust can be seen as very fine dust particles on the stone surface and in the broken mineral structure.

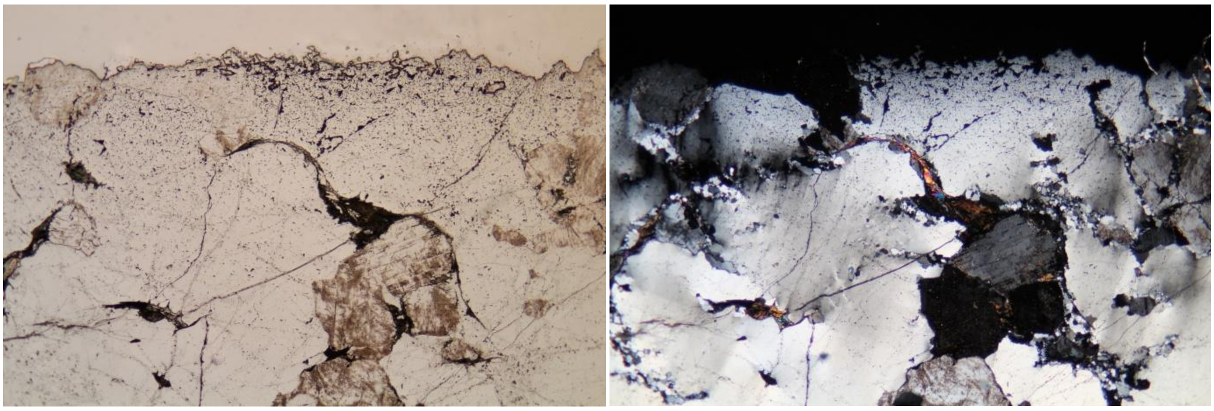

Figure 35. Starting of mineral disintegration on the top part of the sample.

Sample HAP$-2013-36 (Figure 35 and 36) is also showing high weathering degrees, in which microcracks had evolved along the borders and within the minerals.

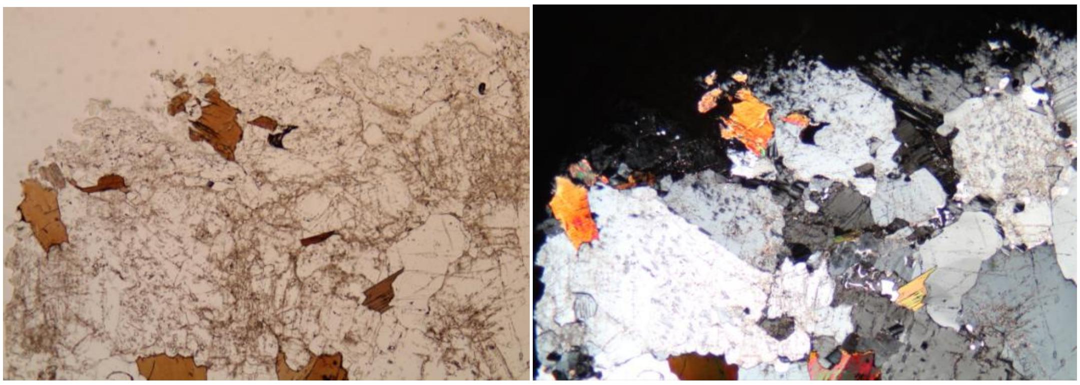

Figure 36. HAP$-2013-36. Broken mineral structure on the stone surface characterized by formation of small internal fractures in feldspar grains.

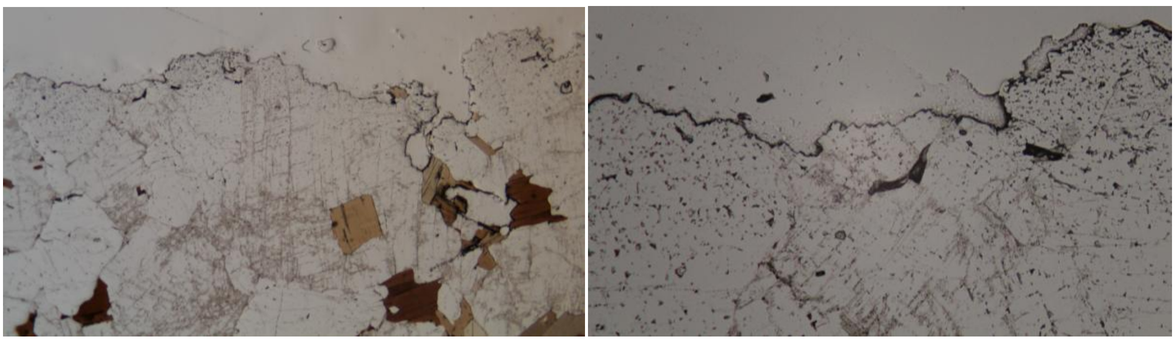

Figure 37. HAP$-2013-36. Weathered stone surface characterized by intensive fracture formation in feldspar grains.

The uusikaupunki granite had shown results of chemical analysis of the sample HAP$-2013-35 visible in Figures 38 and 39. It has typical composition of granite and it does not show signs of pollution or biological fixation. The numerical values are attached in Annex 1.

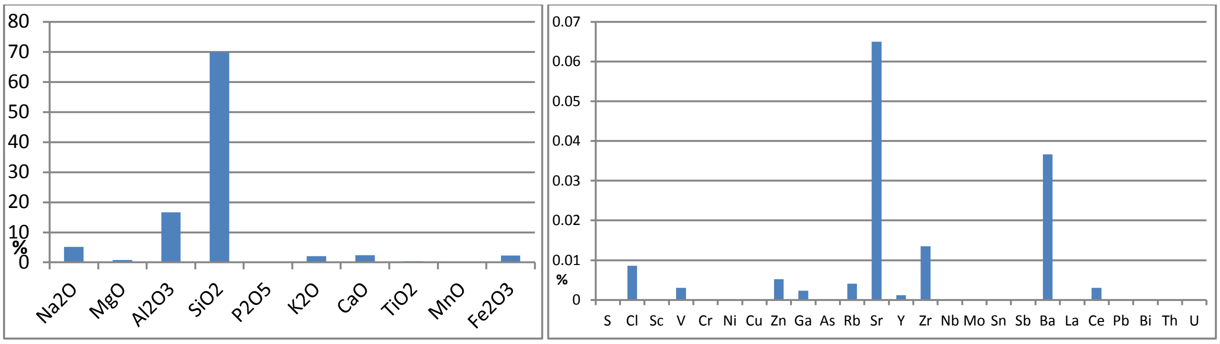

Figure 38. Percentage of the oxides, typical of a granite (on the left) and percentages of the elements (on the right)

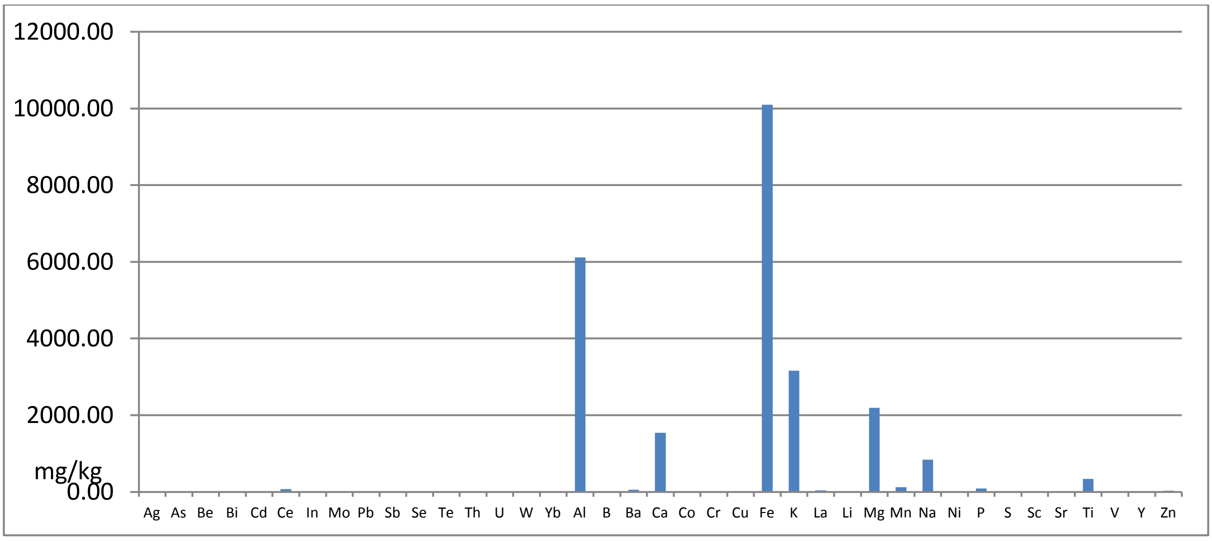

Figure 39. Content in mg/kg of the elements. It is visible that only the main element are relevant, showing no pollution sign.

The other granite sampled had been a red one from the porch; sample HAP-2013-32. The numerical values are attached in Annex 1. From visual inspection didn't show surface weathering problems, while the material itself had heterogeneous degree of oxidation of the minerals. In Figure 40 is visible the percentages of the oxides, that also in this case is typical for a granite and the percentages of the elements while in Figure 41 is shown the chemical composition in mg/kg.

From the petrographic analysis it is visible a weathering phenomenon happening on the surface of the materials, recognized by the fracturing, without being able to really identify changes in mineral compositions. From the chemical analysis is not visible a deterioration process in act, neither the influence of pollution to such an extent to cause chemical changes on these samples.

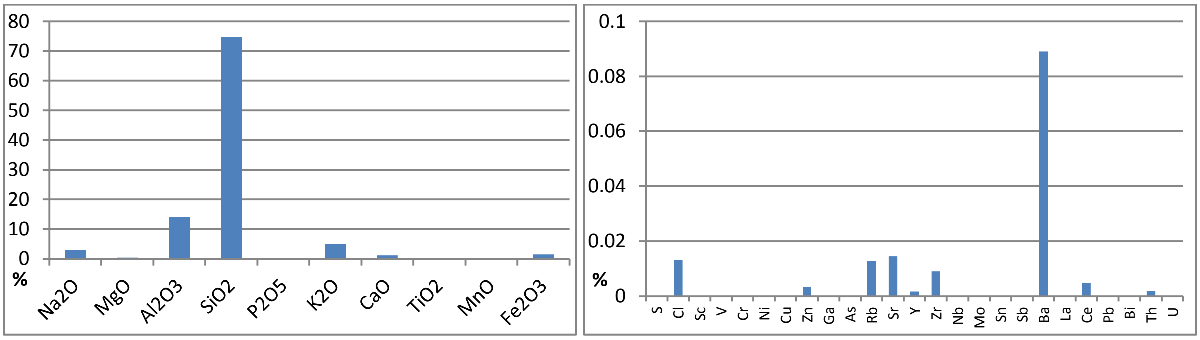

Figure 40 Percentages of the oxides (on the left) and percentage of the elements (on the right) for the sample HAP$-2013-32

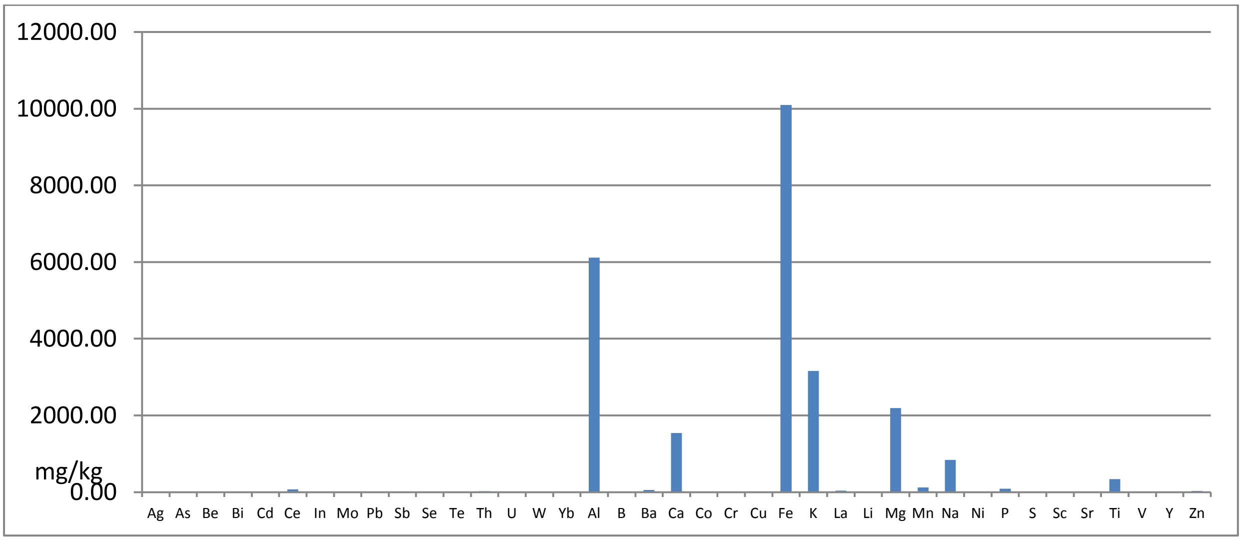

Figure 42. Chemical composition in mg/kg.

Non-destructive research methods

Non destructive research methods have included Ground penetrating radar and Schmidt hammer hardness test performed by the Geological Survey of Finland. Ultra Pulse velocity on specific blocks has been performed in cooperation with the Polytechnic of Turin-Italy while thermal camera measurements have been performed in cooperation with Mikkeli University of Applied sciences.

Ground penetrating radar

Measurements have been performed on the inner yard basement and on the outside walls. A schematic map pictured in Figure 43 shows the points interested by measurements. Several measurements have been performed in order to obtain readable results. Between measurements setting and speed of antenna transfer have been modified. In the report have then been analysed those that gave best results for different construction elements. In Figure44 are shown the measuring line collected from the back side facing the car park towards West-North.

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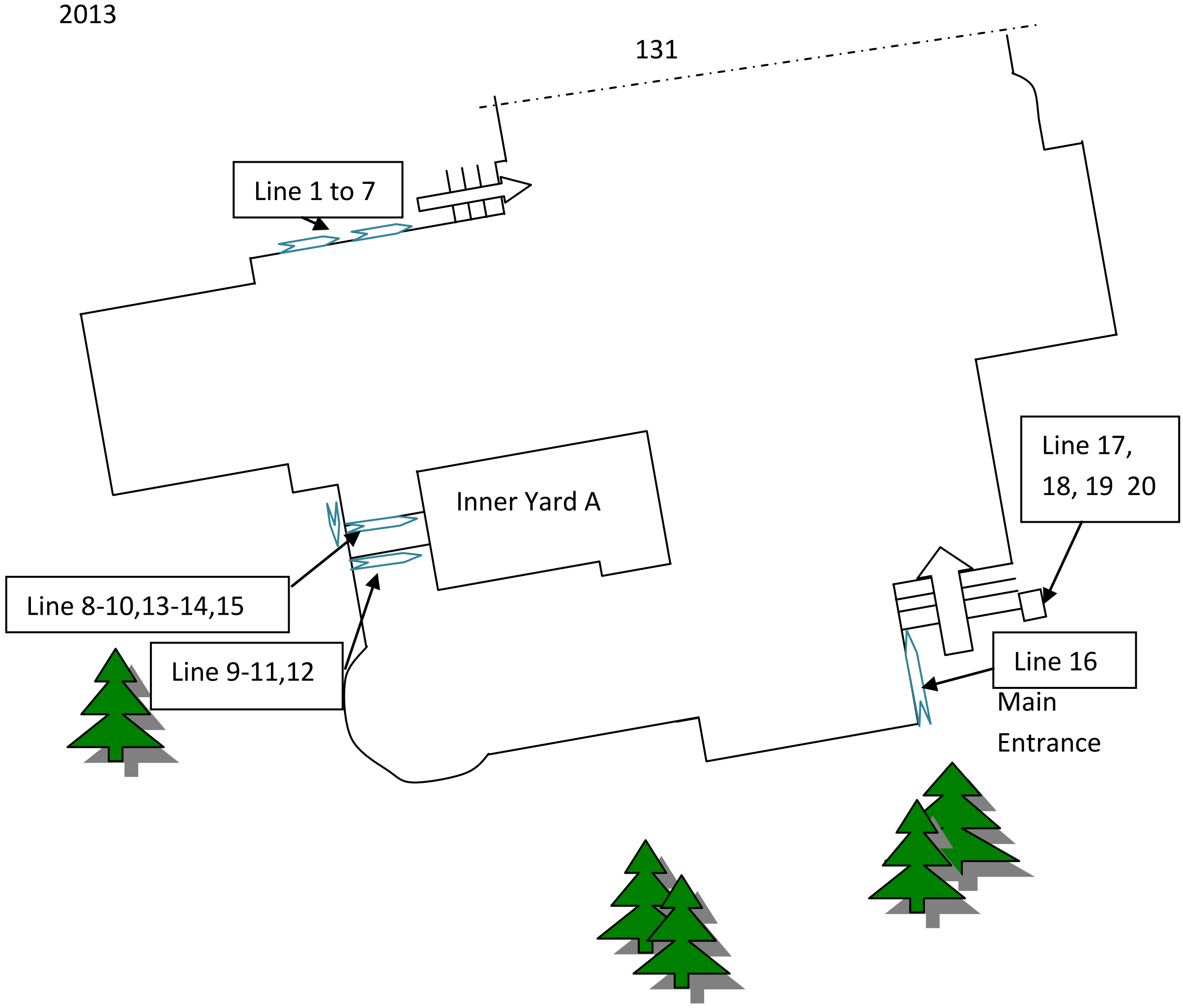

Figure 43 Map of the measurements performed with GPR.

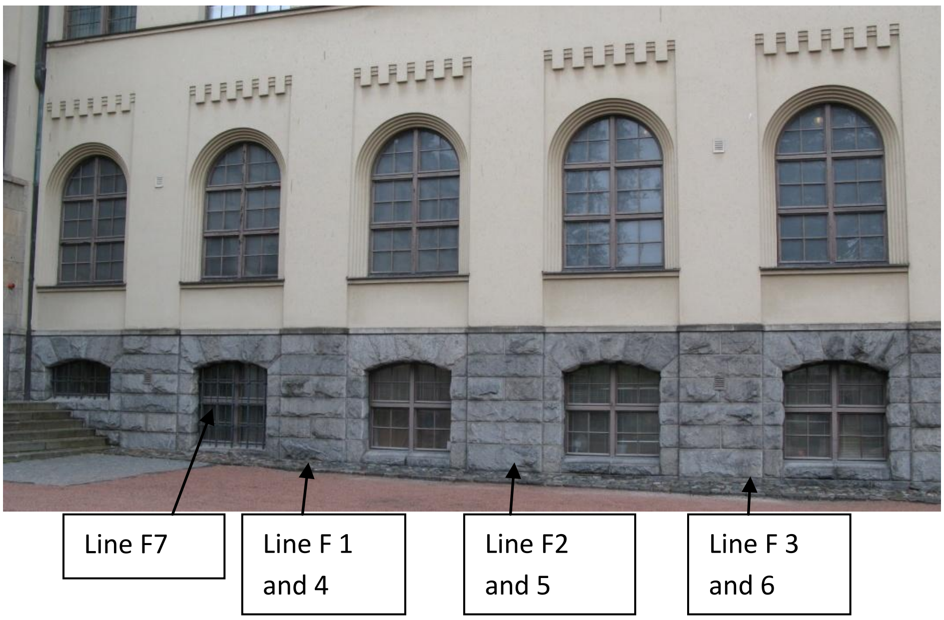

Figure 44. Measurements collected on the North-West wall. (photo:N.Luodes)

Line F 1, 2, 3 are done on the windowsill slowly, Line F4,5,6 are done faster. Line F 7 is done over the wall between the windows at the 3rd raw slowly. Line F4 and Line F7 are seen in detail along the chapter. In this case has been measured Uusikaupunki granite its Er-measurement has been performed on the basement of the bear on a thickness of 100 cm and has been equal to 5,5.

Line F4 is shown in Figure 45 and its GPR interpretation in Figure 46. The surface stone is compact and presents a neat rear surface (kiven alapinta), the surface does not present visible cracks. The joint between the blocks is also visible, giving a clear hyperbole (vertikaalisauma). The material that is behind it is a mixed material that shows several small reflections and some higher ones, it is possible however to identify two deeper construction layers (rakennekerros) of the wall. The measurement has been taken along the sill, that was bent to allow run off of the water, and as visible from the picture, during a rainy day.

Figure 45 Measuring line F4. (photo: Heikki Sutinen)

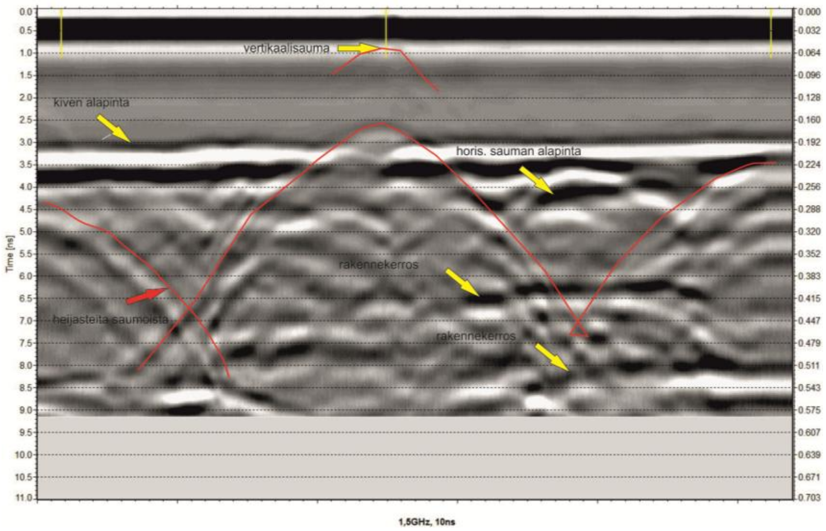

Figure 46. GPR interpretation for line F4 (vertikkalisauma: vertical joint; heijasteita saumoista: reflections from joints, horis. sauma alapinta: horizontal joint indicating the back surface of the stone, rakennekerros: construction layer) (Radardgram: Heikki Sutinen)

Line F7 is the measurement line performed over the wall between the windows as visible from Figure 47. While in Figure 40 is shown the GPR interpretation diagram.

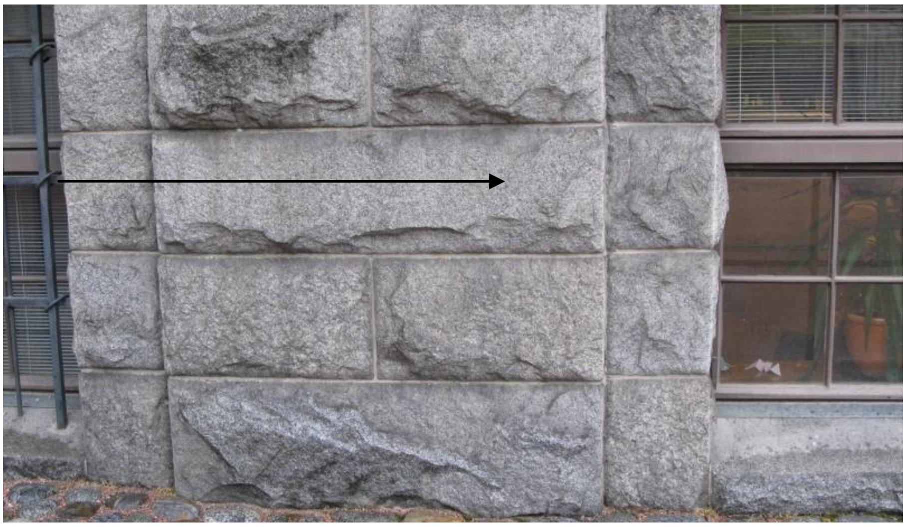

Figure 47. Direction over which has been collected Line F7.(photo: N.Luodes)

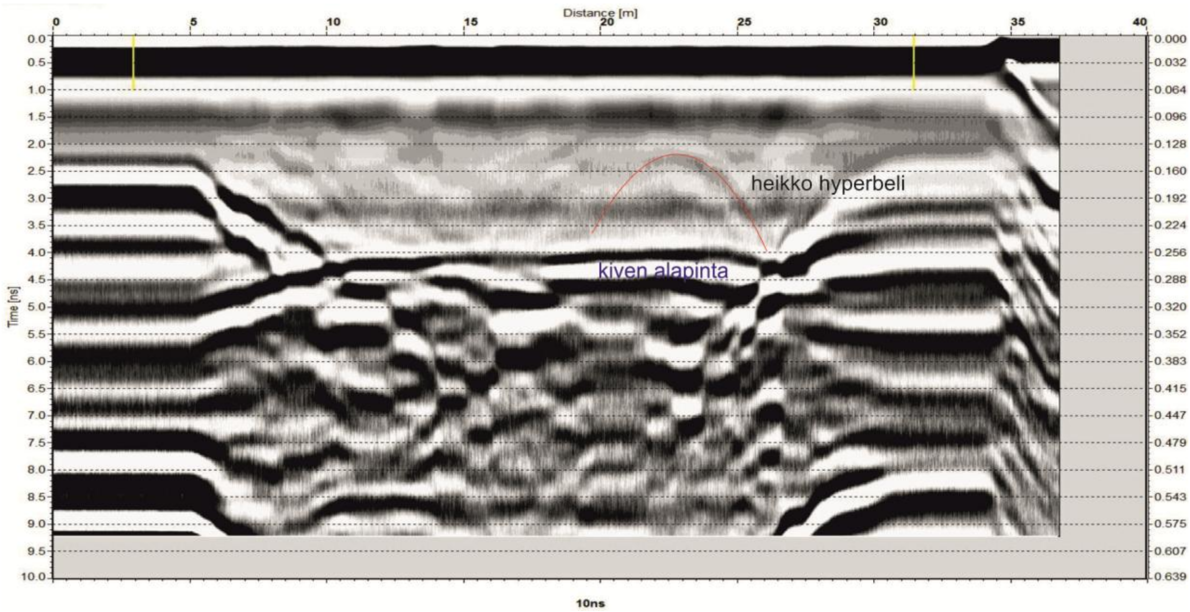

Figure 48 interpretation of GPR results for line F7 (Radardgram: Heikki Sutinen)

From Figure 48 is visible presence of weak hyperbole (heikko hyperbeli) given by an anomaly. Since it is not strong it should not be an iron element, but can be a crack in the back part of the material or a tube attached to it in the back or, still, a small iron element. It is visible clearly the back surface of the blocks (kiven alapinta). Behind the block is visible presence of heterogeneous material, characterized by high scattering.

Line 8 (thickness block 29cm) Line 9 (thickness block 29 cm)

Figure 49. The arc of soapstone, entrance to the Inner Yard A and the measurement lines performed. (photo: Heikki Sutinen, N.Luodes)

The line F8 of the National museum has been taken from the entrance arc to Inner Yard A, the Line 9 is not here discussed but had been measured. In the measurements of Line F8, as visible from Figure 50, there are two strong reflections, that could be have given by iron anchoring (raudoitus). The material is a soapstone and naturally could present some magnetic minerals but their presence should had been visible also elsewhere in the mass of the stone. It is visible a back surface of the stone at approx.25-32 cm. A light reflection in the stone could be given by stone structure (heikko riikonaisuusheijaste).

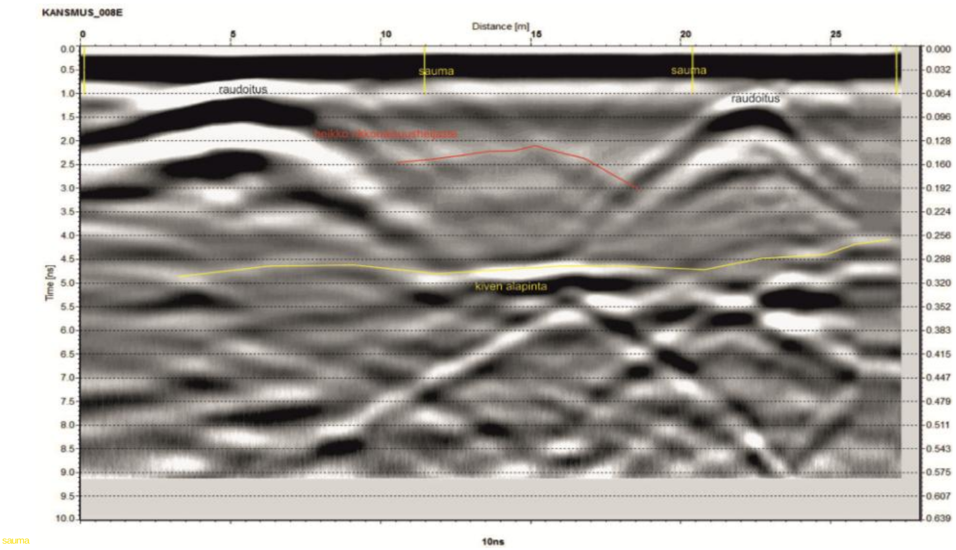

Figure 50. Interpretation of line F8 (Radardgram: Heikki Sutinen)

In the entrance towards the Inner Yard A several lines have been measured as shown in Figure 51. The measurements have been performed from the door to the yard.

Figure 51.Measurement performed from the door to the yard. (Photo N.Luodes)

The Line F10 and F13 have been measured from the left side of the basement on the entrance arc towards the inner yard A (Figure 52). In the interpretation of the measurements, shown in figure 53, are visible 3 neat layers. Could they be attributed to three layers (stone surface of approx.20-25cm, mid stone layer, back layer) or to fractures in the stone , has to be evaluated, also from comparison with the other side of the entrance.

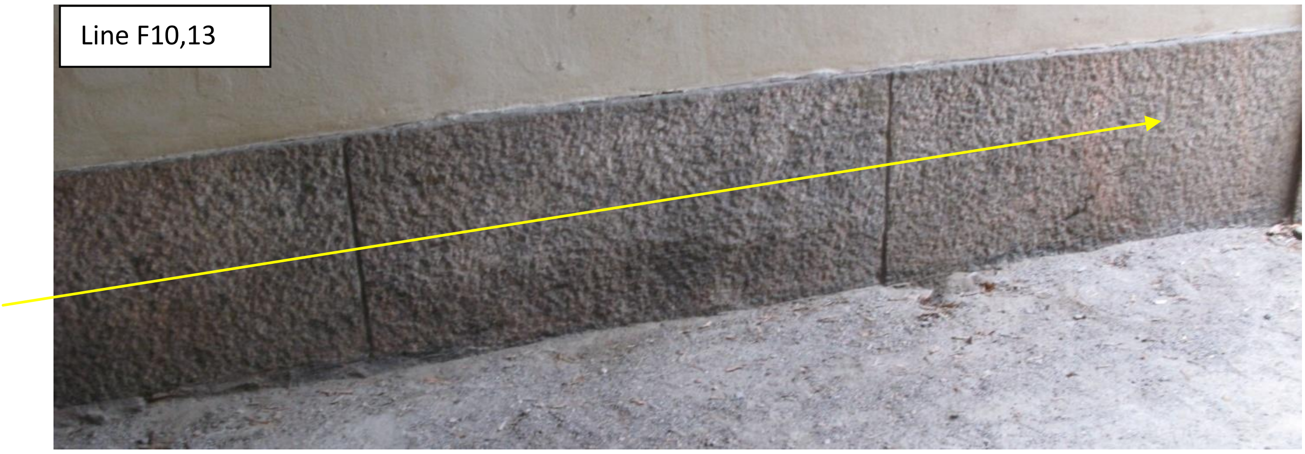

Figure 52 Entrance to Inner Yard A, left side, position of Line F10 (photo N.Luodes)

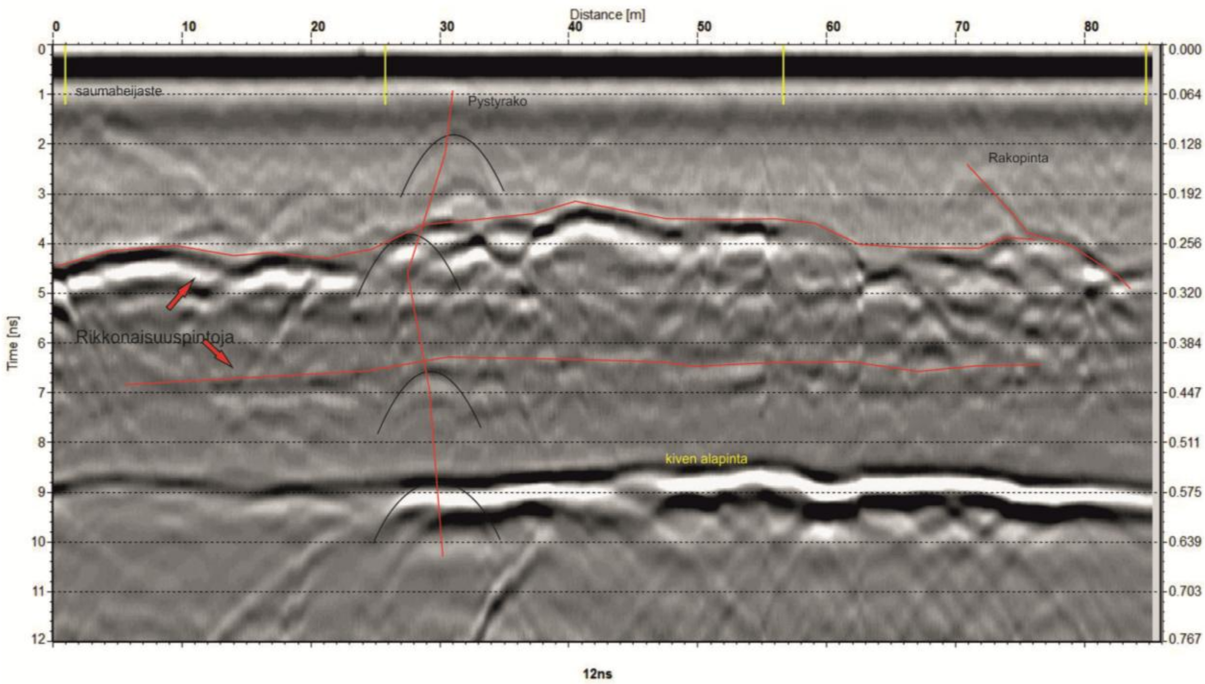

Figure 53 Entrance to Inner Yard A, left side, interpretation of GPR of Line F10 (Radardgram: Heikki Sutinen)

Line F11, visible in Figure 54, is measured on the right side in the entrance arc to the Inner Yard A. In figure 55 are visible a strong back reflection and middle reflections, either given by wall layers or by internal fractures.

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Figure 54. Entrance to Inner Yard A, right side, position of Line F11 (Photo N.Luodes)

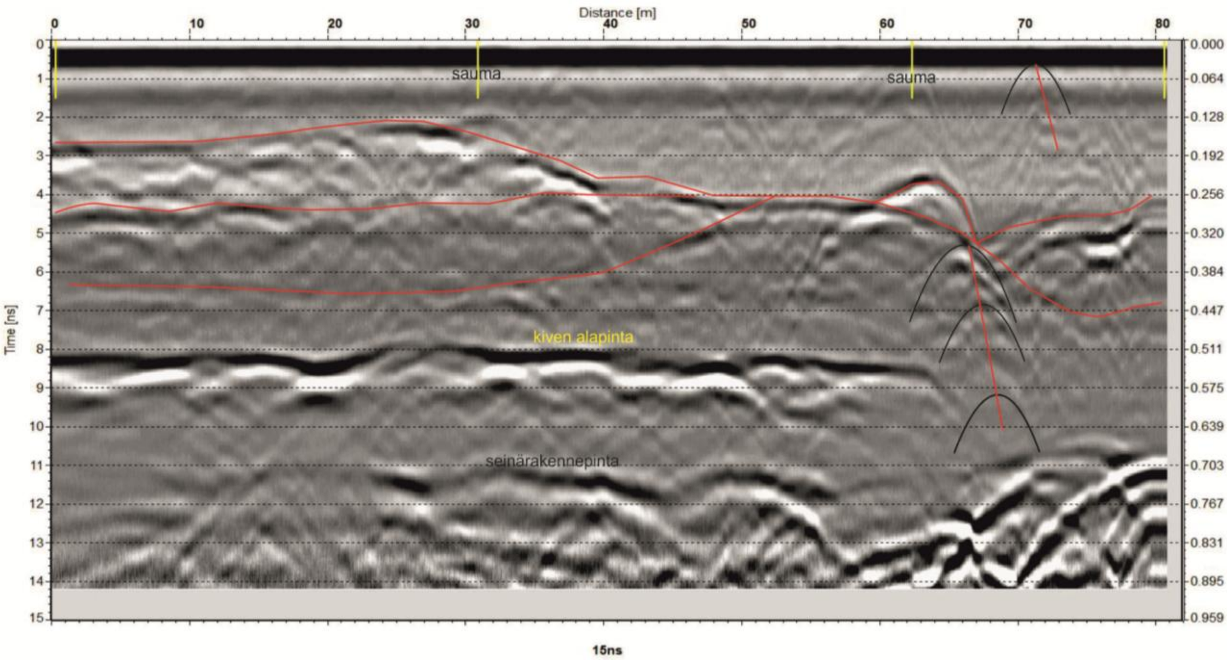

Figure 55 Entrance to Inner Yard A, left side, interpretation of GPR of Line F11 (Radardgram: Heikki Sutinen)

The Line 14 and 15 have been measured on the Corner block at the end of the basement on the inner yard entrance, left side. Its measures have been: 64,5 cm long and 79 cm depth and is visible from Figure 56.

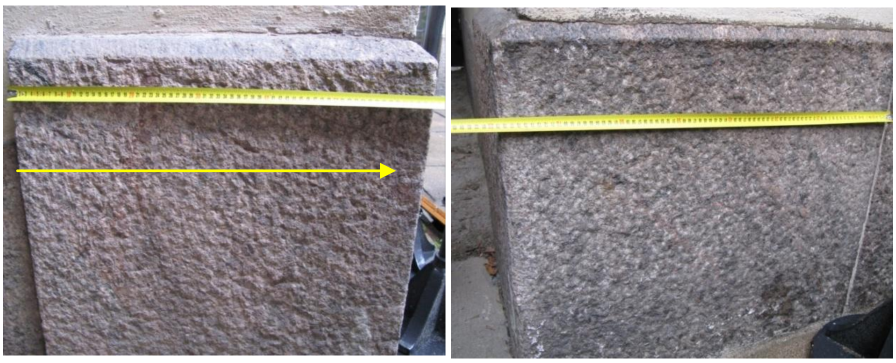

Figure 56. Corner block measures and line of measurements. (photo: N.Luodes)

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First has been used at 15 ns reading time to reach depths of 140cm, then it has been increased to 20 ns. The Er for this red granite has been measured being 5,3.

The interpretation of Line F15, pictured in Figure 57, shows that the back face of the stone is visible (kiven alapinta) and the thickness of the blocks used along the wall has been different. There could be presence of internal discontinuities or microfractures shown in red.

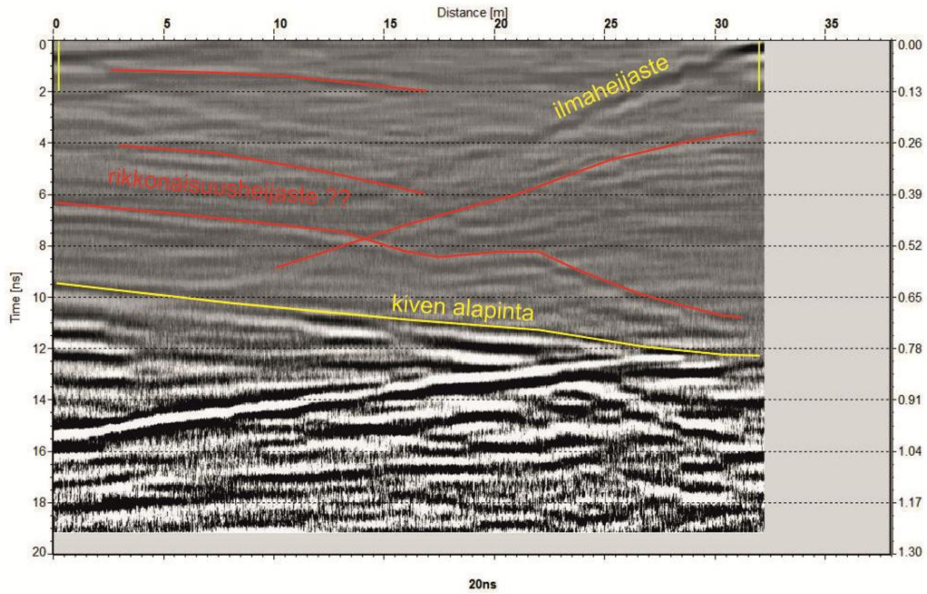

Figure 57. Interpretation of measures run along Line 15. Kiven alapinta: back side of the block, ilmaheijaste: air reflection, rikkonaisuushejaste: fractures. (Radardgram: Heikki Sutinen)

In Figure 58 is shown the measurement performed over the brush hammered part near the entrance. The granite is Uusikaupunki, the radargram showed the presence of the iron anchoring of the window and the three layer wall. Internal cracks have not been visible.

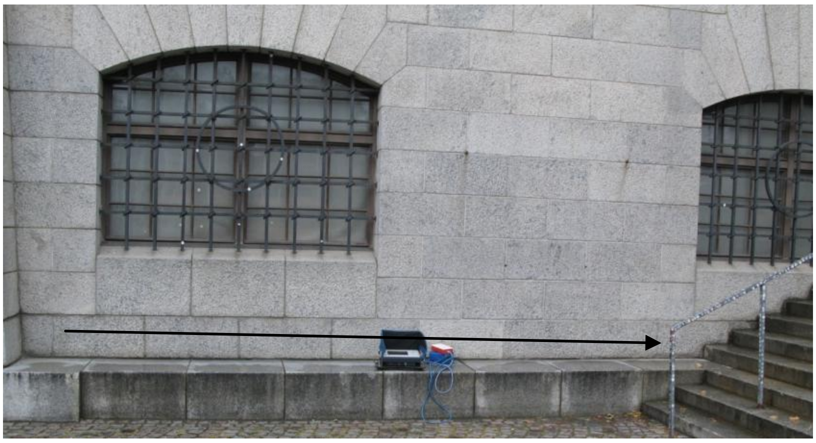

Figure 58. Measurement Line F16 has been collected.

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A special study of the basement of the statue of the bear, located near the entrance, has been done, also in order to try visualization from adjacent sides. The measuring lines and dimension of the statue basement are shown in figure 59.

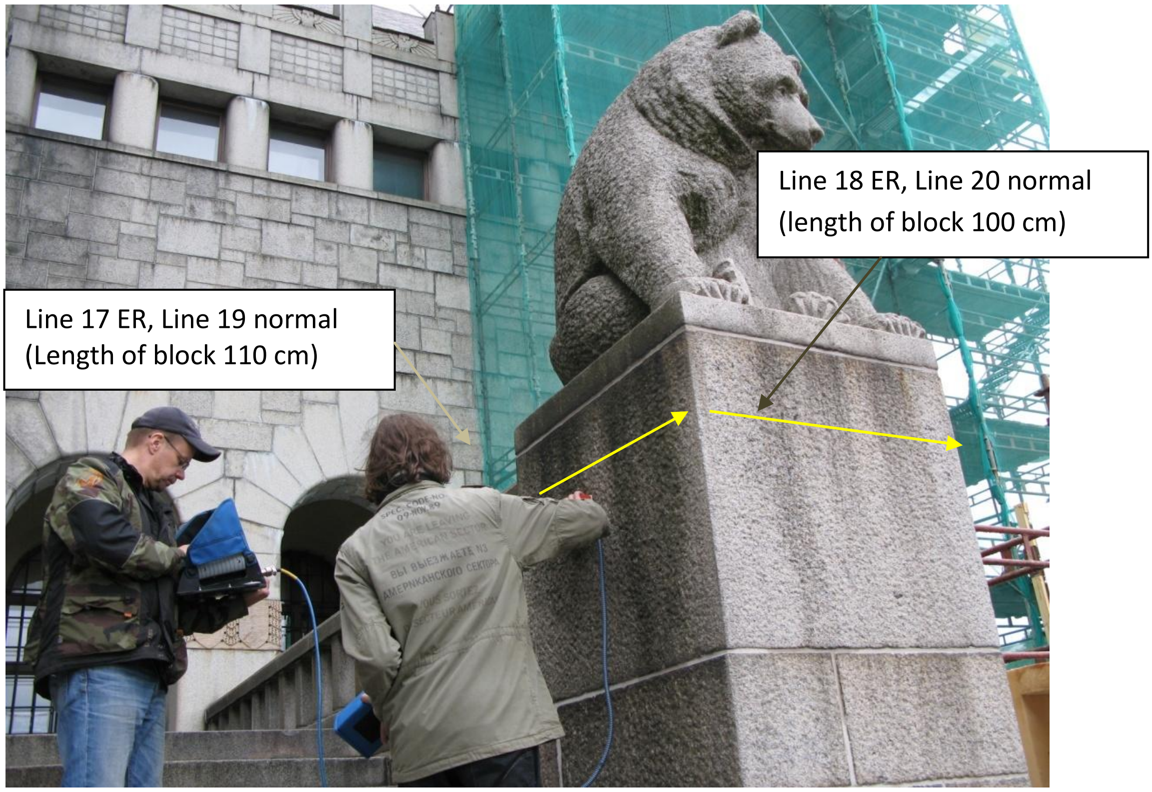

Figure 59. Measuring lines performed over the basement of the statue of the bear.

From the line F19 are visible anomalies. In Figure 60 is has been schematized the meaning of the anomalies, trying to picture on a base map of the pillar their origin.

It is visible the back side of the stone (kiven alapinta) and after it the interference given by the air (kiven alapinta ilmahejasteet).Are also visible two curves, one on the right and one on the left underlined in yellow, determined by the reflection of the corner of the block (ilmaheijaste). There is a curve (visible in red) determined by an internal heterogeneity, that could be a fracture or a vein (rakoheijaste).

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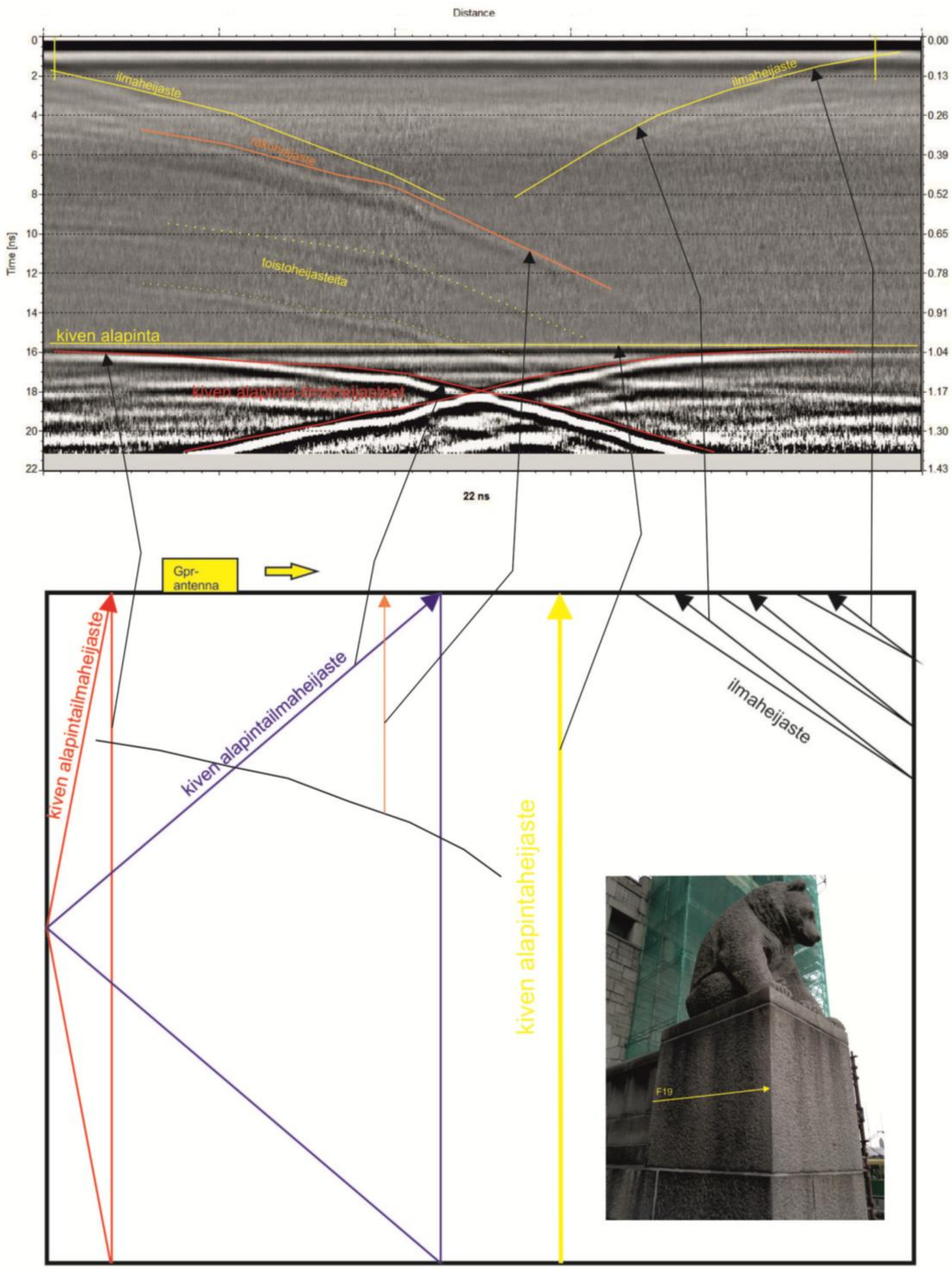

Figure 60. GPR measurement on one side of the basement of the statue of the bear and the explanation and interpretation of the radargram.

In Figure 61 are shown the results from the measurement performed on the adjacent side and it is visible from Line F20 the same curve given by internal heterogeneity.

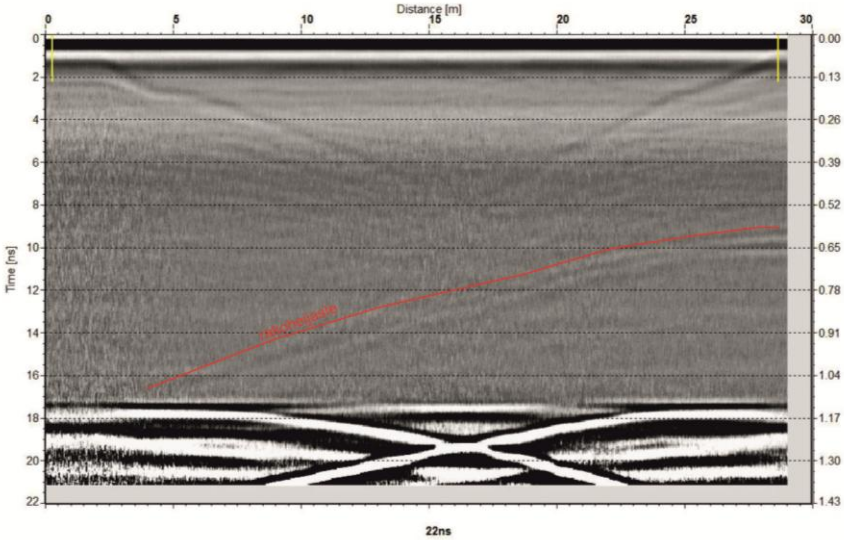

Figure 61.The curve showing the internal anomaly is visible also from this side, as was visible in Figure 60. (Radardgram : Heikki Sutinen)

Ultrasonic measurements (UPV)

The measurements have been performed in an indirect way, along the basement of the building on several blocks and different expositions. The measurements have been performed according to the report “Methodology UPV”, their positions are shown in the map of figure 62, the images of the basements from which had been tested are shown in the following pictures together with the average values of velocity for each exposition. In the evaluation of the velocity the first measuring point has been excluded from the calculations.

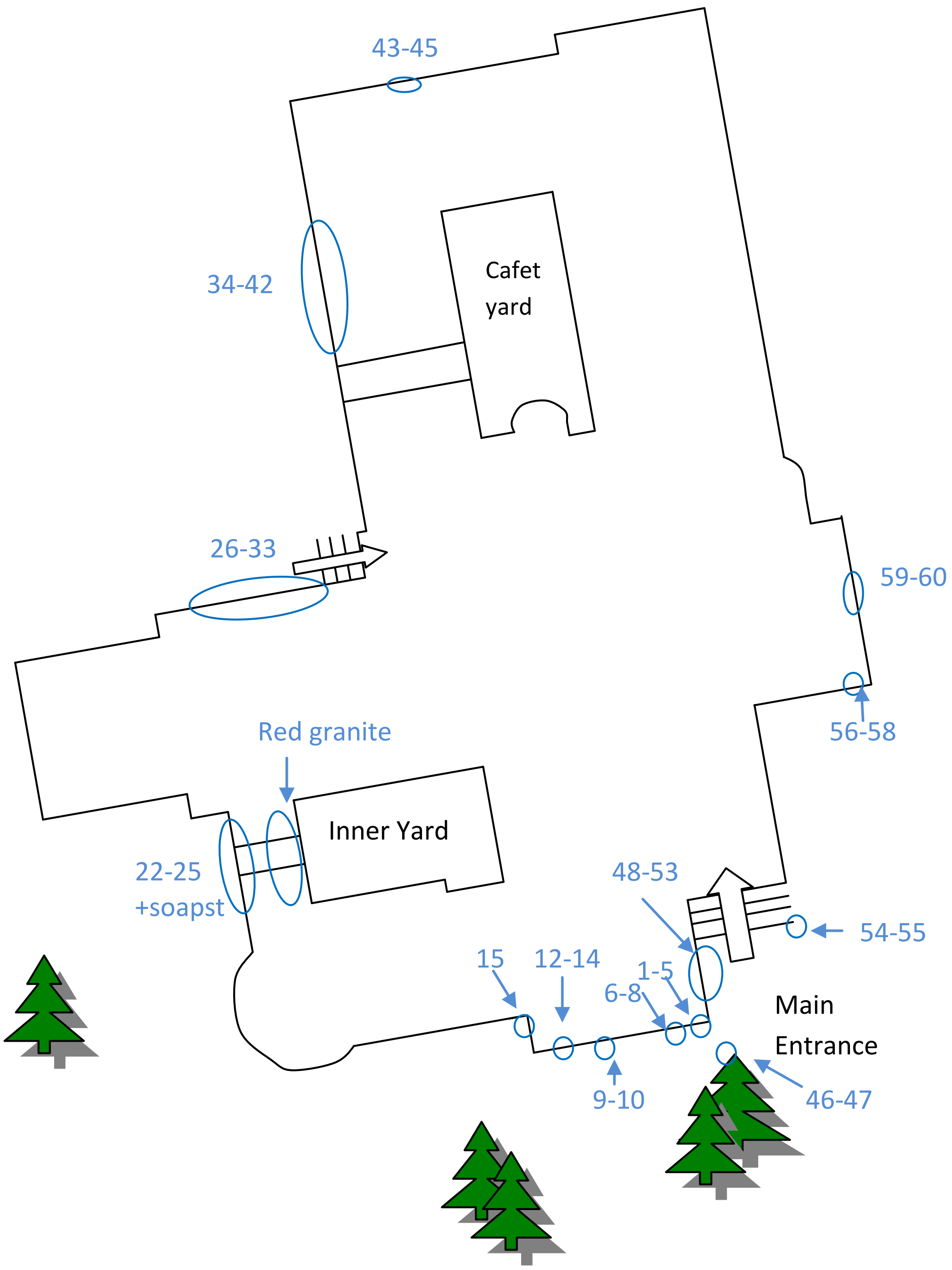

Figure 62. Map of the areas from where the UPV had been evaluated.

First is evaluated the changes of velocity over blocks exposed to South. Measurements have been performed both over sides exposed directly to traffic and to those less affected, facing the garden area. The measurements 1-5 have been performed over a part of the building known to have problem of humidity. The measurements 1-15 have been performed on half shadow in the morning. In the figures 63- 67 are pictured the measured blocks.

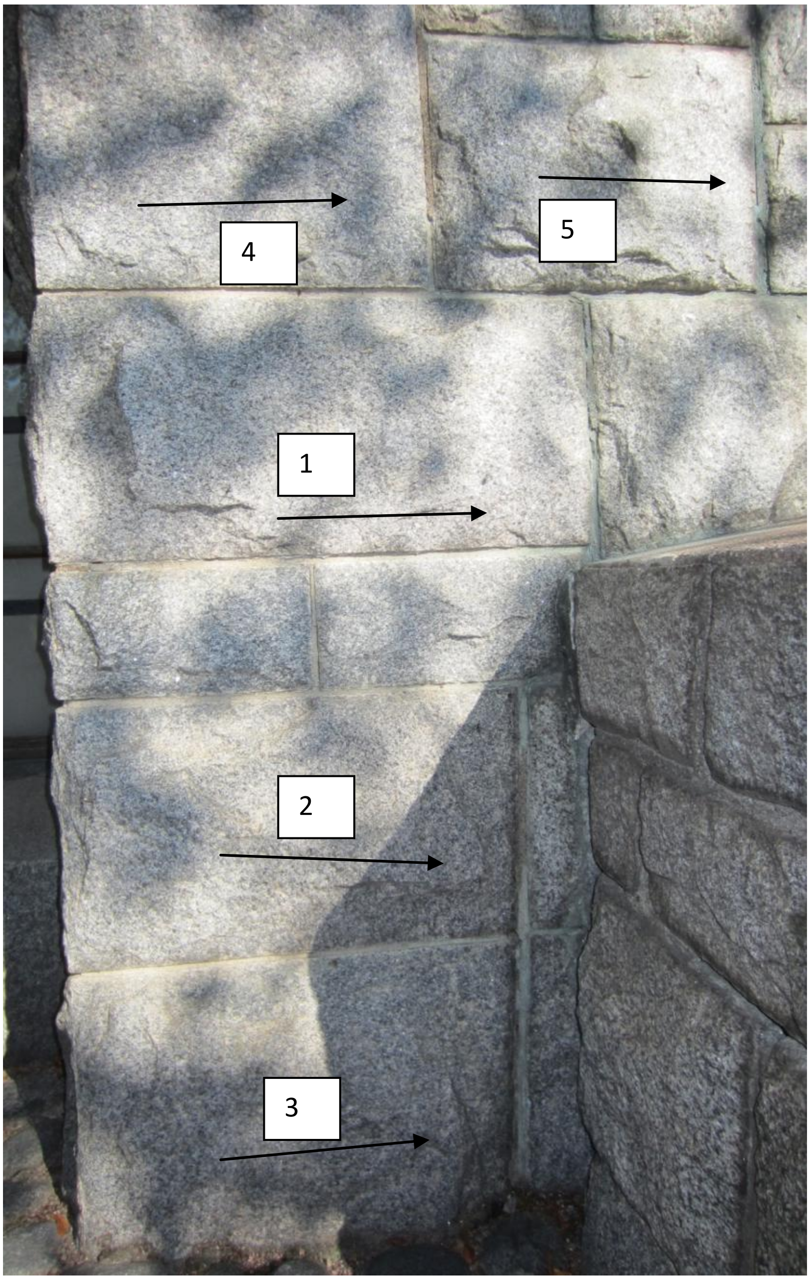

Figure 63. Exposition to the South. Right wall near the first window from right to left, looking the façade. This corner had been sampled for further analysis.

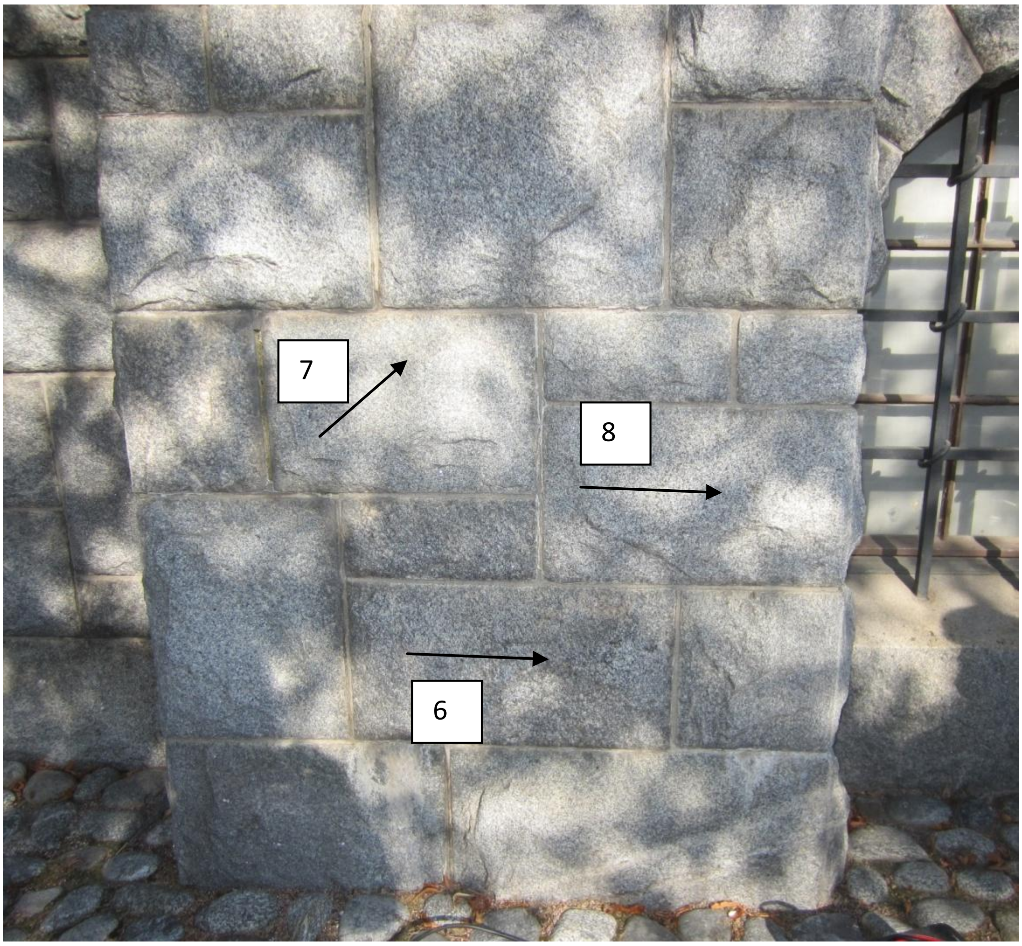

Figure 64 Exposition to the south. Left wall of the first window from right to left, looking the facade.

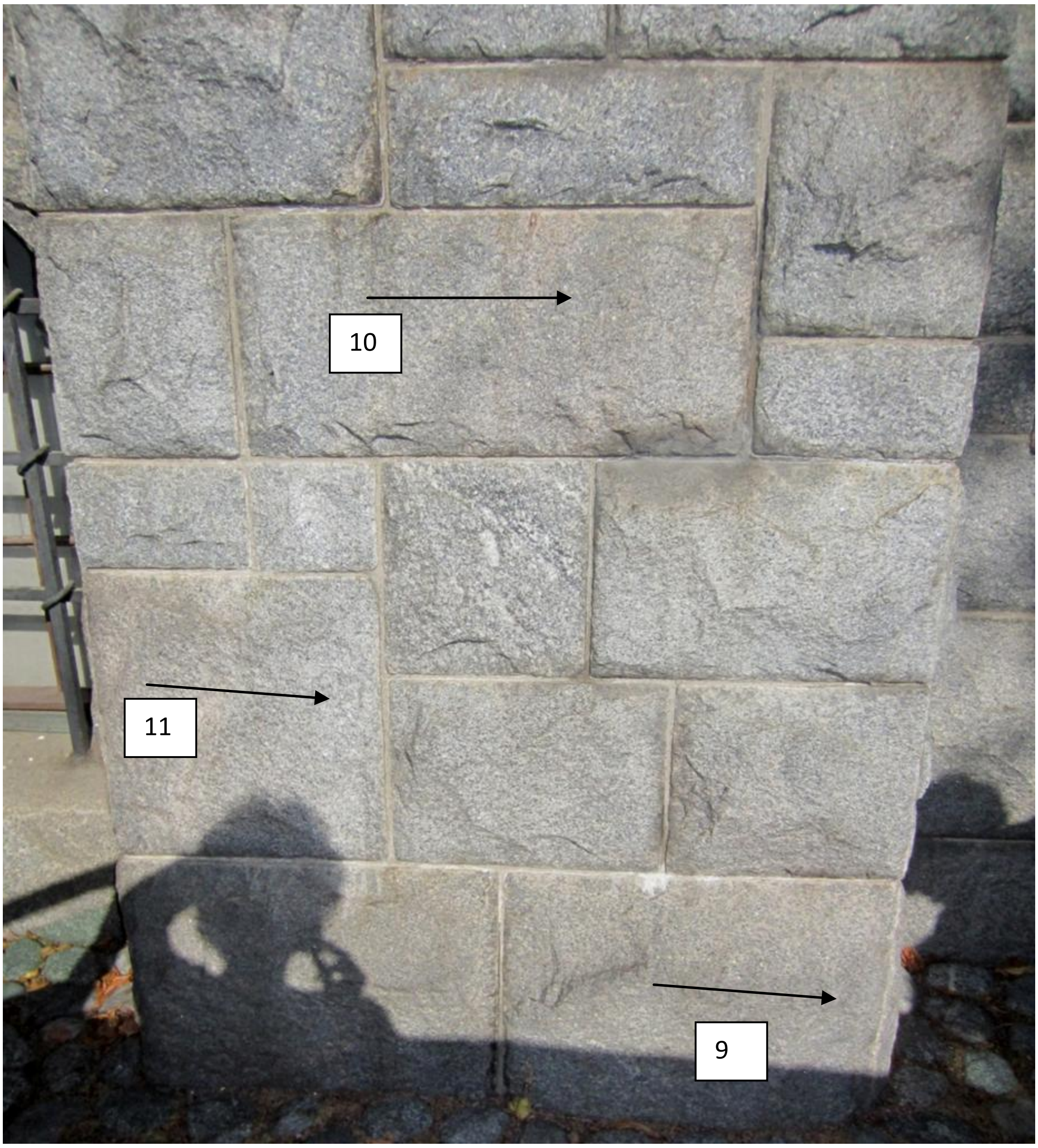

Figure 65 Exposition to the south, right wall of the second window from right to left looking the facade. Blocks 9,10,11 measured.

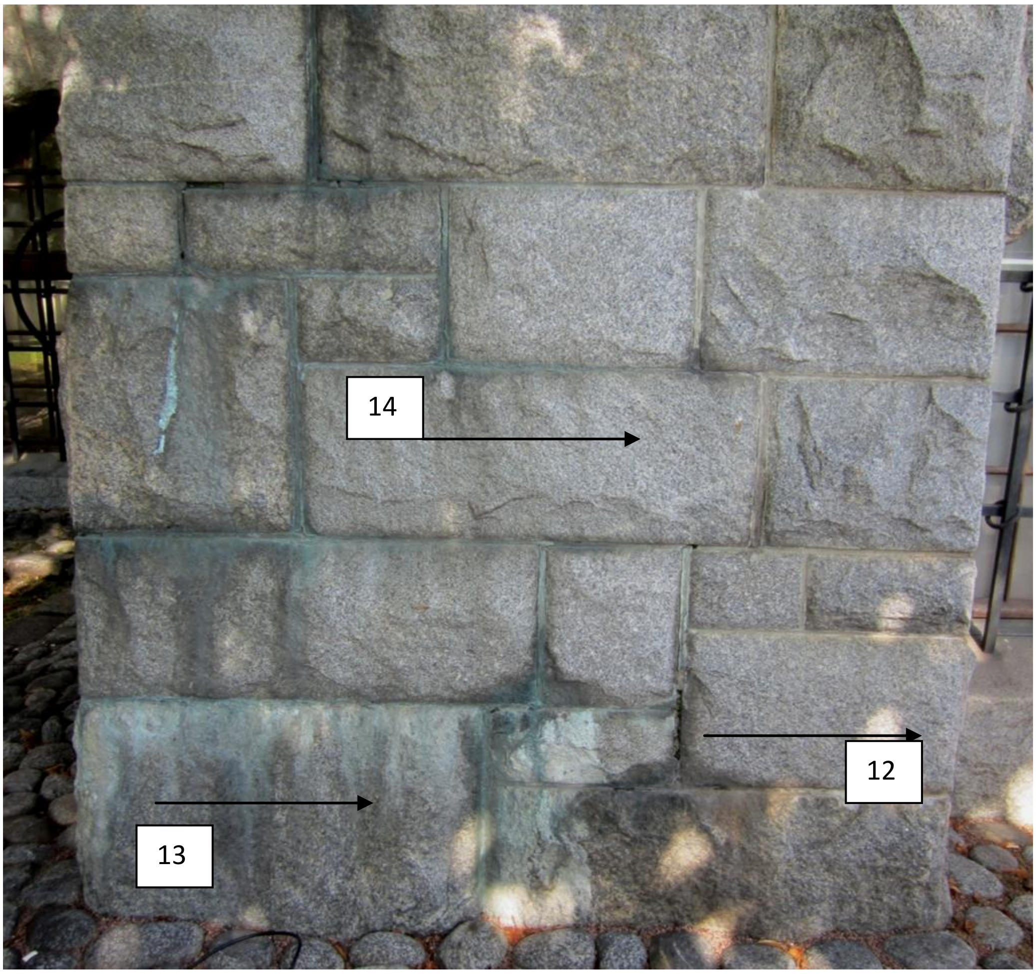

Figure 66. Exposition to the South, left wall of the second window from right to left looking at the façade. Blocks 12,13,14 measured.

The measured n 13 has the last measures (5th and 6th)over the crust given by cupper deposition.

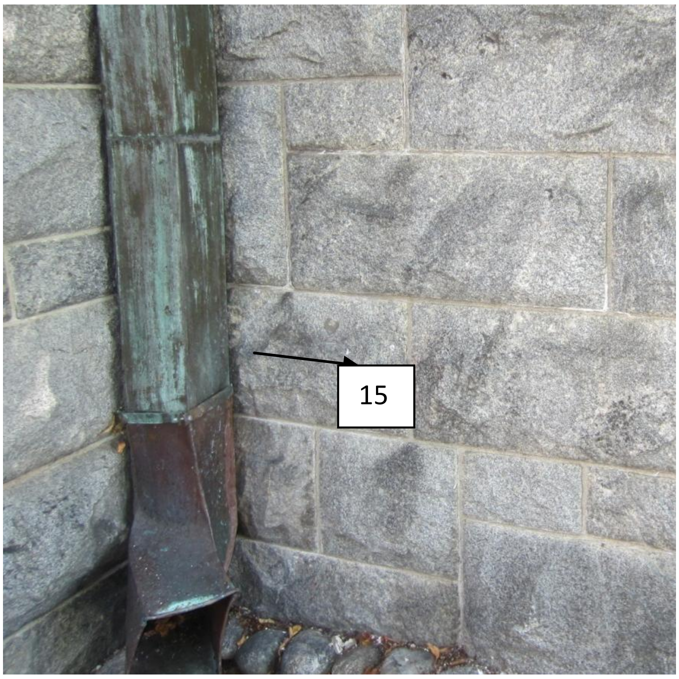

Figure 67. In the figure is visible the block that had been sampled, near the drain pipe, on the corner from the facade facing South, but as a block exposed to West . On it had been evaluated the UPV.

Facing South have been measured also the blocks that are more exposed to traffic, as those near the entrance facing Mannerheimintie and visible from figure 68

Figure 68. Part of the facade facing South but situated towards Mannerheimintie. Blocks 56,57 and 58 had been measured.

In the figure 69 are compared the velocities for each block.

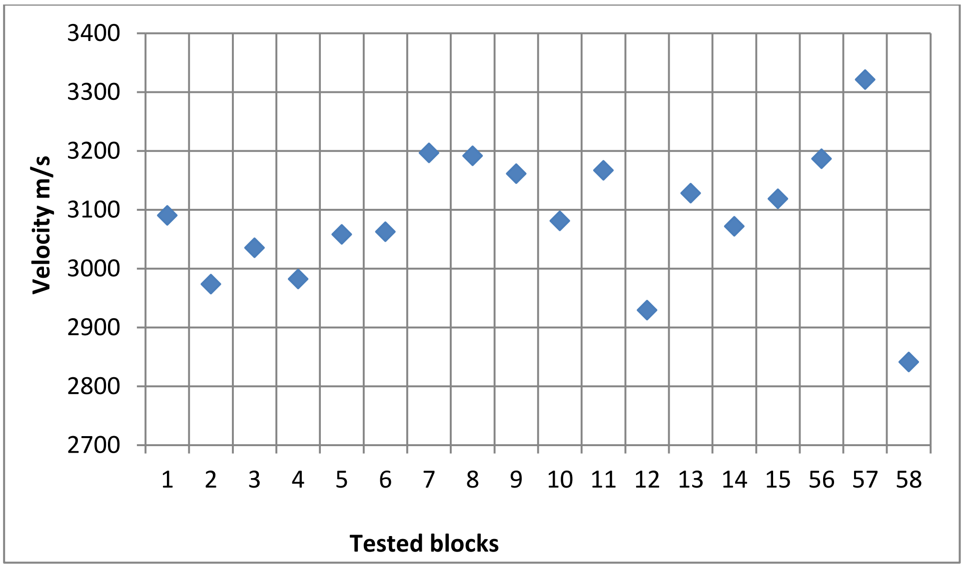

Figure 69 Velocities calculated for each block from the facade facing South.

Blocks 1-5 have been over a part of the building that presented humidity problems but their velocity is quite regular not showing particular deviations over the specific blocks. The block n 13 had been measured partially over the crust given by deposition of cupper but it does not show a deviation in velocity compared to the average.

Blocks 56, 57 and 58 are from a more traffic area compared to the other measurements and the surface is bush hammered, that might be a reason for the higher results obtained over block 57 for example, having the possibility to position better the transducers over the surface. Block 56 is affected by black crust and its value of velocity is in the average. The block 58 presented a crack and that is most probably the reason for the low average velocity over that specific block.

The low velocity measured over block 12 cannot be attributed to a crack or to a deposition layer over the surface, since those had not been determined visually but could be determined by the properties of the material of that block or by its humidity levels.

Even if the material is the same the values are very heterogeneous, with values generally oscillating between 2990 and 3200 m/s.

The facade facing West has been measured near the arc of entrance to Inner Yard A and on the wall facing the car park. Near the inner Yard A measurements over soapstone and red granite have been also performed, besides those collected over specific blocks of Uusikaupunki granite but their results are shown later. In Figure 70-72 are shown the blocks measured of the main facade, facing West.

Figure 70. Blocks at the sides of the entrance to Inner Yard A. Measurements over blocks 22,23,24,25, have been taken. Block 23 had a rusted spot and the measurements have been performed over it.

Part of the West facade, in the area facing the park yard, has been under direct sun.

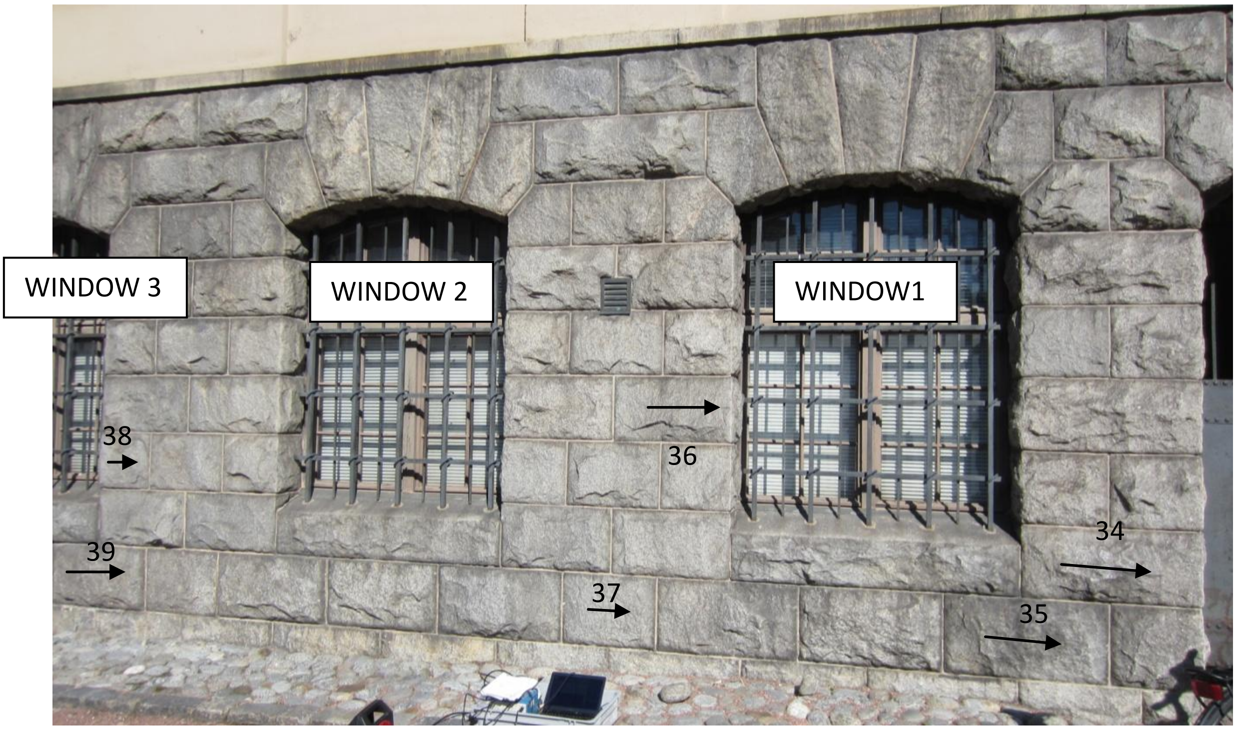

Figure 71 Blocks of the facade facing West from the part that is facing a car park. On the right is visible the entrance to the inner yard that host the cafeteria. Measured blocks 34,35,36,37,38,39 are visible.

Figure 72. Testing on block 40 at the left of window 3 and on blocks 41 and 42 over the semicircular building element on the facade facing West.

In Figure 73 are represented the comparison of the velocities measured along the facade facing West.

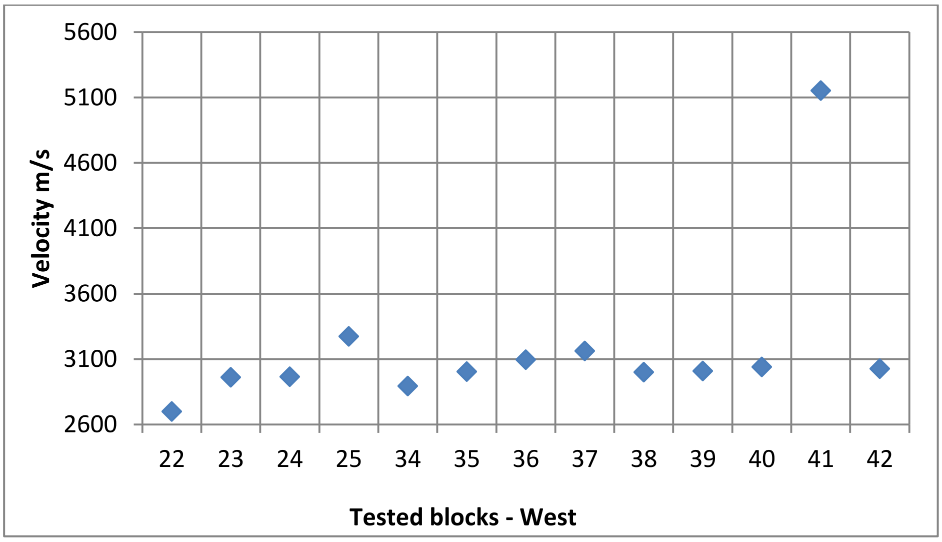

Figure 73. Velocities calculated for each block from the facade facing West

From figure 73 it is visible that block n 41 had shown much higher velocity compared to all the others and in order to visualize the average of the others it is excluded from the evaluation. In Figure 74 is shown the new representation.

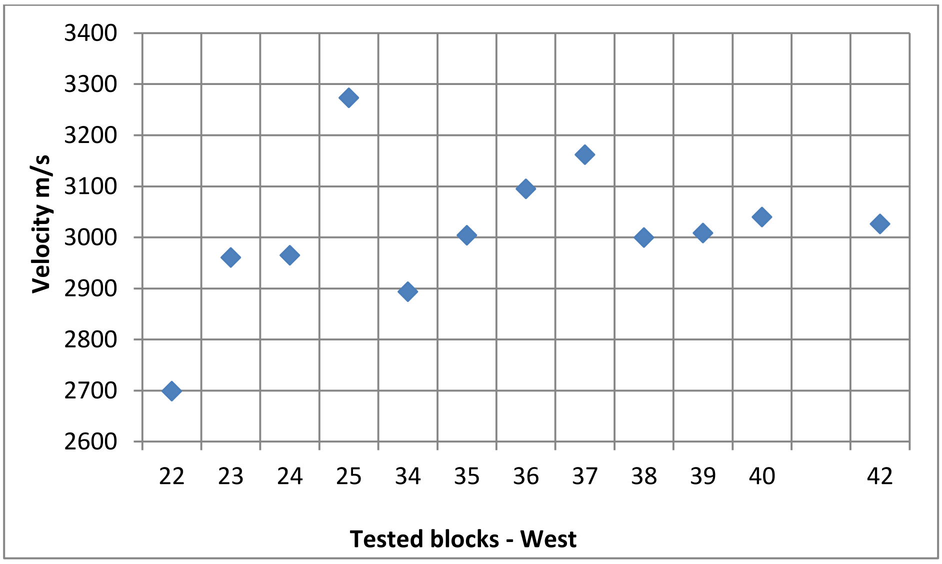

Figure 74. Velocities calculated for each block, excluding block 41, from the facade facing West

Also for this exposition the material show variations between 2990 and 3200 m/s. Block 23 had been sampled over a rusty area but its velocity does not show an increment compared to other average velocities, as well as block 42, while the block 41 showed a high increase in velocity probably given by a higher metal deposition, visually looking as a clear percolation over the surface. Block 41 and 42 are shown in Figure 75.

Figure 75. Block 41 on the left and 42 on the right, over the semicircular element facing West.

The higher velocity of block 25 could not be caused by internal fractures but is probably due either to an increase in humidity or by the influence of its irregular surface. The fact that the measurements have been performed in direct sun from block 34 to 42 does not show a clear effect on the results, as blocks 23,24,35,38, 40 and 42 have shown similar velocities.

The facade facing North has been sampled over the one facing the parking area and visible in figure 76 and on the part at the end of the building visible in figure 77.

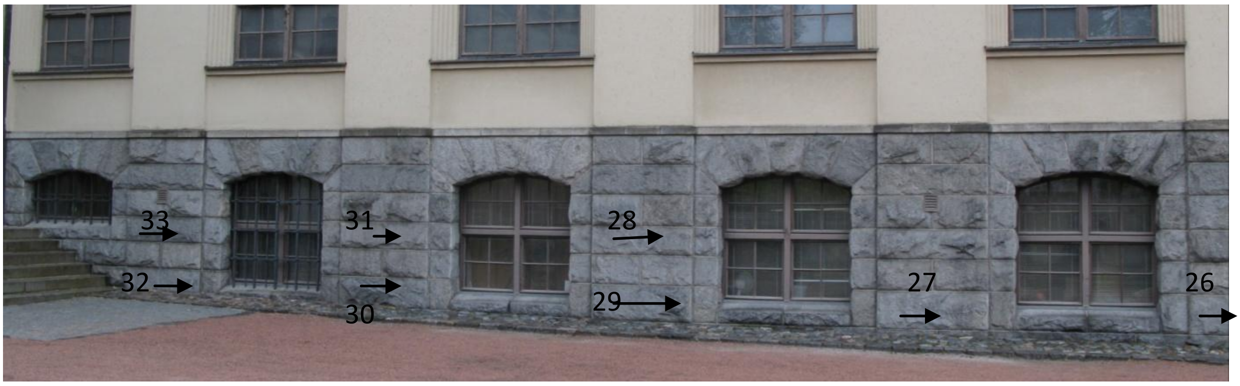

Figure 76 Facade facing North facing the car park, near the rear entrance. Measurements over blocks from 26 to 33 have been performed.

Figure 77 Facade facing North at the end of building, measurement over blocks 43 - 45 had been performed.

The velocities evaluated are shown in the diagram of Figure 78.

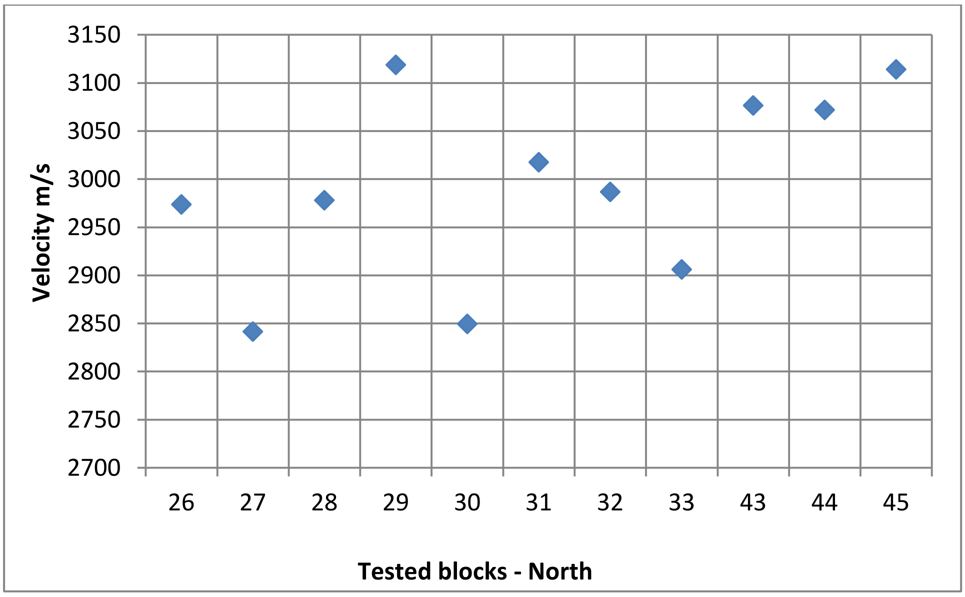

Figure 78. UPV on the blocks evaluated from the basement facing North.

The results are very heterogeneous and oscillating between 2850 and 3100 m/s, in line with the previous values obtained for other expositions.

Measurements near the drill hole sampled from the basement wall of the garden facing Mannerheimintie have been taken in correspondence of two blocks shown in Figure 79 and numbered 46 and 47.

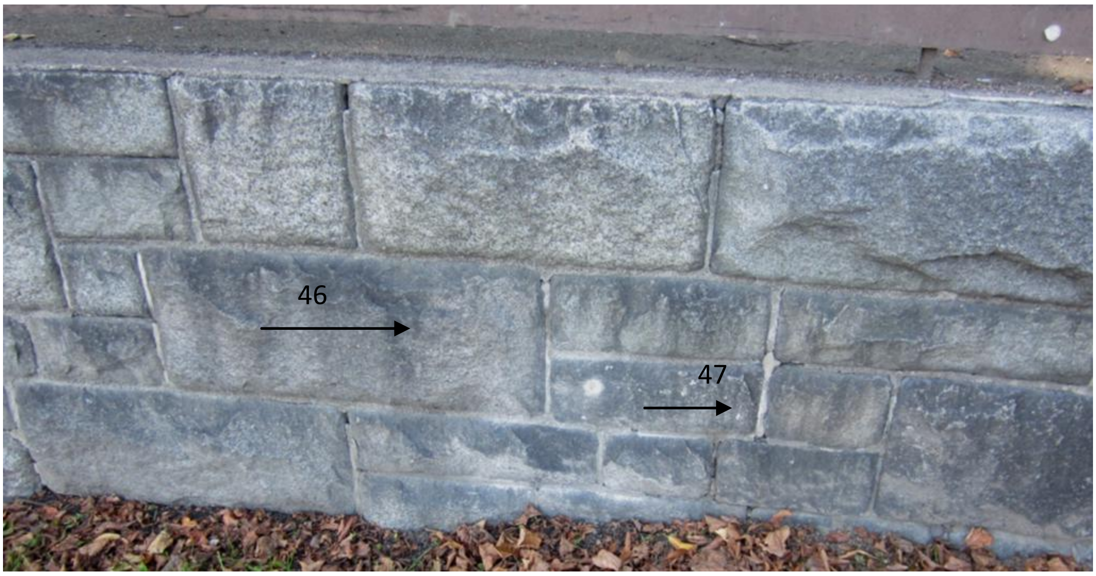

Figure 79 Wall supporting the garden facing Mannerheimintie. Blocks 46 and 47 had been measured.

The main building had been still measured on the stones facing East towards Mannerheimintie.

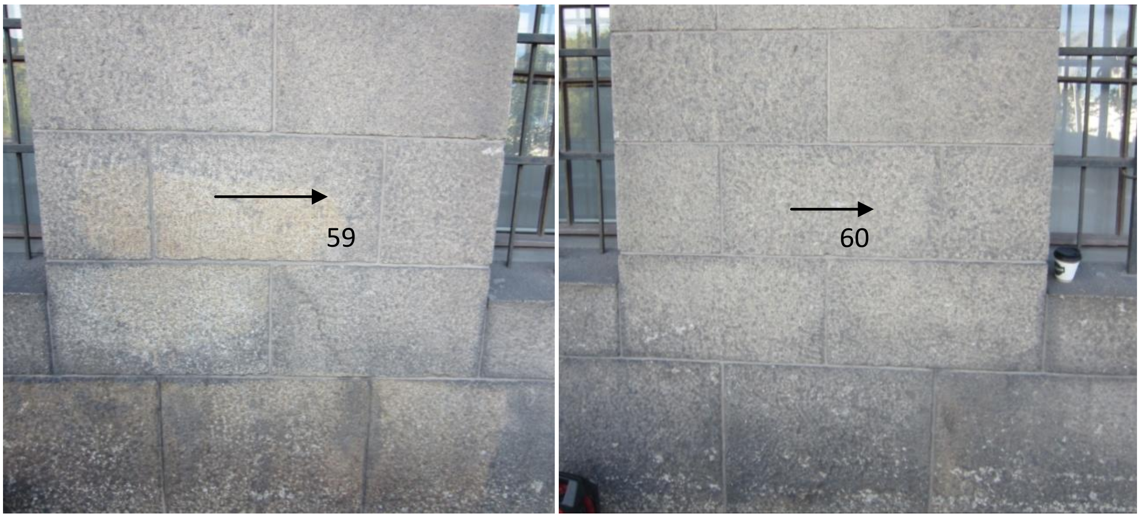

Figure 80. Blocks tested on Mannerheimintie, facing East. The block n 60 tested had been showing flaking deterioration.

Towards East the blocks along the bush hammered facade near the entrance have been measured as shown in Figure 81

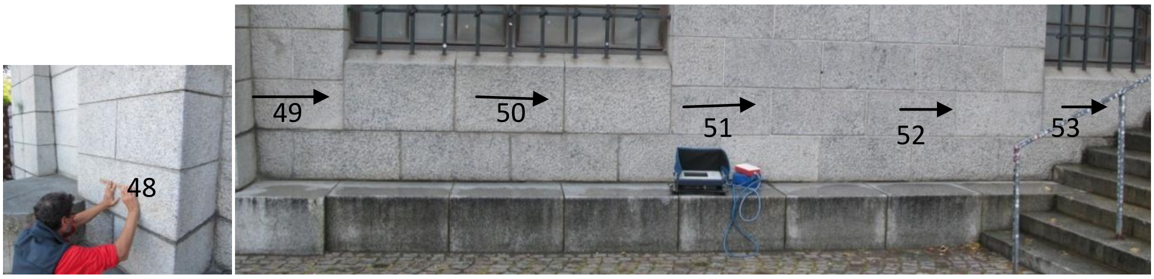

Figure 81 Blocks measured on the facade near the entrance.

In Figure 82 are shown the velocities evaluated for the basement exposed to East

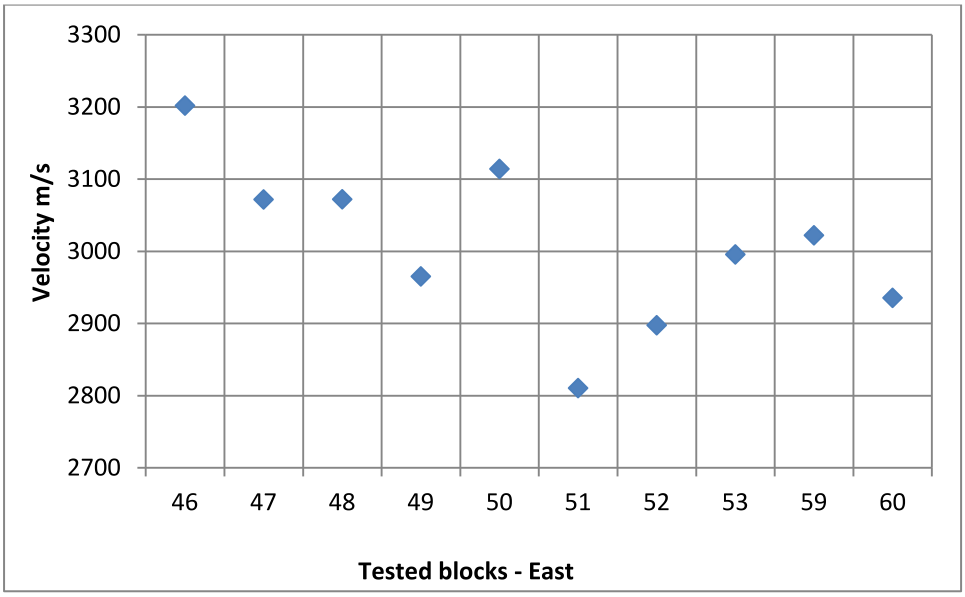

Figure 82. UPV values evaluated for the blocks exposed to East.

Also the pedestal of the bear statue has been measured as shown in Figure 83, over the measuring line 54 has been evaluated a speed of 3100 m/s, while over the measuring line 55 a speed equal to 2939 m/s has been evaluated.

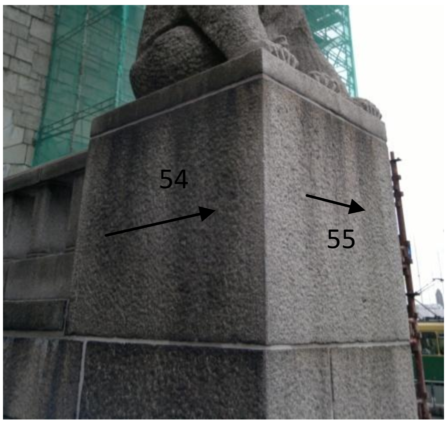

Figure 83 Basement blocks had been measured and numbered 54 and 55.

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As a conclusion it could be seen that the results have been heterogeneous probably because of the heterogeneity of the material. Also the surface finishing could have influenced the results but the measurements performed over the bush hammered blocks have shown similar heterogeneity, thus the surface finishing is not probably the main reason for the changes of velocities. Values have been oscillating between 2800 and 3200 m/s. Blocks that presented surface weathering have shown in some cases changes in speed:

- cracks have blocked or lowered the speed;
- metal depositions have either not altered the speed or, if their thickness and penetration has been significant, have increase the speed, as for block 41;
- black crust has shown higher speed

Some blocks have shown much lower values but it has not been possible to recognize a visible physical cause.

Schmidt hammer

The Schmidt Hammer has been used perpendicular to the surface to be tested, according to the methodology described in "Methods Schmidt Hammer". The blocks tested are shown in Figures 84, 85, 86. Blocks numbered and blocks from which had been collected the drill cores (not shown in the pictures) have been tested.

Figure 84 Schmidt hammer testing blocks on the basement facing South.

Figure 85 Schmidt hammer on blocks bush hammered facing East

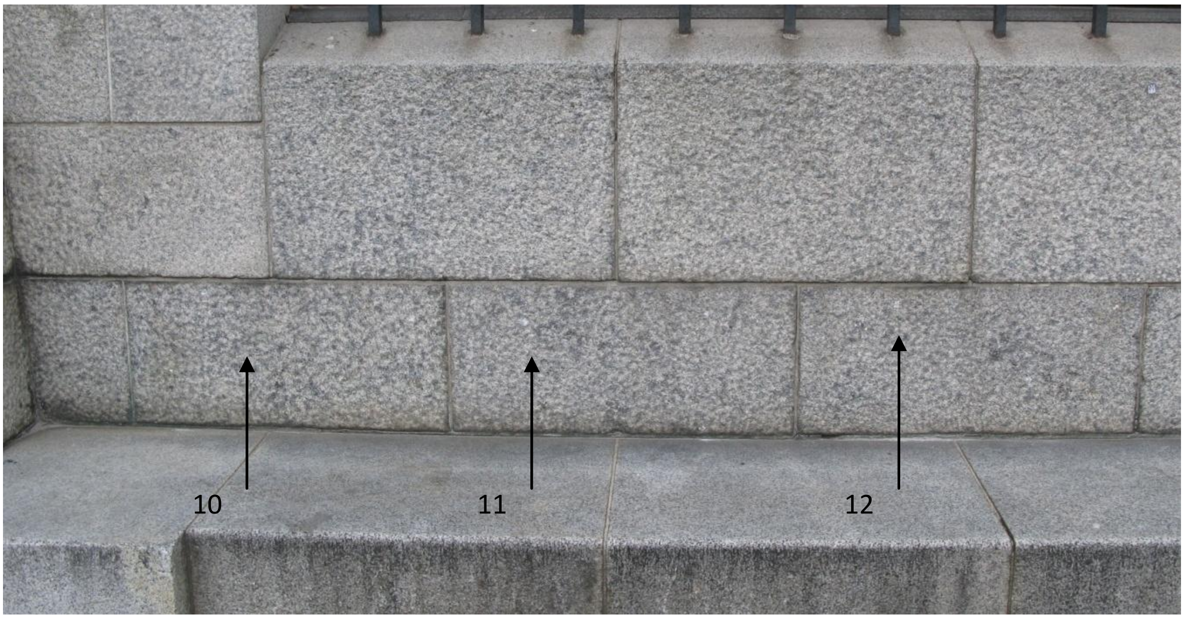

Figure 86 Schmidt hammer on blocks bush hammered facing East, near the entrance stairs.

In Table 1 and 2 are shown the results of Schmidt rebound test of the measurement performed over the blocks.

Table 1. Results from the measurements performed

Block number	1	2	3	4	5	6	7	8	9	10	11	12
Impact readings	58	25	48	45	42	32	32	49	51	42	38	44
	58	50	58	48	49	47	44	48	58	49	56	42
	64	54	60	50	56	42	22	54	64	51	54	45
	50	40	53	38	47	48	43	40	34	45	42	48
	50	58	54	62	52	51	31	34	60	58	55	56
	60	58	53	60	58	54	56	55	60	44	52	58
	48	48	38	42	45	41	41	41	53	41	49	40
	54	32	60	54	52	50	48	42	57	49	50	49
	56	60	54	63	58	43	40	56	58	41	54	49
	50	50	42	43	46	43	42	30	60	37	34	35
	50	58	42	56	53	39	50	53	59	50	44	42
	58	58	58	58	40	56	50	56	62	48	50	52

In light blue on block n1 is shown a part of the block covered with a white crust. In green over block n.8 is a part that is affected by a green biofilm, while the grey one is affected by black crust. The yellow points in block n 9 represent a material that had shown a change in color, towards yellow, as seen in the chapter relative to weathering effects. It is visible that the values measured over the white crust in block n.1 didn't differ from the average value of the block, that had shown an average value even higher than others on the same exposition and same façade. The first two values of this block could have shown that the surface is softer, and after have broken the surface, the bottom part is harder. Measurements over the biofilm in block 8 (average 50) has been a bit higher compared to the mean value of the block, and the black crust on same block (average 43) has shown to be a bit lower compared to the average, 47. Block 9 that presented yellow color, showed a bit lower values of rebound in correspondence of the colored areas but its final average has been the highest of all the blocks.

Table 2. Results from the measurements performed over the blocks sampled

	Uusikaupunki granite			Red granite	
Block number	Kansallismuseo 1 HAP$-2013-35.1-2	Kansallismuseo 2 HAP$-2013-31.3	Kansallismuseo 3 HAP$-2013-36.3	Kansallismuseo 4 HAP$-2013-34	Kansallismuseo 6 HAP$-2013-32.1-2
Impact readings	50	37	52	42	52
	40	52	49	48	60
	54	54	46	50	58
	58	44	44	35	48
	54	37	48	48	53
	54	39	56	45	48
	48	44	42	26	38
	50	36	58	42	52
	54	44	53	53	54
	38	50	50	41	38
	36	59	53	50	48
	60	51	42	53	50

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Schmidt hammer has been performed also on the red granite in the entrance to the Inner Yard A as visible from Figure 87 and 88. The results are shown in Table 3.

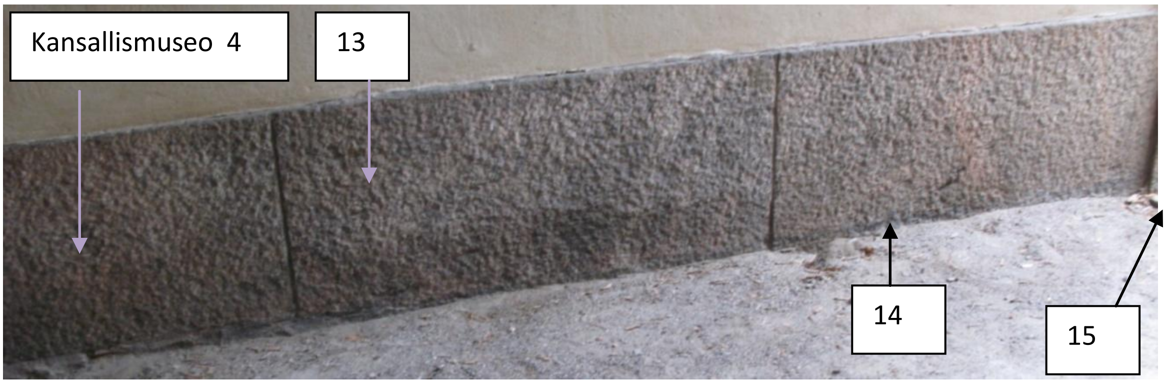

Figure 87 Left side entrance basement to Inner Yard A

Figure 88 Right side entrance basement to Inner Yard A.

Table 3. Schmidt rebound values for the red granite in the entrance to inner yard A.

Block number	13	14	15	16	17	18
Impact readings	57	38	38	51	47	58
	58	36	46	51	55	45
	64	43	33	51	49	45
	50	42	54	39	40	35
	55	52	60	48	42	46
	55	56	64	38	56	49
	52	50	44	37	47	35
	58	52	43	47	46	44
	57	54	57	47	58	45
	48	44		50	51	39
	55	59		59	46	48
	61	58		53	58	46

In grey on specimen n.18 it is shown a tested part over a black crust

In the diagram of Figure 89 are shown the average rebound values for each block for Uusikaupunki granite

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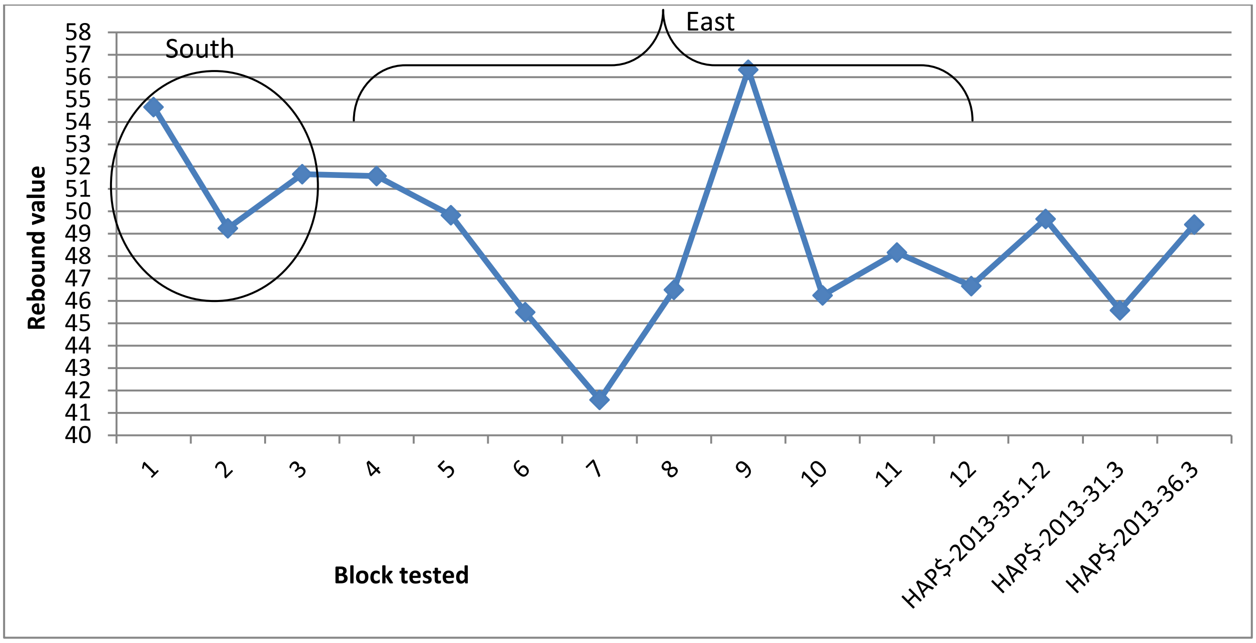

Figure 89. Diagram showing the average rebound for each block of Uusikaupunki granite tested.

The block number 7 has shown the lowest values even if has not shown visual differences compared to other blocks, while block n 9, that presented yellow vein, showed highest values. Blocks 1,2,3 had been measured from the façade facing South, while blocks 4-12 on that facing East. The blocks facing East, bush hammered, are showing change of color, also block n.7 and block n 5 even if the impacting point has not been straight over a yellow area.

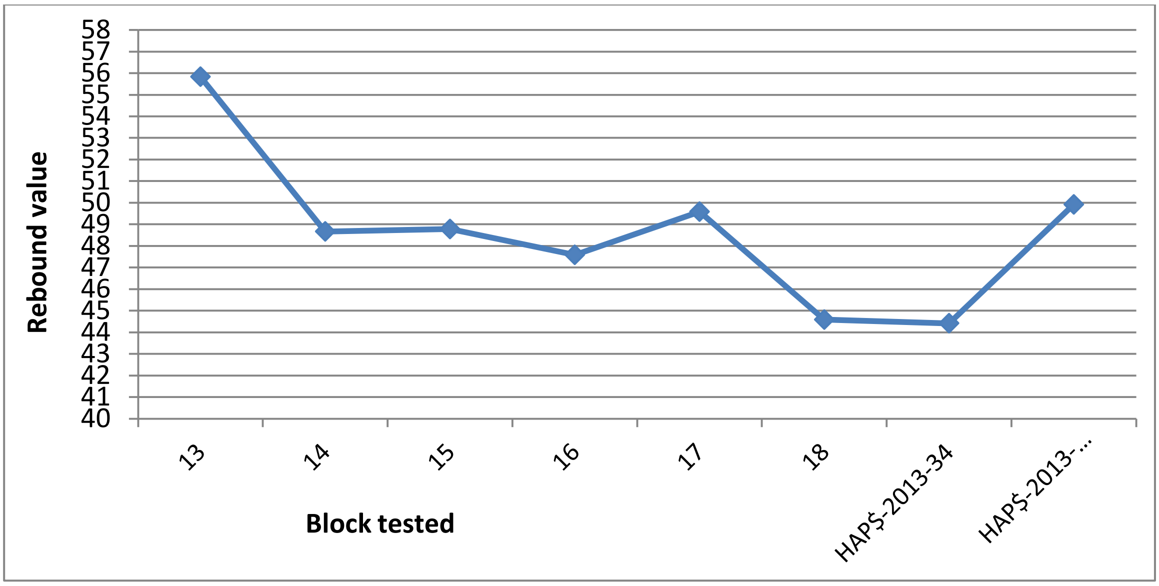

Figure 90.Diagram showing the average rebound for each block of red granite tested from the entrance of Inner Yard A.

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The values are heterogeneous but also the material itself has not been homogeneous. Some blocks show a much lower value, and one of them, block n.18, had been tested over dust deposition or black crust that has lowered the value of rebound. Other instead, as block 13 shows a very high rebound value, indicating that the material has higher surface strength compared to the others, or it is a different material, having more hard minerals compared to the other blocks.

Thermal camera

The measurements have been performed in an evening, not in direct sun, in a cloudy and rainy day. Temperature has been higher in the corners, as also seen in other buildings, it can be seen for example from figure 91.

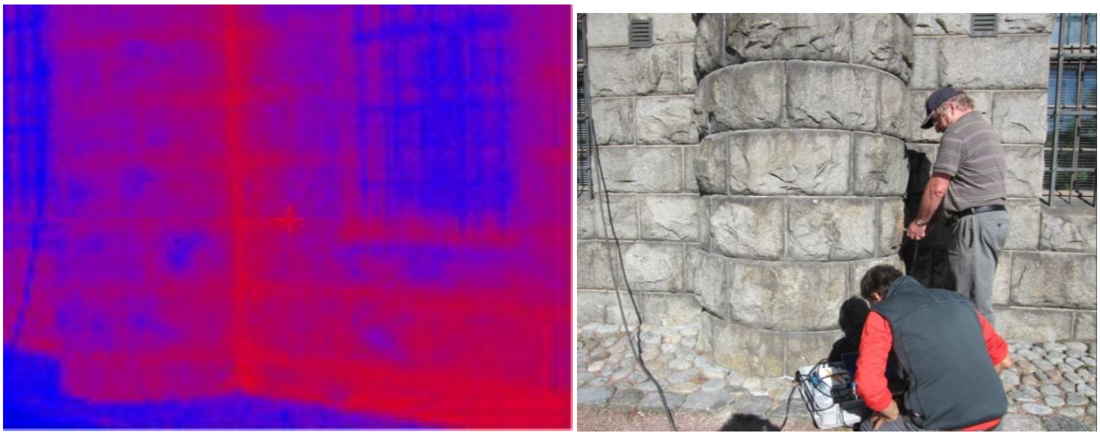

Figure 91 Corner of the semicircular tower facing West

The lower part of the basement has also been showing higher temperatures compared to higher parts as visible from figure 92 and a possible reason is the differences of construction of the walls or different use of the floors.

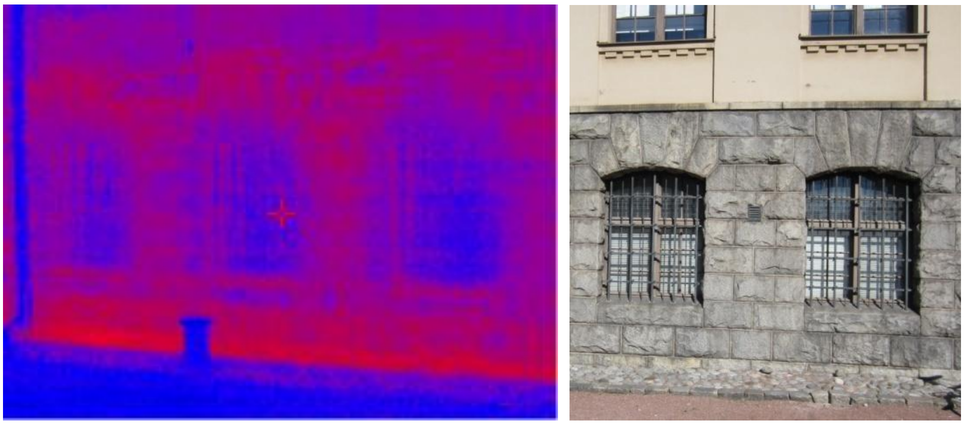

Figure 92. Basement facing West

The basement of the bear statue has also been photographed with the thermal camera, as visible from Figure 93 and it is visible that the basement is warmer than the stairs and along the stairs the parts more exposed to the wind looks colder.

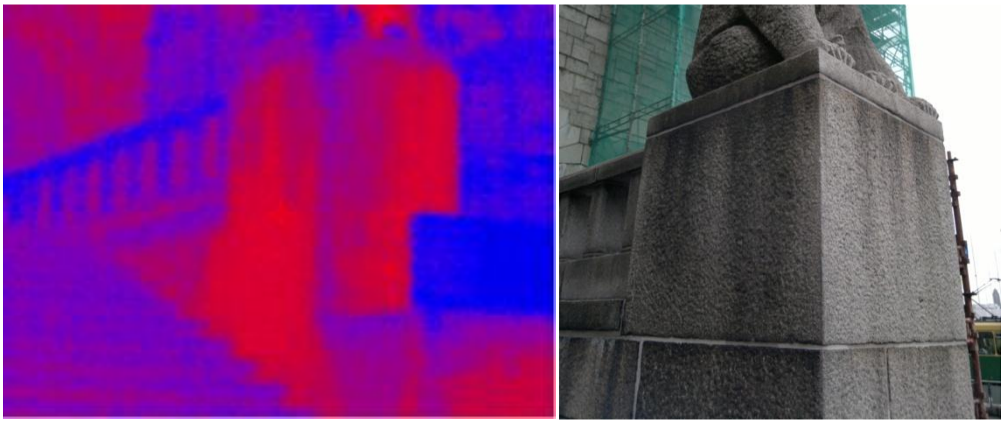

Figure 93 Basement of the bear statue near the entrance

In the yard of the building one interesting picture of mosses and higher plants was taken.

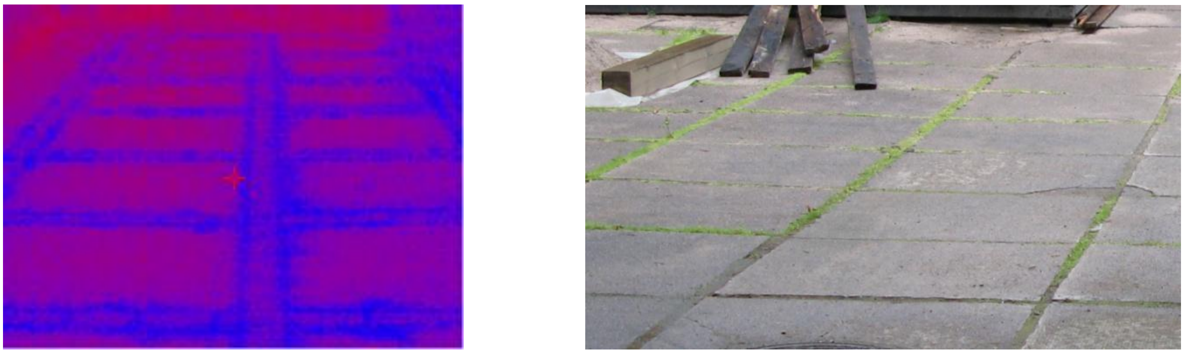

Figure 94 Mosses and higher plants over internal yard paving.

Vegetation appears as a colder part on the image. Depending on weather conditions and on kind of organism colonizing the material it could appear both colder and warmer compared to the stone. Probably it depends on its kind of vegetation, on the amounts of sunlight and on the difference between temperature of surface and air.

Mechanical and physical properties

Water absorption, apparent density and open porosity had been performed on 1 sample: the top and bottom of the drill core HAP$-2013-34 that is a red granite and its results are shown in Table 5 and 6.

Table 5. Water absorption of the sample

	DRY WEIGHT (g)	WET (g)	Water absorption (%)
HAP$-2013-34T	46.09	46.14	0.11
HAP$-2013-34B	47.04	47.07	0.06

Table 6. Results of density and open porosity.

	DRY WEIGHT (g)	UNDER WATER (g)	SATURATED WEIGHT (g)	Apparent density (kg/m3)	Open porosity (%)
HAP$-2013-34T	46.11	28.8	46.16	2651	0.29
HAP$-2013-34B	47.05	29.46	47.09	2663	0.23

The top part shows a higher open porosity and slightly lower apparent density demonstrating that there could had been a weathering of the surface compared to the bottom, but the eater absorption had been slightly lower. In Conclusion, relative to the physical tests, can be told that possible differences between the top and bottom should be considered caused by material heterogeneity more than surface weathering, also considering that the red granite had been in a protected area and does not present visual weathering effects.

REFERENCES

/1/ Official web pages of the National Board of Antiquities.
http://www.nba.fi/en/nationalmuseum/history_of_museum_and_building

/2/World weathered and climated information. Weather in Helsinki, Finland. Available online: http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,Helsinki,Finland

/3/ Suominen, Veli; Fagerström, Pia; Torssonen, Markus 2006. Uudenkaupungin kartta-alueen kallioperä. Summary: Pre-Quaternary rocks of the Uusikaupunki map-sheet area. Kallioperäkartan selitys 1 : 100 000, 1131. 59 p., 5 apps ISBN 951-690-912-4

Annex 1

Chemical compositions

			L14036790	L14036791
			HAP$-2013-32.12	HAP$-2013-35.12
Na2O	%	+ 175X	2.88	5.18
MgO	%	+ 175X	0.398	0.78
Al2O3	%	+ 175X	14	16.7
SiO2	%	+ 175X	74.8	69.9
P2O5	%	+ 175X	0.055	0.078
K2O	%	+ 175X	4.94	2.08
CaO	%	+ 175X	1.11	2.37
TiO2	%	+ 175X	0.101	0.3471
MnO	%	+ 175X	0.014	0.022
Fe2O3	%	+ 175X	1.5	2.33
S	%	+ 175X	<0.006	<0.006
Cl	%	+ 175X	0.0131	0.0086
Sc	%	+ 175X	<0.002	<0.002
V	%	+ 175X	<0.003	0.003
Cr	%	+ 175X	<0.002	<0.002
Ni	%	+ 175X	<0.002	<0.002
Cu	%	+ 175X	<0.002	<0.002
Zn	%	+ 175X	0.0033	0.0052
Ga	%	+ 175X	<0.002	0.0023
As	%	+ 175X	<0.002	<0.002
Rb	%	+ 175X	0.0129	0.0041
Sr	%	+ 175X	0.0145	0.065
Y	%	+ 175X	0.0017	0.0012
Zr	%	+ 175X	0.0091	0.0135
Nb	%	+ 175X	<0.0007	<0.0007
Mo	%	+ 175X	<0.001	<0.001
Sn	%	+ 175X	<0.002	<0.002
Sb	%	+ 175X	<0.01	<0.01
Ba	%	+ 175X	0.0891	0.0366
La	%	+ 175X	<0.003	<0.003
Ce	%	+ 175X	0.0047	0.003
Pb	%	+ 175X	<0.002	<0.002
Bi	%	+ 175X	<0.003	<0.003
Th	%	+ 175X	0.0019	<0.001
U	%	+ 175X	<0.001	<0.001
Ag	mg/kg	511M	0.0239	0.0476
As	mg/kg	511M	1.128	1.108
Be	mg/kg	511M	0.0858	0.1063
Bi	mg/kg	511M	0.0285	0.0402
Cd	mg/kg	511M	0.0212	0.0364
Ce	mg/kg	511M	72.59	22.69
In	mg/kg	511M	<0.02	<0.02
Mo	mg/kg	511M	0.1561	0.1969
Pb	mg/kg	511M	5.198	2.859
Sb	mg/kg	511M	<0.03	<0.03
Se	mg/kg	511M	1.016	0.2808
Te	mg/kg	511M	0.0061	<0.006
Th	mg/kg	511M	24.11	3.355

U	mg/kg	511M	2.94	1.345
W	mg/kg	511M	<0.05	<0.05
Yb	mg/kg	511M	0.1667	0.2217
Al	mg/kg	+ 511P	6120	9990
B	mg/kg	+ 511P	<5	<5
Ba	mg/kg	+ 511P	52.3	79.7
Ca	mg/kg	+ 511P	1540	2080
Co	mg/kg	+ 511P	1.23	4.22
Cr	mg/kg	+ 511P	2.07	6.66
Cu	mg/kg	+ 511P	2.61	2.98
Fe	mg/kg	+ 511P	10100	16600
K	mg/kg	+ 511P	3160	6450
La	mg/kg	+ 511P	37.2	13.8
Li	mg/kg	+ 511P	9.06	49
Mg	mg/kg	+ 511P	2190	4570
Mn	mg/kg	+ 511P	118	235
Na	mg/kg	+ 511P	840	1300
Ni	mg/kg	+ 511P	<2	2.78
P	mg/kg	+ 511P	91.4	307
S	mg/kg	+ 511P	<20	<20
Sc	mg/kg	+ 511P	1.77	3.08
Sr	mg/kg	+ 511P	9.15	21
Ti	mg/kg	+ 511P	338	1580
V	mg/kg	+ 511P	5.07	21.9
Y	mg/kg	+ 511P	6.1	3.18
Zn	mg/kg	+ 511P	27.8	46.1

URHO KEKKONEN MUSEUM - TAMMINIEMI

Documentation and research methods

Information had been collected from NBA site (1), research works and articles (2/3). The house had been owned by Amos Anderson who donated to the Finnish state in 1940. It had been used as an official residence by the Finnish presidents Ryti, Mannerheim, Kekkonen until 1981. Since 1987 has been a museum showing the house and uses of the presidents mainly from the 70's. Within 2009-2012 it has been renovated.

Description of the building

Name of building	Urho Kekkosen Museo - Tamminiemi
Architect	Sigurd Frosterus and Gustaf Strengell
Address	Seurasaarentie 15, 00250 Helsinki
Built (year)	1904

The building has been built as a summer residence and is a nice example of Jugend style architecture. Its shape is balanced, never massif, with stairs, terraces and openings of different shapes and dimensions that create an harmonic complex from outside and interesting environment from inside. Some views are shown in Figure 1, 2 and 3.

Figure 1 On the left, view from the park (West), opposite to the see view. On the right the view from the sea side. Photo: N.Luodes, GTK.

The side of the building facing the see present a bow-window that allow to enjoy the see panoramic view, over which opens a terrace.

Figure 2. Views from the South side of the building (Photo: N.Luodes, GTK)

Even secondary entrances are enhanced with arches and patios, to light up the façade. Small bow-window is also breaking a squared shape and giving more light to internal rooms.

Figure 3. Particulars of the windows on the basement and of the water drein. (Photo: N.Luodes, GTK)

Characterization of the environment

The area where the building is located is far away from direct traffic of the Helsinki metropolitan area. It is near the sea and affected by its climate and winds.

Local environment (architecture etc.)

The building is open to the sea on its East side, while is facing a park from the West where it is located over a hill. It has nearby vegetation but cannot be told that it is protected by it, since it has quite large breathing space.

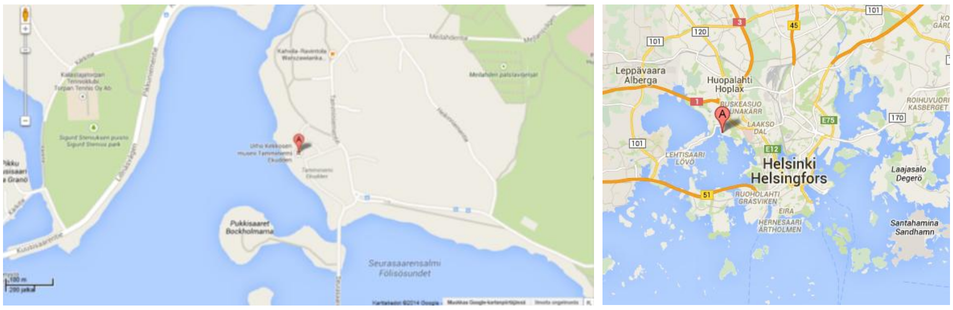

Figure 4. Map of the building (www.maps.google.fi)

Climatic conditions, microclimate, etc.

The environment is a sea environment, characterized by wind and high humidity mainly given by the surrounding waters than by precipitations. The bay is anyway a bit protected from open sea as visible from Figure 4.

Photographic documentation

The site has been documented photographically in detail by Gigapan photos, normal camera photos of the complex and of the architectonic elements and finally by high definition photos of the samples. The processes of sampling and testing have also been recorded.

Gigapan photos

One gigapan photo has been collected from the north and it is visible at full dimension from www.gigapan.com Photos have been taken by J.Toivanen. In Figure 5 are shown a map and a normal camera view of the side photographed by Gigapan.

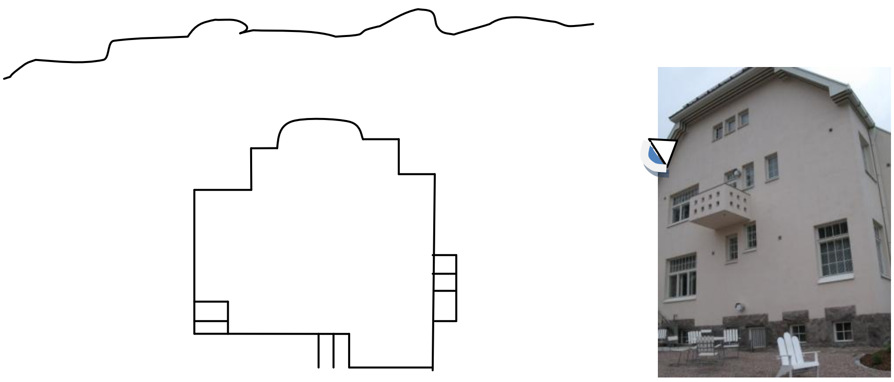

Figure 5. Map of the house showing the point from which had been photographed in high definition (on the left), normal photo of the facade (on the right)

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Visual inspection

No detailed mapping had been done for this building also because the stone area had interested mainly the basement, and had not shown big problems. Only in one point had been noticed deposition of metals over stone surface (Figure 6) probably caused by previous metal fence.

Figure 6. Metal/rustiness deposition over the blocks, probably in correspondence of previous metal fence. (Photo: N.Luodes, GTK)

Samples

Samples from the basement have been taken and are visible in figure 7 and 8.

Sampling methods

Sampling has been performed in 2013. Cores have diameter of 20 mm with depth reaching few cm.

Sampling locations

Description of the environment

The samples have been taken on two blocks. The material looks homogeneous and clean.

Location of the sampling sites

On the maps (Figure 7) is possible to schematise the sampling areas (Figure 8).

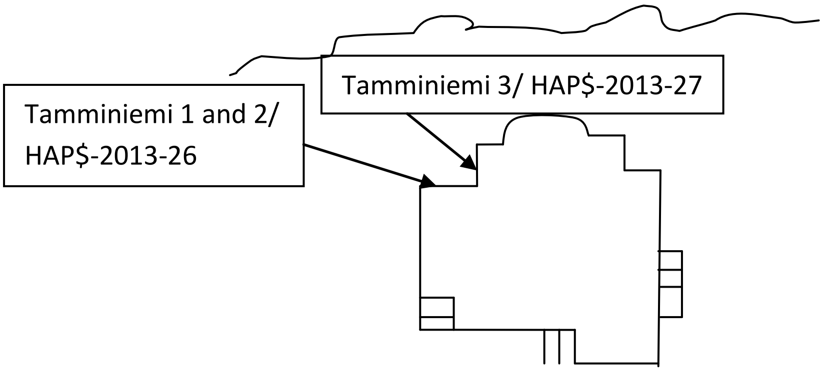

Figure 7 Map of the area sampled and samples codes on the left, view of the side from which had been collected on the right.

Figure 8 Positions and detail of the sampling points. Two samples had been collected from the same block and one from a different block, even if the material looked quite homogeneus.

Sample types

All the samples had been used for further testing.

Thin sections: HAP$-2013- 26.3 has been used for petrographic analysis.

Chemical analyses: Drill cores. Chemical analysis has been performed on HAP$-2013-26.1-2, as a full sample.

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Surface samples: no other surface samples have been collected from the site.

Mechanical and physical tests: In October 2013 have been performed water absorption, density and open porosity and for it have been used the sample HAP$-2013-27.

Photos of Samples

Normal photos

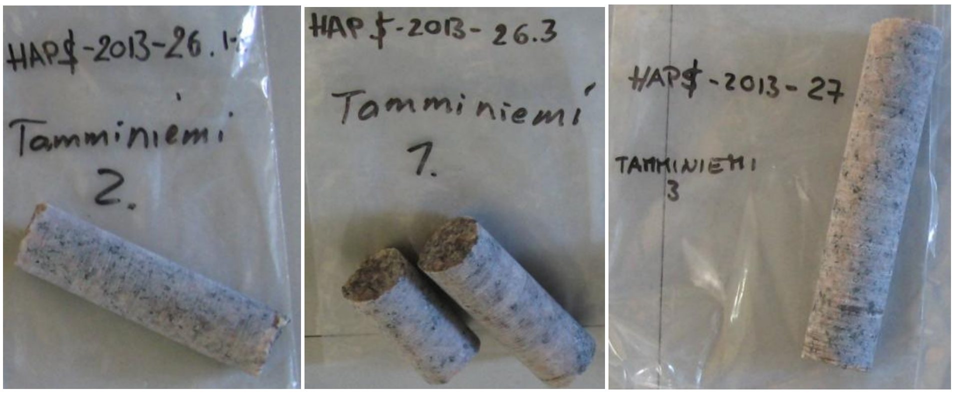

Figure 9 Normal photo of the specimen from the building sampled in 2013 (From the left: HAP$-2013-26.1-2; HAP$-2013-26.3; HAP$-2013-27) .(Photo: N.Luodes)

Stacking photos

In Figures 10-11 are shown the samples.

Figure 10 Samples HAP$ -2013-26.1-2, HAP$ -2013-26.3 to HAP$ -2013-27, from left to right, weathered surface. (Photo by J. Ranua GTK)

Figure 11 Samples HAP$ -2013-26.1-2, HAP$ -2013-26.3 to HAP$ -2013-27 from left to right, unweathered surface (Photo by J. Ranua GTK)

The high definition pictures allow to zoom and see in detail the surface of the material as visible from Figure 12.

Figure 12 Detail of the weathered surface of the sample HAP$ -2013-26.1-2 showing dust deposition and iron oxidation (up-right). (Photo by J. Ranua GTK)

Petrographic and chemical properties

Results of chemical analysis

Chemical elements of the material are shown in the following graph and as numerical table in Annex 1

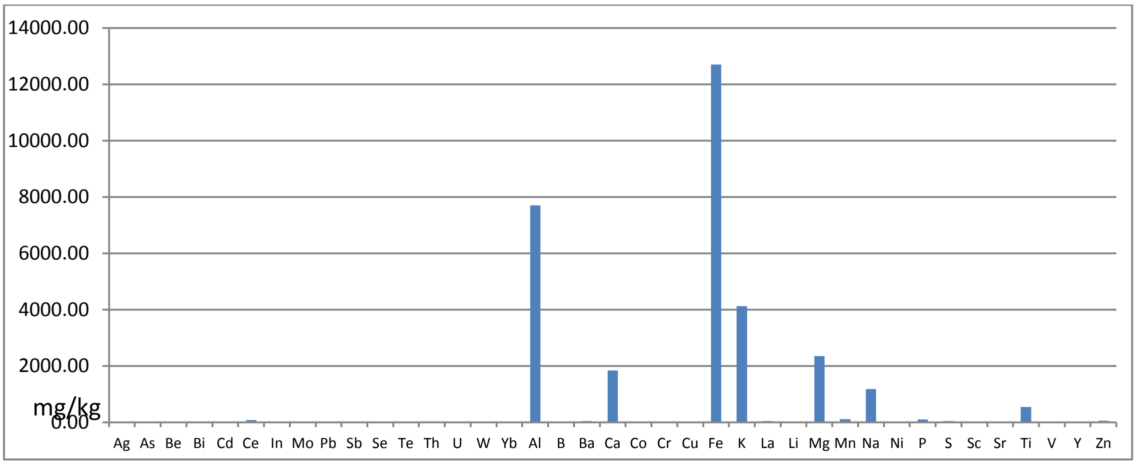

Figure 13. Chemical composition of the sample material as a whole sample.

Analysing the component percentages are visible the main elements (Figure 14), typical of a granitic material.

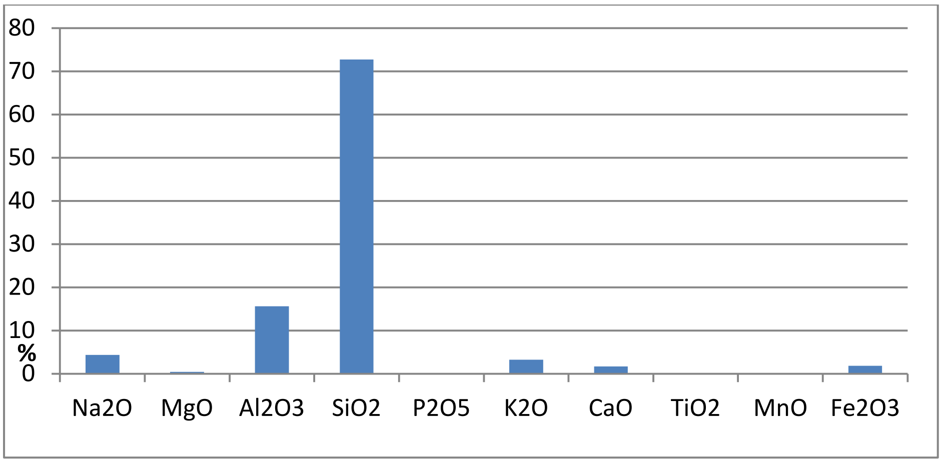

Figure 14. Percentages of the oxides

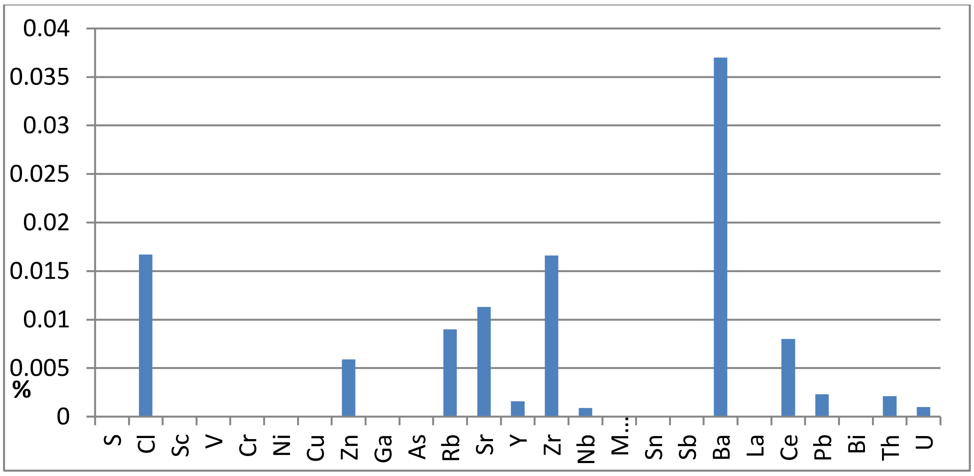

Figure 15 Percentages of the elements

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From the analysis done the material shows a typical composition with no weathering active process.

Non-destructive research methods

Non destructive research methods have included Ground penetrating radar and Schmidt hammer hardness test performed by the Geological Survey of Finland. Ultra Pulse velocity on specific blocks has been performed in cooperation with the Polytechnic of Turin-Italy while thermal camera measurements have been performed in cooperation with Mikkeli University of Applied sciences.

Ground penetrating radar

Measurements have been performed on a flower pot, on the side of the stairs and over the wall as shown in Figure 16.

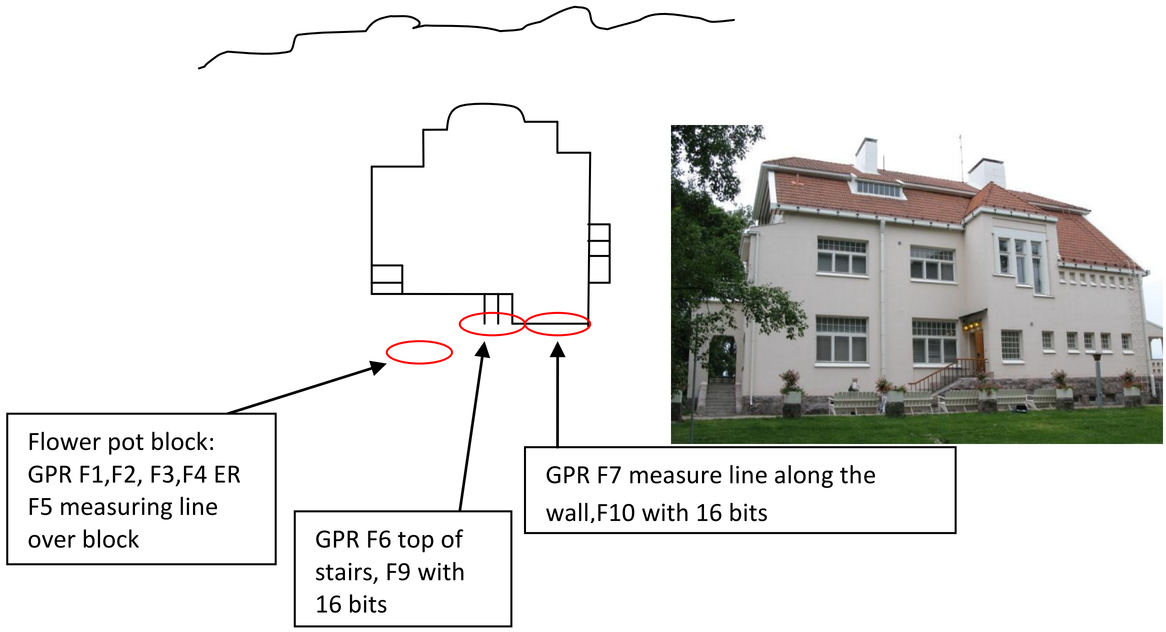

Figure 16. Map of the measurements performed and photo.

The first measurement had been performed over a flower pot to check the accuracy of the instrument over a similar material to the one used on the basement. The antennae had been placed over the outer side of the blocks and carried slowly at constant velocity.

The flower pot had been showing surface weathering but the accuracy of the GPR is able mainly to detect structural anomalies more than material chemical changes. Here are shown the results got from a measurement performed over the stair (Figure 17)

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Figure 17. GPR measurements performed over the stairs.

There is presence of anomalies visible as reflections. Those coming to surface are given by mortar joints, the strong ones deeper are given by the lower and side surface of the blocks. Following are the elaborated images of the radargram collected.

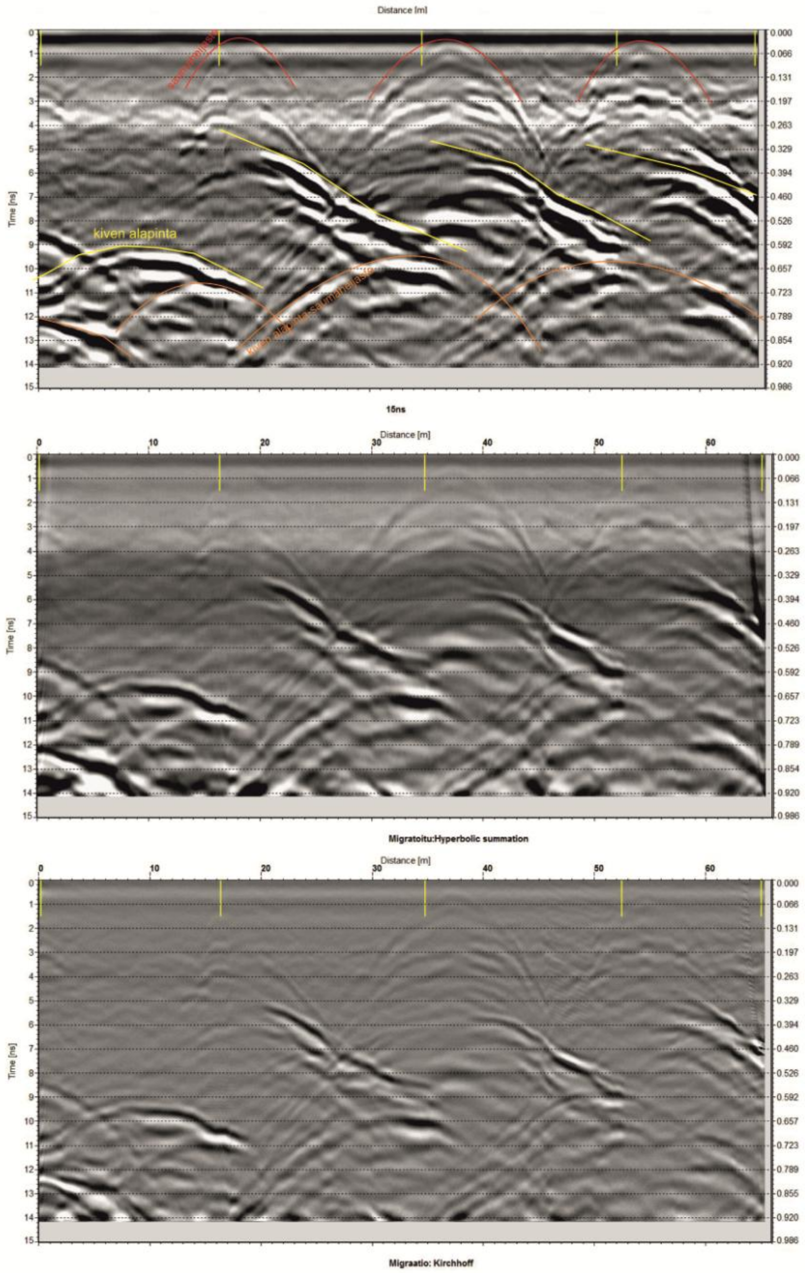

Figure 18. Analysis of the radargram measurements (in yellow: reflection given by block's lower face, in red: reflection given by mortar joints, in orange: reflections given by mortar joints of the lower surface of the blocks)

From the analysis done over the wall the material does not present fractures. GPR technique had been able to identify the changes in thickness of the wall, thicker in the first part of the wall and thinner, as multi-layer wall, in correspondence of the room underground (visible in detail in Figure 19).

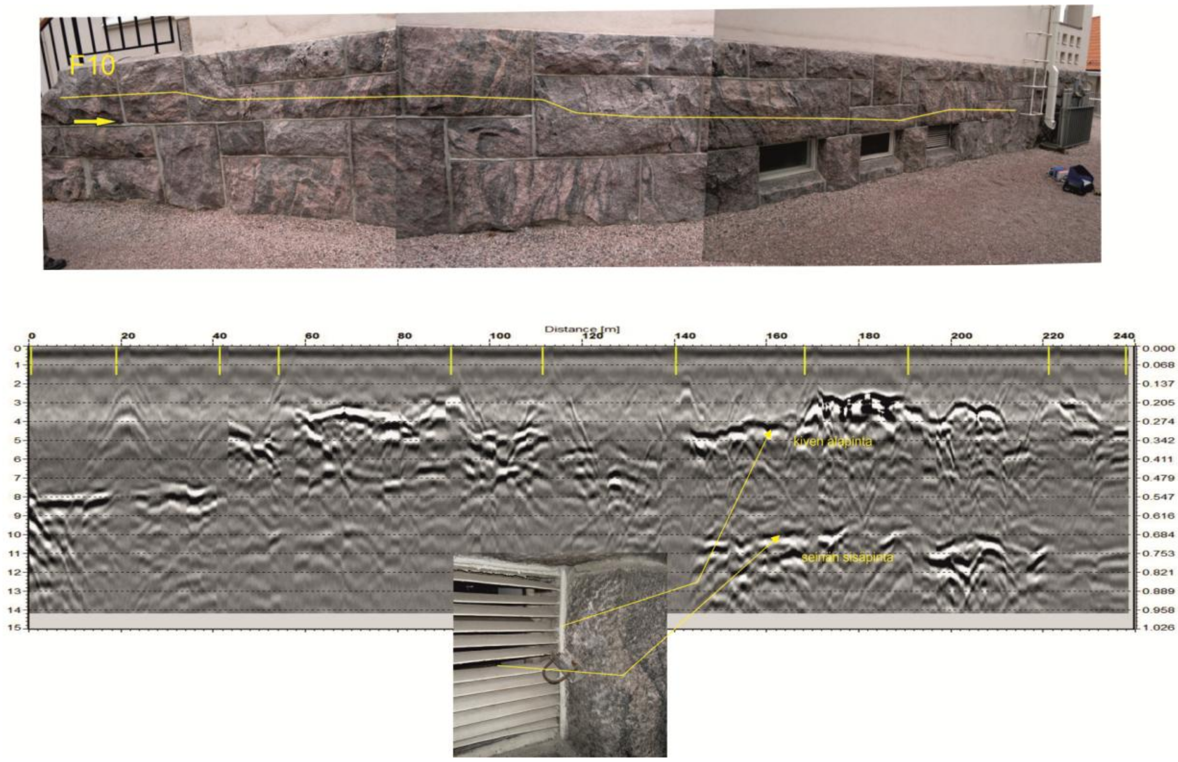

Figure 19. On the top are shown the positions of the GPR measurements collected over the wall, F10, on the bottom is shown the radargram collected along the measuring line.(In yellow are shown: Kiven alapinta: stone's lower surface, Seinän sisäpinta: wall's internal surface).

Ultrasonic measurements (UPV)

Totally 6 measurements have been done over the side of the stair in Tamminiemi, same area where also GPR had been performed. The ultra pulse velocity had been evaluated with indirect way according to the report "Methodology UPV".

Figure 20. Positions of the measurements performed over the stairs on Tamminiemi. (Photo: N.Luodes)

The results have been showing a very compact material, not affected by weathering, with high speed and linear graphics, even if the material had been presenting irregular surface and visible veins. The diagrams of the velocities for the 6 measurements are shown in the graphic of Figure 21.

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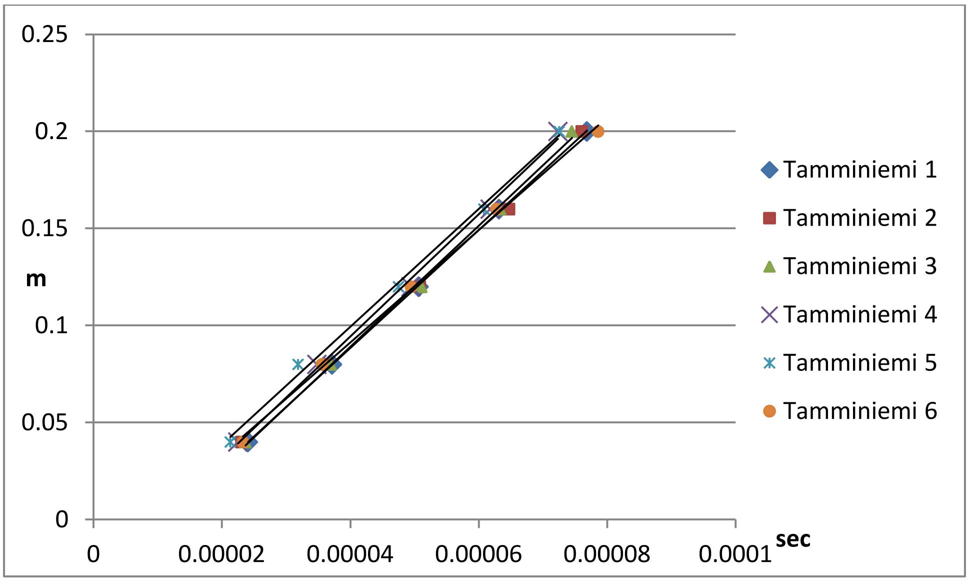

Figure 21. Graphic of the measurements performed

Schmidt hammer

The Schmidt Hammer has been used perpendicular to the surface to be tested, according to the methodology described in “Methods Schmidt Hammer” and has been performed on the same blocks that had been sampled. The results are visible in Table 1.

Table 1. Results of Schmidt hammer test

	HAP$-2013-26	HAP$-2013-27	On a more red block on the left of HAP$-2013-27
Rebound values	56	46	40
	55	55	56
	51	58	53
	36	47	33
	44	42	49
	53	46	62
	41	51	42
	58	53	46
	58	50	58
	48	47	56
	49	52	56
	58	49	36

The results show homogeneous characteristics of the material, that is compact and hard, as also seen from the UPV results.

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Thermal camera

The measurements have been performed during a partially cloudy day, has been noticed mainly the wet areas: the contact area of the basement to the ground (Figure 22, and Figure 23), differences in temperature between the mortar joints and the stone blocks (Figure 23), moisture areas in correspondence of the drain pipes (Figure 24).

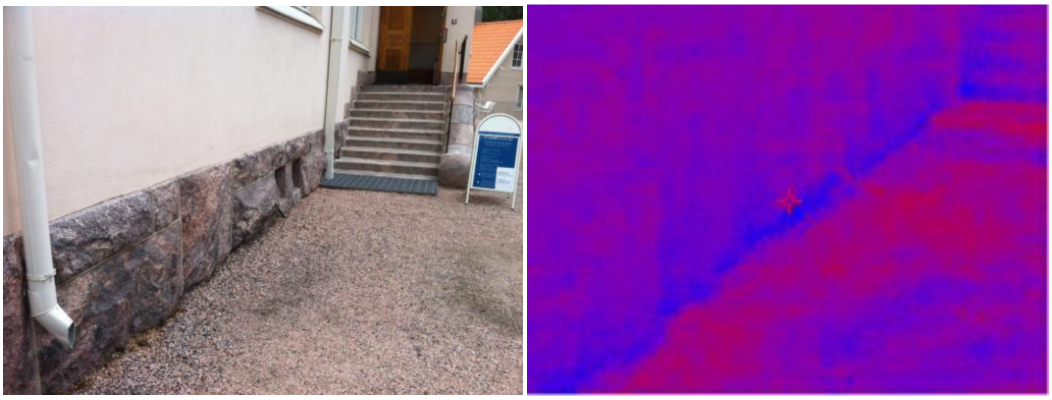

Figure 22 Contact area between the basement and ground (Photo: A. Shkurin)

Figure 23 Contact area between the basement and the ground as colder, while as warmer the mortar compared to the stone material (Photo. A Shkurin)

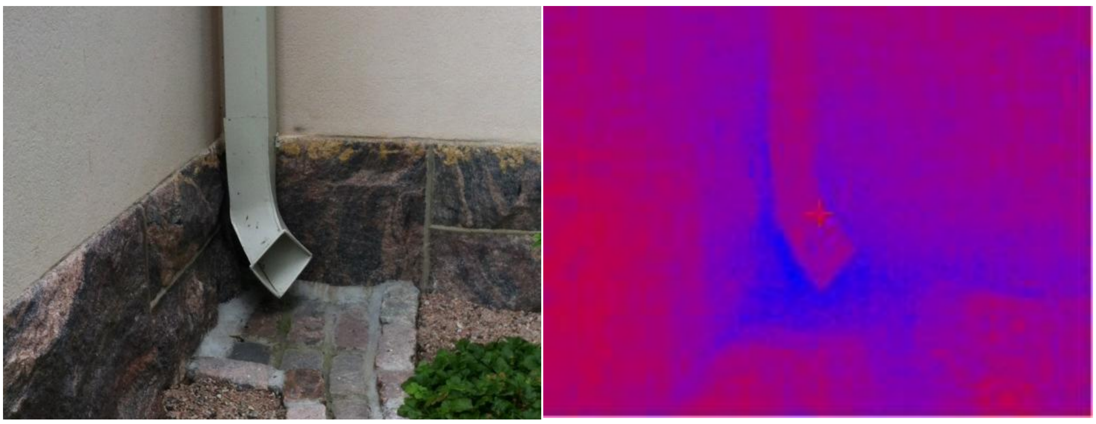

Figure 24 Moisture areas in the corner in correspondence of the drain pipes (Photo. A Shkurin)

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Mechanical and physical properties

Water absorption, Density and Open porosity (and water absorption)
Density and open porosity had been tested over one drill core and the results are shown in Table 2 the material shows a higher porosity in the bottom part of the sample as well a lower density, while it is showing a lower water absorption (Table 3)

Table 2 results of density and open porosity.

	DRY WEIGHT (g)	UNDER WATER (g)	SATURATED WEIGHT (g)	Apparent density (kg/m3)	Open porosity (%)
tamminiemi HAP$-2013-27 T	39.35	24.68	39.37	2673	0.14
tamminiemi HAP$-2013-27B	48.55	30.42	48.58	2668	0.17

One sample had been tested for water absorption and the results are shown in Table3

Table 3. Results of water absorption (T= Top, B=Bottom)

	DRY WEIGHT (g)	SATURATED WEIGHT (g)	Water absorption (%)
tamminiemi HAP$-2013-27 T	39.32	39.37	0.13
tamminiemi HAP$-2013-27B	48.52	48.58	0.12

The results show that the material is hard and compact and natural deviations could have been the reason for the differences between top and bottom part, the material in fact presents veins.

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http://www.kemia-lehti.fi/wp-content/uploads/2013/02/kem612_tamminiemi.pdf

3/ Meilahden huvila-alue ympäristöhistoriallinen selvitys - Luonnos 6.3.2013 - Maisemasuunnittelu Hemgård - Kati Salonen ja Mona Schalin Arkkitehdit Oy 2013
http://www.hel.fi/hel2/ksv/Aineistot/meilahti/Meilahti_YHS_LUONNOS_osa4.PDF

Annex 1 HAP$-2013-26.12

Na2O	%	+ 175X	4.34
MgO	%	+ 175X	0.413
Al2O3	%	+ 175X	15.6
SiO2	%	+ 175X	72.7
P2O5	%	+ 175X	0.055
K2O	%	+ 175X	3.19
CaO	%	+ 175X	1.69
TiO2	%	+ 175X	0.144
MnO	%	+ 175X	0.009
Fe2O3	%	+ 175X	1.78
S	%	+ 175X	<0.006
Cl	%	+ 175X	0.0167
Sc	%	+ 175X	<0.002
V	%	+ 175X	<0.003
Cr	%	+ 175X	<0.002
Ni	%	+ 175X	<0.002
Cu	%	+ 175X	<0.002
Zn	%	+ 175X	0.0059
Ga	%	+ 175X	<0.002
As	%	+ 175X	<0.002
Rb	%	+ 175X	0.009
Sr	%	+ 175X	0.0113
Y	%	+ 175X	0.0016
Zr	%	+ 175X	0.0166
Nb	%	+ 175X	0.0009
Mo	%	+ 175X	<0.001
Sn	%	+ 175X	<0.002
Sb	%	+ 175X	<0.01
Ba	%	+ 175X	0.037
La	%	+ 175X	<0.003
Ce	%	+ 175X	0.008
Pb	%	+ 175X	0.0023
Bi	%	+ 175X	<0.003
Th	%	+ 175X	0.0021
U	%	+ 175X	0.001

Ag	mg/kg	511M	0.0396
As	mg/kg	511M	2.159
Be	mg/kg	511M	0.1017
Bi	mg/kg	511M	0.072
Cd	mg/kg	511M	0.0503
Ce	mg/kg	511M	74.27
In	mg/kg	511M	0.0219
Mo	mg/kg	511M	0.1574
Pb	mg/kg	511M	8.659
Sb	mg/kg	511M	0.0587
Se	mg/kg	511M	1.337
Te	mg/kg	511M	0.0107
Th	mg/kg	511M	26.06
U	mg/kg	511M	7.84
W	mg/kg	511M	<0.05
Yb	mg/kg	511M	0.1912
Al	mg/kg	+ 511P	7700
B	mg/kg	+ 511P	6.06
Ba	mg/kg	+ 511P	42.2
Ca	mg/kg	+ 511P	1840
Co	mg/kg	+ 511P	1.44
Cr	mg/kg	+ 511P	3.3
Cu	mg/kg	+ 511P	4.36
Fe	mg/kg	+ 511P	12700
K	mg/kg	+ 511P	4120
La	mg/kg	+ 511P	37
Li	mg/kg	+ 511P	14.6
Mg	mg/kg	+ 511P	2350
Mn	mg/kg	+ 511P	112
Na	mg/kg	+ 511P	1180
Ni	mg/kg	+ 511P	2.07
P	mg/kg	+ 511P	97.2
S	mg/kg	+ 511P	39.8
Sc	mg/kg	+ 511P	1.7
Sr	mg/kg	+ 511P	7.87
Ti	mg/kg	+ 511P	546
V	mg/kg	+ 511P	5.69
Y	mg/kg	+ 511P	8.98
Zn	mg/kg	+ 511P	49.4

CYGNAEUS GALLERIA

Documentation and research methods

Source of information has been collected verbally during meeting and from available information from the National Board of antiquities web pages. /1,2,3/.

Description of the building

Number	
Name of building	Cygnaeus Gallery- Fredrik Cygnaeus' summer villa
Architect	J. W. Mieritz
Address	Kalliolinnantie 8 FI-00140 Helsinki
Built (year)	1869-70
Remark_built	
Modifications 1	1996 put mortar over the stone basement

The building is one of the few old wooden buildings built in the 19th century still admirable in Helsinki. It's position is shown in figure 1. It has been built by the architect J. W. Mieritz in the years 1869-70.The same architect had also been building other two houses in the same park. When the house of Cygneus had been constructed , there were no direct neighbors, except a wind mill and later a private house. The first block houses came in the '90s /3/

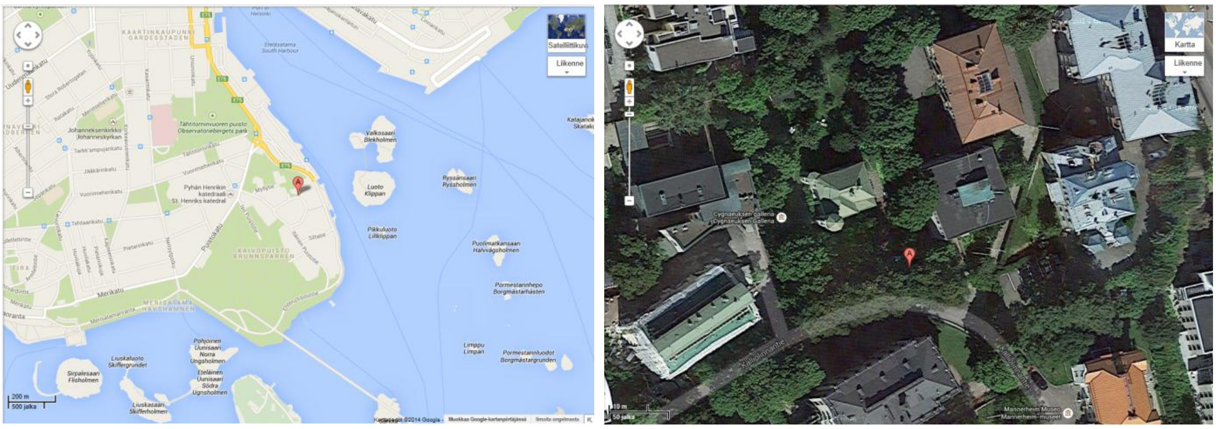

Figure 1. Map of the building (www.maps.google.fi)

The building is based directly over the bedrock as visible from Figure 2 and originally had a heated basement where the apartments of the house keeper, kitchen and entrances had been located. The upper floor, not heated and used

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as summer house, was dedicated to office, reading room (in the higher tower) and art exhibition of the owner, Cygnaeus. The interiors and the painting collected, were those that he liked, mainly romantic and dark common for the ‘800. /3/

Figure 2. Particular of the basement where it is visible that the blocks are laying over the bedrock (Photo: Nike Luodes, GTK).

Figure 3. A view from the South side of the building (Photo: N.Luodes)

The building had undergone several reconstructions mainly interesting the interiors, the wall insulation and the heating system. It presents two towers that are having a higher stone basement compared to the other walls, while the upper part is constructed in wood (Figure 3), the stone basement had been covered with mortar in 1996. There are several elements of this building that make it important from a cultural and architectural point of view. The basement part, of stone, is not the most relevant, compared to the upper wood level and the harmonic disposition of the volumes. In figure 4, 5 and 6 are shown the facades and some architectonic details.

Figure 4. View from the North side of the building on the left, and of the West side on the right.(Photo: N.Luodes)

Figure 5. Particulars of the windows (Photo: N.Luodes)

Figure 6. Particular of the semi-columns and capitels from the façade facing South, on the left, and of the entrance from the East side, on the right (Photo: N.Luodes)

Characterization of the environment

The area where the building is located is far away from direct traffic of the Helsinki metropolitan area, even being within the city centre. It is near the sea and affected by its climate and winds even if protected by surrounding vegetation.

Local environment (architecture etc.)

The building is located near the sea in the Kaivopuisto park, an area presenting several embassies and ambassador's residences. The house is separated from others by a garden area, partially covered by trees and it is considered a quiet area devoted to walking more than to car traffic.

Climatic conditions, microclimate, etc.

The environment is a sea environment, characterized by wind and high humidity mainly given by the surrounding waters than by precipitations. The Kaivopuisto seemed benefitting of cooling sea winds during summer heat, but also presenting cooler environment during winter, being immersed in a park /4/.Nevertheless other studies had found presence of isopods in the park area, showing that probably the area had been somehow presenting a "temperate microclimate". /5/

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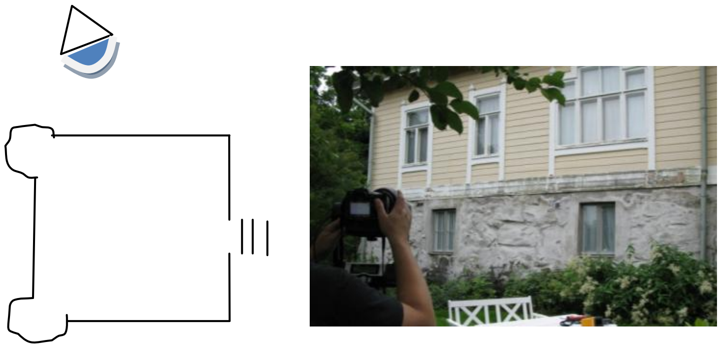
Photographic documentation

The site has been documented photographically in detail by Gigapan photos, normal camera photos of the complex and of the architectonic elements, of the deterioration problems and of the materials and finally by high definition photos of the samples. The processes of sampling and testing have also been recorded.

Gigapan photos

One gigapan photo has been collected and it is visible at full dimension from www.gigapan.com Photos have been taken by Joonas Toivanen.



Visual inspection

No detailed mapping of each construction had been done for this building. The blocks used for the construction of the building have been probably erratic blocks or blocks blasted and collected from the site. Different stone types and shapes form the basement of the building that has been covered by mortar and it is difficult to assess the weathering typologies of the stone material.

Samples

Samples from the basement of a tower have been taken in the part not covered by mortar.

Sampling methods

Sampling has been performed in 2013. Cores have diameter of 20 mm with depth reaching few cm.

Sampling locations

<u>*Description of the environment*</u>

The samples have been taken on two blocks that looked of similar material and on one of different material, trying to sample a more clean area and affected by biological activity.

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Location of the sampling sites

On the maps (Figure 7) is possible to schematise the sampling areas (Figure8).

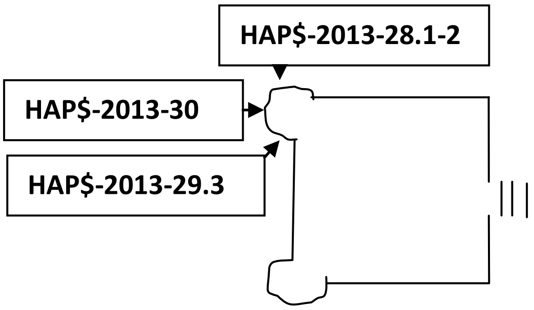

Figure 7 Map of the areas sampled and sample codes

The samples collected and the site from which had been collected as shown in figures 8,9.

Figure 8 Positions and detail of the sampling points. The rocks from which HAP$-2013-30 had been sampled had been tested with Schmidt hammer. (Photo: N.Luodes)

Sample types

All the samples had been used for further testing.

Thin sections

HAP$-2013-29.3 has been used for petrographic analysis.

Chemical analyses

Drill cores

Chemical analysis has been performed on HAP$-2013-28.1-2 for chemical analysis.

Surface samples

No other surface samples have been collected from the site.

Biological analysis

Not done on these specimens

Mechanical and physical tests

Samples for water absorption, density and porosity

In October 2013 have been performed the tests and for it have been used the sample HAP$-2013-30.

Photos of Samples

Normal photos

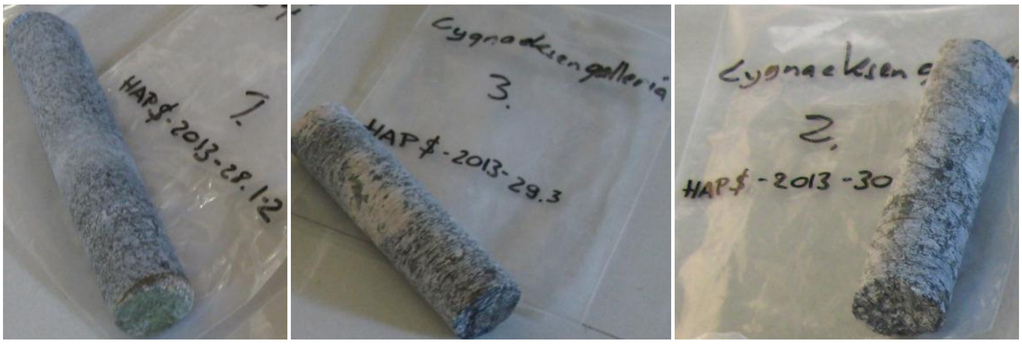

Figure9 Normal photo of the specimen from the building sampled in 2013.(Photo: N.Luodes)

Stacking photos

In Figures 10,11,12 are shown the samples pictured with high definition.

Figure 10 Samples HAP$ -2013-28, HAP$ -2013-29 to HAP$ -2013-30, from left to right, weathered surface. (Photo by J. Ranua GTK)

Figure 11 Samples HAP$ -2013-28, HAP$ -2013-29 to HAP$ -2013-30 from left to right, unweathered surface (Photo by J. Ranua GTK)

The high definition pictures allow to zoom and see in detail the surface of the material as visible from Figure 12.

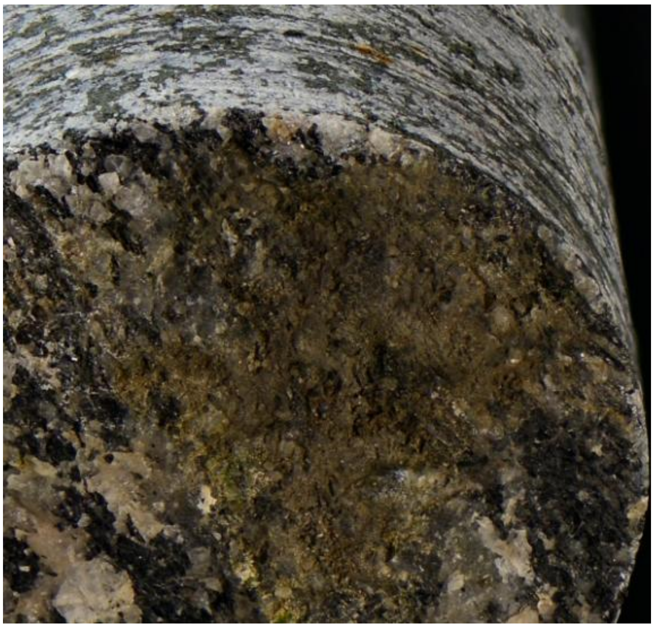

Figure 12 Detail of the weathered surface of the sample HAP$ -2013-29 showing dust deposition and fixation. (Photo by J. Ranua GTK)

Petrographic and chemical properties

Chemical elements of the material are shown in the following graph and as numerical table in Annex 1

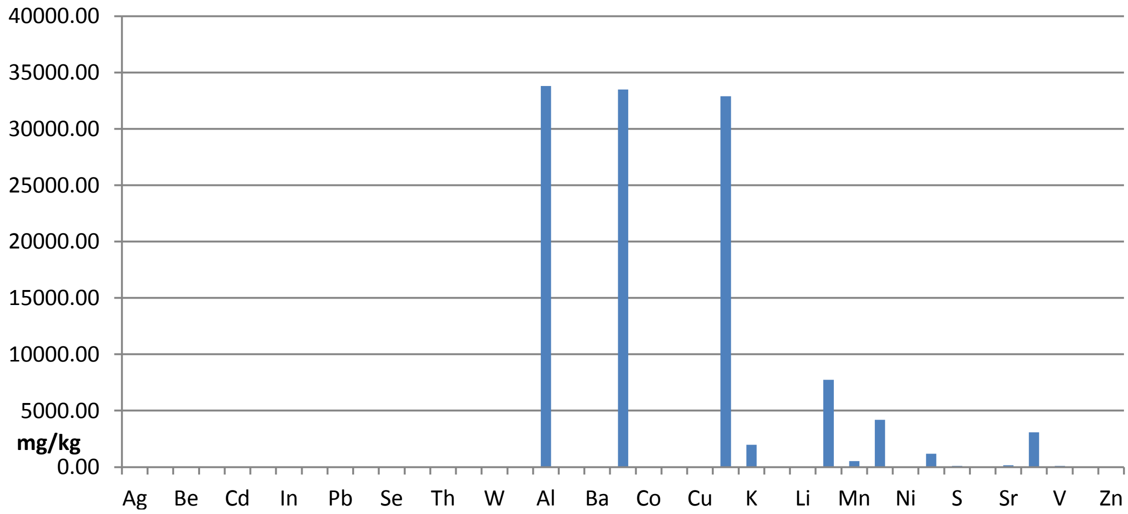

Figure 13. Chemical composition of the sample material as a whole sample.

Analysing the component percentages it is visible that the main elements are those typical of the rock (Figure14) Aluminium oxides, silicates and iron oxides and from the analysis of the minor elements (visible in Figure 15) it is not visible a strong effect of pollution on the material.

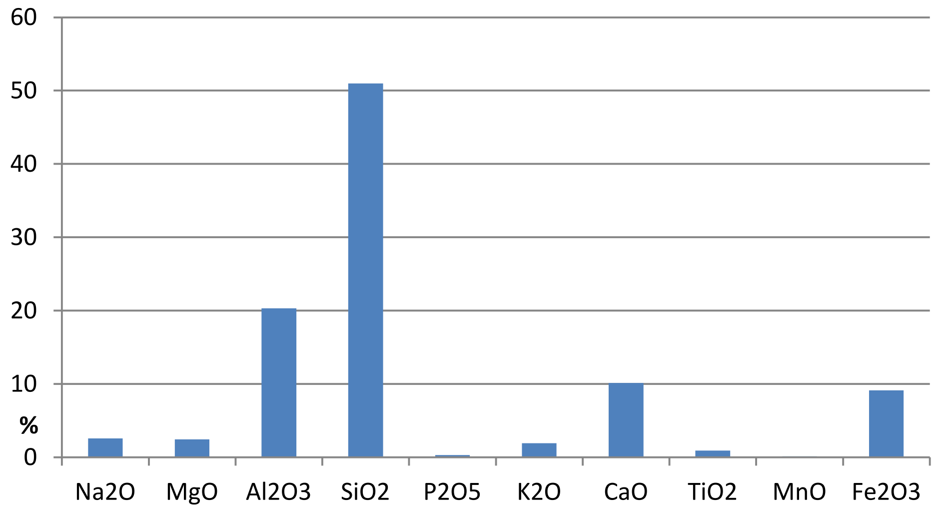

Figure 14 Percentages of the oxides

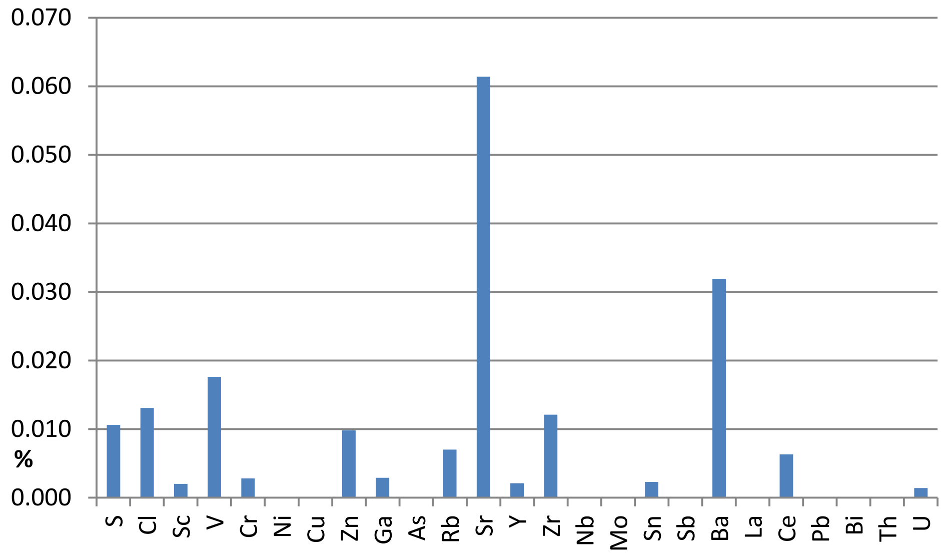

Figure 15 Percentages of the elements

Non-destructive research methods

Non destructive research methods have included Ground penetrating radar and Schmidt hammer hardness test performed by the Geological Survey of Finland. Ultra Pulse velocity on specific blocks has been performed in cooperation with the Polytechnic of Turin-Italy while thermal camera measurements have been performed in cooperation with Mikkeli University of Applied sciences.

Ground penetrating radar

Measurements have been performed over the basement of the tower sampled. The antennae had been placed over the outer side of the blocks and carried slowly at constant velocity.

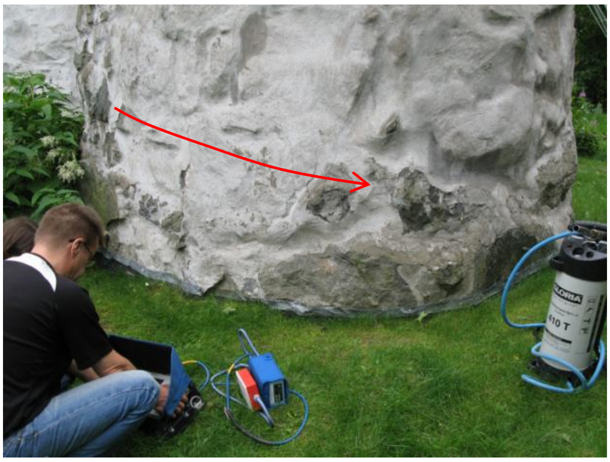

Figure 16. Are shown the positions of the GPR measurements collected F1 and F2. (Photo: N.Luodes)

The results had been difficult to be interpreted because of the heterogeneity of the wall structure. Anomalies given by contact of the blocks had been giving strong reflection, minimizing possible structural deficiencies.

Ultrasonic measurements (UPV)

The measurements have been performed in an indirect way according to the report “Methodology UPV”. The blocks tested, shown in Figure 17, have been near the ground floor, on the blocks sampled for other analysis.

Figure 17. Positions of the measurements performed over Cygneuksen Galleria basement. (Photo: N.Luodes)

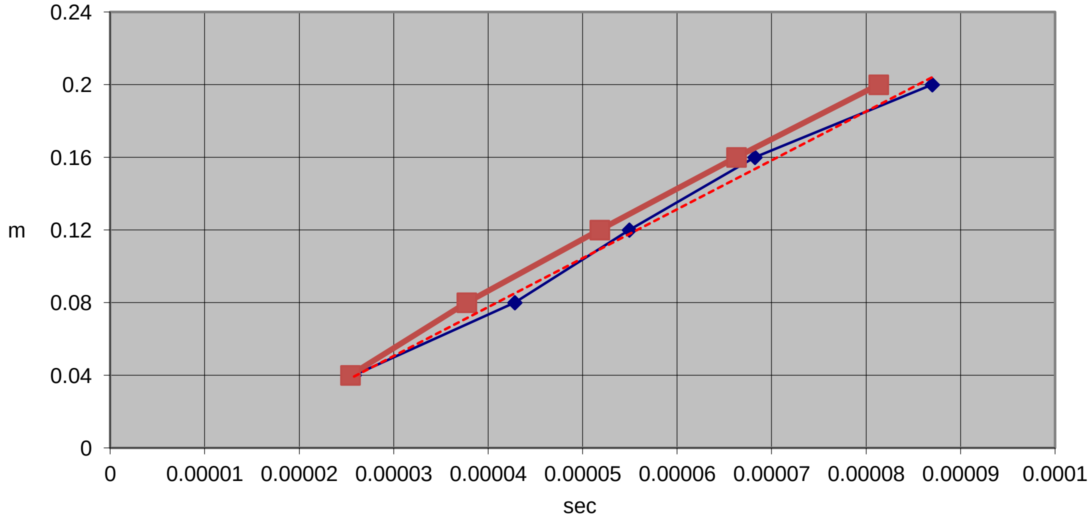

Figure 18. Diagram showing the measurements collected on the two blocks of the Gallery (red squares are for HAP$-2013-28 and blue squares are for HAP$-2013-29).

Velocities are: 2850 and 2706 m/s excluding the first point of measure to reduce uncertainties. The curves show that there have been slight deviations from the expected readings, this could be caused by irregularities of the surface and by shistosity of the stone. The structure is formed by unshaped heterogeneous blocks of different kind of rock. The velocities are a bit lower than what could be expected for this material.

Schmidt hammer

The Schmidt Hammer has been used perpendicular to the surface to be tested, according to the methodology described in “Methods Schmidt Hammer” and has been performed on the same blocks on which has been sampling (Fig 19).The measurements are shown in table 1. Comparing the results got with this tests to those got with other tests and other analysis can be seen that the results have been lower than the expected values for the kind of stone and its compactness. Rebound values in fact had not been very high, showing that the material might have been affected by humidity, lowering its properties. The blocks have been heterogenic so they presented different mineral composition and possibly different level of surface weathering.

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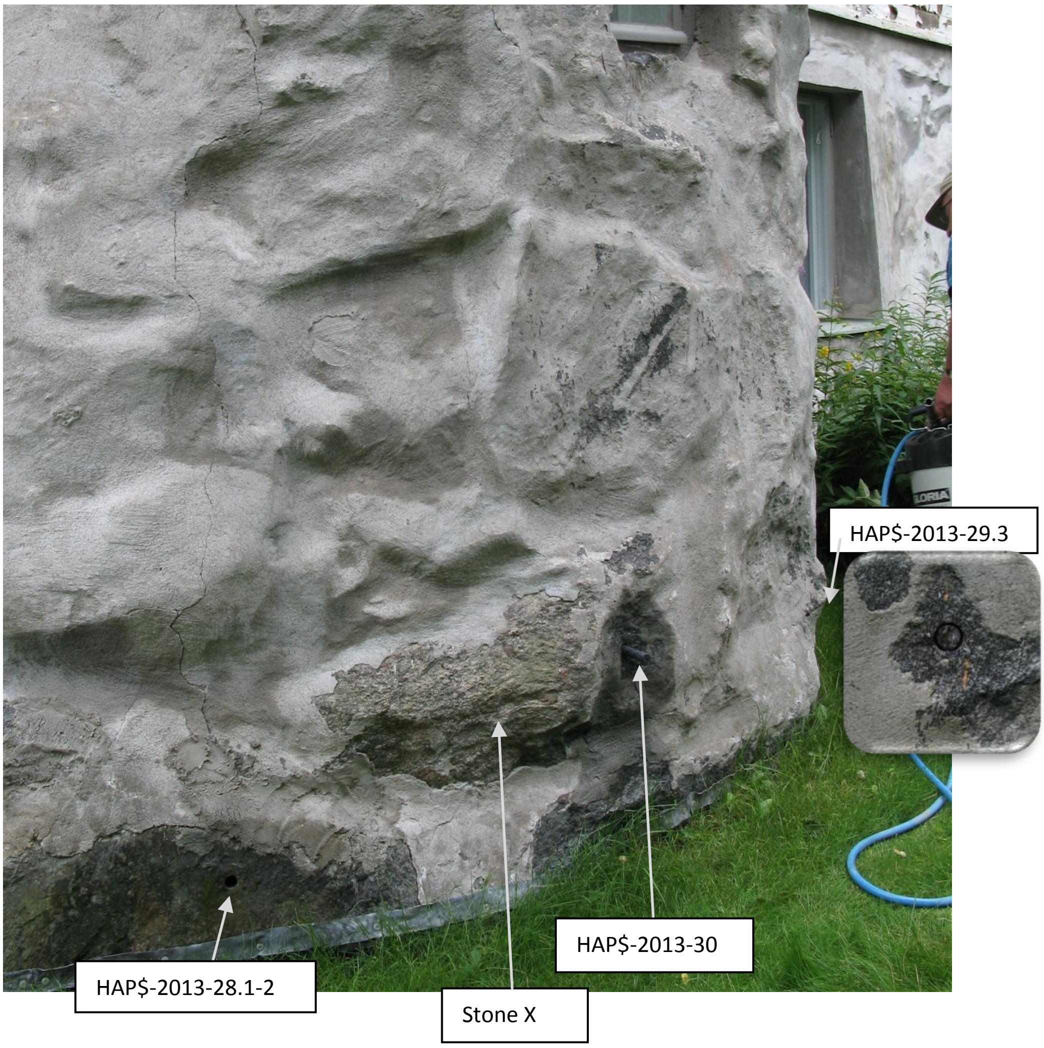

Figure 19 Positions and detail of blocks tested with Schmidt hammer

Table 1. Results of Schmidt hammer test

	HAP$-2013-28.1-2	HAP$-2013-30	HAP$-2013-29.3	Stone X
Rebound values	46	36	34	18
	48	30	54	48
	50	50	52	30
	49	30	54	28
	54	48	60	48
	54	40	58	48
	44	48	48	38
	50	48	48	48
	50	50	50	48
	49	30	48	44
	56	44	46	42
	56	44	48	44

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Thermal camera

The measurements have been performed during a partially cloudy day, after a rainy period. The thermal inspection showed that humid areas had been characterized by different temperature compared to drier ones and they are visible also through the mortar, visually and through thermal camera images. The parts of rock not covered by plaster had shown generally higher temperatures compared to the part of walls covered.

Figure 20. Humidity visible during visual inspection shows up also by thermal analysis as warmer areas between the rocks (Photo. A Shkurin)

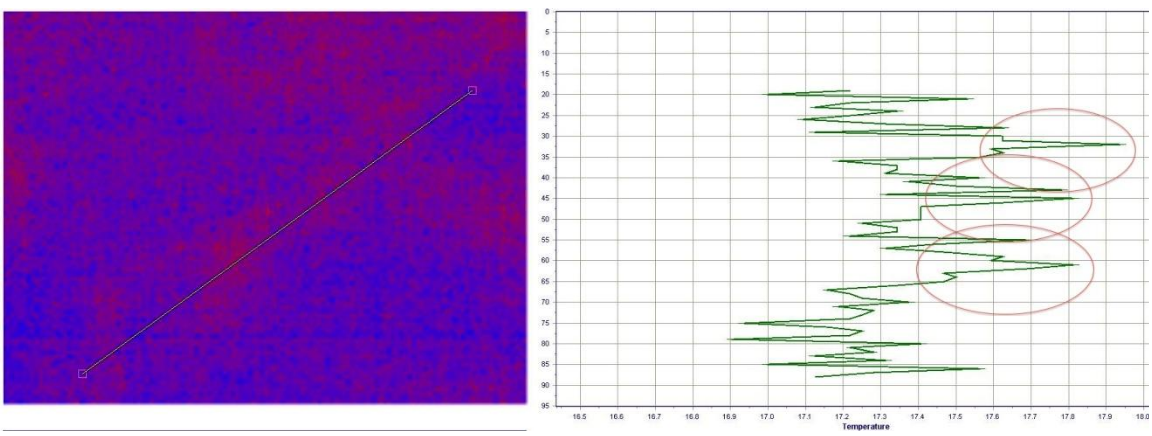

Figure 21. Higher temperatures are shown in correspondence of the mortar joints between the rocks of the basement, showing different behavior of the two structural components.

Thermal image allows also identifying the position of the stone blocks covered by plaster and the analysis had shown presence of humidity.

Mechanical and physical properties

Water absorption, density and open porosity had been tested over one drill core and the results are shown in Table2. The material shows a higher porosity in the bottom part of the sample as well a lower density(table 3), while it is showing a lower water absorption (table 2).

Table2.results of density and open porosity.

	DRY WEIGHT (g)	UNDER WATER (g)	SATURATED WEIGHT (g)	Apparent density (kg/m3)	Open porosity (%)
Cygneuksen galleria 4T (HAP$2013-30)	41.02	26.72	41.06	2855	0.28
Cygneuksen galleria 4B(HAP$2013-30)	47.02	29.33	47.08	2644	0.34

Table 3. Results of water absorption (T= Top, B=Bottom)

	DRY WEIGHT (g)	SATURATED WEIGHT (g)	Water absorption (%)	
Cygneuksen galleria 4T (HAP$2013-30)	41.00	41.06	0.15	Grey, a bit darker surface
Cygneuksen galleria 4B(HAP$2013-30)	43.63	43.68	0.11	grey

The results show that the material is hard and quite compact, the fact that bottom sampled had lower properties compared to the top would show that the results are affected by natural deviations more than by weathering actions, even taking into consideration possible effects given by top sample surface depositions, or biofilms .

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/2/National Board of Antiquities - Web Pages: http://www.nba.fi/en/museums/other_sites/cygnaeusgallery

/3/Kohde id:200006 Cygnaeuksen galleria on the NBA web pages:
http://kulttuuriymparisto.nba.fi/netsovellus/rekisteriportaali/rapea/read/asp/r_kohde_historia_list.aspx?KOHDE_ID=200006

/4/ Helsinki weather information - Helsinki urban heat island - http://www.helsinkiweather.info/urbanheatisland/HelsinkiUrbanHeatIsland.html

/5/ http://www2.univet.hu/users/vilisics/html/3Vilisics-1.pdf -(Inspection on materials contributing to the knowledge of terrestrial Isopoda (Crustacea, Oniscidea) in Finland - Ferenc Vilisics & Juhani Terhivuo- Memoranda Soc. Fauna Flora Fennica 85:9–15. 2009)

ANNEX 1 HAP$-2013-28.12

Na2O	%	+ 175X	2.56
MgO	%	+ 175X	2.43
Al2O3	%	+ 175X	20.3
SiO2	%	+ 175X	51
P2O5	%	+ 175X	0.299
K2O	%	+ 175X	1.9
CaO	%	+ 175X	10.12
TiO2	%	+ 175X	0.9302
MnO	%	+ 175X	0.127
Fe2O3	%	+ 175X	9.14
S	%	+ 175X	0.0106
Cl	%	+ 175X	0.0131
Sc	%	+ 175X	0.002
V	%	+ 175X	0.0176
Cr	%	+ 175X	0.0028
Ni	%	+ 175X	<0.002
Cu	%	+ 175X	<0.002
Zn	%	+ 175X	0.0098
Ga	%	+ 175X	0.0029
As	%	+ 175X	<0.002
Rb	%	+ 175X	0.007
Sr	%	+ 175X	0.0614
Y	%	+ 175X	0.0021
Zr	%	+ 175X	0.0121
Nb	%	+ 175X	<0.0007
Mo	%	+ 175X	<0.001
Sn	%	+ 175X	0.0023
Sb	%	+ 175X	<0.01
Ba	%	+ 175X	0.0319
La	%	+ 175X	<0.003
Ce	%	+ 175X	0.0063
Pb	%	+ 175X	<0.002
Bi	%	+ 175X	<0.003
Th	%	+ 175X	<0.001
U	%	+ 175X	0.0014

Ag	mg/kg	511M	0.0622
As	mg/kg	511M	3.276
Be	mg/kg	511M	0.5047
Bi	mg/kg	511M	0.2145
Cd	mg/kg	511M	0.1092
Ce	mg/kg	511M	38.92
In	mg/kg	511M	<0.02
Mo	mg/kg	511M	0.9624
Pb	mg/kg	511M	7.297
Sb	mg/kg	511M	0.0898
Se	mg/kg	511M	0.6954
Te	mg/kg	511M	<0.006
Th	mg/kg	511M	5.663
U	mg/kg	511M	1.892
W	mg/kg	511M	0.3857
Yb	mg/kg	511M	1.295
Al	mg/kg	+ 511P	33800
B	mg/kg	+ 511P	6.12
Ba	mg/kg	+ 511P	27.5
Ca	mg/kg	+ 511P	33500
Co	mg/kg	+ 511P	10.2
Cr	mg/kg	+ 511P	9.51
Cu	mg/kg	+ 511P	15.6
Fe	mg/kg	+ 511P	32900
K	mg/kg	+ 511P	1970
La	mg/kg	+ 511P	21.7
Li	mg/kg	+ 511P	27
Mg	mg/kg	+ 511P	7740
Mn	mg/kg	+ 511P	536
Na	mg/kg	+ 511P	4200
Ni	mg/kg	+ 511P	3.91
P	mg/kg	+ 511P	1180
S	mg/kg	+ 511P	94.7
Sc	mg/kg	+ 511P	8.15
Sr	mg/kg	+ 511P	150
Ti	mg/kg	+ 511P	3080
V	mg/kg	+ 511P	96
Y	mg/kg	+ 511P	12.3
Zn	mg/kg	+ 511P	52.5

SUOMENLINNA

Documentation and research methods

Source of information has been the site of Suomenlinna /1/ where a lot of historical information has been collected. Technical research data have been collected from the research reports.

Description of the building

Number	
Name of building	Suomenlinna Fortress
Architect	Augustin Ehrensvärd
Built (year)	From 1748
Modifications 1	The fortress grew along the years and the site http://www.suomenlinna.fi/en collect all the information about modifications done to the historical buildings and fortifications

The fortress is distributed over several islands and its construction started in 1748, the majority of the buildings had already been erected in mid 18th century. The fortress is formed by several bastions and buildings according to the terrain. Its role changed during the time and works to implement its defence efficiency had been done, it has been ruled by Swedish and Russians until 1918 and it has always been used for military purposes until 1973. A part of it, the dry dock, has been created already in 1750-1756 and its use has been an alternation of naval purposes and ware house, even for building airplanes, ending for hosting submarine base in the Second World War and finally coming back as a dry dock for construction and restoration of ships. / 1/ In Figure 1 is shown a map of the fortress.

Figure 1. Map of the fortress / 1 /

The studies have been focused on the southern island called Kustaanmiekka that represented an external bastion of the fortress and on Suusisari where is located the dry dock. Some images of the island are shown in Figure 2-8.

Figure 2. A view from the East side of Kustaanmiekka, along the coast (Photo: H.Pirinen)

Figure 3 A view of the weapons (Photo: H.Pirinen)

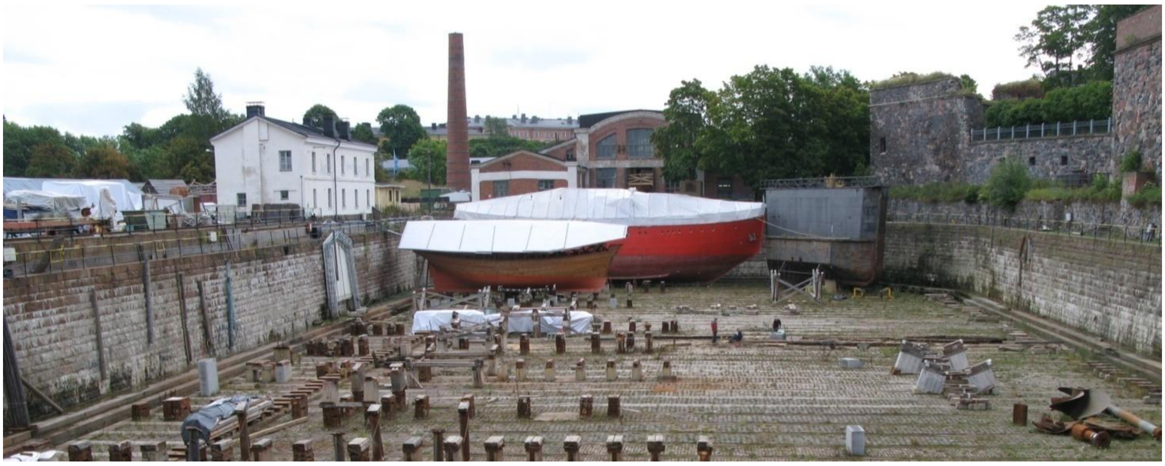

Figure 4 A view of the dry docks (Photo: H.Pirinen)

Figure 5 Particular of the stairs in the dry dock. They have been carved from a bigger block probably during later reconstruction. (Photo: P. Härmä)

Figure 6 two particulars of the walls. (Photo: P. Härmä)

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Figure 7 King's gate designed in 1753-1754. (Photo: P. Härmä)

Figure 8 Particulars of the underground constructions (H.Pirinen)

Generally, the stone materials used for the construction of the fortress bastions and houses have been quarried on the site. The king's gate presented Swedish sandstone and the dry dock has been reconstructed using quarried granite from outside. Decorative elements of limestone have been done with material quarried from Finland.

Characterization of the environment

The fortress is located in south Finland on an island. The vegetation is nowadays present on the island as trees but mainly as grass fields. There is presence of ducks and there is limited car access.

As deterioration action can be considered that the site is not exposed to traffic but more to weather conditions.

Local environment (architecture etc.)

Suomenlinna is a sea fortresses located on an island in front of Helsinki as visible from figure 8 and it is formed by several islands and several constructions.

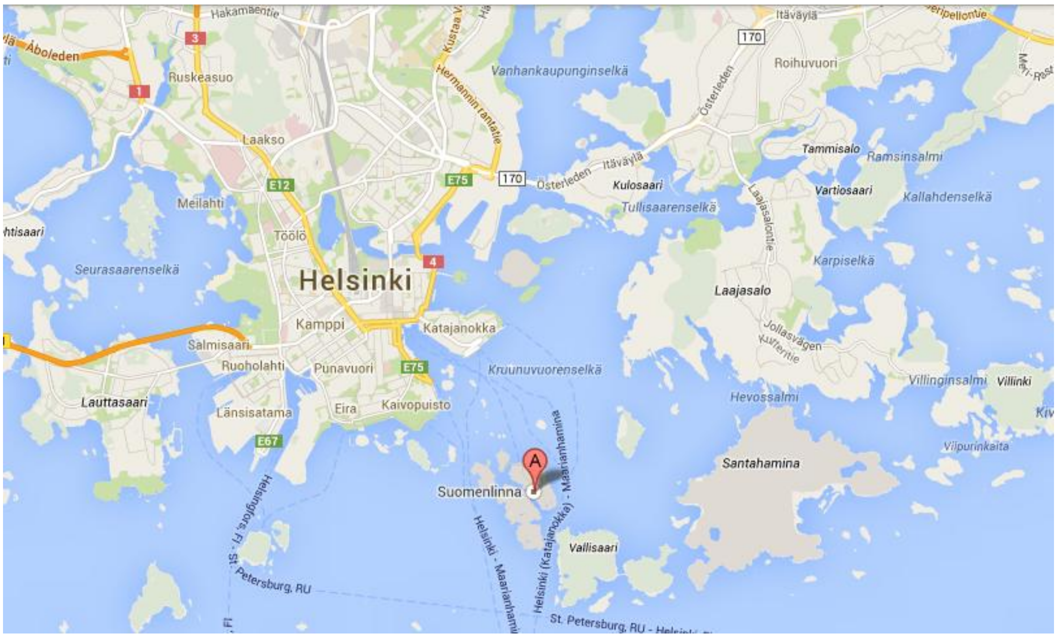

Figure 8. Area where the heritage is located (Google Maps)

Climatic conditions, microclimate, etc.

The environment is a sea environment, characterized by wind and high humidity mainly given by the surrounding waters than by precipitations. While the temperature is more tempered in autumns, in spring snow can last longer compared to the main land. / www.suomenlinna.fi /High seas tides have been damaging the banks and the submerged structures of the fortress and the faster freeze thaw cycles have been weathering the rock walls. Salt deposition has also been studied over the structures of the island. /2/

Photographic documentation

The site has been documented photographically in detail by Gigapan photos, normal camera photos of the complex and of the architectonic elements, of the deterioration problems and of the materials and finally by high definition photos of the samples. The processes of sampling and testing have also been recorded.

Gigapan photos

Several gigapan photos have been collected and they are visible at full dimension from www.gigapan.com while in the Figure 10-14 are shown the correspondent low definition ones. In Figure 9 is shown on the map the location from which they have been collected. Photos have been taken by J.Toivanen.

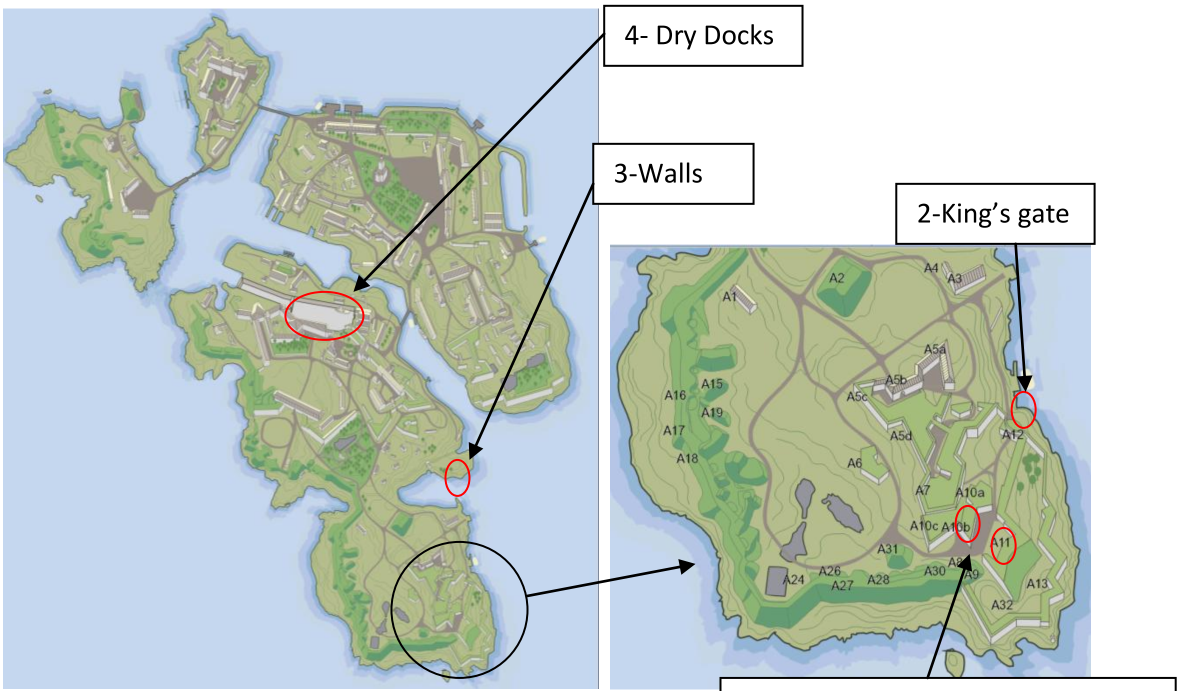

Figure 9 Location of the shooting of gigapan photos

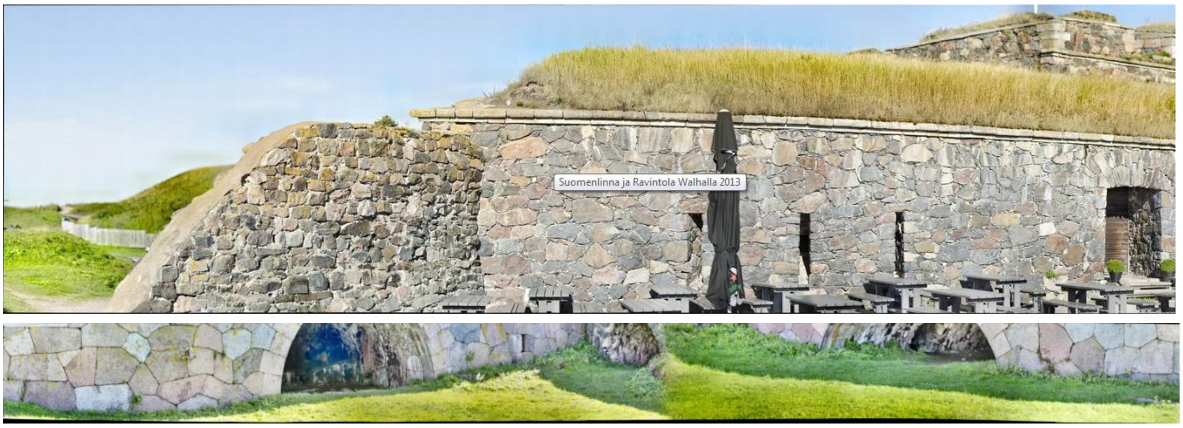

Figure 10 (1) Photos taken to the Walhalla restaurant and to Tenaille Kyhlenbeck.

Figure 11 (2)King’s gate

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Figure 12 (3) Walls

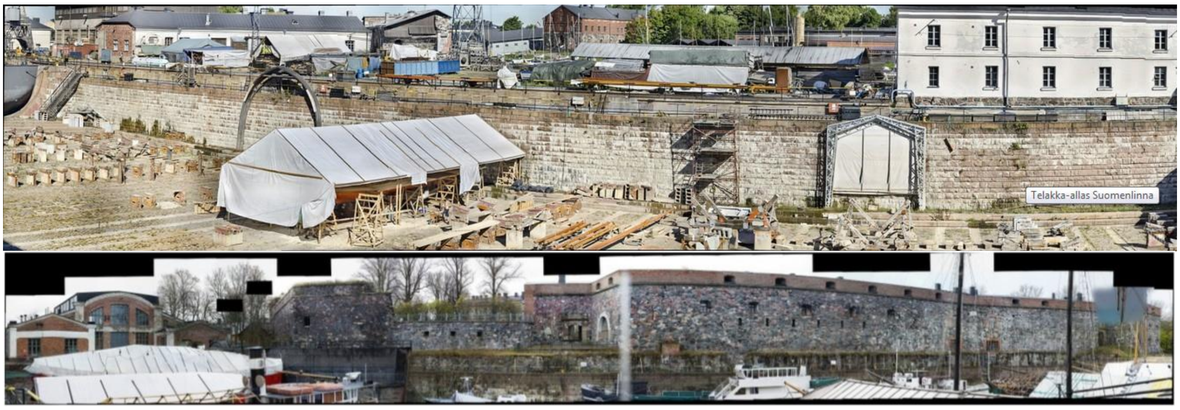

Figure 13 (4) Dry docks.

Figure 14. Panorama of the internal walls

Visual inspection

No detailed mapping of each construction had been done for this building.

Detection of weathering types

The blocks used for the construction of the fortress have been erratic blocks or blocks blasted and collected from the site as visible from Figure 15. The fortress has been undergoing modifications, reconstructions and restorations during the years but different weathering effects have been still visible.

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Figure 15. On the left the marks of the holes for wedges for detaching blocks, and on the right a block presenting the holes for wedges for splitting a larger block into a smaller one. (Photo: P. Härmä)

Peeling and exfoliation

The limestone used to reconstruct the front part of the king's gate in 1925 is showing weathering effects probably given by the sea and that are typical of limestones: exfoliations as visible from Figure 16.

Figure 16 Example of exfoliation on limestone in front of King's gate. (Photo: P. Härmä)

Rude surfaces

The surface of the blocks in some parts present changes on the original surface of the material, increasing the roughness as visible from Figure 17.

Figure 17 Increased roughnesses of some blocks (Photo: P.Härmä)

On the external walls where had been used differnet stone types can be seen that softer materials started to weather faster than harder ones.Generally the diabase kind, the black ones, do not show visual weathering effects, while the light ones show at least an increase of routhness of the surface as visible from figure 18.

Figure 18 Blocks of different stone materials showing different level of weathering. (Photo: P.Härmä)

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Deepenings and cavities

A limestone slab installed in 1925 used in front of the King's gate had shown deepening probably due to sea water effects, passage of people and dung of birds as shown in Figure 19.

Figure 19. Limestone weathered

Hollows and chipping

Not yet chipping, but starting of surface fractures to determine a consequent chipping has been noticed on the block of the dry dock, is the part that will be submerged during filling, as visible from figure 20.

Figure 20 Granit block of dry dock showing a starting of chipping weathering.

Stone flaking-off

This has not been noticed on the blocks.

Granular disintegration , decohesion of single crystals or mineral grains

Some of the material used had shown this problem as visible from Fig. 21. In this case a vein of potassium feldspar had been weathering faster than the gneissic matrix rock, leaving to granular disintegration of the potassium. On the left the granite is also showing possible weathering of the potassium feldspar.

Figure 21 Example of granular disintegration by potassium feldspar in a gneissic rock (Photo: H.Pirinen)

Fractures and fissuring

The material that suffered the most had been probably the softer one used on the structure, As visible from Fig.22 the decorations of limestone of the king's gate showed fissuring, as natural manifestation of weathering.

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Figure 22. The king's port presents two kinds of materials used: the split blocks and the shaped limestone. The limestone bricks show fracturing along the layers caused by material deterioration. (Photo: P.Härmä, H.Pirinen)

Cracks are also due to man's actions, being a fortress has undergone several attacks.(Fig. 23)

Figure 23 The stones over the window show impacts of anthropogenic origin.(Photo: P.Härmä, N.Luodes)

Deformations

Some blocks had shown cracks due to structural movements as visible in figure 24, on the left. Structural movements in this kind of construction should bring to cracks between the rocks (weaker point) than into the rocks (stronger element). Moreover the fortress had been subjected to strong impacts during battle and some impacts could had been causing some of the cracks. Also actions of winds and of waves can cause the erosion of the mortar between the stone blocks and determine their detachment, as visible from figure 24, on the right.

Figure 24 Crack on the corner of a stone on the left, and loss of outer part of a wall on the right.

Limestone stair had shown cracking (Fig.25)that can be caused by basement movements or by impact on a material that had already been suffering from weathering actions and that had lowered its resistance.

Figure 25 Cracks on a limestone slab in front of the king's gate.

On the wall in front of Walhalla restaurant could be noticed a fracture in a corner of a block of the arc (Fig. 26) that could be caused by compressive action, and on the same wall there has been dislocation of a block because of the pressure of the terrain (Fig. 27)

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Figure 26 The granite block of the arc present a fracture that could had been cause by structural deformation, being in the compressed part of the arc.

Figure 27 Dislocation of a block caused by the pressure of the terrain (Photo: N.Luodes)

Fungus

Not evaluated its presence (Not tested)

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Seaweed

In an area on the dry dock where had been collected sample HAP$-6 (Suomenlinna 1) there was presence of water and plants, probably seaweeds (Fig. 28).

Figure 28 Block of the dry dock in dry and wet conditions presenting growing of biofilm/seaweed

Lichens

Lichens have been growing abundantly on the structures, privileging some materials but definitely colonizing also those less favourable for their growth, as can be seen from figure 29. It is visible that the colonization starts from a stone material that probably can offer better substrate for their grown, but after several years they are able to colonize also the other stone kinds.

Figure29 On the left a part of the wall in the King's gate where colonization of lichens started probably after a refurbish of the wall in recent years, on the right a wall that present diffuse colonization. (Photo: P.Härmä, H.Pirinen)

It has been noticed mainly one kind of lichen as visible from figure 30 on the flt, but also other type could occur as shown in Figure 30 on the right.

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Figure30 Detail of the most diffused lichen on the left, and a particular with a different lichen colonization on the right. (Photo: N.Luodes, H.Pirinen)

Mosses and higher plants

The ground covering is a structural part of the fortress, while the mosses and higher plants growing between the blocks of the walls are causing possible weathering of the mortar and loosing of the blocks. They have been growing between the rocks in several parts of the walls (Figure 30) but many structures are not showing visible extensive colonization as can be seen in Figure 31.

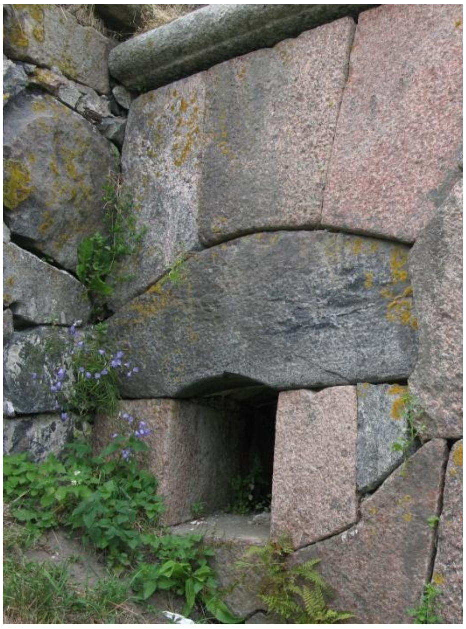


Figure 31 Mosses and higher plants growing on the wall in front of the Walhalla restaurant and on a upper wall facing the dry dock. (Photo: N. Luodes, H.Pirinen)

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Figure 32 Walls of the fortification in Kustaanmiekka (Photo: H.Pirinen)

Bio-films of different composition

Biofilm has been recognized in some more humid areas as for example at the contact with ground on the upper walls facing the dry dock, as visible in Figure 33. The biofilm had been generally of green color.

Figure 33 Examples of biofilm found on the basement of the upper buildings facing the dry docks: on the left limestone basement of the portal, on the right basement of the walls.(Photo:N.Luodes)

Dung of birds

Ducks are living on the island and on the paving stones their impact should be considered, as for example on the limestone stairs in front of the king's gate (Figure 34). Ducks are generally not circulating over building structures and seagulls are not so numerous to cause a problem to the main defence structures. They could cause a problem if they are collecting in a specific place on a building or an area, but the behaviour of the birds has not been monitored during this study.

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Figure 34. Duck over the limestone steps in front of the king's gate (Photo: P.Härmä)

Atmospheric particle depositions and fixation

Suomenlinna is not affected by traffic impacts but is mainly affected by salt deposition and the salt has been considered main problem also for other brick constructions of the heritage. Studies have shown that there has been high concentration of salt coming as salt mist from the marine environment. Traces are visible also on the stone walls as visible from figures 35-37.

Figure 35 Deposition of salts on the walls in an inner wall and an outer wall of the fortress. (Photo: H.Pirinen)

Figure 36 Diffused deposition of salt on the buildings facing the dry dock (Photo: H.Pirinen)

Figure 37 Examples of salt crusts, as migration of salts from the mortar or inner layers, or as deposition of salt mist. (Photo: H.Pirinen)

Crusts

Seen as deposition and fixation of salts, or migration of mortars and fixation into limestone.

Loss/change of colour

The material is very heterogeneous and it is not easy to evaluate a change of colour, but it is very probably that has occurred for many blocks

Ovoid weathering

It is not visible since the material has not tendency to this kind of weathering

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SAMPLES

From Suomenlinna have been taken samples from the dry dock and from the outer walls near the king's gate, samples from other parts facing sea , as the old entrance to the dry dock and a block dismounted from the shore have been also collected. Chemical and petrographic analysis has been performed and a part has gone for biological analysis of the thin surface crust.

Sampling methods

In Suomenlinna sampling has been performed in 2012 and 2013. Cores have diameter of 17mm and 20 mm with depth reaching few cm.

Sampling locations

Description of the environment

The samples have been taken on different materials and from blocks that showed different deterioration effects, crusts, seaweeds, biological activity, biofilms and lichens and clean material.

Location of the sampling sites

On the maps is possible to schematise the sampling areas (Figure38-40).

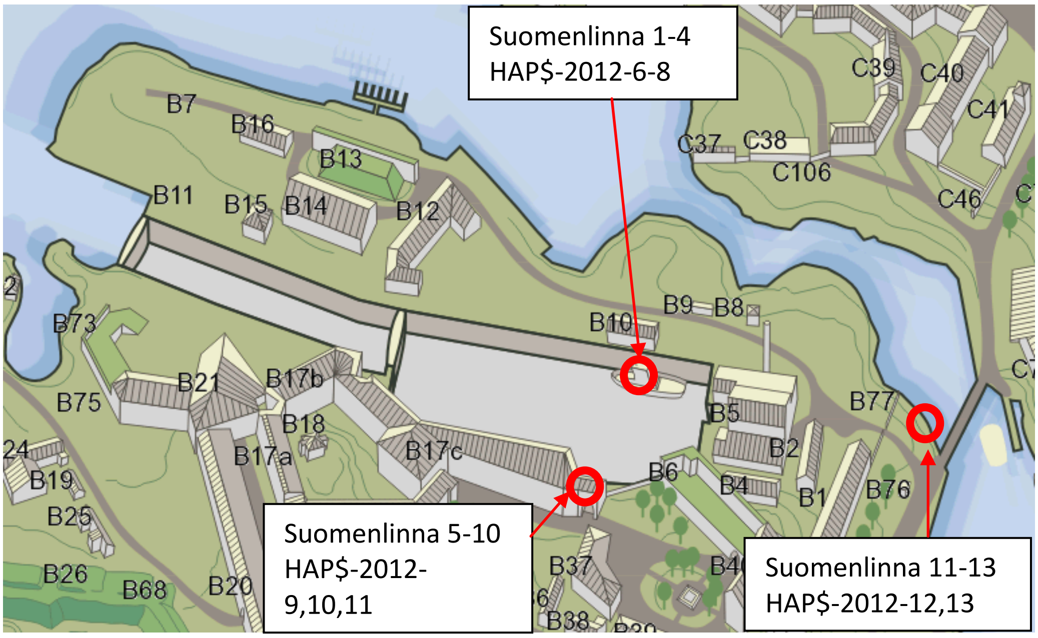

Figure 38 Map of the areas sampled in the dry dock and samples codes

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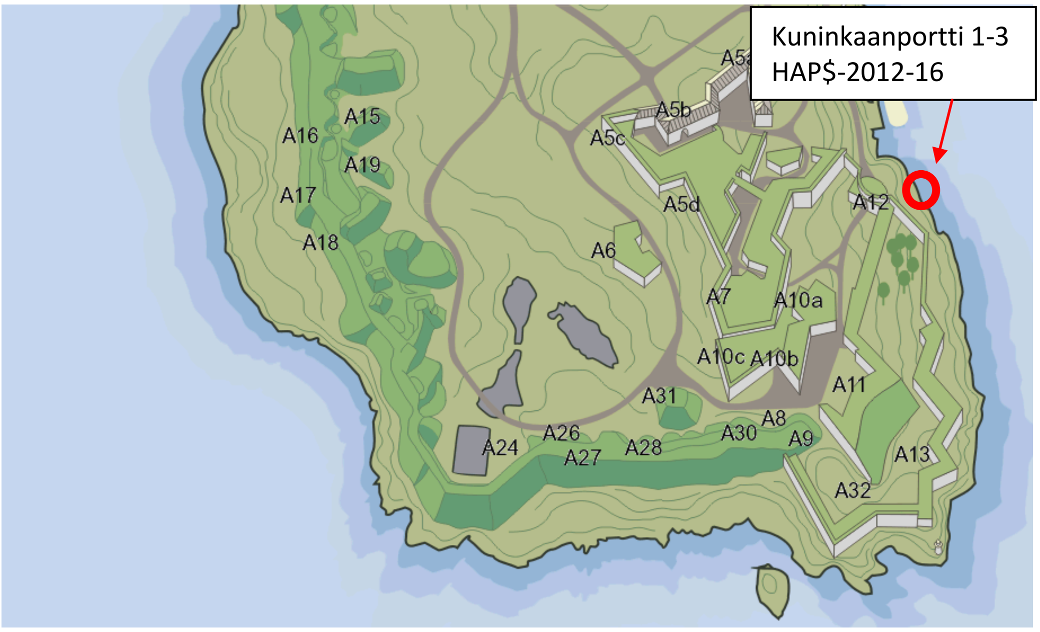

Figure 39 Map of the areas sampled in Kustaamiekka, near the king's gate and sample codes

Figure 40 Map of the area sampled near the pier, blocks dismounted from the shore.

The specimens used for further testing have been re-coded as shown in Table 1

Table 1. Samples collected on site (on left column) and new code (on right column) for proceeding in testing

Suomenlinna 1	HAP$-2012-6
Suomenlinna 2	HAP$-2012-7
Suomenlinna 3	HAP$-2012-8
Suomenlinna 6	HAP$-2012-9
Suomenlinna 7	HAP$-2012-10
Suomenlinna 9	HAP$-2012-11
Suomenlinna 11	HAP$-2012-12
Suomenlinna 12	HAP$-2012-13
Suomenlinna 15	HAP$-2012-14
Suomenlinna 16	HAP$-2012-15
Kuninkaanportti 1	HAP$-2012-16

The samples collected and the site from which had been collected as shown in figures 41-48.

In figure 41 are shown the samples collected in the lower part of the dry dock.

Figure 41 from left to right Suomenlinna 3 (HAP$-2012-8), Suomenlinna 4, Suomenlinna 2 (HAP$-2012-7) and Suomenlinna 1 (HAP$-2012-6)

From the upper buildings of the dry dock have been collected samples shown in Figure 42 and 43.

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Figure 42 From left to right: Suomenlinna 9 (HAP$-2012-11), Suomenlinna 6 (HAP$-2012-9), Suomenlinna 5 and 10 have been taken from the same block but on clean and crusted surface.

Figure 43 From left to right: Suomenlinna 7 (HAP$-2012-10) and Suomenlinna 8 on the limestone portal

From the king’s gate have been sampled and tested one block shown in Figure 44.

Figure 44 Kuninkaanportti 1 (HAP$-2012-16)

Other specimens collected from the king's gate area have been those shown in Figure 45 and they have not been tested for chemical analysis neither for petrographic description.

Figure 45 Kuninkaanportti 2 (on the left) and 3 (on the right)

For the old entrance to the dry dock have been sampled three blocks, one generally submerged, visible on the right in Figure 46 and two on the side walls.

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Figure 46 From left to right Suomenlinna 12 (HAP$-2012-13), Suomenlinna 13, Suomenlinna 11 (HAP$-2012-12)

Blocks HAP$-2012-13 and HAP$-2012-12 have been sampled again in 2013 as shown in Figure 47

Figure 47 Second samples taken from blocks HAP$-2012-13 (on the left) and HAP$-2012-12 (on the right)

From blocks detached from shore structures and deposited temporarily near the pier have been collected samples shown in Figure 48.

Figure 48 From left to right: Suomenlinna 14, Suomenlinna 15 (HAP$-2012-14), Suomenlinna 16 (HAP$-2012-15)

Sample types

From the fortress the samples listed in table 1 have been prepared for further analysis, all the other have been spared and some have been used for physical tests.

Thin sections

HAP$ 2012-11 to HAP$ 2012-16 have been sampled again in 2013 collecting drill cores with diameter of 20 mm, coded HAP$2012-11.3 to HAP$ 2012-16.3 have been cut to prepare thin sections of the surface.

Chemical analyses

Drill cores

Chemical analysis has been performed on drill core samples collected in 2012 and shown in Table 1 coded HAP$ 2012-11.1-2 to HAP$ 2012-16.1-2 depending if it was the surface or the bottom part of the drill core.

Surface samples *No other surface samples have been collected from the site.*

Biological analysis

Surface sections from collected samples and drill cores showing presence of algae.

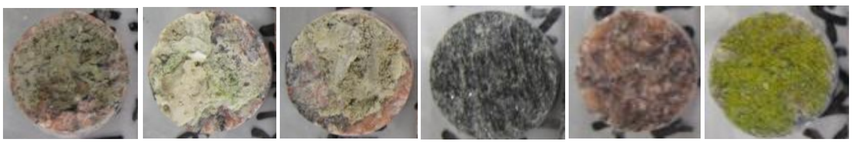

Figure 49. From left to right: Suomenlinna 1,2,3(lower dry dock),6,7,9(upper dry dock)

Figure 50. From the left to right: Suomenlinna 11 and 12 (old dock entrance), 15,16 (armour stones),king's gate 1

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Mechanical and physical tests

Samples for water absorption and compression tests

In October 2013 have been performed density and open porosity and for it have been used the part of samples collected in 2012 Suomenlinna 4, 10, 13,14 and Kuninkaan portti 2 and 3 and most presented some surface weathering effect.

Photos of Samples

Normal photos

From Suomenlinna have been taken normal photos from the samples sampled in 2013 (Fig.51) and for those sampled in 2012 and used as surface samples for biological analysis.

Figure51 Normal photo of the specimen from the fortress sampled in 2013.(Photo: N.Luodes)

Stacking photos

The high definition photo of the drill cores collected during 2013 do not show the one used for chemical analysis. In Figures 52-55 are shown the samples.

Figure 52.Samples HAP$ -2012-6 to HAP$ -2012-8 from left to right, weathered surface. (Photo by J. Ranua GTK)

Figure 53 Samples HAP$ -2012-9 to HAP$ -2012-11, from left to right, weathered surface. (Photo by J. Ranua GTK)

Figure 54 Samples HAP$-2012-12 and HAP$-2012-13 surface (on the left) and bottom part of the drill core (on the right) (Photo by J. Ranua GTK)

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Figure 55 Samples HAP$-2012- 16, HAP$-2012-17, HAP$-2012-18 from left to right, weathered surface of the drill cores. (Photo by J. Ranua GTK)

The high definition pictures allow to zoom and see in detail the surface of the material as visible from Figure 56.

Figure 56 Detail of the weathered surface of the sample HAP$ -2012-14. (Photo by J. Ranua GTK)

Petrographic and chemical properties

Samples HAP$ 2012-12,HAP$ 2012-13, HAP$ 2012-14 are shown in Figure 57,58,59. The images had been collected by optical microscope, magnification has been 50x.

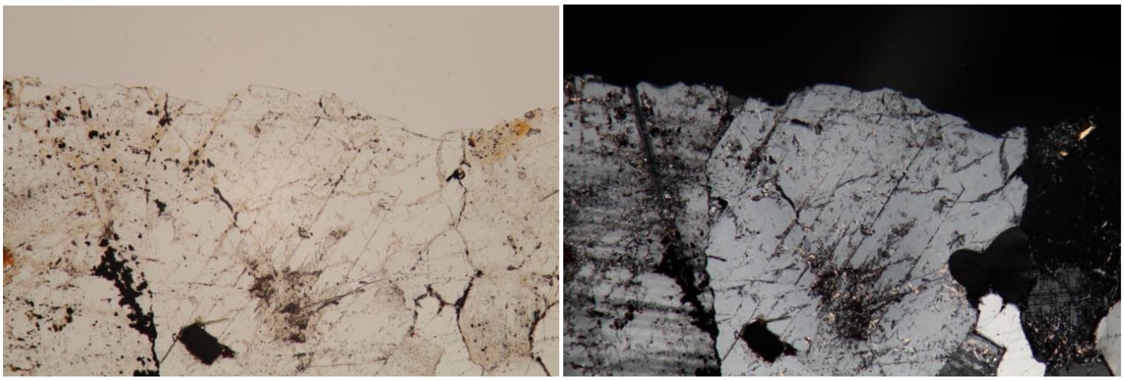

Figure 57. HAP$ 2012-12 Disintegration and breaking of the minerals on the top surface of the sample, visible from the fracturing

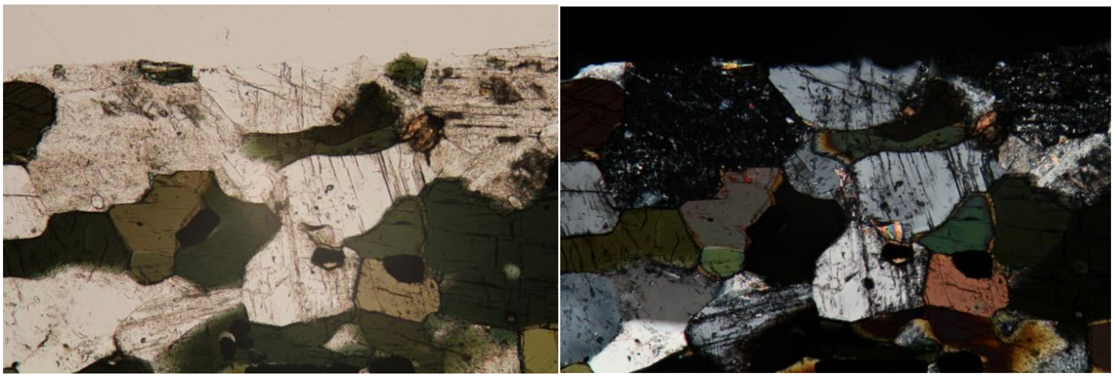

Figure 58. HAP$ 2012-13, open fissures of the mineral visible as fractures interesting the mineral itself

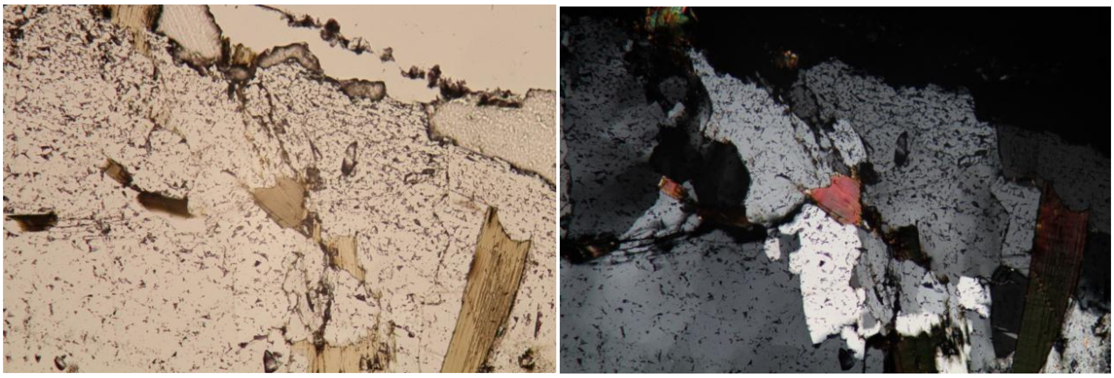

Figure 59. HAP$ 2012-14 Opening of the mineral internal structure with small cavities.

HAP$ is 2012-14 is a granite gneiss, composed by quartz, potassium feldspar, plagioclase, biotite, hornblende, with accessories magnetite, carbonate, epidote and serizite. Its structure is fine to medium grained matrix, with feldspar grains (porfiroclasts) and weak orientation and gneissic bending.

From Suomenlinna also HAP$ 2012-6 has been determined in structure and composition:

It is a granite consisting of potassium feldspar, plagioclase, serizite, chlorite and iron idroxide with small amount of biotite, muscovite and magnetite. It is fine to medium grained, weakly porifiritic and un-oriented.

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HAP$-2012-7 is a granite with quartz, plagioclase, potassium feldspar, biotite and small amounts of serizite, muscovite, and opaque minerals. It is un-oriented, porfiritic, from medium to coarse grained.

HAP$ 2012-8 is a granite with potassium feldspar, quartz, plagioclase, biotite, small amounts of serizite, muscovite , chlorite, apatite and iron hydroxide. It is from medium to coarse grained, porfiritic and unoriented.

HAP$-2012-10 is granite gneiss, with potassium feldspar, quartz, plagioclase, iron hydroxide, serizite, chlorite. With small amount of hematite. Fine to medium grained, un-oriented. Quartz seems to be re-crystallized.

Concerning chemical analysis, in some cases the sample from surface was too small and it has not been performed the total chemical analysis and in that case the sample from the bottom had been analysed. Generally anyway had been possible to compared which had been the chemical lost or enrichment of the surface layers compared to the bottom layers of the drill core, as from graphs in figures 60 and 61.

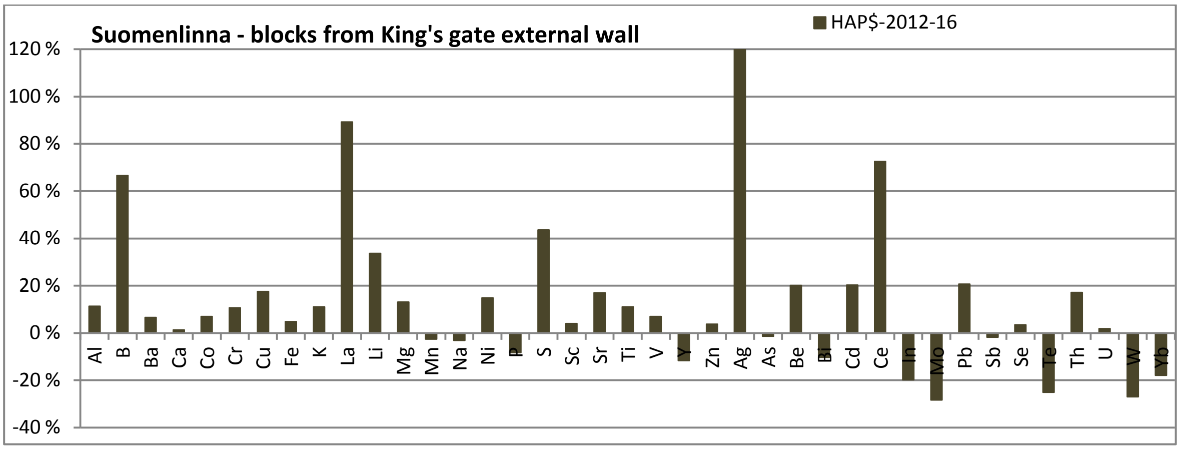

Figure 60.Changes in percentages between top and bottom samples of the sample from the external wall of the king's gate. (Ag is exceeding the scale and its value is equal to 344%)

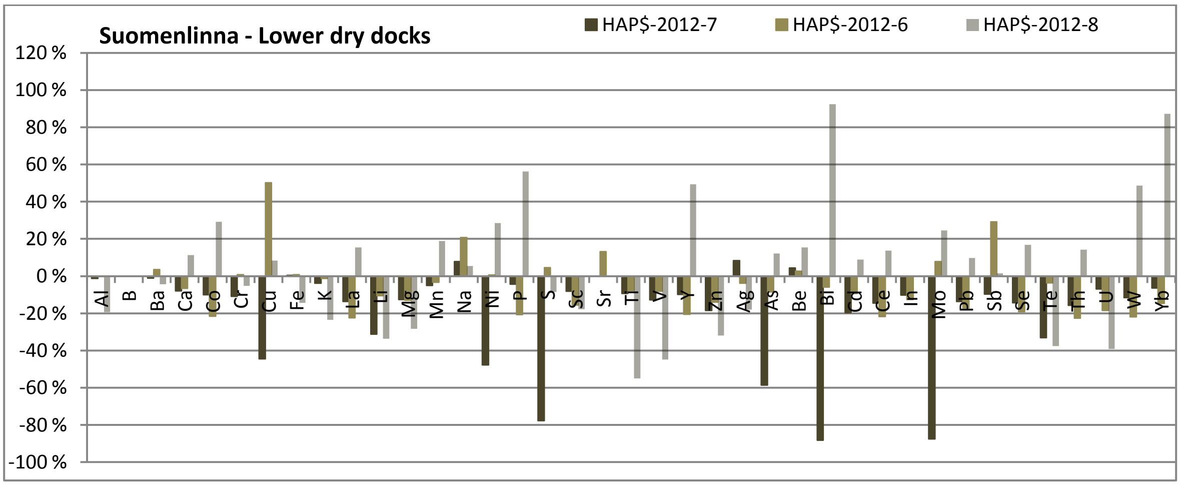

Figure 61.Changes in percentages between top and bottom samples of the sample from the samples collected from the lower walls of the dry dock

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High levels of Ag in Figure 60 could be due to a loss from the drill. The specimens HAP$-2012-6, HAP$-2012-7, HAP$-2012-8 are all from the lower part of the dry dock and are sampled on different surfaces. HAP$-2012-6 over a surface covered with seaweeds or organic film, HAP$-2012-7 covered by thick crust, HAP$-2012-8 clean material.

Figure 62. From left to right HAP$-2012-6, HAP$-2012-7, HAP$-2012-8

Specimen HAP$-2012-6 showed an increase of some heavy metals on the surface, as Pb,Mn,Co and W, Yb, P and Ni, while a higher leaching of Ti,V,Zn,Te,U compared to others. HAP$-2012-7 that presented the crust had a higher leaching of some elements but didn't show an increase on the surface of Ca as it would had been expected.

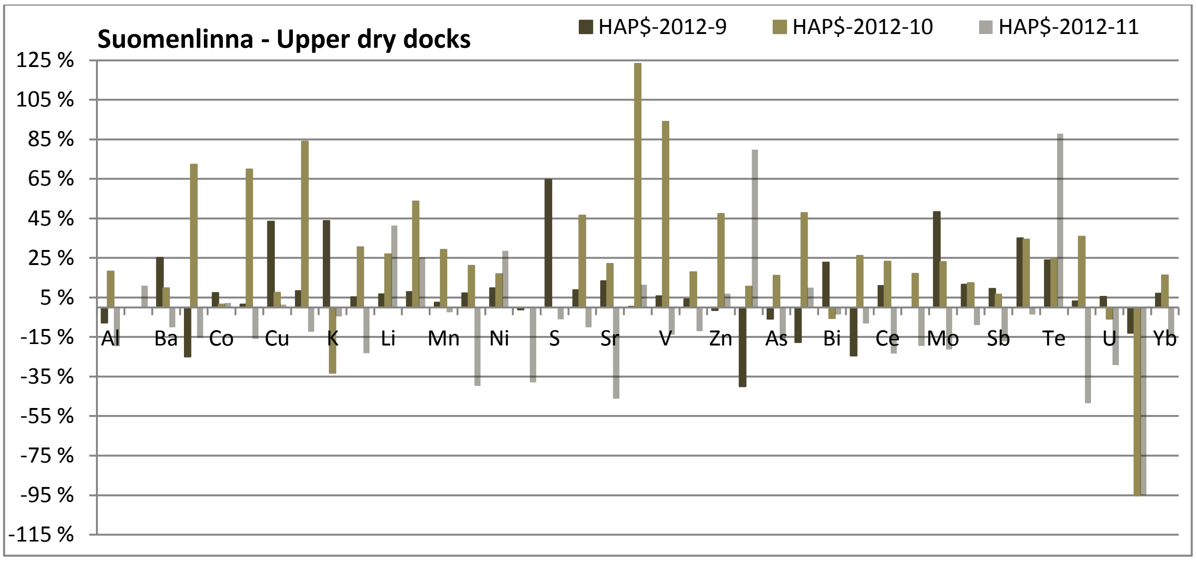

Figure 63. Changes in percentages between top and bottom samples of the sample from the walls of the upper buildings of the dry dock

Samples are from different kind of stones and their composition has been different originally (Fig.64).

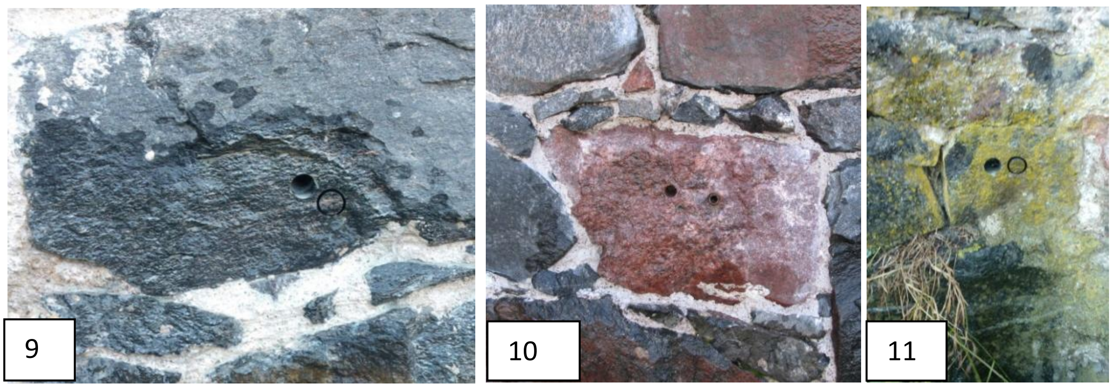

Figure 64. Blocks of the buildings over the dry dock

Their exposition has been probably similar on the building site but their weathering level could had been different at the moment they had been picked up to be installed on the walls. Partially similar trend have been followed by sample HAP$-2012-9 and 10, while a completely different one has been followed by HAP$-2012-11 but the sample 11 has been also presenting lichens and biological activity over it.

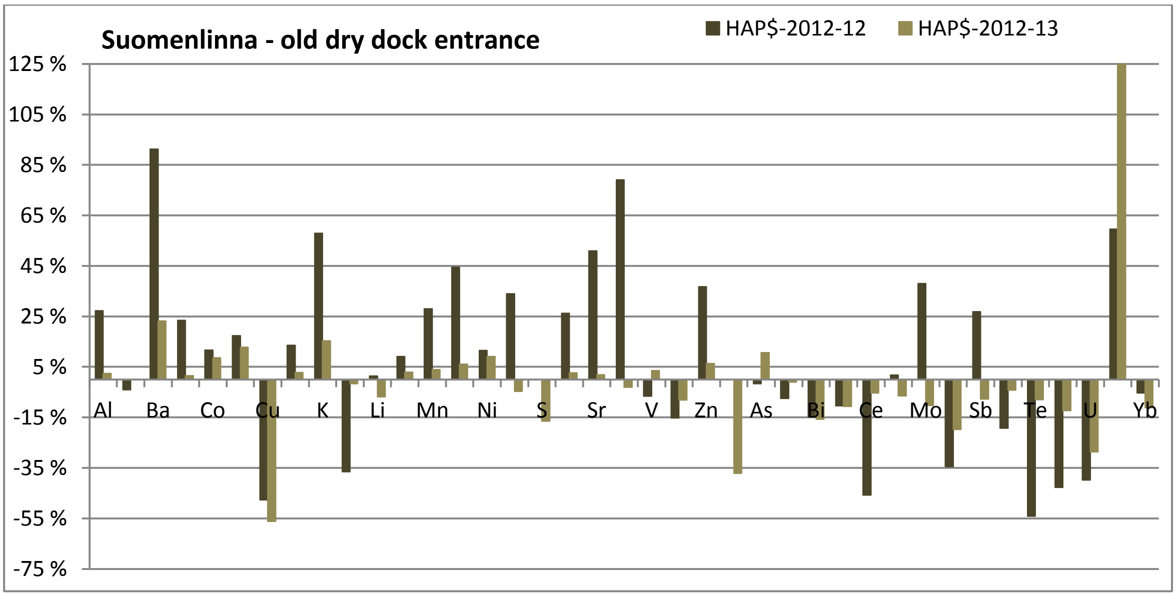

Figure 65. Changes in percentages between top and bottom samples of the sample from the old entrance to the dry dock (W is exceeding the scale and is equal to1855%)

The excess of W could have been a mistake since it is so high. From the figure can be seen that Cu has been leached, so the surface present lower quantity compared to the bottom part. Same has happened for the radioactive elements. Surface has been instead enriched in quite all the other elements but not at the same rate for both of the blocks examined.

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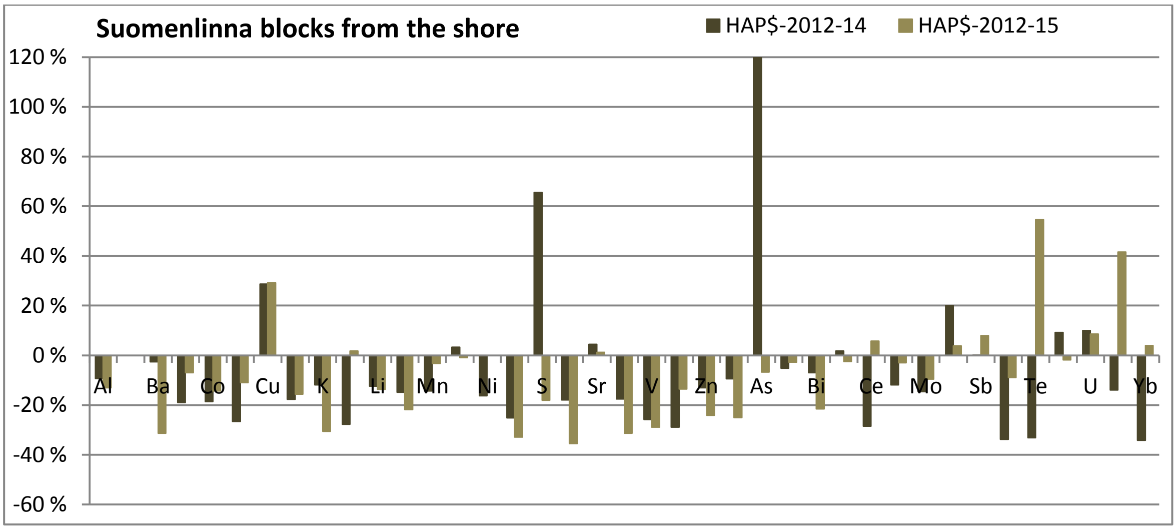

Figure 66. Changes in percentages between top and bottom samples of the sample from blocks dismounted from the pier-shore area. (As is exceeding the scale and it is equal to 234%)

The samples present quite similar trend except for As, S, Ce, Te, W and Yb. Looking at the images of the blocks it is visible that HAPS-2012-14 had been sampled over a clean surface while HAPS-2012-15 over a dirty one, either mortar or calcareous concretions, even if it does not show from the chemical analysis, where for both there has been loss of Ca.

Figure 67 From left to right: HAP$-2012-14, HAP$-2012-15

The graphics of the changes of chemical compositions of each sample are collected in Annex 1.

Non-destructive research methods

Non destructive research methods have included Ground penetrating radar and Schmidt hammer hardness test performed by the Geological Survey of Finland. Ultra Pulse velocity on specific blocks has been performed in cooperation with the Polytechnic of Turin-Italy while thermal camera measurements have been performed in cooperation with Mikkeli University of Applied sciences.

Ground penetrating radar

Measurements have been performed along the granite arc of the Tenaille Kylembeck reshaped by Russians in 1852, on the blocks of the dry dock in the lower part and on the building in the upper part of the dry dock. Their position is shown on the map in Figure 68.

Figure 68 Map of the areas where non destructive tests have been performed: GPR and UPV

In Figure 69 are shown the GPR measurement lines taken from the Tenaille.

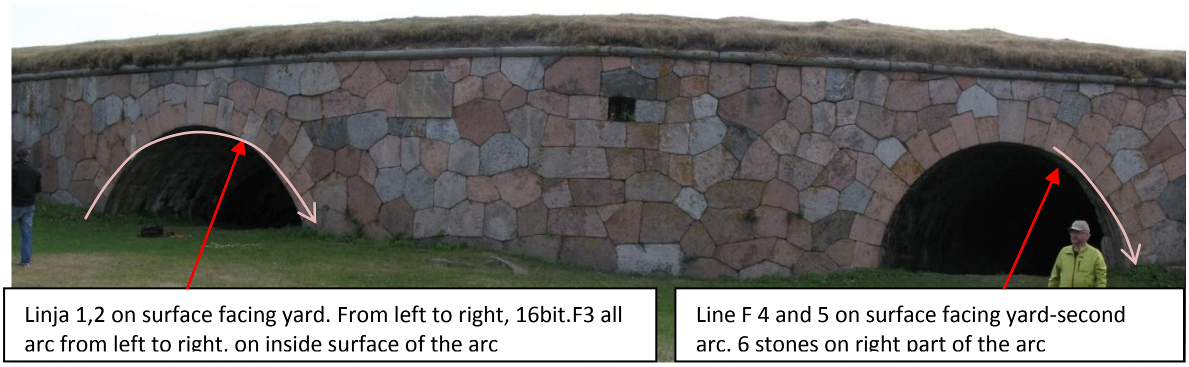

Figure 69 Position of the GPR measurement lines over the Tenaille in Kustaanmiekka.

The antennae had been placed over the outer side of the blocks and carried slowly at constant velocity. Detail of GPR radargram interpretation collected from Line 1,2 for blocks 1-5 from the left arc is shown in Figure 70.

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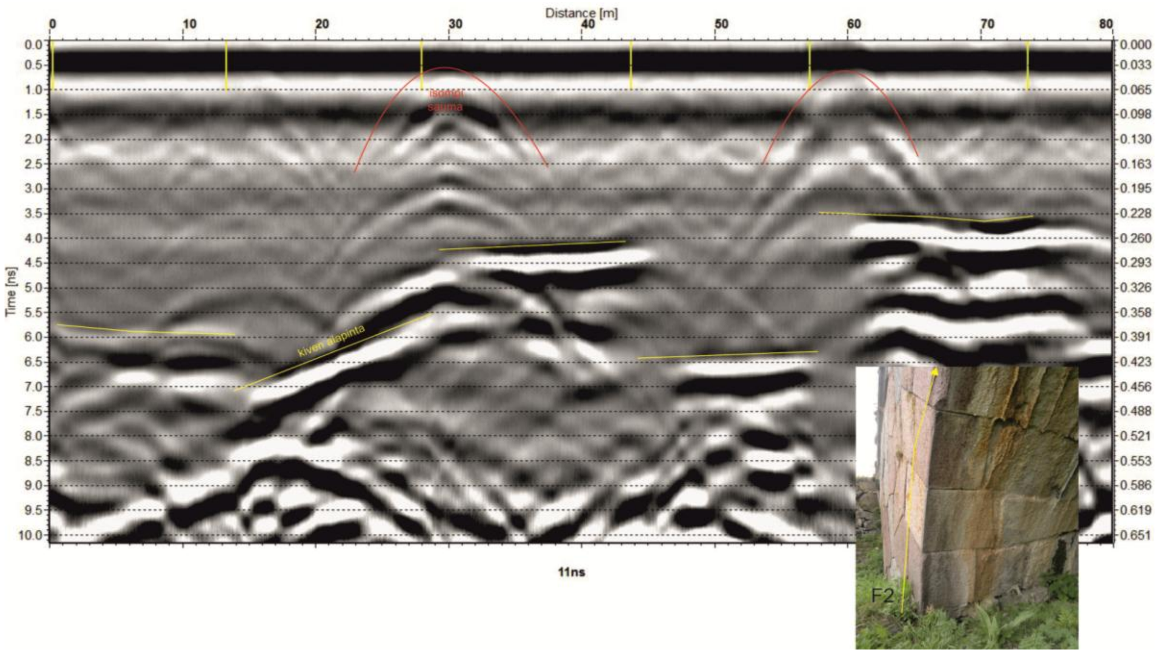

Figure 70 Blocks 5-7 from GPR measurement line 1,2.

In the interpretation of the radargram can be seen clearly the back side of the blocks, that are shaped in irregular way and present different thicknesses. A strong parabole is visible in the area between blocks 2 - 3 and 4 – 5, this could be caused by the wide joint or a by an anchoring between the blocks. In Figure 71 are shown the next blocks of the arc: 8-14

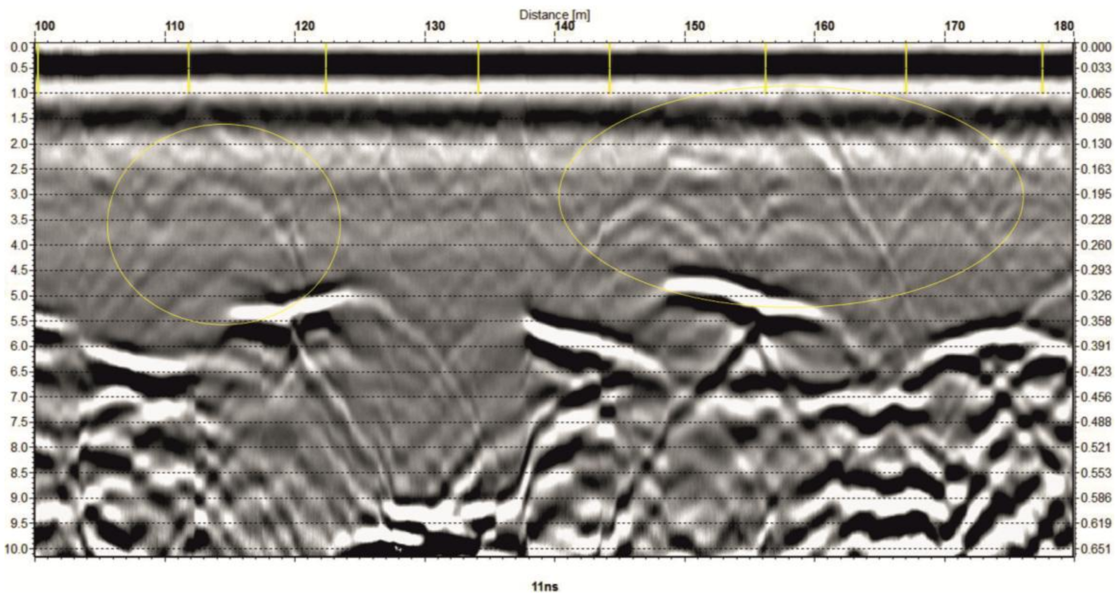

Figure 71 Blocks 8-14 from the left arc from GPR measurement line 2.

The material seems to present some discontinuities in mass, probably some veins, as there are weak internal refraction in the material itself. They could rapresent internal cracks while it is improbable that they would be iron

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anchoring, because of their weakness, still could be possible that they would be wood anchors between blocks since their position is always at the right (quite in correspondence) of a joint between two blocks. Block n 9 is showing a very strong reflection, as visible from figure 72. It is might also be cause by a fracture or opening in the block.

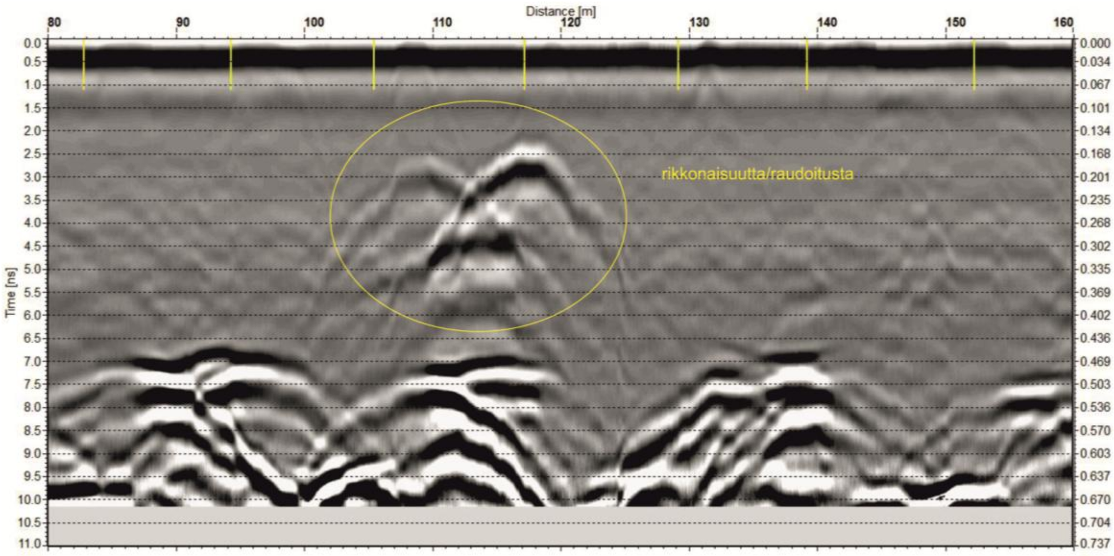

Figure 72 Block n.9 showing high reflection, probably due to a metal anchoring.

In Figure 73 is shown the radargram interpretation of the full arc. In it are visible the stronger reflections probably caused by anchoring, openings or cracks, and the weaker ones, more diffused, probably caused by reflection of the wave against the walls of the blocks or by the joints or still by the heterogeneity of the material.

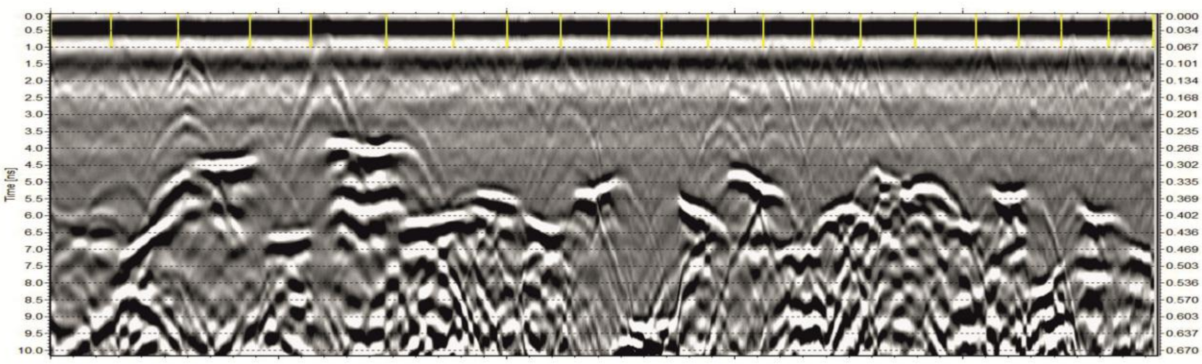

Figure 73 Radargram interpretation of the whole arc

The back sides of the blocks are well defined and blocks show irregular thicknesses. Clear image of the backparts of the blocks is also shown in Figure 74 where radargram interpretation of the second arc of the Tenaille is analysed, in this case placing the antenna in the inside of the arc.

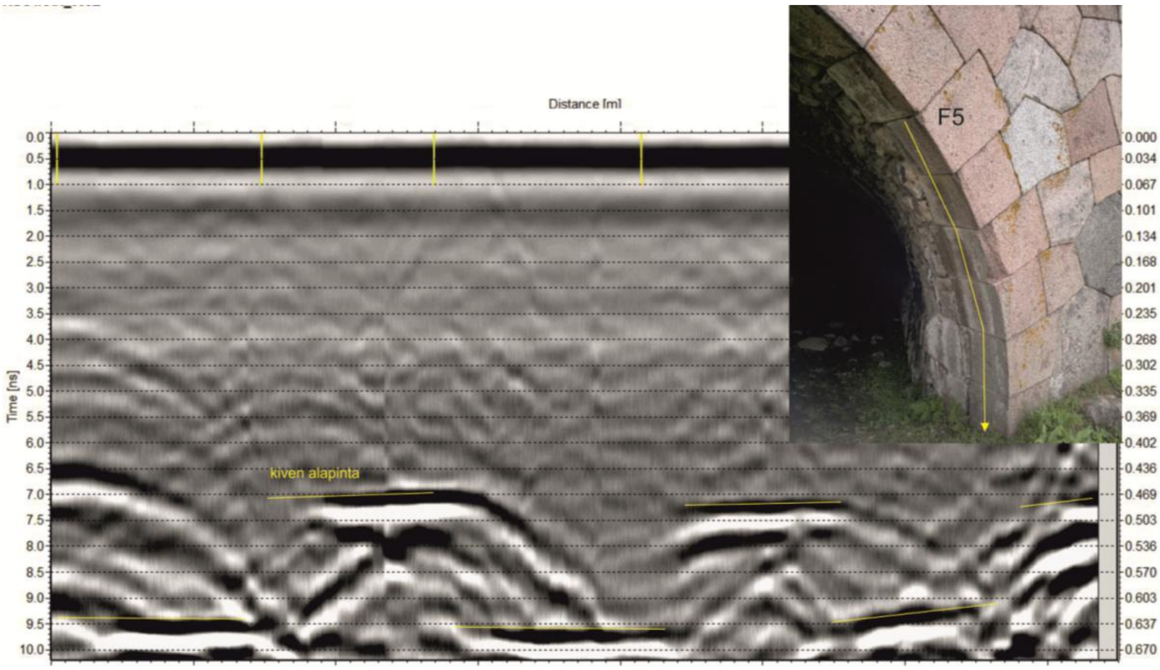

Figure 74. GPR measurement line F5 on the second arc of the Tenaille.

Even if from figure 74 is not visible presence of possible cracks in the material, in the measurements collected from the outside part of the arc (Fig.75) a reflection that is within the material and separated from the joints is visible. In this case the reflection could have been caused by an internal fracture in the back surface of the block.

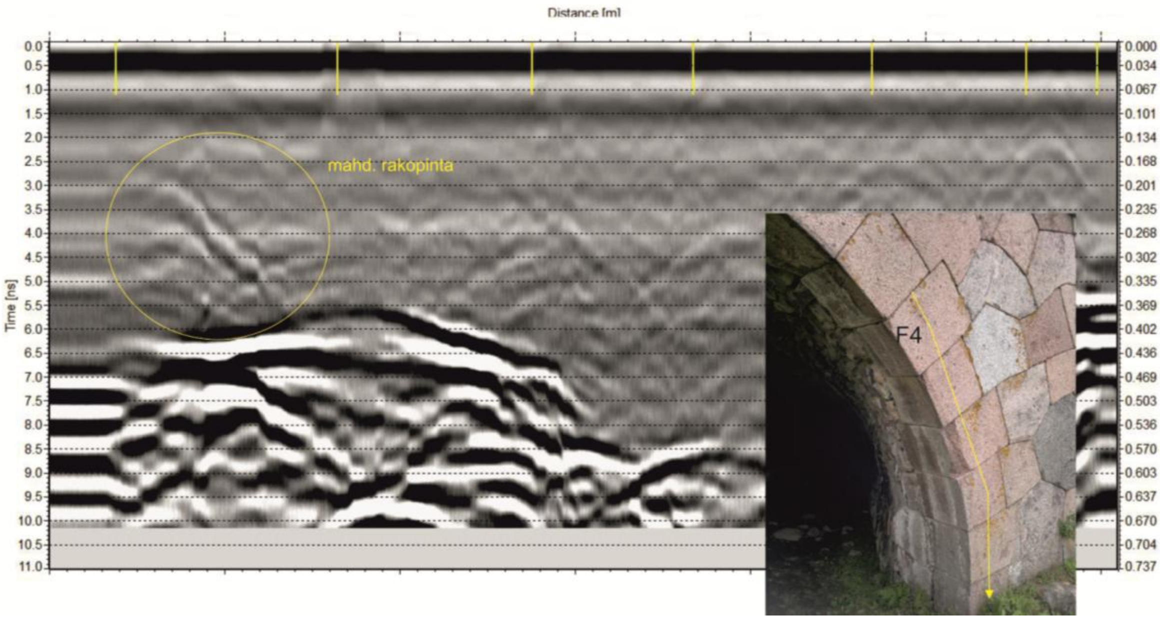

Figure 75 Radargram interpretation over the right arc of the Tenaille along measurement line F4

Positions of the measurements performed in the dry dock are shown in Figure 76 where a GPR Line coded F6 had been attempted on blocks that looked mostly flat near Suomenlinna 3 and a more detailed study has been performed over the steps.

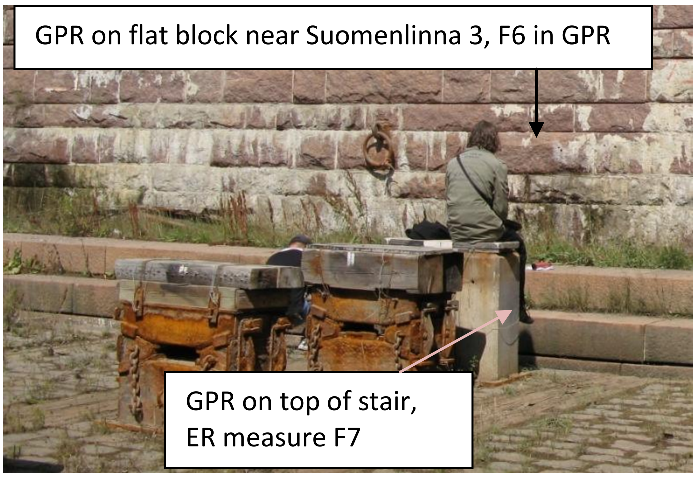

Figure 76 Position of the measurements in the dry dock, near the sampling areas.

From the measurement along the wall (Fig.77) is visible that the thickness of the blocks varies and that the blocks lie on a compact back wall since the scattering of the wave is much lower compared to a wall back-filled with loosen or small size material. The external blocks tested do not present fractures and a reflection is just on the right of the joint and it could had been caused by the joint itself.

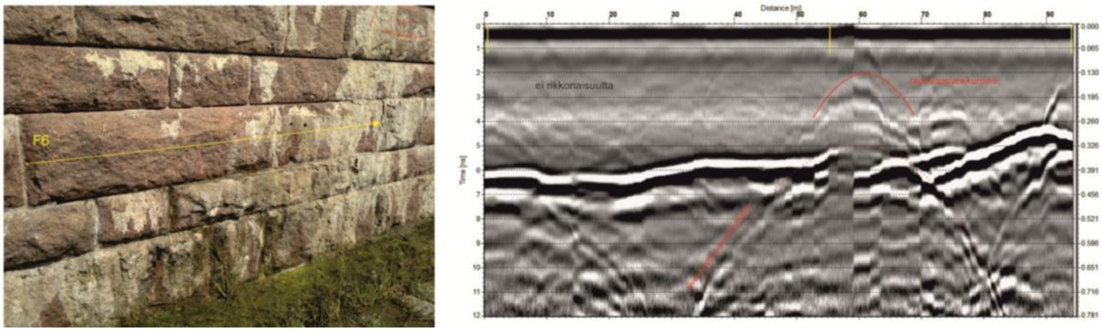

Figure 77. Measurement line F6 performed over the wall of the dry dock on the sampled blocks.

The Er of the material has been calculated from the steps because they presented a thickness that could be measured. Er value has been 5,3.

The steps represented an opportunity to understand what could be recognized using the instrument and evaluated at which definition could operate on stone constructions. In figure 78 is shown a comparison of the refraction of the signal and the construction element. It can be seen the different layers and back surface reflections of the blocks (in yellow), the parables given by reflections against the sides of blocks in correspondence of the joints, can be seen that it is visible also the second back face of the lower block but it is not shown the joint between blocks at that level, while in blue could be seen probably the parable given by third level of blocks downwards.

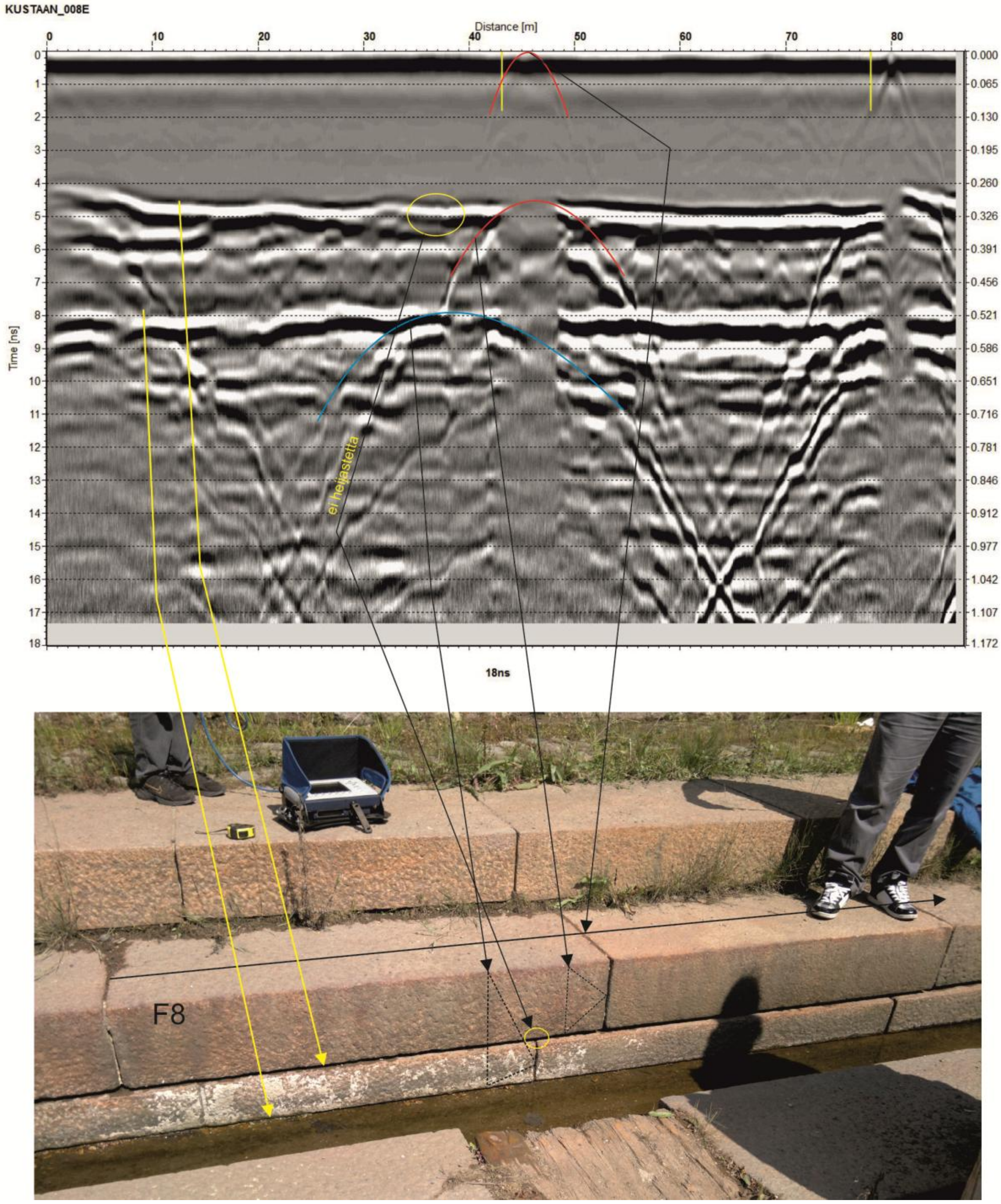

Figure 78. Comparison of the radargram analysis and the construction element of the steps.

Also in the upper part of the dock have been performed GPR measurements along parts of the wall that presented as homogeneous and flat surface as possible as visible from Figure 79. GPR had been taken also along the sandstone door frame, named F3 on a stone thick 22cm.

Figure 79 GPR lines from left to right F1, F3 and F2.

Ultrasonic measurements (UPV)

The measurements have been performed in an indirect way according to the report "Methodology UPV". The blocks tested are shown on Figure 80.

Figure 80 Position of the blocks tested over the left arc of the Tenaille. (Photo: H.Pirinen)

The measurement n 5 had been performed on two places, over the stone(5) and over the stone and white crust (5b). The results are shown in Figure 81 and it is visible that the measurements over the crust had been giving much lower velocity.

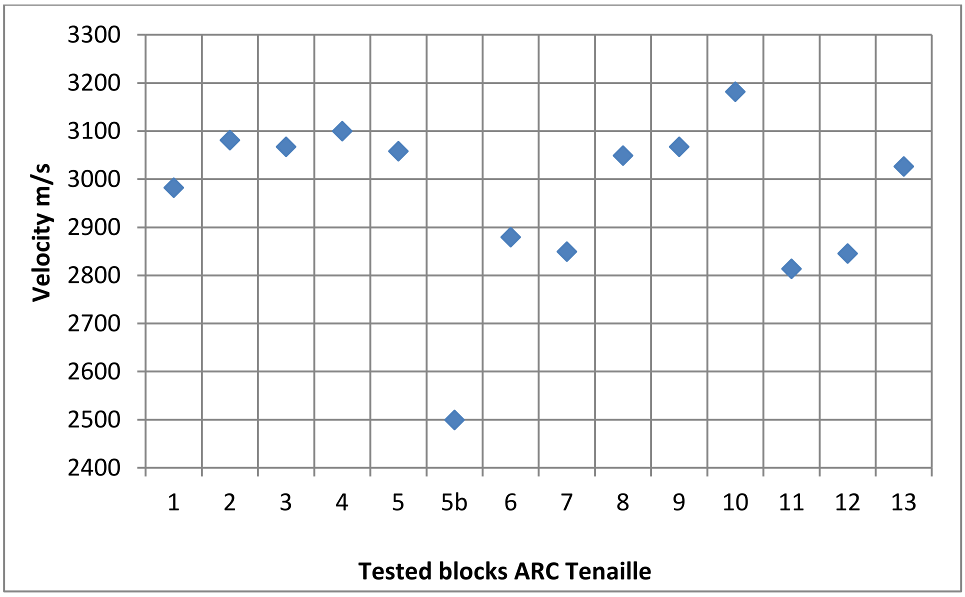

Figure 81 Graph of the velocities calculated for the blocks of the arc Tenaille.

Even if the blocks had been quarried the variation of velocities is high. Apart from the velocity estimated over the crust, that is lower, measurements 6 and 7 and 11 and 12 show lower results compared to the others. The interpolation line of the data collected is anyway very good and from the pictures of the blocks cannot be seen weathering or cracks (Figure 82).

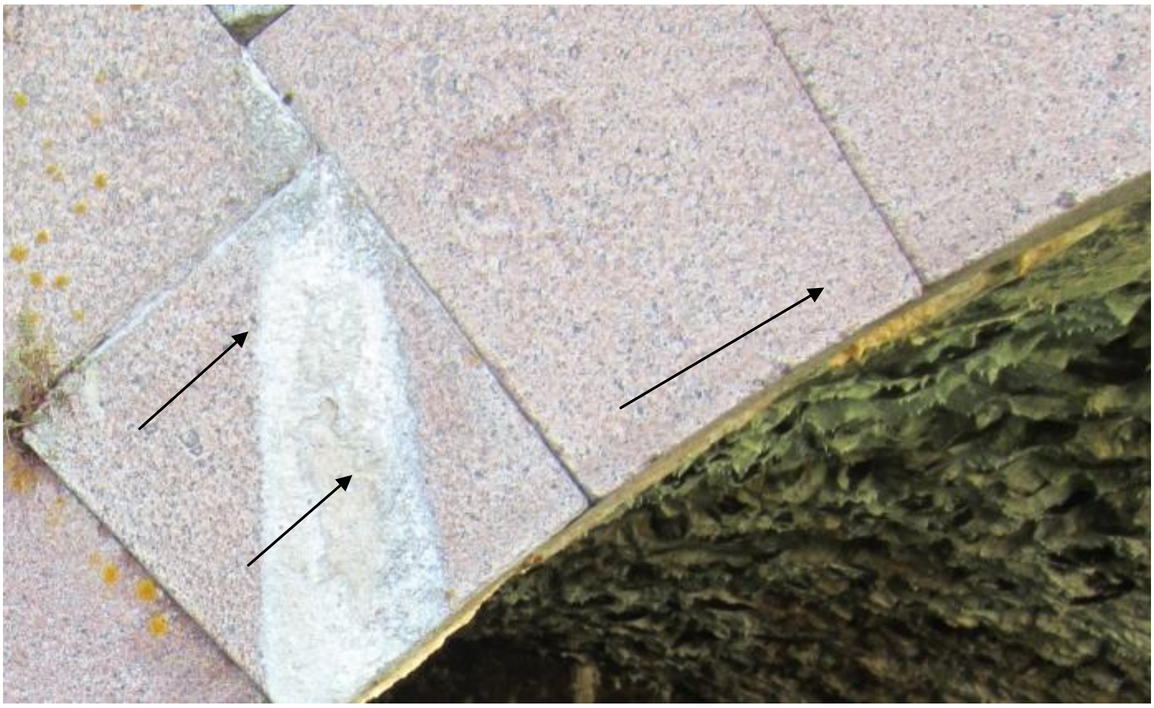

Figure 82.Measurements line 5, 5b (over white crust),6.

Measurement line 6 and 7 , on the other side, have been done near the edge of the block and in a high position, difficult probably to exercise a higher pressure over the transducers. In figure 83 are shown the values collected on the dry dock.

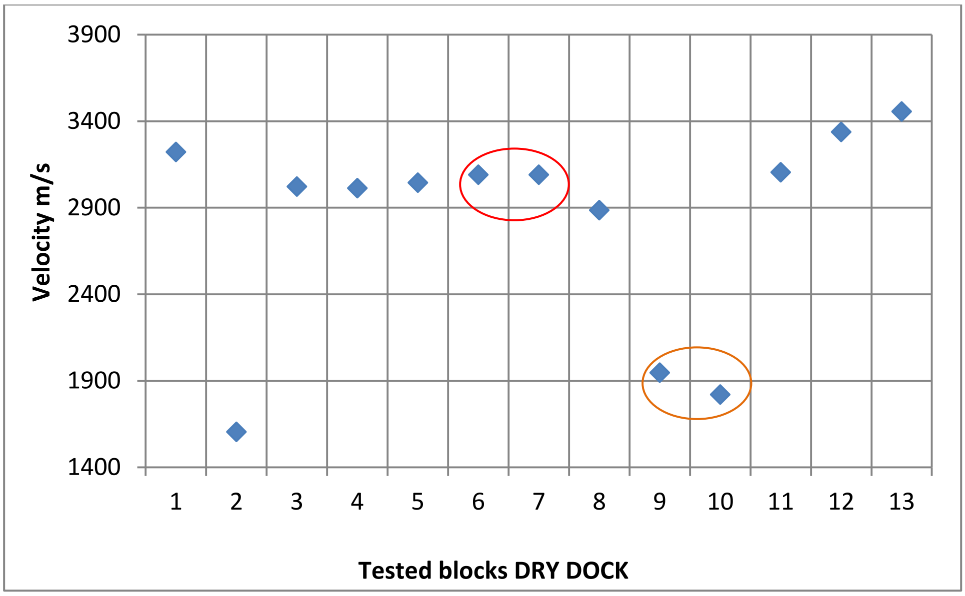

Figure 83. Diagram of mean velocity measured on the dry dock materials (lower and upper parts).

Measurements 1 to5 have been performed over the lower part, on the walls. The measurement 2 had been performed over the white crust, that has been measured being of 14 mm. The crust, probably of calcium carbonate, present much lower velocity compared to the clean rock.

The measurement n.1 is done over the block affected by seaweeds, sampled also for other analysis.

The measurements 6 and 7 have been done over the steps as also the georadar measurements have been performed.

Figure 84. Measurement 5 on the left, and 3 (measured over the block sampled for testing) and 4 on the right

Figure 85. UPV measurements 6 and 7, over the steps of the lower part of the dry dock

In figure 86 are shown the same averages values excluding the sandstones of the arc of entrance in the upper part(9,10- visible in Figure 87) and the tests performed over the crust (n.2) in the lower part. The aim is to evaluate the changes on velocity in the compact material.

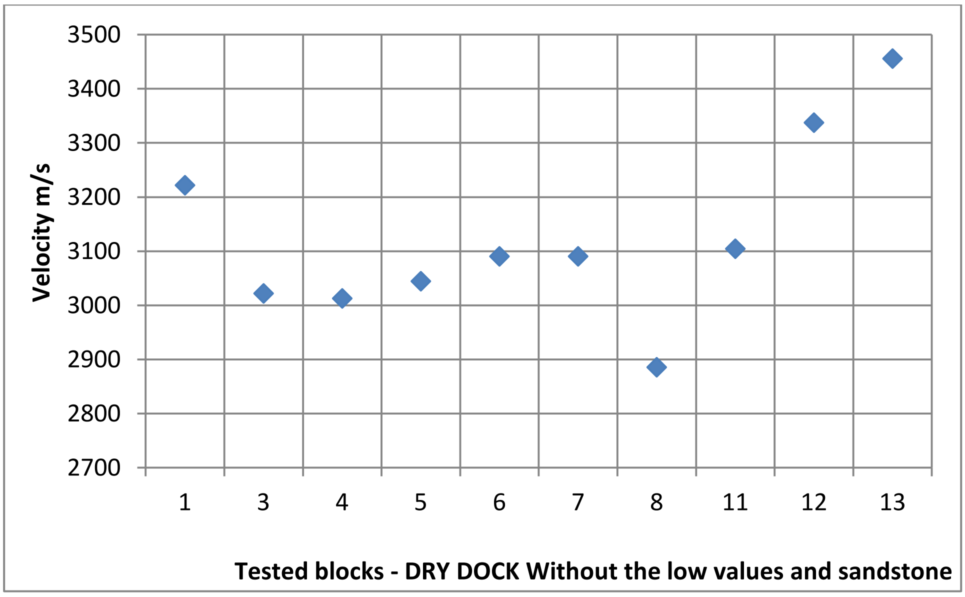

Figure 86 Diagram of the velocities excluding the points that presented low velocity.

Measurement 8, 11,12,13 have been done over the upper part of the dry dock and on the blocks also sampled for testing. Their velocities are very heterogeneous and block n 8 present the lowest velocity. The blocks have different weathering levels also given by the fact that had been unshaped blocks collected from the site.

Figure 87 The upper buildings of the dry dock and position of the measurements of UPV.

Measurements 13 and 14 have been taken over the blocks sampled. Measurement 11 over the block measured also with georadar (Fig.88)

Figure 88. Measurements 11, 12 and 13 on the other wall of the buildings over the dry dock.

Schmidt hammer

The Schmidt Hammer has been used perpendicular to the surface to be tested, according to the methodology described in “Methods Schmidt Hammer” and has been performed on the same blocks on which has been done the GPR measurements and has been sampling. Not all the blocks have been included. The measurements are shown in the next figures and tables.
The values obtained testing some blocks of the left arc of Tenaille are shown in Table 2, while the positions of the blocks are shown in Figure 90.

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Figure 89 Schmidt hammer performed on the outer wall near the king's gate

Table 1. Results of Schmidt hammer performed over the outer walls of the fortress, near King's gate.

	1KG	2KG	3KG	4KG
Rebound values	34	52	56	54
	34	46	60	54
	40	54	56	56
	26	46	56	42
	32	60	56	50
	56	68	52	48
		60		56
				54
				60

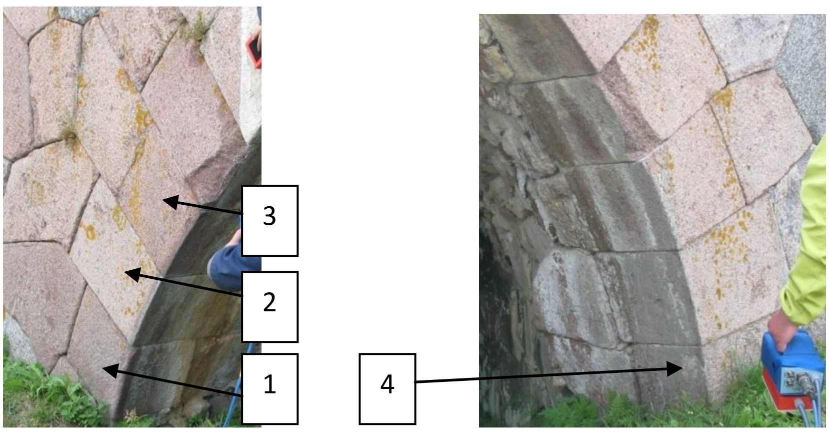

Figure 90. Blocks tested in the left arc of the Tenaille

Table 2 Blocks over which the Schmidt hammer has been performed on the left arc in the Tenaille

	1	2	3	4
Rebound values	48	56	50	54
	56	58	56	52
	50	60	56	54
	38	62	56	64
	50	68	56	64
	52	62	60	62
	48	58	50	48
	52	60	54	48
	56	58	60	58
	48	50	44	38
	48	58	50	38
	50	60	52	56

Table 3: Rebound values of the tests performed over the sampled blocks in the lower part of the dry docks

	Suomenlinna 1	Suomenlinna 2	Suomenlinna 2	Suomenlinna 3	Suomenlinna 4	Suomenlinna 4
	HAP$-2012-6.3	**HAP$-2012-7.3**	**HAP$-2012-7.3**	**HAP$-2012-8.3**		
Rebound values	In mould	All white	On clean stone	Clean surface	On white	On clean stone
	38	38	34	42	33	48
	52	54	44	58	38	52
	58	48	54	52	50	56
	54	15	36	44	20	40
	42	24	54	52	28	58
	58	28	58	52	38	60
	52	10	52	44	28	30
	58	10	58	54	28	54
	60	10	54	56	40	54
	36	20	30	38	28	54
	54	28	30	38	40	62
	34	30	58	48	52	60

In the upper part of the dry dock have been tested the blocks that have been sampled as shown in figure 91

Figure 91. Blocks tested in the upper building of the dry dock

Table 4: Rebound values of Schmidt hammer performed over the blocks sampled and the sandstone of the basement of the portal

	HAP$-2012-10.1-2	**HAP$-2012-11.1-2**	**HAP$-2012-9.1-2**	Sandstone	Sandstone
Rebound values	32	50	41	46	Low left block
	51	50	52	46	
	40,5	59	54	52	
	52,5	54	31	42	
	58	33	36	48	
	56	46	48	50	
	38	35	35		
	38	44	50	38	Second block over
	48	46	56	34	
	38	31	46	46	
	48	46	52	40	
	58	39	52	56	
				56	

Table 5: Rebound values over the blocks of the upper part of the dry dock tested also with georadar

	Georadar line F1:	
	Black rock	Red rock
Rebound values	57	62
	62	58
	64	61
	58	53
	64	59
	56	61
	44	62
	48	64
	47	65
	56	55
	60	62
	64	62

	Georadar line F2:	
	1st smaller rock	2nd bigger rock
Rebound values	58	38
	60	44
	58	40
	41	59
	60	58
	52	58
	38	50
	47	61
	57	63
	41	50
	48	58
	58	48

The results are rapresented on a diagram in Figure 92.

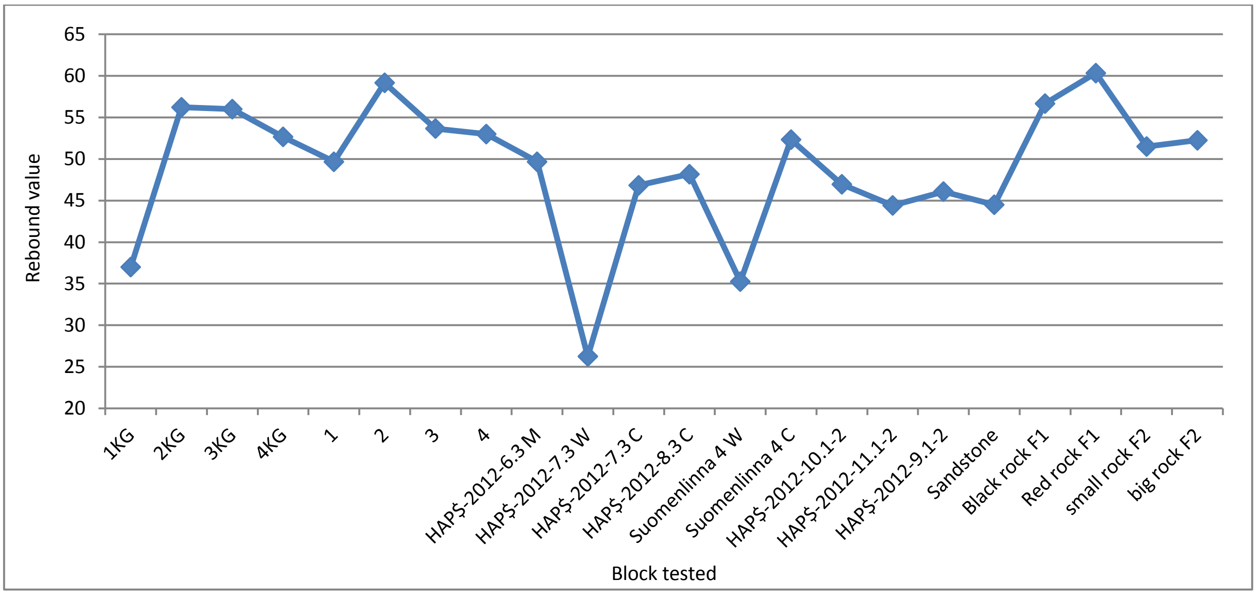

Figure 92 Diagram of the average rebound values for each block tested on site. C: Clean surface, M: biofilm,W:white crust

It is visible that the material is heterogeus, but is also visible that the blocks that presented salt or likmestone crust over their surface presented lower rebound values compared to the same parts of the blocks not covered by the deposition (example: HAP$-2012-7.3 W and C; Suomenlinna 4W and C). The blocks of the dry dock show high variation even comapring the results got on clean material. Sandstone presented quite good rebounds values compared to the other hard rock block tested.

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The blocks of the arc (1,2,3,4) have showed values differing even if the material is quarried and looks more homogeneus.

Thermal camera

The measurements have been performed during a sunny day. The first images collected during morning have been those from the blocks sampled near the King's gate as visible from figure 93.

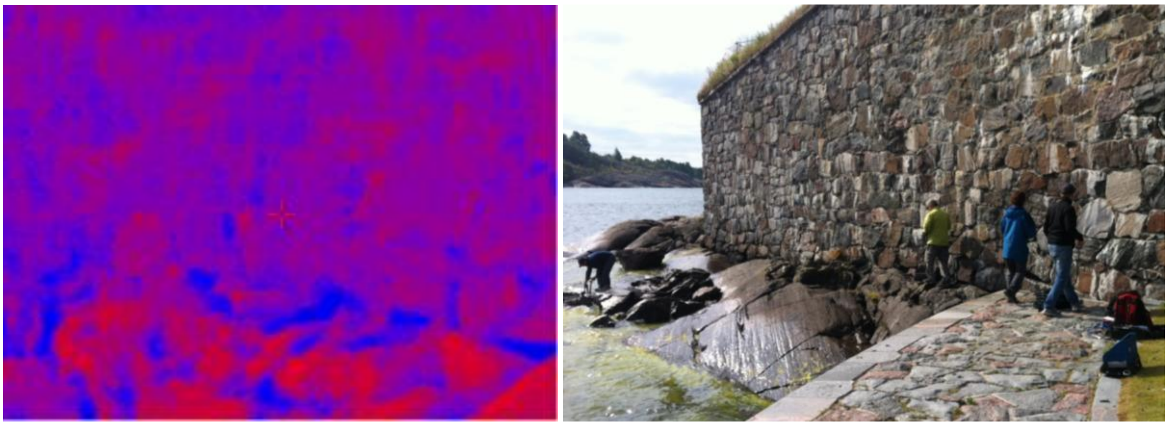

Figure 93 Thermal image and normal photo f the walls near the king's gate (Photos: A.Shkurin)

The walls present quite homogeneous temperature, showing as hotter points those that are reflecting mostly the light, as the bedrock in front of the wall towards the sea. When the drilling is performed and it is taken an image of the specific block can be distinguished as colder the hole. The joints have been appearing as colder.

The images collected from the arc of the tenaille, taken in the morning and in the shadow, show that the inside of the arc is colder as visible from Figure 94, joints between rocks looks a bit colder and looking at a detail of a block can be seen the likens looks wormer. The deposition of salt over a block is also appearing as wormer, probably because of its different thermal conductivity.

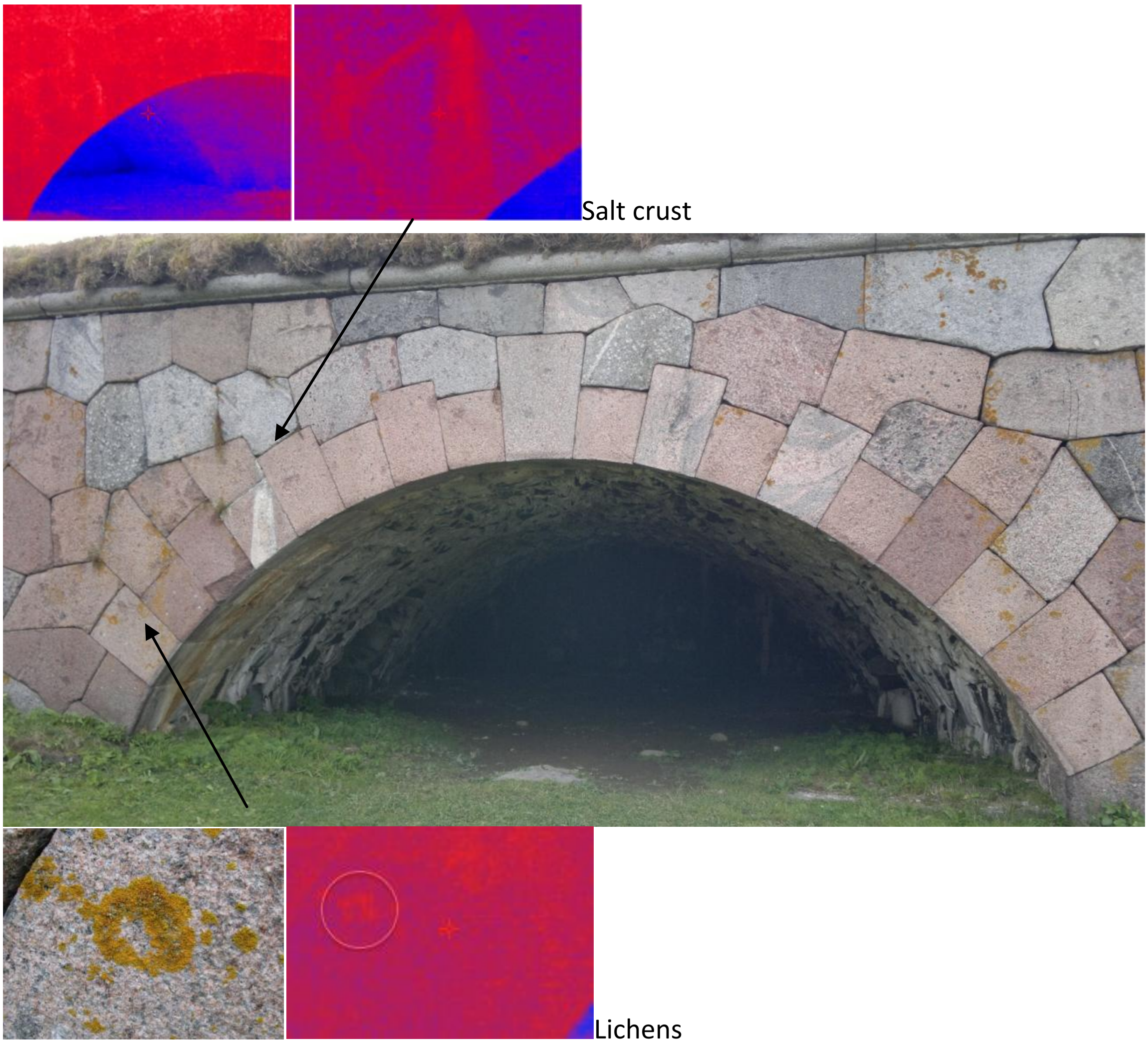

Figure 94 Thermal camera images and their correspondent position on the arc (Photo: A.Shkurin, H.Sutinen, N.Luodes)

Thermal conductivity of the blocks can be noticed in the blocks that are partially exposed to shadow and partially exposed to direct sun as visible in figure 95 the temperature different of the blocks is this case been from 16 ºC to 28 ºC.

Figure 95 Lower part of the dry dock, photo and thermal image (A.Shkurin)

Measurements on the upper part of the dry dock have been performed in the afternoon. On that wall a spot presented a much lower temperature compared to the whole wall (12 °C against 17°C of average of the surface) as shown in Figure 96

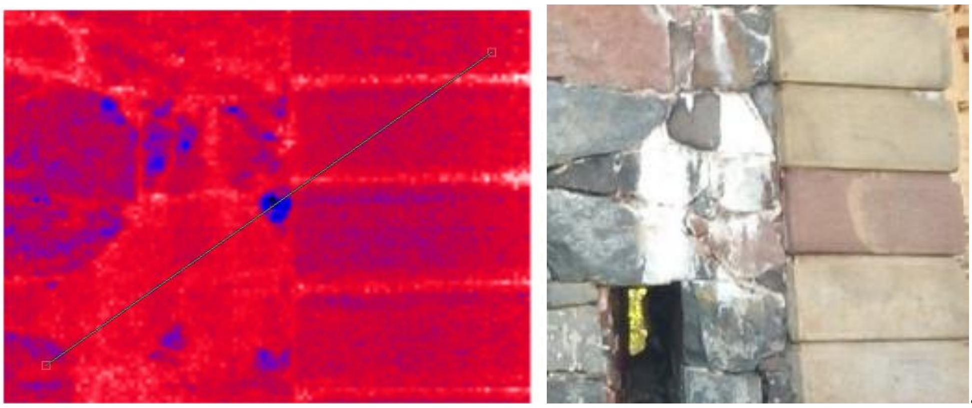.

Figure 96 Particular of the wall near the portal of the upper buildings of the dry dock.(Photo: A.Shkurin)

Mechanical and physical properties

Several samples have been tested for the fortress and the results of density and open porosity are shown in table 6. On the right column are indications about the weathering effects visible from their surface.

Table 6. Results of density and open porosity.

	DRY WEIGHT (g)	UNDER WATER (g)	SATURATED WEIGHT (g)	Apparent density (kg/m3)	Open porosity (%)	
SUOM 4T	39.2	24.35	39.37	2605	1.13	telakka
SUOM 4B	43.64	28.39	43.69	2847	0.33	
SUOM 10T	16.73	10.71	16.78	2751	0.82	white deposition,salt and limestone
SUOM 10B	23.55	15.03	23.57	2752	0.23	
SUOM 13T	22.53	14.74	22.56	2875	0.38	a bit draker surface
SUOM 13B	27.58	18.06	27.62	2879	0.42	
SUOM 14T	20.91	13.21	20.95	2696	0.52	weathered surface
SUOM 14B	23.99	15.14	24.02	2696	0.34	
Kunin Portti 2T	18.02	11.57	18.04	2780	0.31	dark surface, biofilm?
Kunin Portti 2B	18.65	11.87	18.66	2741	0.15	
Kunin Portti 3T	20.12	12.87	20.14	2762	0.28	black, biofilm?
Kunin Portti 3B	21.65	13.83	21.67	2756	0.26	

The results can be visualized in the graph of Figure 97

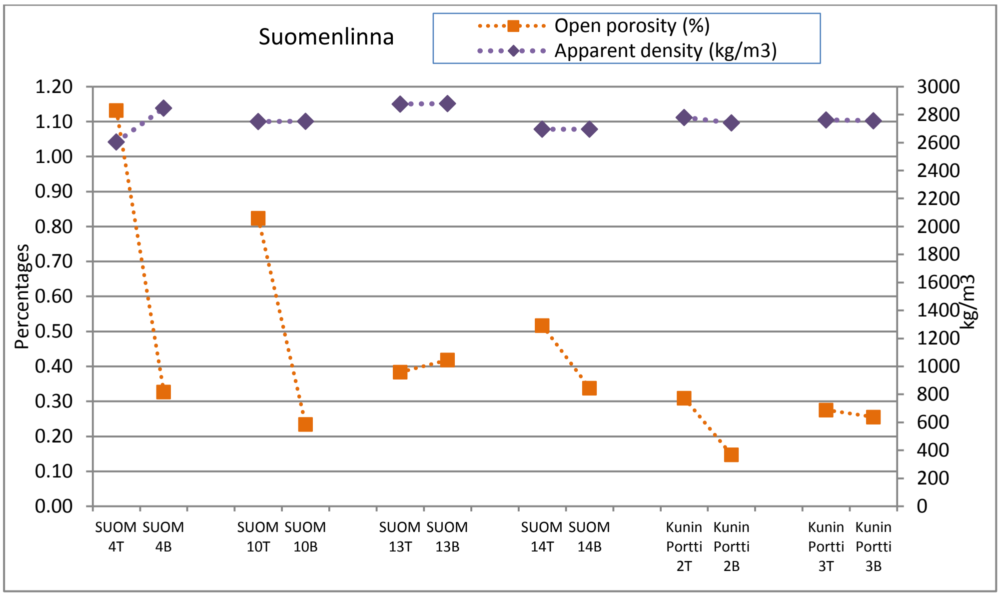

Figure 97. Graph of the values of densities and open porosities calculated for the specimens not tested otherwise. T= Top, B=Bottom

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From the diagrams is visible that the bottom parts present generally lower open porosity compared to the surface ones, especially in specimens that present salt or limestone crusts that alter completely the performance of the stone surface. All the specimens have been presenting different kind of weathering effects and they all have shown a change in the porosity, while densities have been quite constant except for the dry dock material Suomenlinna 4.

In Figure 98 are shown the results of Water absorption while in Table 7 are the numerical values of the test performed.

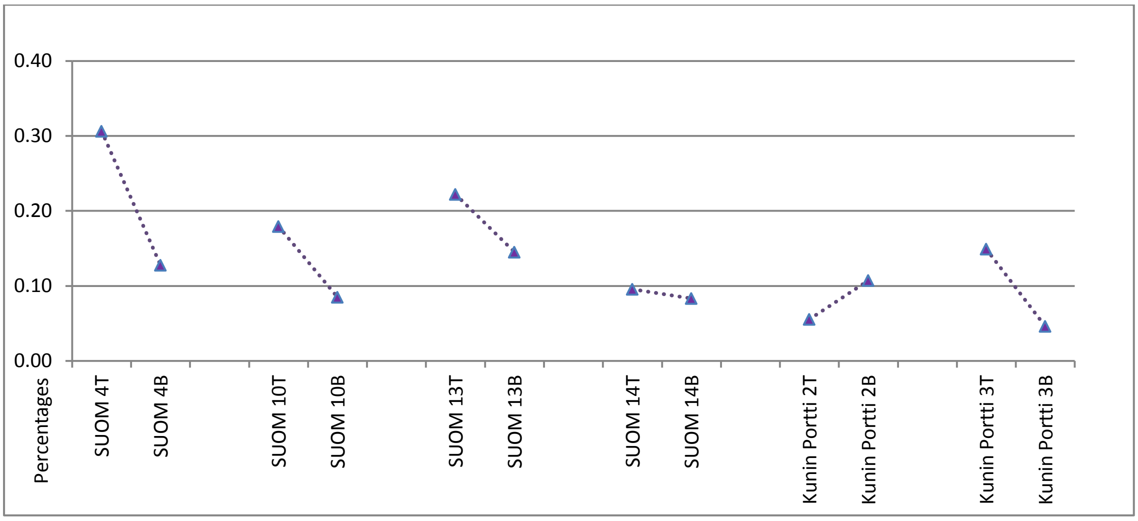

Figure 98. Water absorption of the samples from the fortress.

Table 7. Values of water absorption from the tests performed

	DRY WEIGHT (g)	WET (g)	Water absorption (%)	
SUOM 4T	39.18	39.30	0.31	Dry dock
SUOM 4B	46.99	47.05	0.13	
SUOM 10T	16.73	16.76	0.18	white deposition-salt and limestone
SUOM 10B	23.54	23.56	0.08	
SUOM 13T	22.51	22.56	0.22	a bit darker surface
SUOM 13B	27.57	27.61	0.15	
SUOM 14T	20.92	20.94	0.10	weathered surface
SUOM 14B	24.00	24.02	0.08	
Kunin Portti 2T	18.02	18.03	0.06	dark surface- maybe biofilm
Kunin Portti 2B	18.63	18.65	0.11	
Kunin Portti 3T	20.11	20.14	0.15	Black, maybe biofilm
Kunin Portti 3B	21.65	21.66	0.05	

The results show that the material has some level of weathering on the surfaces, that have tendency to absorb more compared to the more compact bottom part. That is generally in harmony with the lower porosity of the bottom part compared to the top samples.

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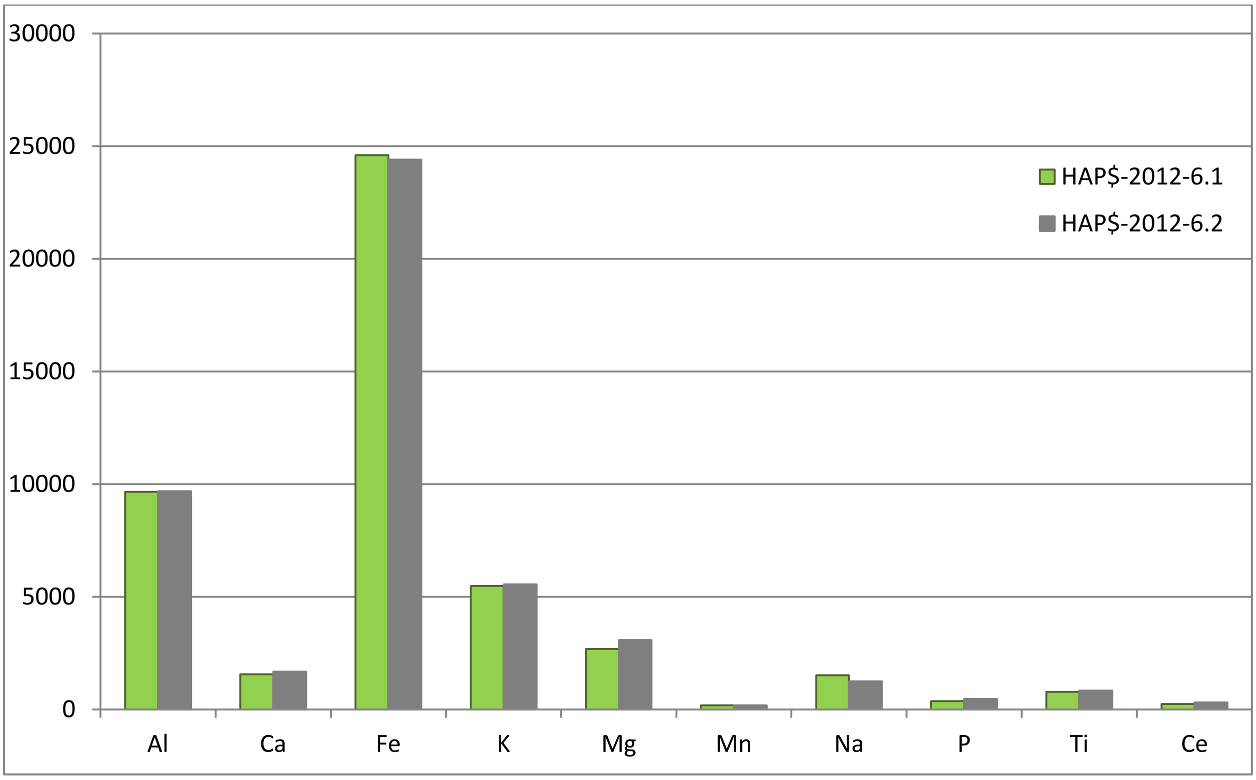
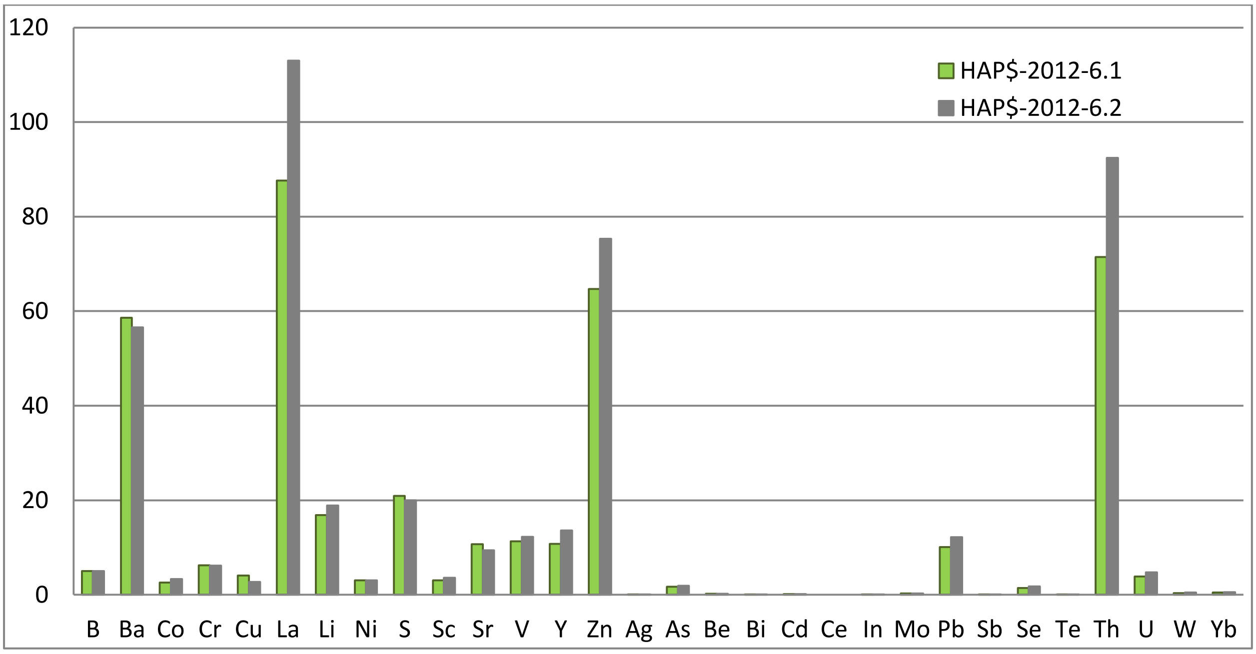
ANNEX 1 SUOMENLINNA

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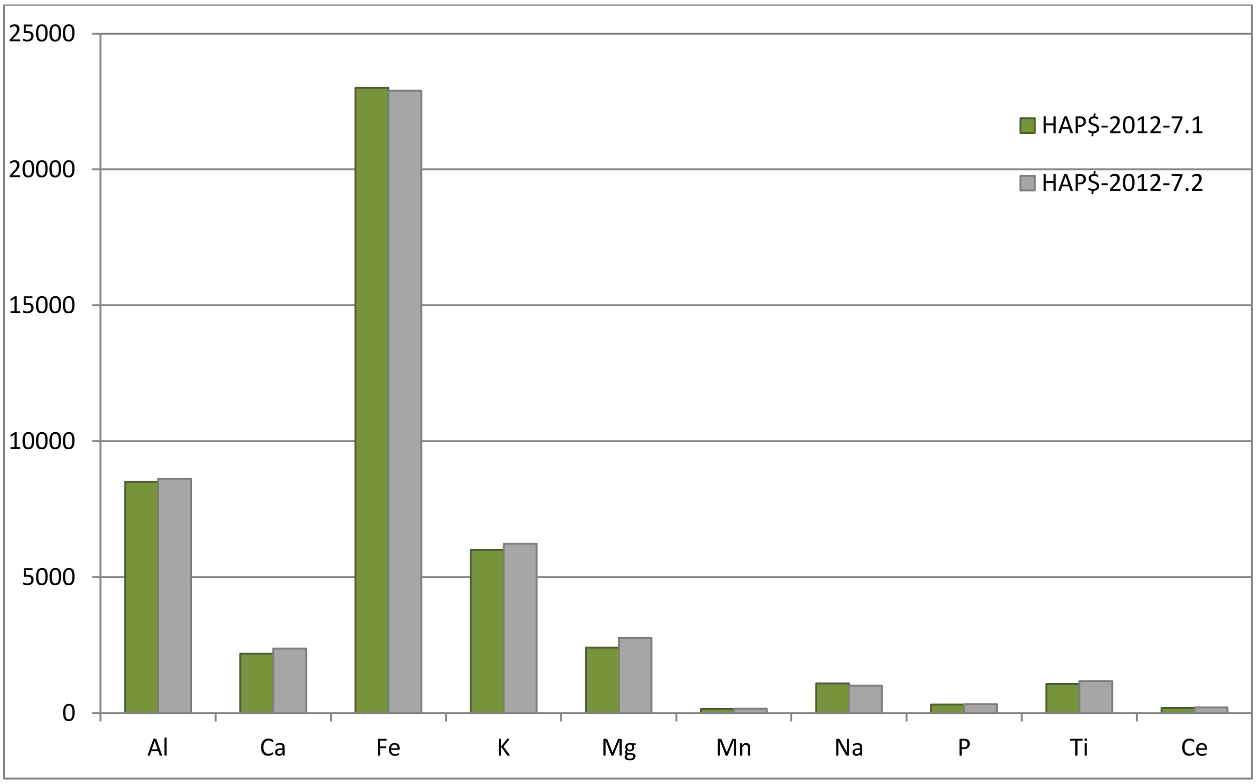

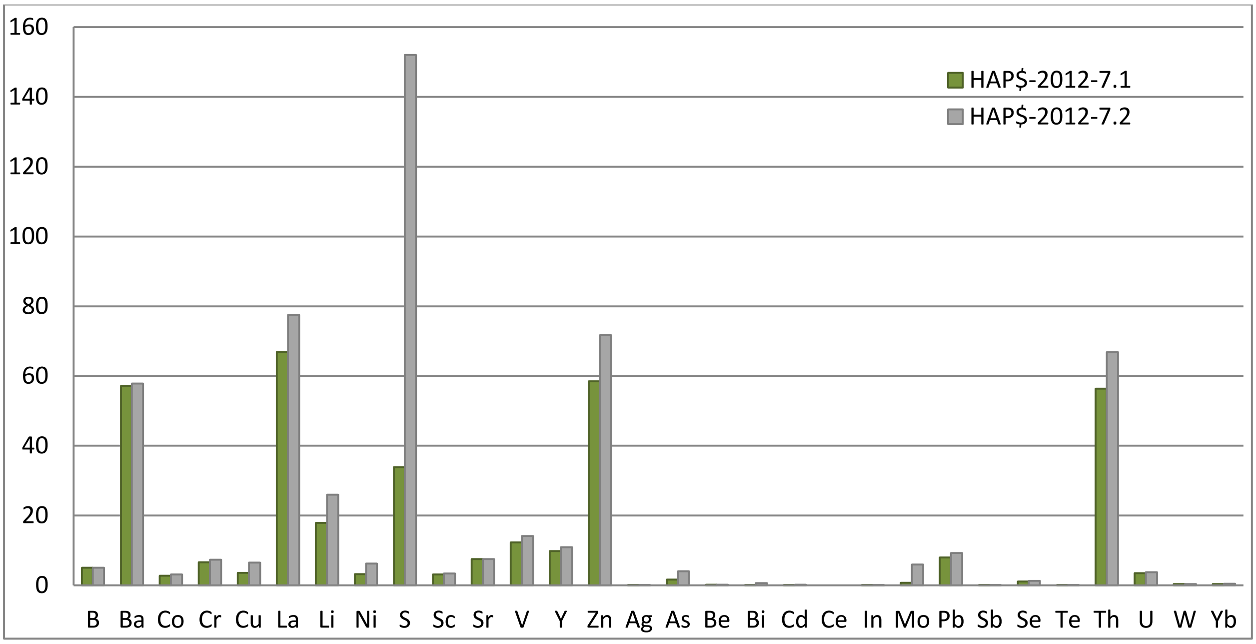

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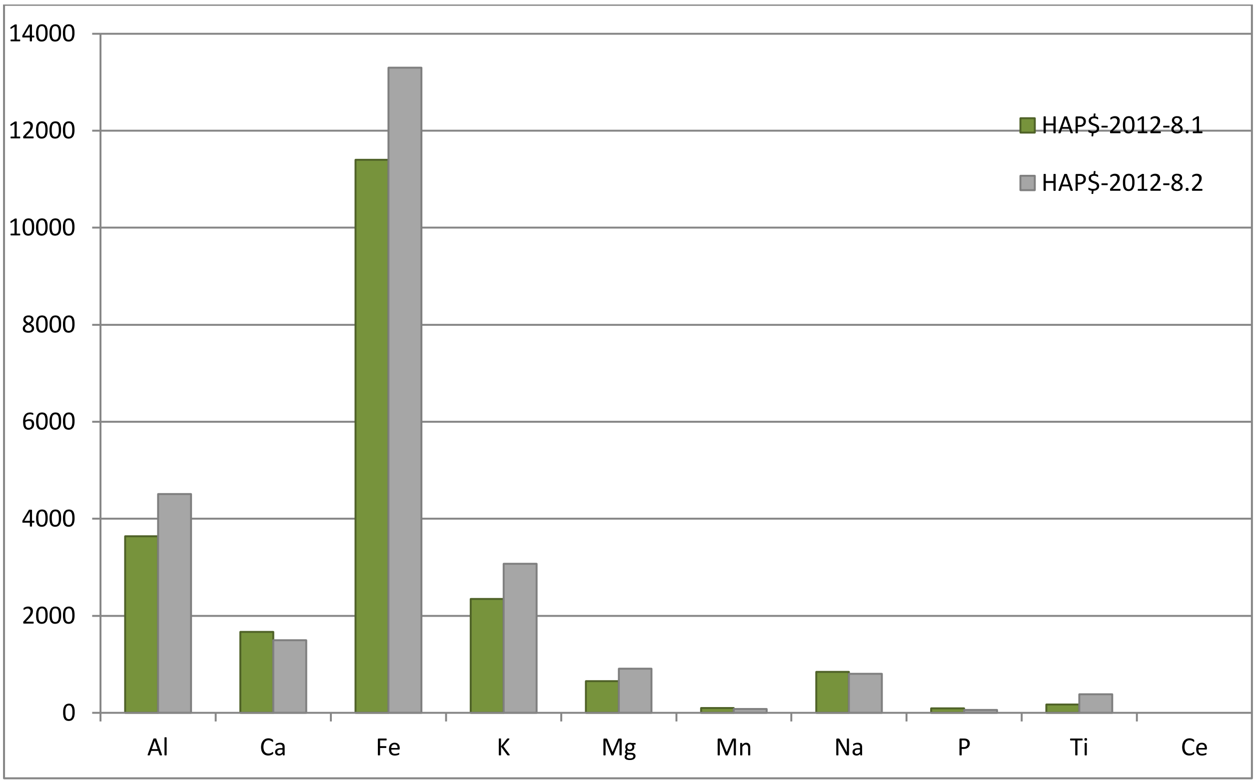

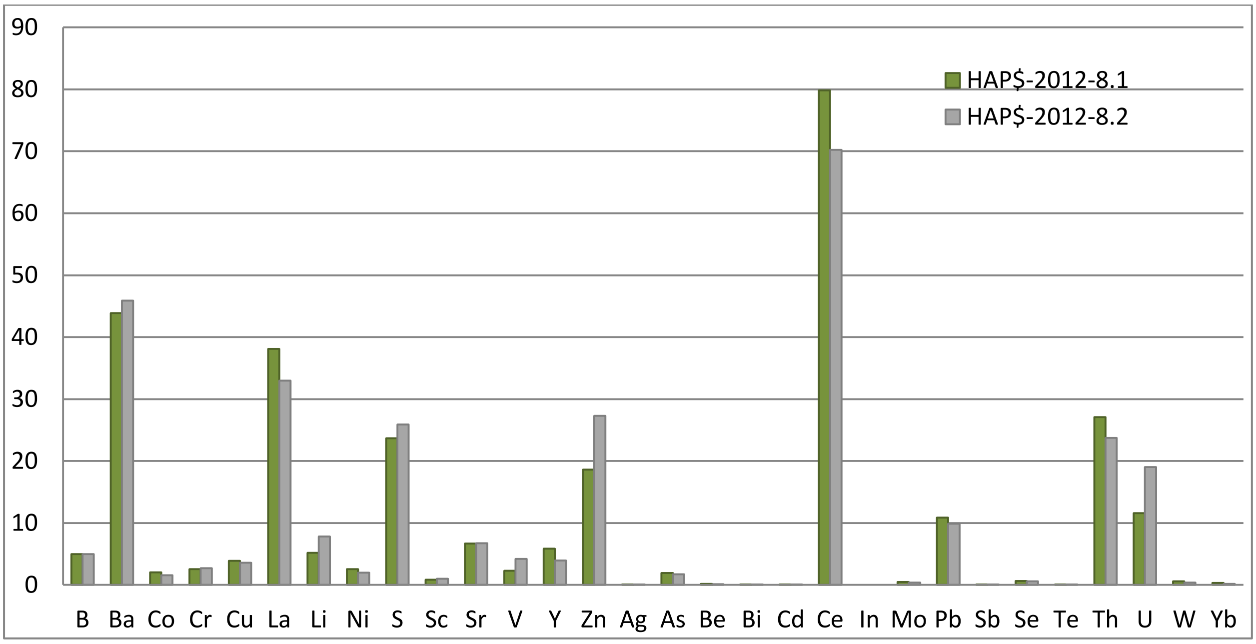

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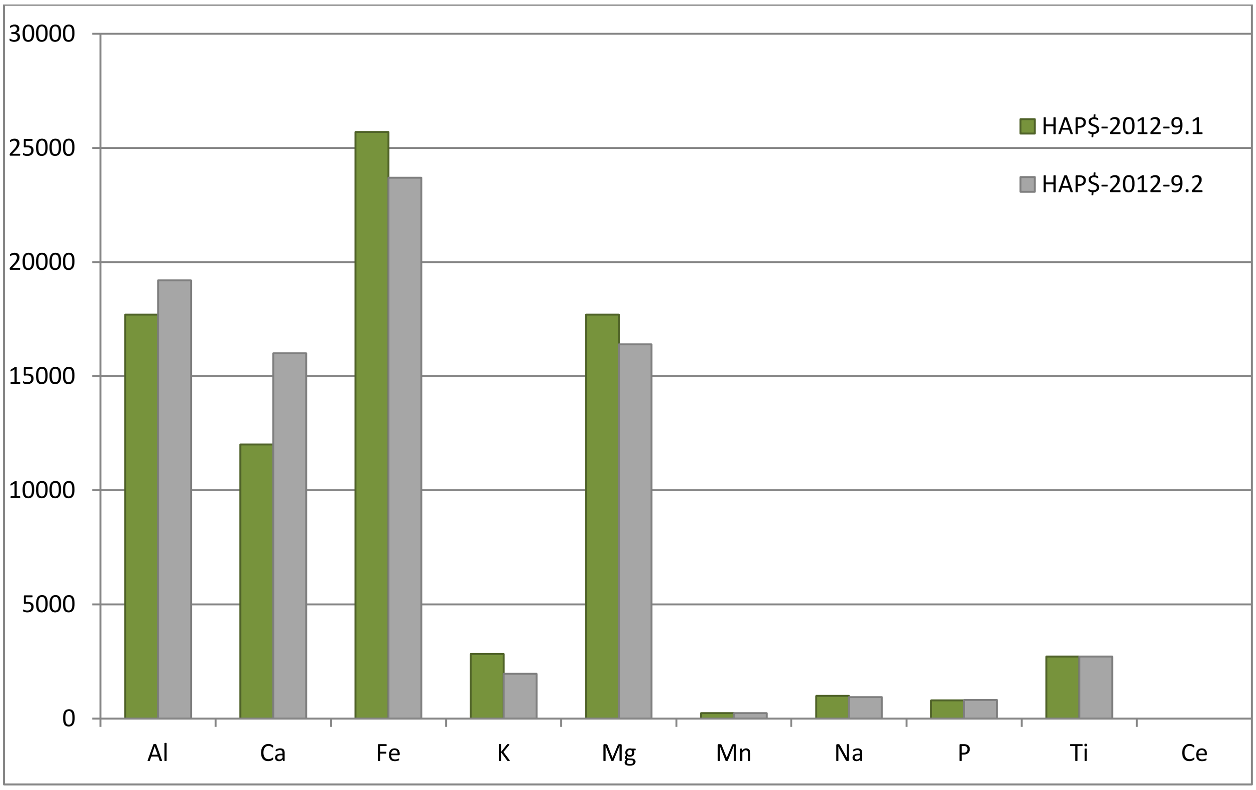
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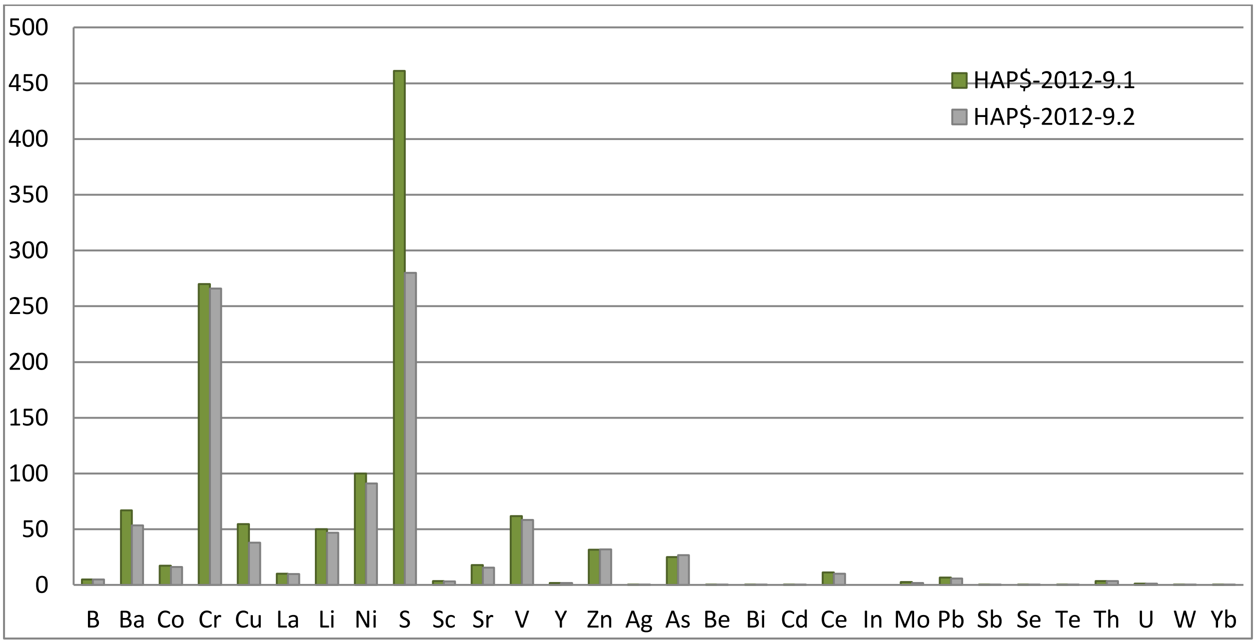
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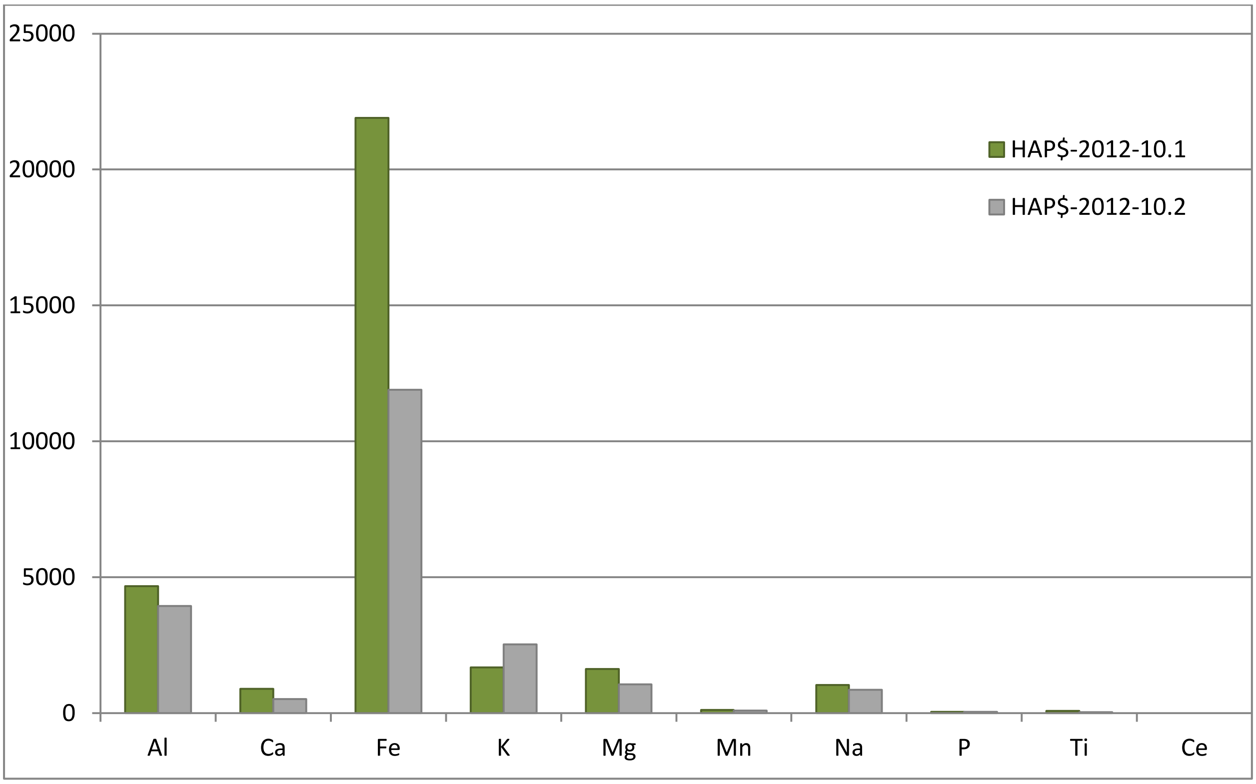

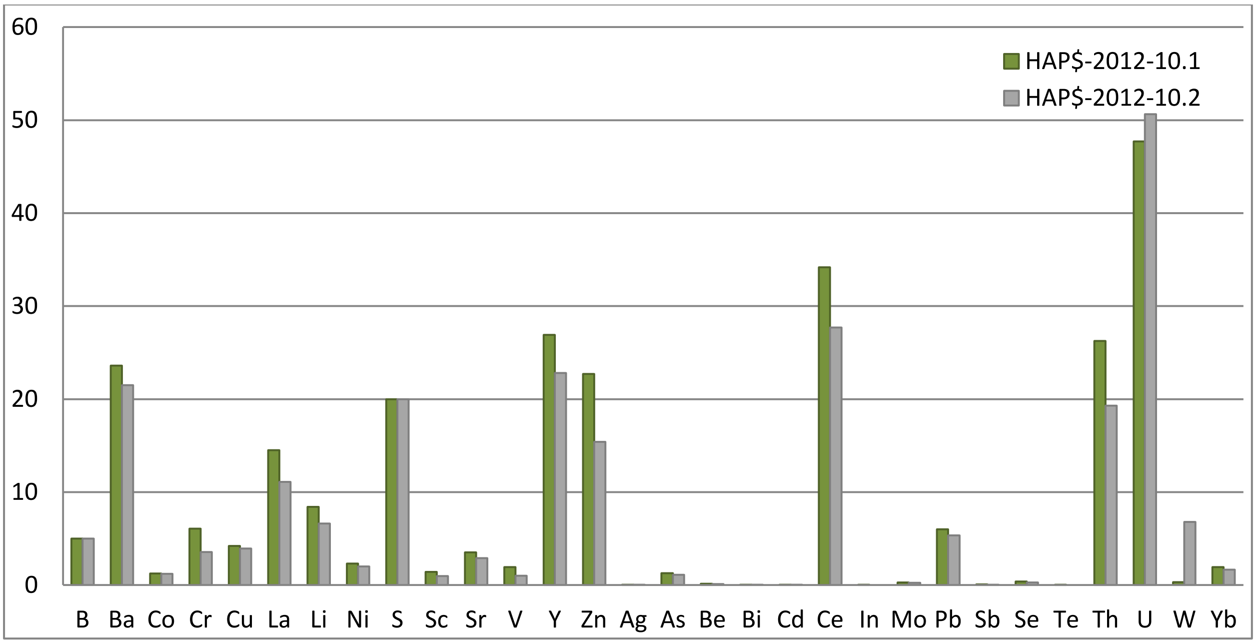

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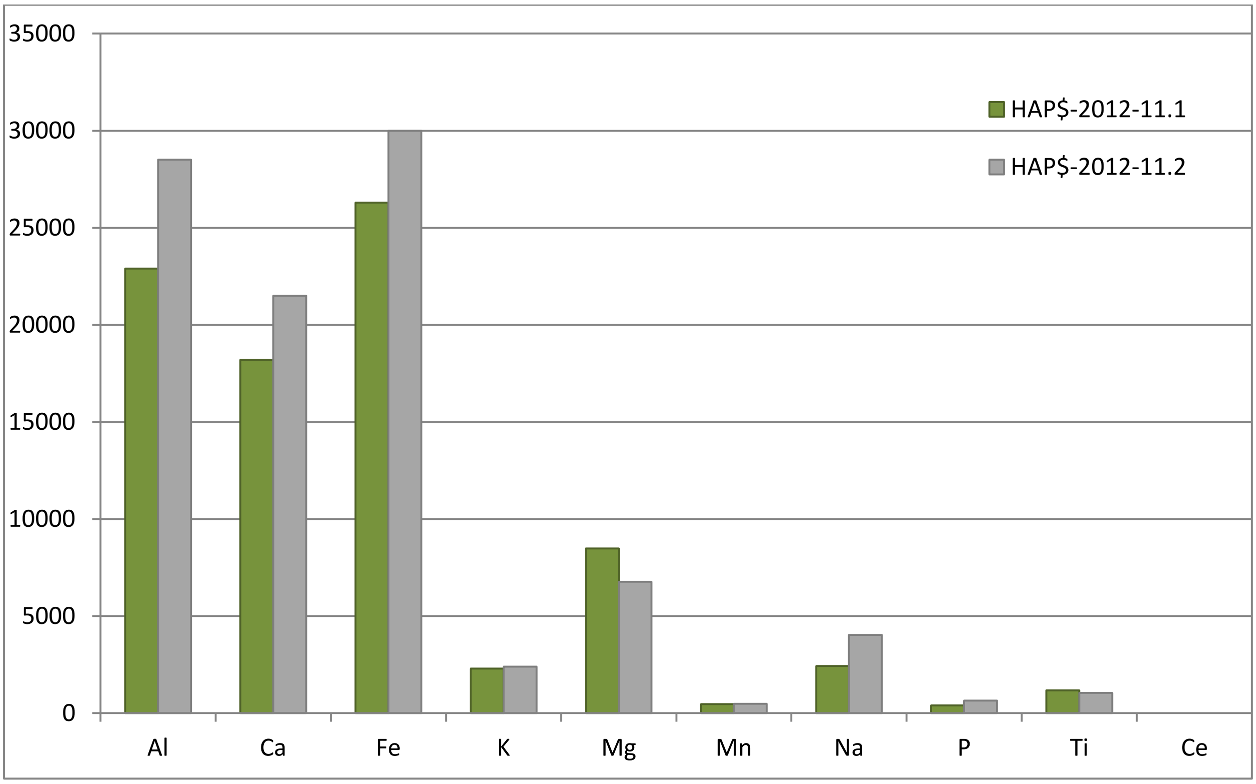

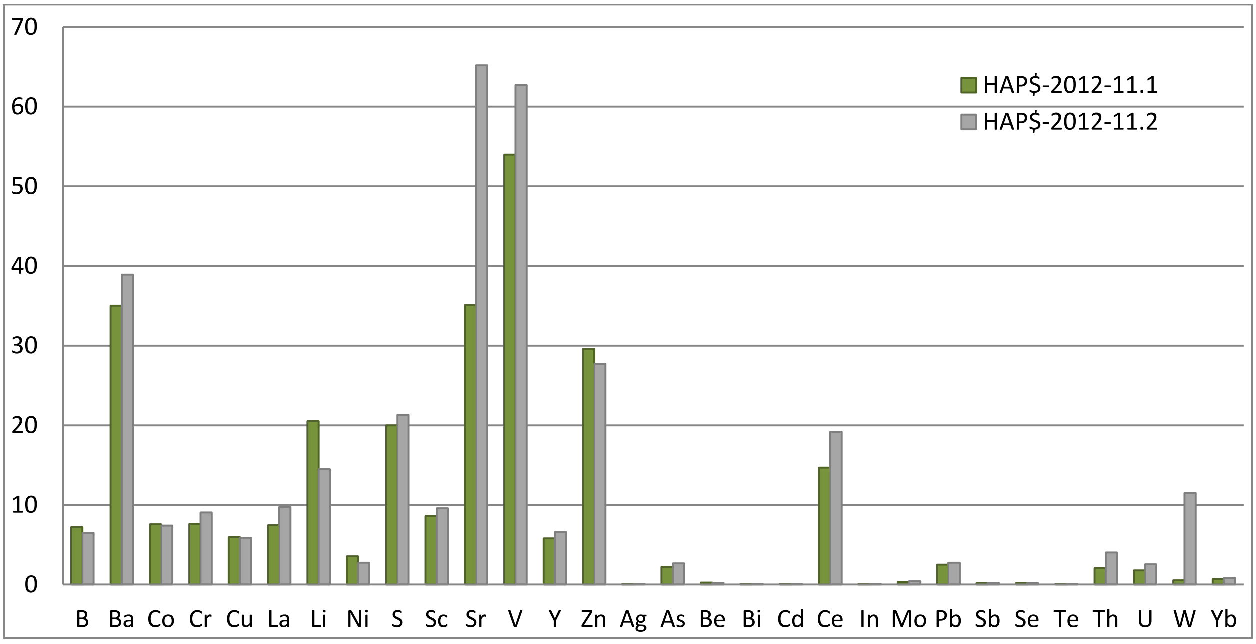

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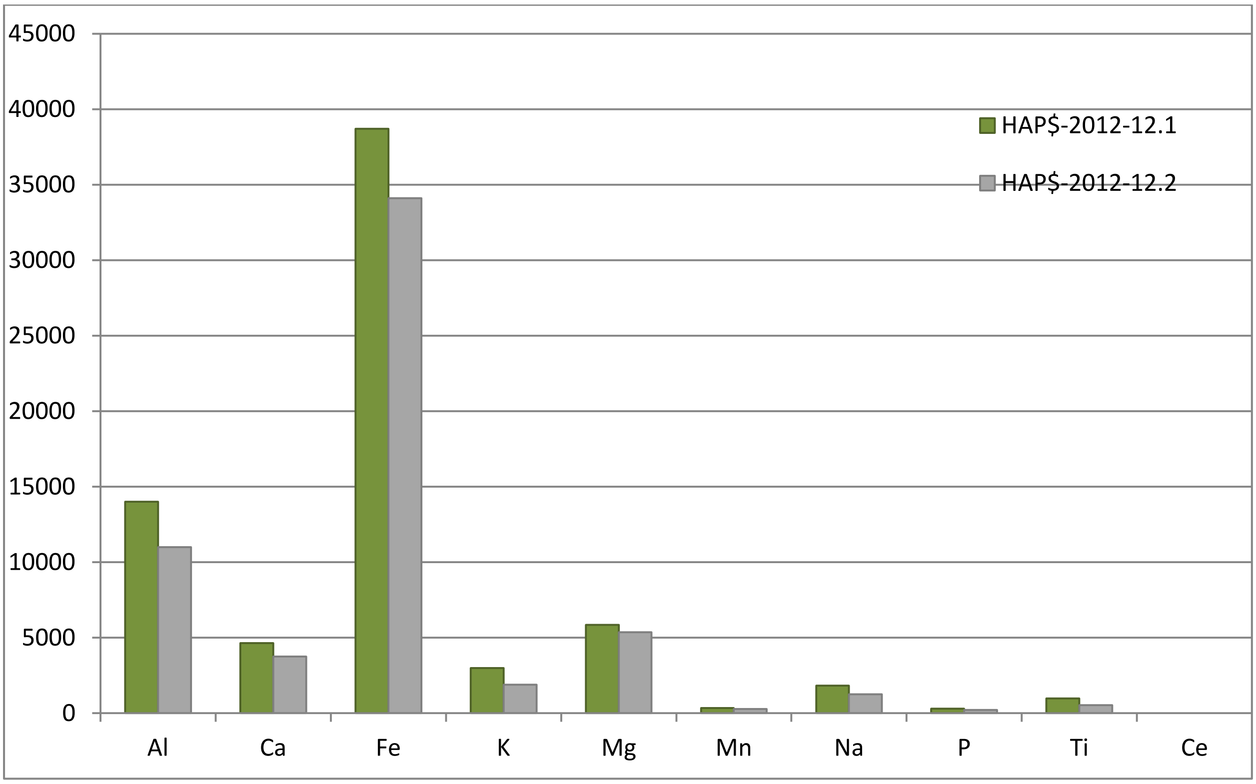
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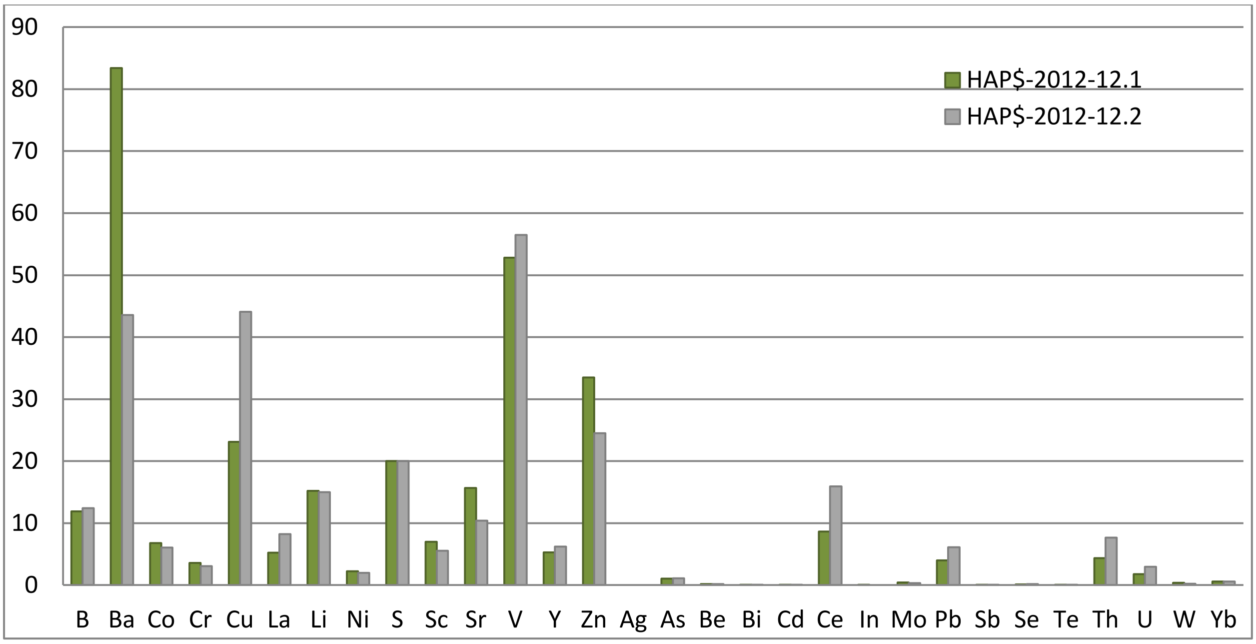
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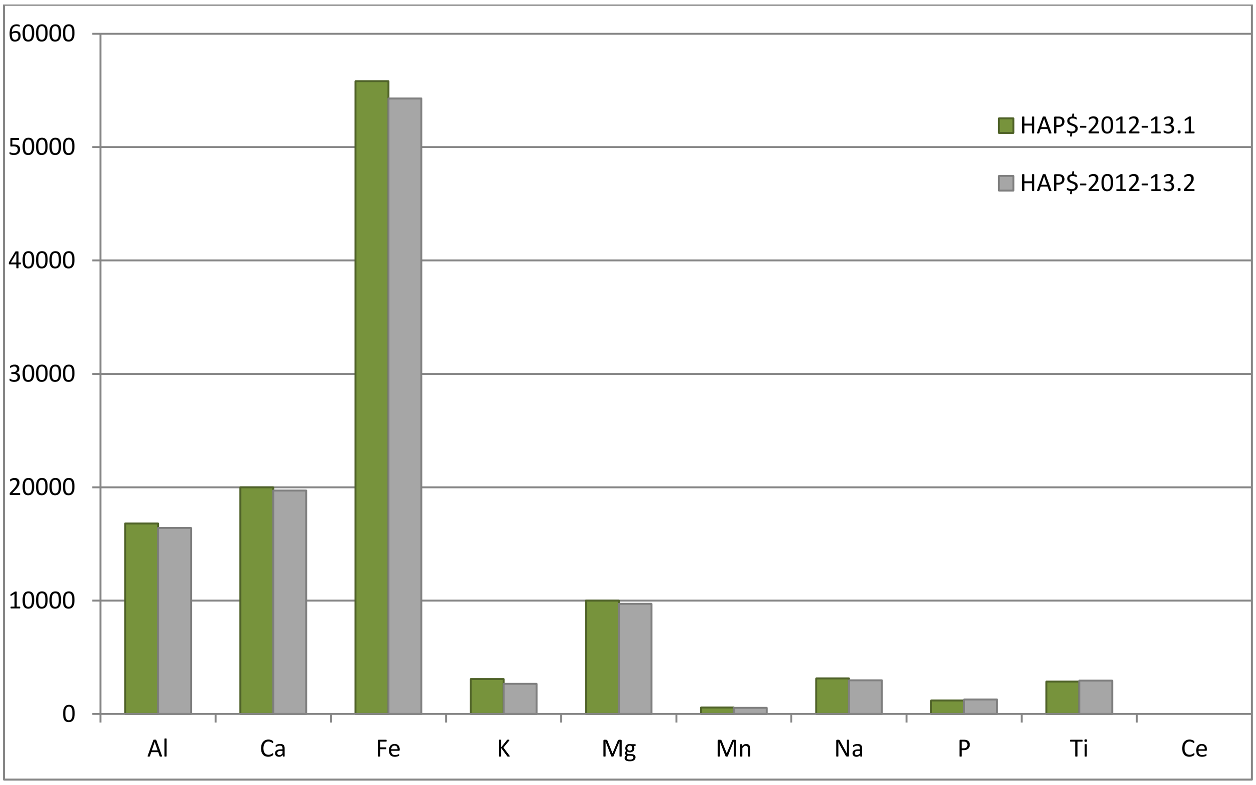
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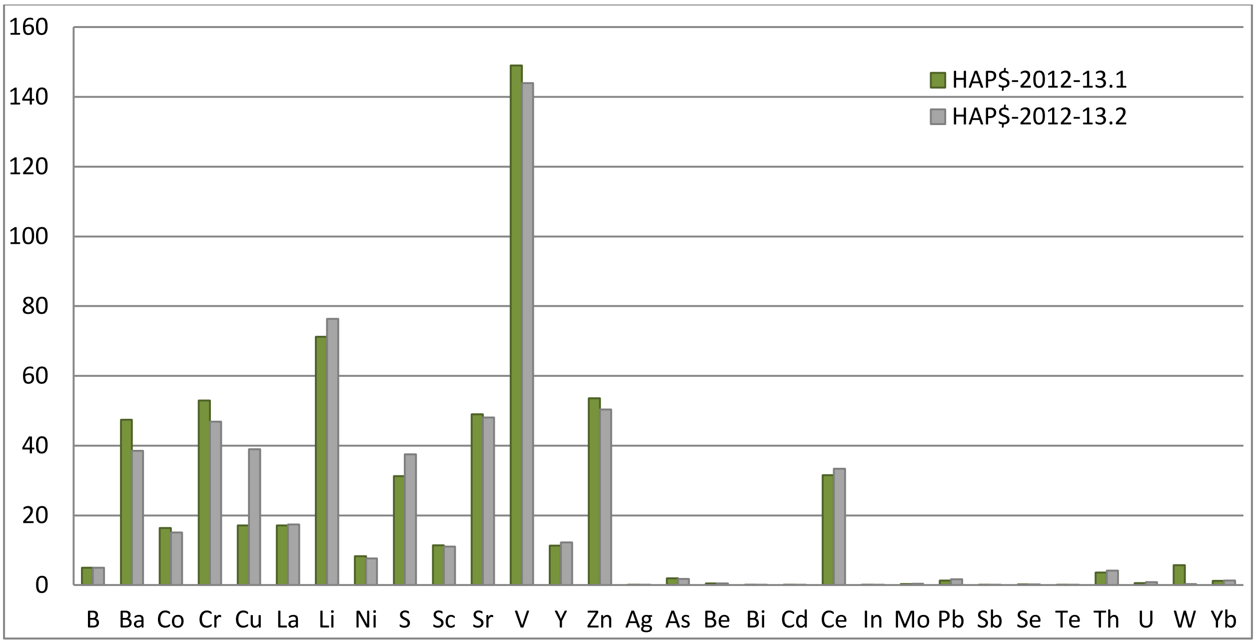
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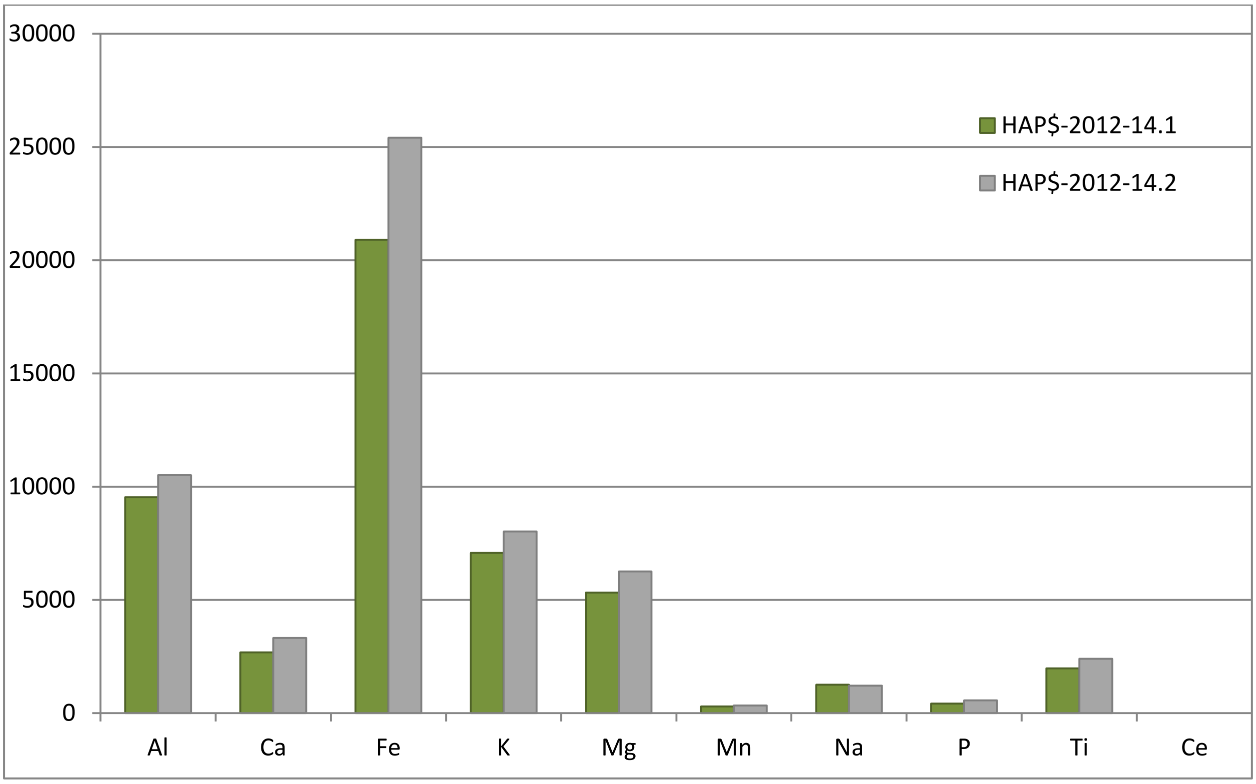
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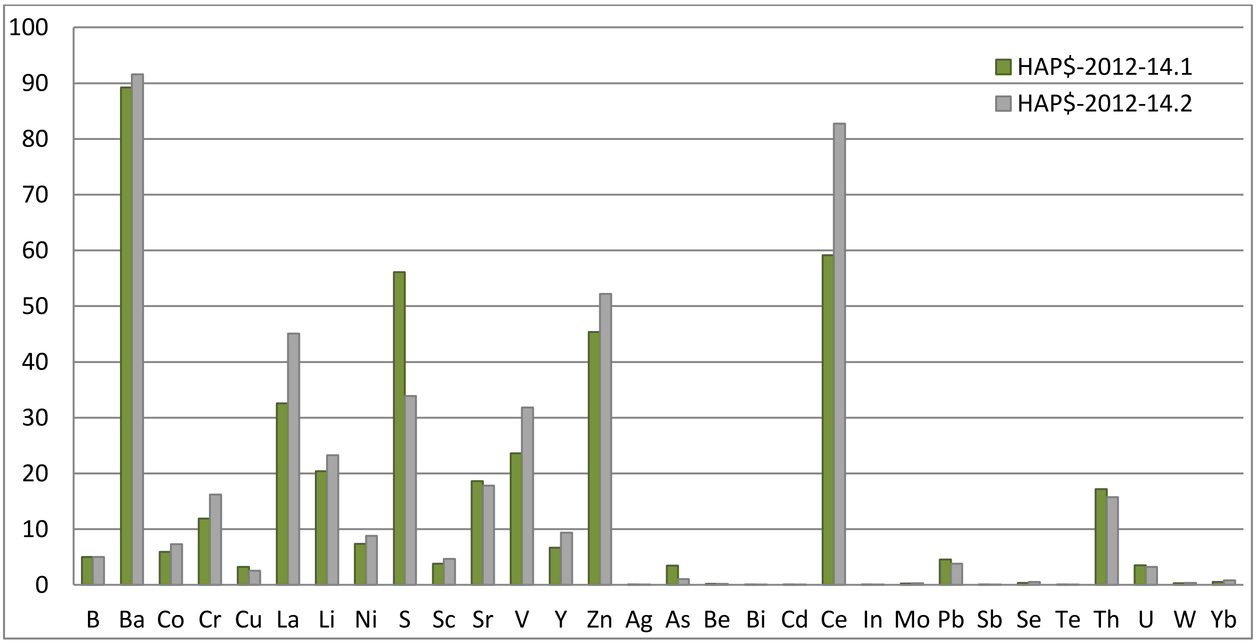
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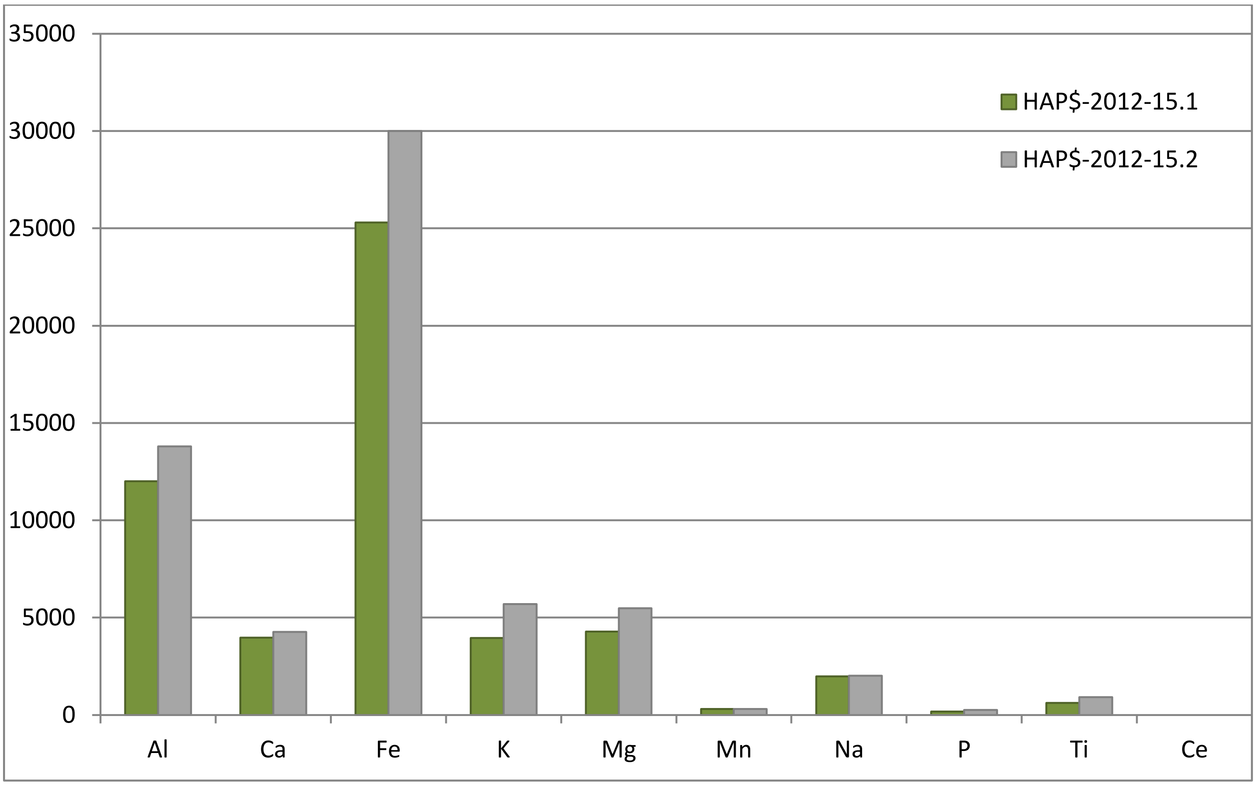

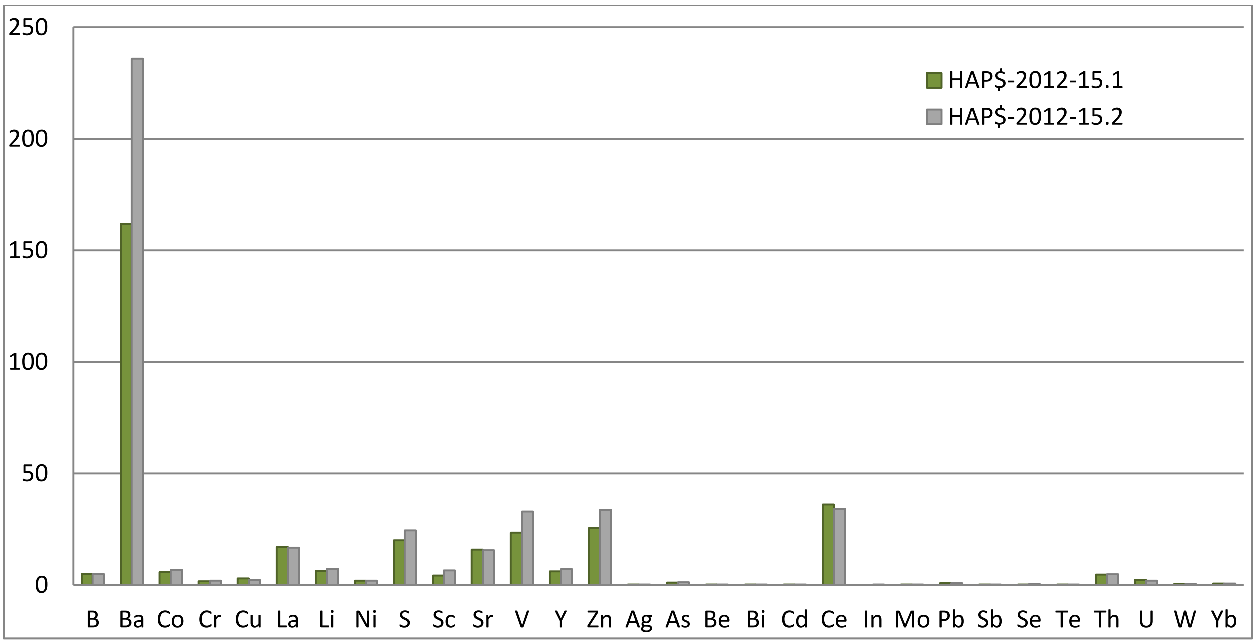

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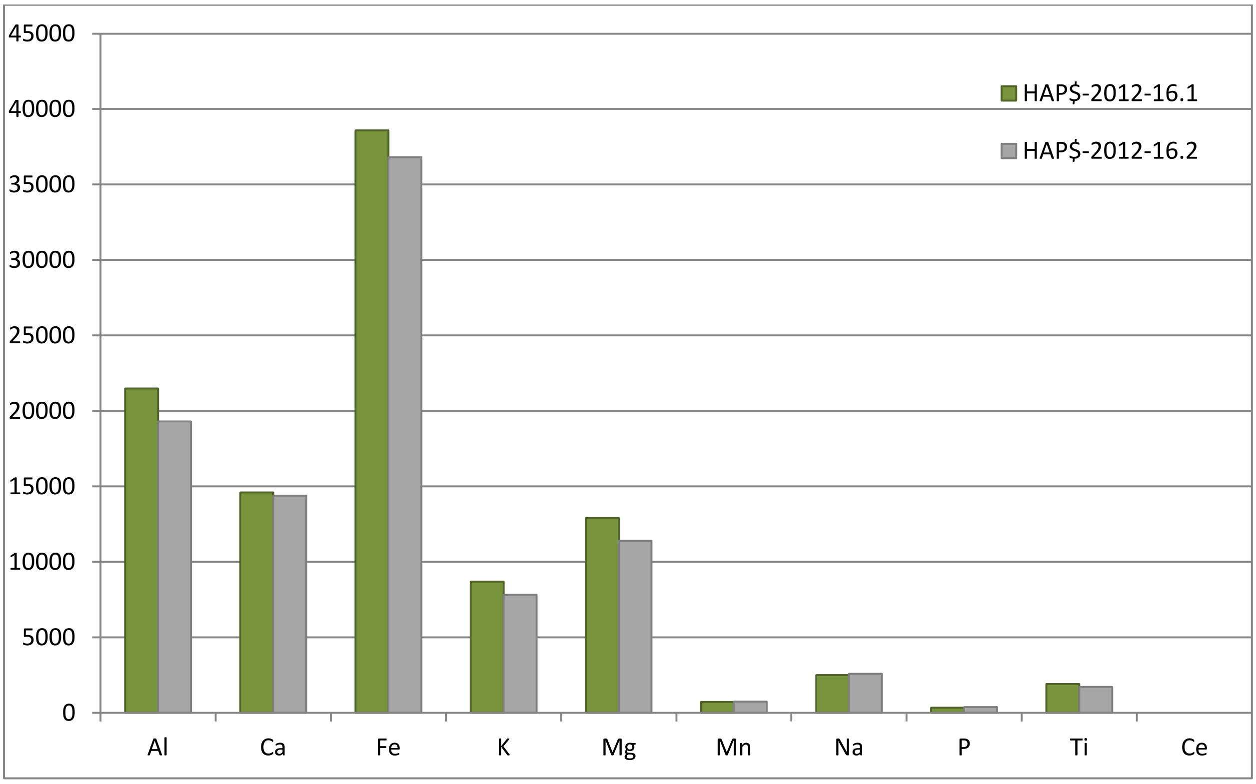
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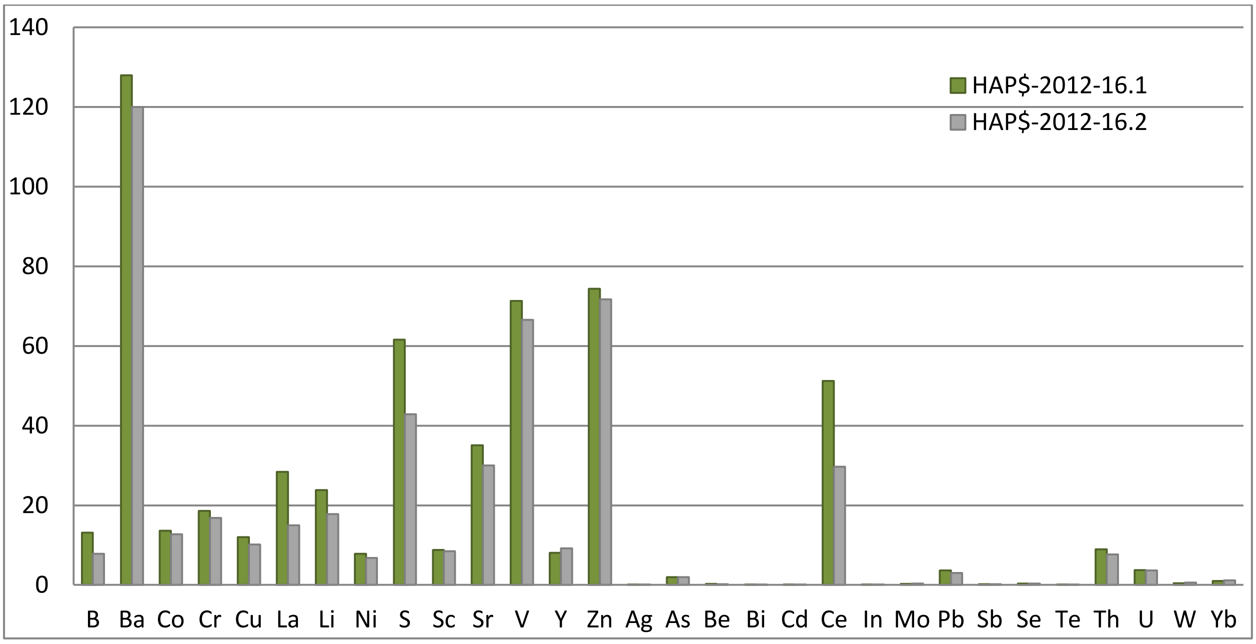
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OLAVINLINNA

Documentation and research methods

Detailed information can be found from the National board of antiquities web site, where also renovation work reports and actions taken to restore the castle are documented and archived since the last 1900.

Description of the building

Number	
Name of building	Olavinlinna
Architect	Found by: Danish Knight Erik Axelsson Tott
Address	
Built (year)	1475
Modifications 1	1743
Remark_mod 1	Bastions and castle renovation
Modifications 2	1961-1975
Remark_mod 2	Restoration works
Use 1	
Rock type 1	Erratic blocks and quarried material from the area

The castle was founded by Eerik Axelsson Tott, a Danish knight governor of Vyborg Castle, to strengthen the defense against the Russians. The first castle with three towers was completed in approx. 10 years, while in late 1400 was completed the fortification, added of 2 towers and covering 5 islands. The castle had undergone several battles and had been under Russian(1714-1721, 1743-1847) and Swedish control alternatively. Since the Middle ages its architectonical characteristics had changed not just because of destruction during war periods but also for defense needs. The Russians had improved the defense constructing angular bastions and changing distribution of some areas.3D modeling of the evolution of the castle had been done by the National Board of Antiquities and is visible online: http://www.nba.fi/fi/museot/olavinlinna/rakennusvaiheet in the Figure 1 are shown some images collected from the video. The original middle age structure is not well known since there has come many changes and are not original drawings.

Figure 1. From left to right: Middle ages- 1730-1799 (NBA web pages)

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The castle importance as a defense point had declined in the years. The castle instead had increased its importance as an historical monument. In 1870 had been damaged by a fire and had been restored, the main restoration work was done within 1961 and 1975. /1/

Figure 2. View from the entrance (Photo. H. Pirinen)

Figure 3. Views from the internal yard (on the left) and from the walls of the bastions (on the right) (Photo. P. Härmä)

Characterization of the environment

Local environment (architecture etc.)

The building is located on an island and the town had been slowly growing around it. The castle by itself in occupying the whole island and has no nearby constructions. The microenvironment in which is located can be considered as a lake shore, so affected by waves and humidity but also not protected by winds.

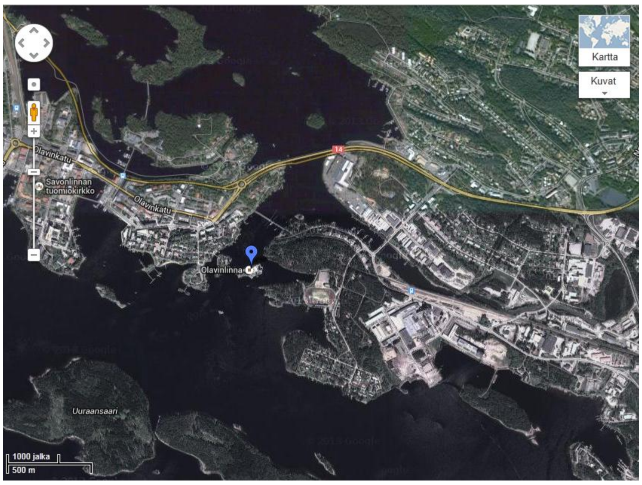

Figure 4. Area where the building is located (Google Maps)

Climatic conditions, microclimate, etc.

Savonlinna is located on South- East Finland in the lake district on the large lake Saimaa that is also effecting on the microclimate. This lake is the only one hosting ringed seals. In the area the Nordic climate is somehow mitigated by the presence of the lake, having generally cold winter but without reaching extreme peaks, cool summers with humidity and rainfalls present all the year round./2/

Photographic documentation

The site has not been inspected in detail and has been documented photographically by Gigapan photos and normal camera photos of the complex.

Gigapan photos

A gigapan photo had been taken from the internal yard (Figure 5)

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Figure 5. Low definition image of the correspondent gigapan image.

Visual inspection

No mapping had been done for this building in 2013 and it has not been checked in detail the weathering phenomena that the material is showing.

Samples

The sampling had been reported in a separate report attached in Annex 1.

Thin sections

Had not been done

Chemical analyses

Drill cores

Chemical analysis has been performed on drill core sample collected in 2012 and coded HAP$-2012-1.1,2 to HAP$-2012-5.1,2distinguishing the top and bottom part of the drill core.

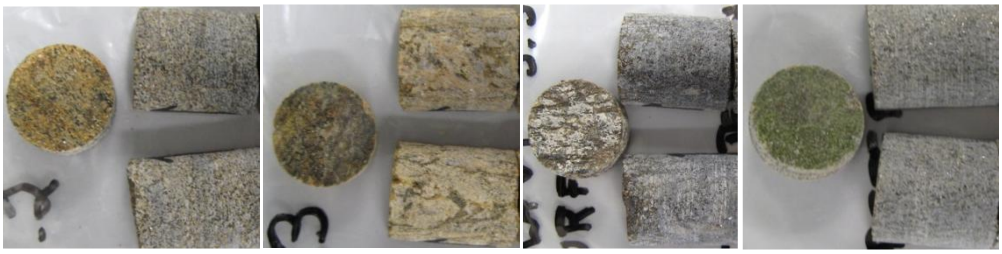

Figure 6. From left to right 2.2 -2.3 -3.3 -4.1

Surface samples

During inspection hand samples detached from the wall had been found and it was given permission to collect them, they are shown in detail in Annex 1.

Biological analysis

It was not performed

Mechanical and physical tests

Samples from Olavinlinna had not be tested because had been all used for other purposes

Photos of Samples

Normal photos

Are visible in Annex 1.

Stacking photos

The high definition photos had not been taken

PETROGRAPHIC AND CHEMICAL PROPERTIES

The samples had been re-coded and are shown in Table 1:

HAP$-2012-1.1	Olavi 2.2 pinta
HAP$-2012-1.2	Olavi 2.2 pohja
HAP$-2012-2.1	Olavi 2.3 pinta
HAP$-2012-2.2	Olavi 2.3 pohja
HAP$-2012-3.1	Olavi 3.3 pinta
HAP$-2012-3.2	Olavi 3.3 pohja
HAP$-2012-4.1	Olavi 4.1 pinta
HAP$-2012-4.2	Olavi 4.1 pohja
HAP$-2012-5.1	Olavi 4.2 pinta
HAP$-2012-5.2	Olavi 4.2 pohja

The chemical compositions are listed in Table 1 in Annex 2. Comparing the concentration (mg/kg) for top and bottom samples of all the samples it is noticeable that the material contains common main elements typical of the hard rock type

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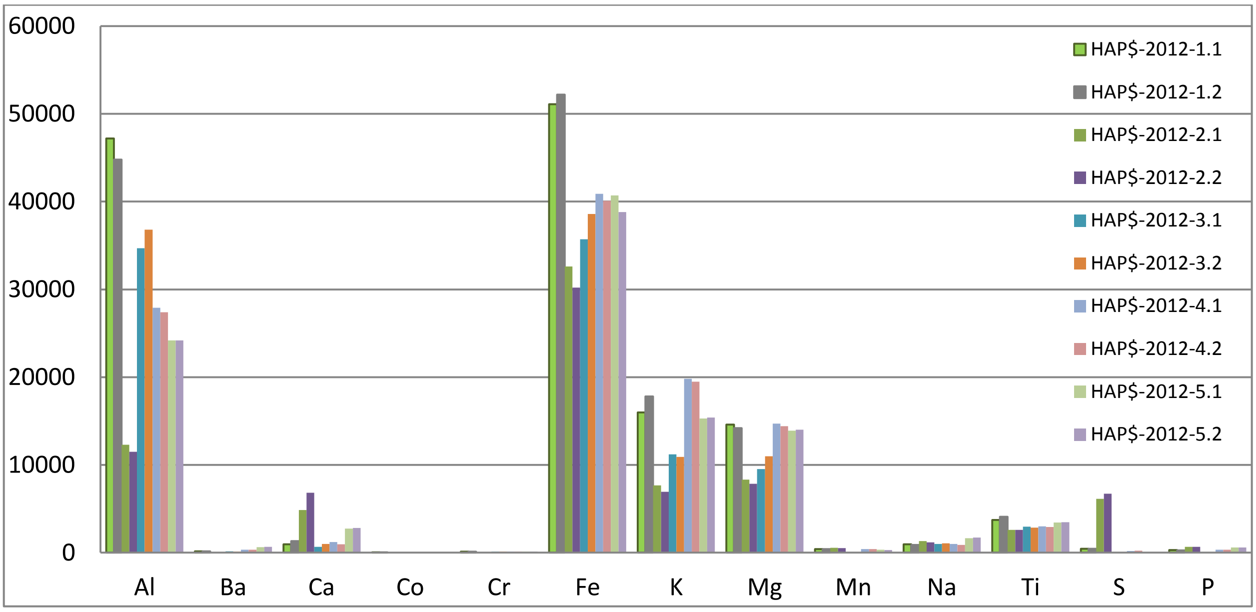

Figure 7. Main element concentration of the material tested(X: elements Y : mg/kg or ppm)

In the figures 8,9 and 10 are shown the depletion of elements calculated as : elements in the top-elements in the bottom/elements in the bottom

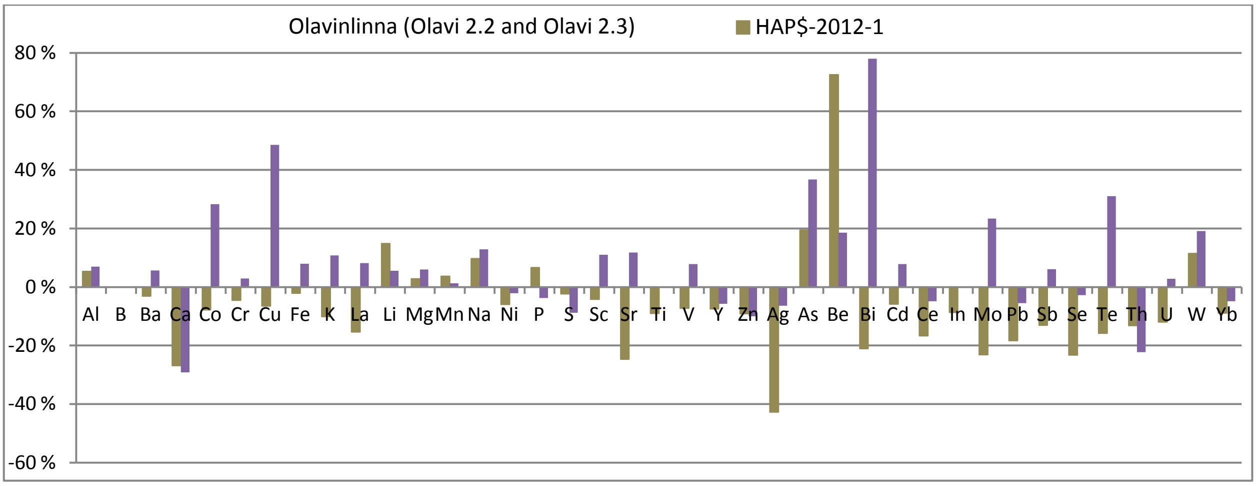

Figure 8 Depletion of elements from the blocks of the Kello Torni, belonging to the oldest part of the castle

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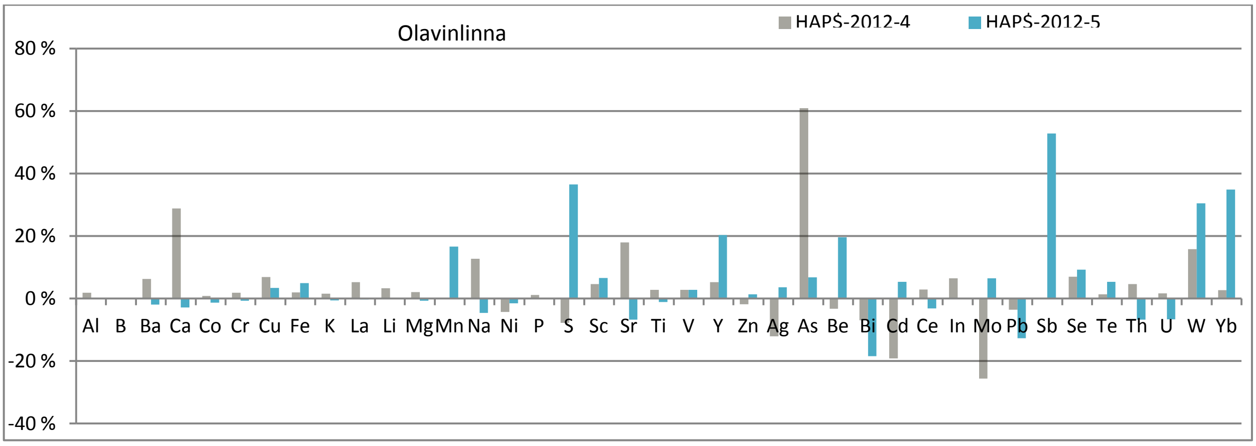

Figure 9 Depletion of elements from the blocks in the internal yard, belonging to the oldest part of the castle

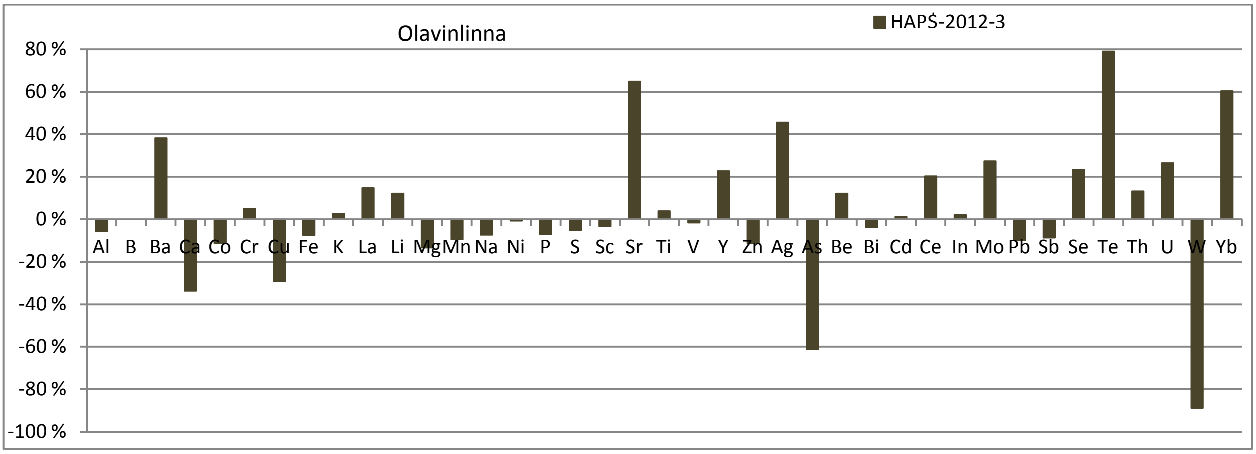

Figure 10 depletion of the elements from the blocks from the bastions built in the more recent Russian time.

There is a similar behaviour in some elements from the oldest part of the castle, as for example the increase of A and W on the surface, opposite in behaviour to the material sampled from the more recent Russian bastion. Lead had been depleted in all the samples. In Figure 11 are shown the percentages of the oxides that show high content of iron and aluminium oxides besides the silicates

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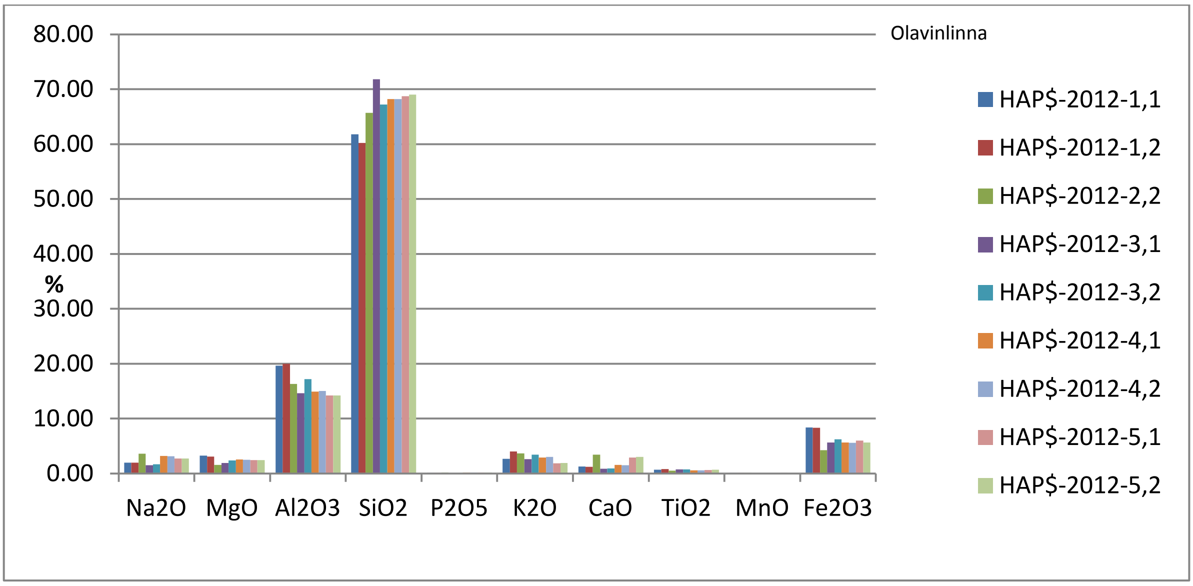

Figure 11.Oxides composition in the samples collected from Olavinlinna

Non-destructive research methods

Ground penetrating radar has been performed by the Geological Survey of Finland and Ultra Pulse velocity on specific blocks has been performed in cooperation with the Polytechnic of Turin-Italy.

Ground penetrating radar

Measurements have been performed in three areas: along the Kello torni,in the terrace under it and in an internal yard. The aim had been to evaluate the structure of the wall. Because of the thickness of the walls an antenna of 900 MHz had been used together with the 1,6 GHz.

Figure 12 Map of the measurement areas (Map from NBA web pages)

On the Kello Torni the measurements had been performed in the external perimeter of the tower and in the internal, measuring also along the depth of the wall as shown in Figure13 and 14.

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Figure 13 From left to right measurements performed over the outer wall, width of the wall, and inner wall of the Kello Torni

The measurements with the 1,6 GHz antenna had shown two anomalies that are highlight in the radargram of figure 15

Figure 14 Line F1

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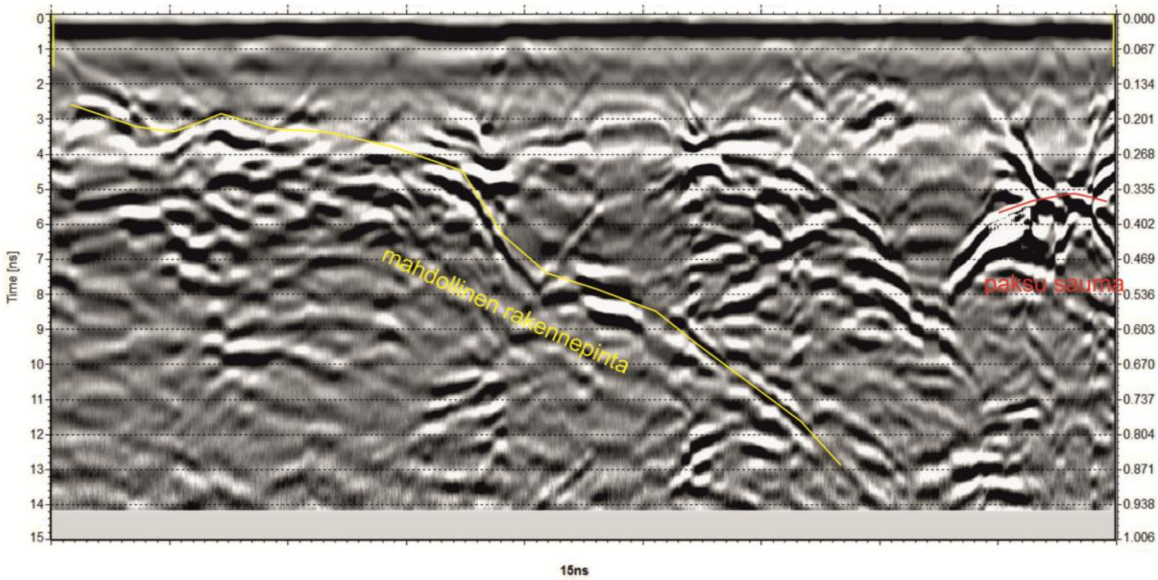

Figure15 Radargram of Line F1 done with the antenna of 1,5GHz

The measurements with 1,5GHz show the first row of blocks quite clearly, reaching 20cm depth and with joints between the blocks. The inner structure of the wall is then affected by the several reflections and refractions on the surfaces, it would anyway be possible to tell that inner wall has some smaller blocks and less regular structure compared to the visible one. There is a clear continuous line that could represent an internal wall surface and anyway represents presence of a discontinuity in the wall. Other two strong reflections could be given by internal joints or by the fact that there are fractures around the blocks. The 900 MHz antenna show a bit the same trend, as visible in Figure 16, but in this case is also visible a line between 0.4 and 0.5 m and another one at 1.34-1.47 m, that would probably show the surface of the internal wall of the tower

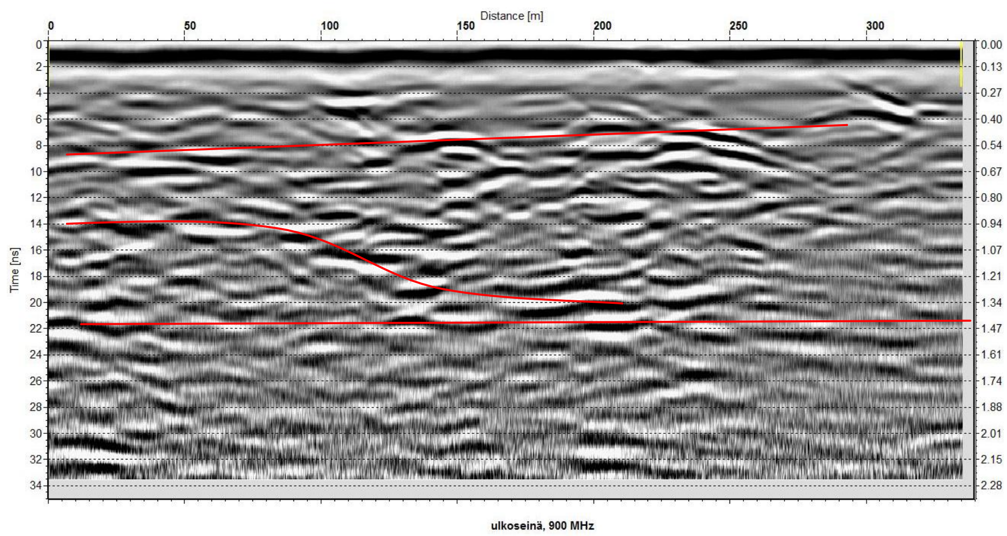

Figure 16 Measuring line F4 done with 900 MHz antenna on the line as F1 done with 1,5GHz.

Another line had been collected in the inner yard, the radargram and normal picture are shown in

Figure 17 and 18

Figure 17 Measurements done in the inner yard wall, line F9

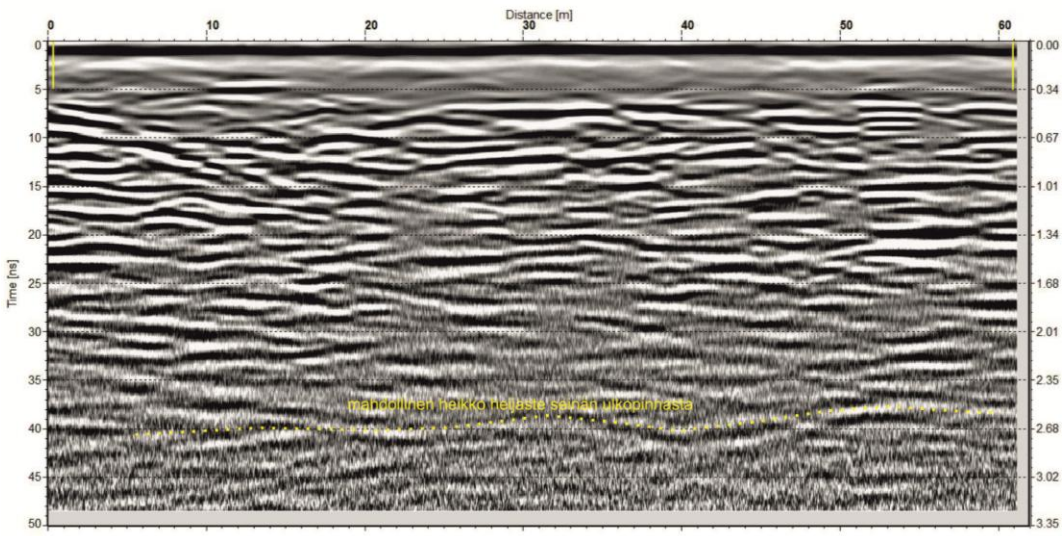

Figure18 Radargram of measuring line F9 over the inner yard wall

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Between 2,35 m and 2.68 m is visible a continuous line that could rapresent the surface of the external wall. The radargram show that the wall is full and blocks are placed regularly visible from the linear and rather parallel reflection lines running along the measuring line. There are some higher reflections given by the change of surfaces and probably the inner wall has smaller material size compared to the surfaces.

Another measurement had been collected along the wall of the building facing the terrace (figure 19).

Figure 19. Image of the wall showing the measuring line F10

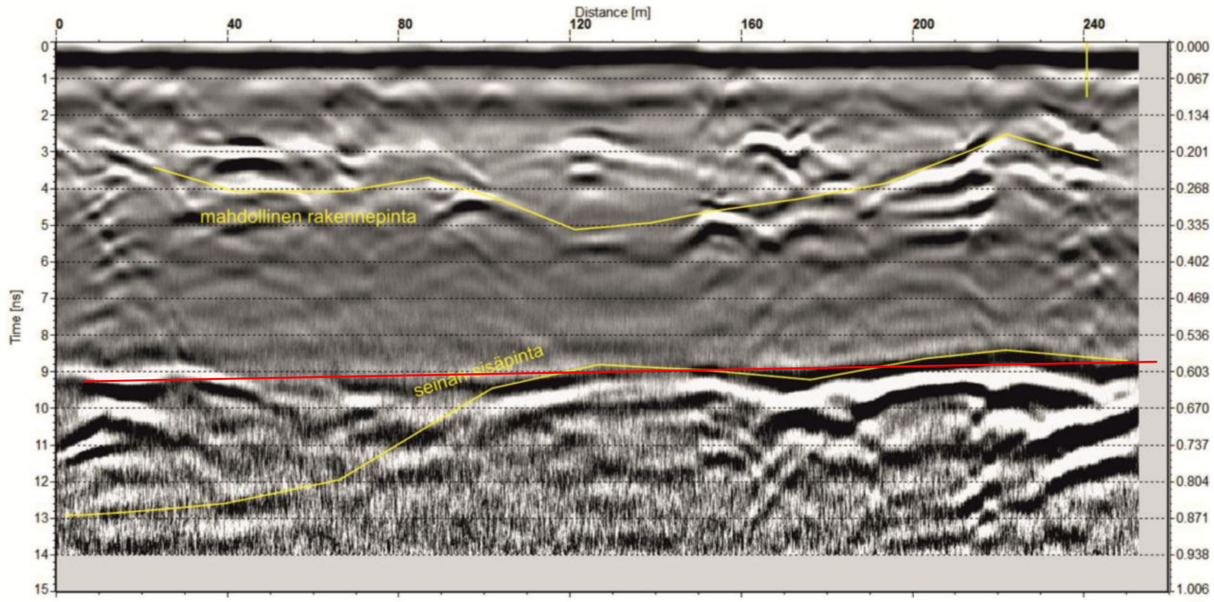

Figure 20. Radargram of the wall over the terrace. (10ns)

In the radargram of Figure 20 are visible the internal wall structure, with some reflections between blocks that would show presence of air possibly by thicker mortar or slightly open joints between the blocks (yellow line named mahdollinen rakennepinta). The second line shows the internal wall surface (seina sisäpinta). This, also signed in red, is the internal part of the wall, done with very homogeneous material thick approximately 30 cm. Considering the regularity of the surface (visible in Figure 21) they are possibly bricks.

Figure21. The internal wall where the Line F10 had been collected. The first 60cm of measurements are done over a wall thick 90 cm, while after that the wall is about 55cm.

The radargram show also a strong reflection in correspondence of the thickening of the wall, probably the corner is formed by two separate walls presenting a joint between them.

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Ultrasonic measurements (UPV)

The measurements have been performed in an indirect way according to the report “Methodology UPV”. The blocks tested had been those also sampled for other tests whose location is shown on the map. The same areas tested with ground penetrating radar (GPR) and sampled had also been tested with UPV.

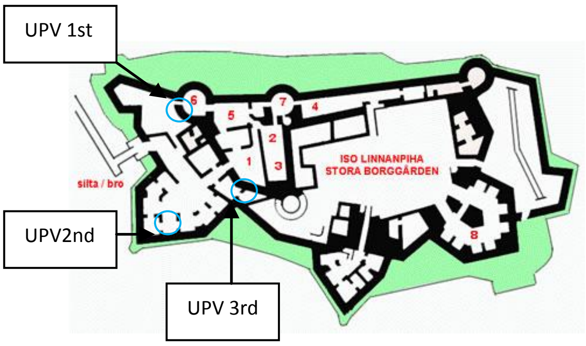

Figure 22. Schematic map of the area tested for UPV.

Measurements had been performed over the Kello Torni and the blocks tested are shown in figure 23. It is visible for both of them the sealing of the drill hole after sampling.

Figure 23.Detail of the first blocks tested on the Kello Torni (left:savonlinna 1, right: savonlinna 2)

Measurements had been performed in the second place in the inner yard as visible from Figure 24 and 25.

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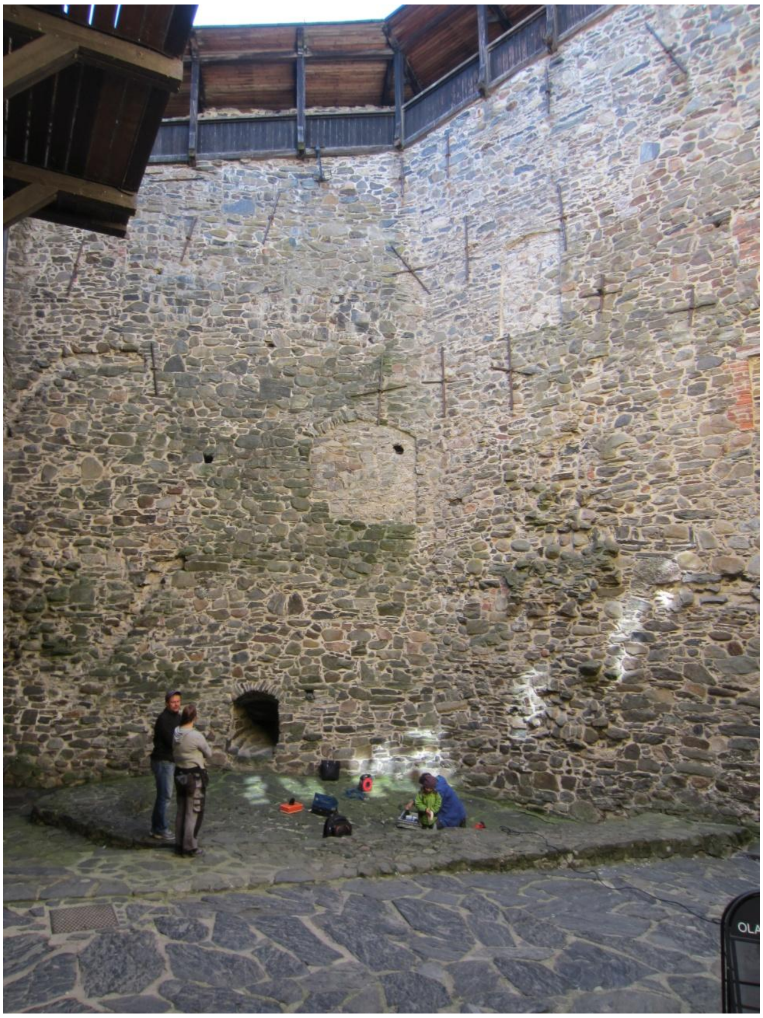

Figure 24. General view of the inner yard

Figure 25. Detail of the two blocks tested (Savonlinna 3 on the left, and Savonlinna 4 on the right)

The velocities collected from the blocks tested are:

Savonlinna 1:2697 m/s including all the measurements, but the diagram is not linear. Eliminating the last measure the diagram improve, reducing the errors, but the velocity decrease to 2457 m/s.

Savonlinna 2:2584 m/s showing a diagram affected by high uncertainties, eliminating the first and last measurement, the average velocity decrease to 2307m/s while the diagram becomes more linear. Possibly there had been some errors in measuring the last point.

Savonlinna 3: 2847 m/s with a linear diagram

Savonlinna 4:1745 m/s presents only one deviation from the linear regression line in correspondence of the 4rth measure but because of the dimensions and shape of the block it had not been possible to perform all the points. Probably the measures had been affected by an error that had lower down the average velocity.

The measurements performed had shown a material that presents some level of weathering, with lower velocity compared to the kind and compactness of the material.

REFERENCES

/1/ Official web pages of The National Board of Antiquities http://www.nba.fi/fi/museot/olavinlinna/historia
/2/ Weather online web pages http: //www.weatheronline.co.uk/

Annex 1 Sampling

In the three year project ”Efficient use of natural stone in The Leningrad region and South-East Finland” that is a project co-funded by the European Union, the Russian Federation and the Republic of Finland through the European Neighbourhood and Partnership Instrument (ENPI), with the Geological Survey of Finland (GTK) as the leading partner. The project aims to define through bibliographic, laboratory and field research the durability properties of stone materials used in the Nordic urban environment (focusing on Helsinki and St. Petersburg), their availability and the available local reserves. In order to assess the durability to long term weathering was needed to collect samples used on sites for more than 100 years. Samples are collected drilling chosen areas in the buildings, sampling cores of approx. 20mm diameter and 100mm length. The samples had been divided in two or three sections, the top section is analyzed for biological growth, chemical analysis is done on the top and bottom core, petrographic analysis is done on the top part to evaluate changes in the structure, physical tests are done on top and bottom parts if the material had been available after the previous tests.The project started in the year 2012 and in it are working the University of St. Petersburg, St. Petersburg Geological Expeditio and SAIMIA University of applies sciences from Lappenranta. Companies involved in the project are Palin Granit Oy and Ylämaa Group Oy.Olavinlinna didn’t belong to the project area but it is the oldest Finnish stone building. In the year 2012 had been taken contact with the National Board of Antiquities and it has been got permission to sample in 2.11.2012.

From the walls of Olavinlinna had been collected 7 drill core samples of 20mm diameter and length 40-70mm, moreover had been taken 3 pieces that had been detached from the wall and one that had been detached because of the weathering.

In 2012 the samples had been collected by:

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Heikki Pirinen (East Finland unit)

Pentti Toivanen (East Finland unit)

Joonas Toivanen (East Finland unit)

Paavo Härmä (East Finland unit)

National Board of Antiquities representatives:

Tuija Väli-Torala

Riina Kangasluoma

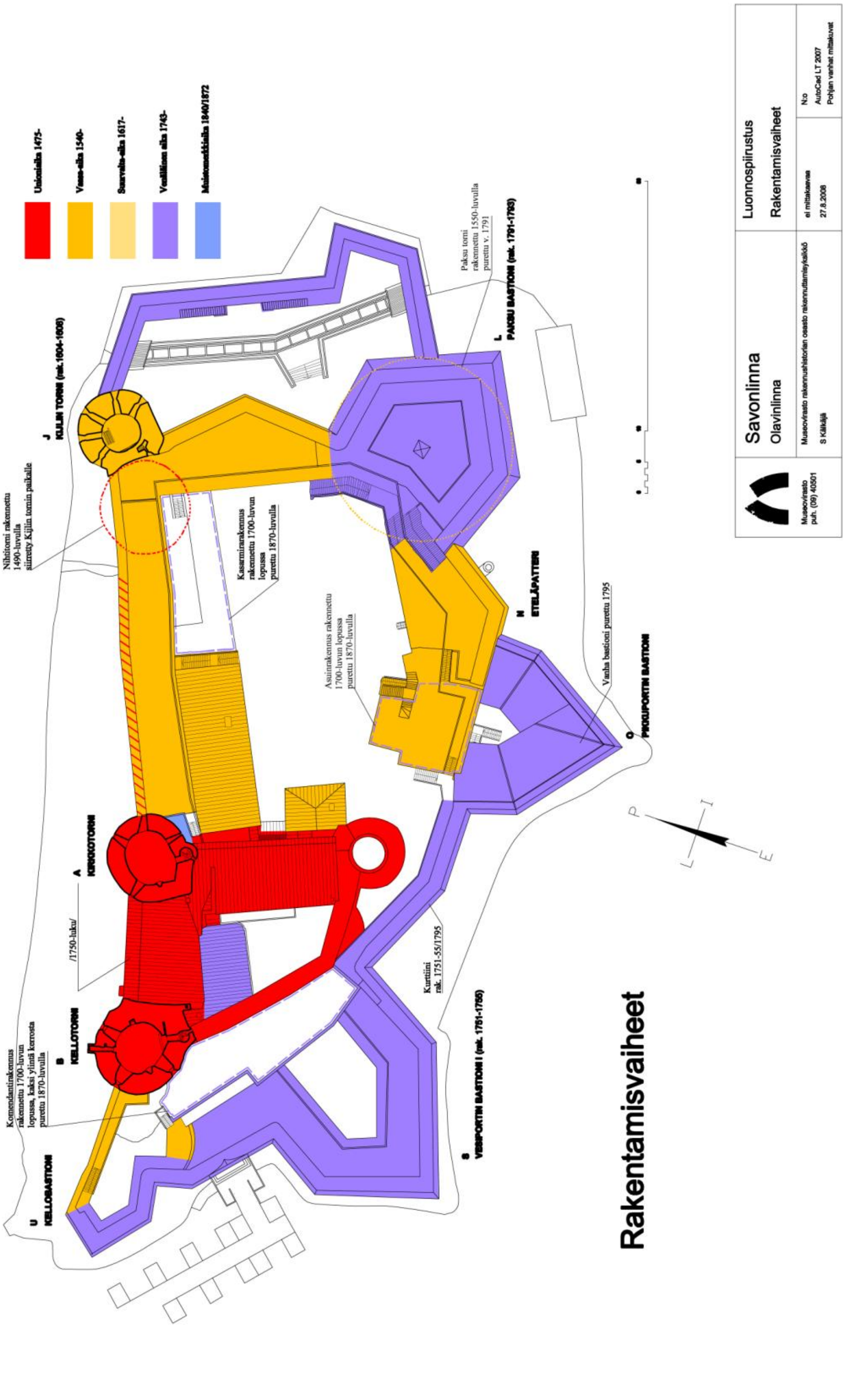

Figure 1. Changes in the construction

3 Sample 1 (Olavi 1)

Sample 1 is from the lower board of the large internal wall (Figure 2 and 3)

Figure 2. Samples (Näyte) collected from the construction are shown on the map

Figure 3. Detail of Sample 1

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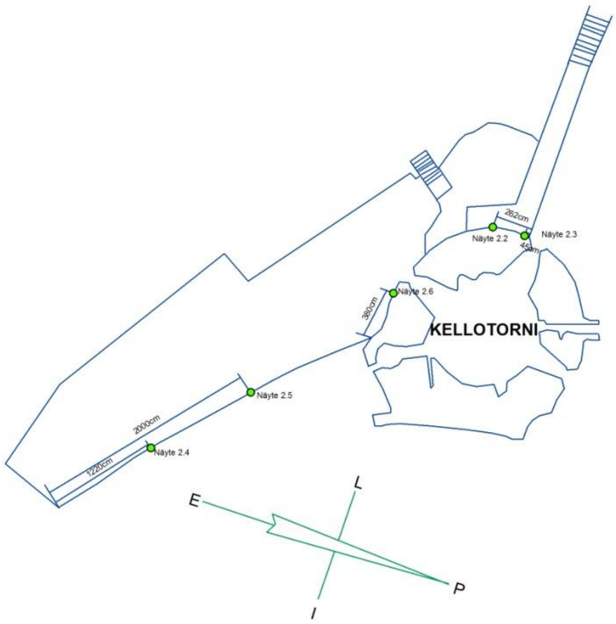
4 Samples 2.2-2.6 (Olavi 2.2-2.6)

Sample 2.1 does not exist since the sampling numbering started from 2.2. Samples 2.2 ja 2.3 are 20mm diameter drill cores from the oldest part of the castle, Kello Torni. Their sampling position is shown in detail in Figure 4 and their image and sampling place in Figure 5. Sample 2.2 is 30cm high from the walking balcony, while sample 2.3 is 90 cm high from the level of the balcony. Samples 2.4 and 2.5, visible from figure 6 and 7, are parts detached from the wall facing the lower terrace. Sample 2.6, figure 8, is a small piece fallen down from the Kello Torni (Bell Tower),that has been covered by cupper alteration products brought by the drainage water, probably malachite.



Kuva 4. Map of the samples (näyte) 2.2-2.6 collected from the castle.

Figure 5. Samples 2.3 and 2.2 (Olavi 2.3 and Olavi 2.2) on the left, in the center sampling of sample Olavi 2.2 and on the right the place where sample Olavi 2.3 had been collected.

Figure 6. Sample 2.4 (Olavi 2.4) and the place from where it had been collected.

Figure 7. Sample 2.5 (Olavi 2.5) (on the left) and the position where it had been collected (on the right)

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Figure 8. Sample 2.6 (Olavi 2.6), on the left, and the place where it had been collected on the right

5 Samples 3.1-3.3 (Olavi 3.1-3.3)

Samples 3.1-3.3 are 20mm diameter drill cores from the bastions constructed by the Russians. Their image and their position are shown in detail in Figure 9. Sample 3.1 is taken at a height above the ground of about 153cm while sample 3.2 at about 140cm and sample 3.3 at 90cm.

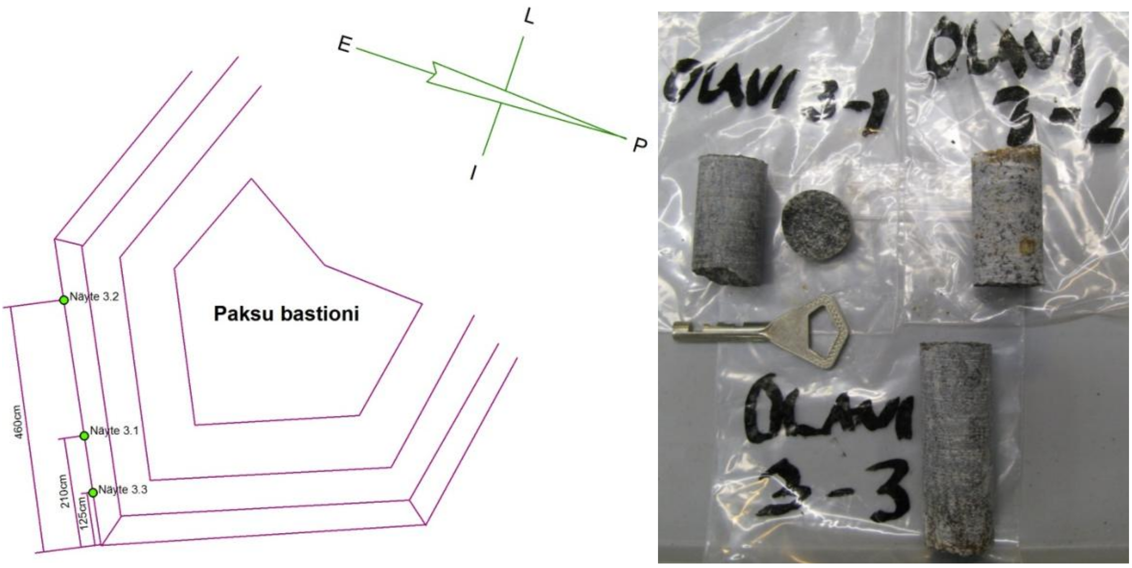

Figure 9. Map with sample points of samples (Olavi) 3.1-3.3 (on the left), on the right photo of the samples

Figure 10. Sampling Olavi 3.1 (on the left), drill holes visible from the sampling of Olavi 3.1 and 3.3. on the bastions (on the right)

Figure 11. Sampling place of Olavi 3.2

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6 Samples 4.1 and 4.2 (Olavi 4.1-4.2)

Samples 4.1 and 4.2 (Figure 12) are 20mm diameter drill cores collected from the oldest part of the building in an internal yard. The sampling points are shown in detail on the map in Figure 12 and in the phots in figure 13. The samples had been collected from 20cm above the ground in a place affected by humidity where visible vegetative growth had been noticed.

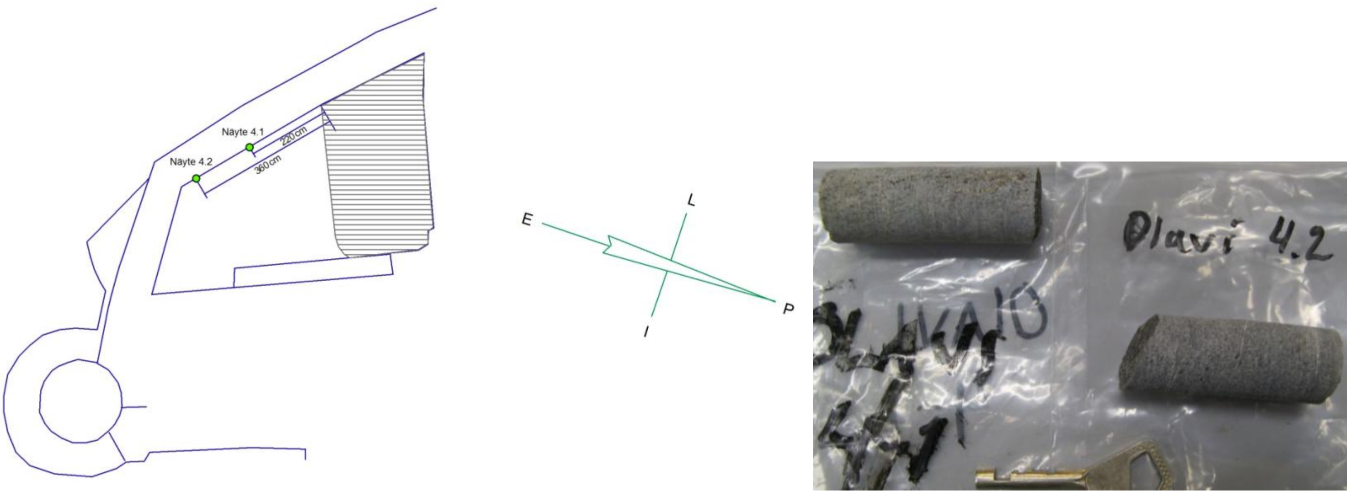

Figure 12. Map of the sampling points of samples Olavi 4.1 and 4.2 on the left, samples are shown on the right: Olavi 4.1 (left one), Olavi 4.2 (right one)

Figure 13. Sampling of Olavi 4.1 and 4.2 on the left, detail of sampling 4.2 on the right

Annex 2

Chemical composition of the samples.

			HAP$-2012-1.1	HAP$-2012-1.2	HAP$-2012-2.1	HAP$-2012-2.2	HAP$-2012-3.1	HAP$-2012-3.2	HAP$-2012-4.1	HAP$-2012-4.2	HAP$-2012-5.1	HAP$-2012-5.2
Al	mg/kg	+ 511P	47200	44800	12300	11500	34700	36800	27900	27400	24200	24200
Ba	mg/kg	+ 511P	154	159	52	49	170	123	357	336	642	655
Ca	mg/kg	+ 511P	980	1340	4850	6850	670	1010	1230	955	2750	2830
Co	mg/kg	+ 511P	13.0	14.1	6	5	12	13	13	12	15	15
Cr	mg/kg	+ 511P	127	133	21	21	122	116	112	110	134	135
Fe	mg/kg	+ 511P	51100	52200	32600	30200	35700	38600	40900	40100	40700	38800
K	mg/kg	+ 511P	16000	17800	7680	6930	11200	10900	19800	19500	15300	15400
Mg	mg/kg	+ 511P	14600	14200	8330	7860	9520	11000	14700	14400	13900	14000
Mn	mg/kg	+ 511P	419	404	546	539	96	106	431	430	343	294
Na	mg/kg	+ 511P	970	884	1320.0	1170.0	1000	1080.0	1010.0	896	1640.0	1720.0
Ti	mg/kg	+ 511P	3720	4090	2600	2600	2960	2850	3000	2920	3440	3480
S	mg/kg	+ 511P	451	462	6140	6730	75	79	202	219	34	25
P	mg/kg	+ 511P	304	285	660	686	64	69	350	346	600	599
B	mg/kg	+ 511P	5	5	5	5	5	5	5	5	5	5
Cu	mg/kg	+ 511P	43	46	25	17	6	8	9	9	4	4
La	mg/kg	+ 511M	31	37	22.50	20.80	39	34	32	31	30	30
Li	mg/kg	+ 511M	83	72	27	25	43	38	32	31	141	141
Ni	mg/kg	+ 511P	39	42	5	6	51	51	34	35	53	54
Sc	mg/kg	+ 511P	18.4	19.2	4	4	12	12	11	11	10	10
Sr	mg/kg	+ 511P	10.1	13.4	28	25	24	15	9	8	29	31
V	mg/kg	+ 511P	128	138	57.7	53.5	120	122.0	85.2	83	99.0	96.3
Y	mg/kg	+ 511P	6.8	7.4	6.3	6.7	8	6.7	6.0	6	11.2	9.3
Zn	mg/kg	+ 511P	95	105	56	62	70	79	74	76	75	74
Ag	mg/kg	+ 511P	0.01	0.02	0.3	0.3	0	0.0	0.0	0	0.0	0.0
As	mg/kg	+ 511P	1.47	1.23	145	106	1	3	3	2	1	1
Be	mg/kg	+ 511M	2.02	1.17	0.13	0.11	1	0.96	0.41	0	0.62	0.52
Bi	mg/kg	+ 511M	0.20	0.26	0.70	0.39	0	0.05	0.16	0	0.16	0.20
Cd	mg/kg	+ 511M	0.05	0.05	0.09	0.08	0	0.04	0.04	0	0.09	0.09
Ce	mg/kg	+ 511M	56.83	68.19	32.04	33.69	75	62.40	61.44	60	53.13	54.84
In	mg/kg	+ 511M	0.10	0.10	0.03	0.03	0	0.05	0.05	0	0.08	0.08
Mo	mg/kg	+ 511M	0.40	0.52	1	0	1	0.78	0.34	0	0.35	0.33
Pb	mg/kg	+ 511M	3.52	4.31	6.28	6.65	3	3.18	5.29	5	2.74	3.13
Sb	mg/kg	+ 511M	0.04	0.05	1.12	1.06	0	0.04	0.05	0	0.07	0.04
Se	mg/kg	+ 511M	0.63	0.82	0.67	0.69	1	0.45	0.52	0	0.48	0.43
Te	mg/kg	+ 511M	0.052	0.062	0.02	0.01	0	0.02	0.01	0	0.02	0.02
Th	mg/kg	+ 511M	9.96	11.47	6.67	8.58	11	10.05	8.77	8	6.63	7.11
U	mg/kg	+ 511M	2.15	2.45	3.130	3.045	2	1.490	1.993	2	1.512	1.619
W	mg/kg	+ 511M	0.62	0.55	1.38	1.16	1	12.65	0.96	1	1.72	1.32
Yb	mg/kg	+ 511M	0.38	0.41	0.65	0.68	0	0.27	0.35	0	0.97	0.72

Total chemical composition of the samples:

			HAP$-2012-1,1	HAP$-2012-1,2	HAP$-2012-2,2	HAP$-2012-3,1	HAP$-2012-3,2	HAP$-2012-4,1	HAP$-2012-4,2	HAP$-2012-5,1	HAP$-2012-5,2
Na2O	%	+ 175X	1.93	1.93	3.59	1.51	1.64	3.17	3.12	2.7	2.69
MgO	%	+ 175X	3.23	3.04	1.53	1.92	2.36	2.54	2.51	2.41	2.42
Al2O3	%	+ 175X	19.6	20	16.3	14.6	17.2	14.9	15	14.2	14.2
SiO2	%	+ 175X	61.8	60.2	65.7	71.8	67.2	68.2	68.2	68.7	69
P2O5	%	+ 175X	0.106	0.113	0.167	0.04601	0.053	0.132	0.135	0.148	0.148
K2O	%	+ 175X	2.65	3.98	3.64	2.62	3.44	2.88	3.02	1.87	1.88
CaO	%	+ 175X	1.28	1.2	3.42	0.88	0.89	1.56	1.47	2.92	3.02
TiO2	%	+ 175X	0.7002	0.7802	0.5101	0.7502	0.7102	0.5701	0.5601	0.6402	0.6502
MnO	%	+ 175X	0.07301	0.065	0.069	0.007747	0.009994	0.045	0.047	0.067	0.049
Fe2O3	%	+ 175X	8.35	8.3	4.24	5.61	6.21	5.66	5.57	5.98	5.65
S	%	+ 175X	0.0519	0.0547	0.7901	0.0129	0.0123	0.0256	0.0238	0.006	0.006
Cl	%	+ 175X	0.0064	0.0077	0.0086	0.0078	0.0073	0.006	0.006	0.0065	0.006
Sc	%	+ 175X	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
V	%	+ 175X	0.0108	0.0123	0.0055	0.0107	0.0118	0.0078	0.0086	0.0089	0.0094
Cr	%	+ 175X	0.0122	0.0146	0.0021	0.0144	0.0125	0.0126	0.0132	0.0142	0.0133
Ni	%	+ 175X	0.0038	0.0046	0.002	0.0038	0.0042	0.003	0.0031	0.0052	0.0053
Cu	%	+ 175X	0.0039	0.0042	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Zn	%	+ 175X	0.0138	0.0135	0.0069	0.0126	0.0138	0.0078	0.0074	0.0074	0.0082
Ga	%	+ 175X	0.0028	0.0027	0.0023	0.002	0.0021	0.002	0.0022	0.002	0.0022
As	%	+ 175X	0.002	0.002	0.0101	0.002	0.002	0.002	0.002	0.002	0.002
Rb	%	+ 175X	0.0156	0.0208	0.0096	0.0116	0.0136	0.0112	0.0115	0.0107	0.0111
Sr	%	+ 175X	0.0134	0.0181	0.0548	0.0129	0.0152	0.02	0.0201	0.0372	0.0384
Y	%	+ 175X	0.0031	0.0031	0.0012	0.0032	0.0031	0.0025	0.0026	0.0026	0.0025
Zr	%	+ 175X	0.014	0.0156	0.0191	0.0221	0.0167	0.0157	0.0164	0.0194	0.0199
Nb	%	+ 175X	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007
Mo	%	+ 175X	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sn	%	+ 175X	0.002	0.0021	0.002	0.002	0.002	0.002	0.002	0.0021	0.002
Sb	%	+ 175X	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ba	%	+ 175X	0.0412	0.0749	0.0587	0.0445	0.0545	0.1059	0.1211	0.0715	0.0659
La	%	+ 175X	0.0031	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Ce	%	+ 175X	0.0076	0.0093	0.0036	0.0121	0.0091	0.0061	0.0059	0.0065	0.0067
Pb	%	+ 175X	0.002	0.0027	0.0036	0.002	0.002	0.002	0.002	0.002	0.002
Bi	%	+ 175X	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Th	%	+ 175X	0.0015	0.0019	0.001	0.0019	0.0017	0.0015	0.0015	0.0012	0.001
U	%	+ 175X	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
F	%	+ 175X	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

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CONCLUSIONS

The research performed in Finland included 3 sites in Kuopio (Niirala School, Kuopio Lyceum, Art Museum), 3 sites in Helsinki (Cygneuksen galleria, Tamminiemi and the National Museum), Suomenlinna sea fortress and Olavinlinna castle in Savonlinna. The material had been generally hard silicatic rock, either collected as erratic blocks as in the case of Olavinlinna, or quarried, as in the cases of the National museum and Niirala school. In some cases different architectural solutions had used both materials, as in the Kuopio Lyceum. The research consisted on visual inspections, mechanical, physical and chemical tests to integrate information for better understanding the level of weathering of the material on site.

The blocks that presented problems had been sampled and tested using different techniques as shown in the methodology report and those of the sites. Combining the information collected from the inspections could be told that Schmidt hammer, Ultra Pulse velocity and the physical laboratory tests (open porosity and water absorption) had been given information on the weathering level of the material together with petrographic and chemical analysis. Ground penetrating radar had been able to give information of the structure of the parts of the buildings inspected.

Results showed that granite has been a durable material. The material that probably had shown the lowest performance values had been the boulder blocks used in the basements and in the castles. The weathering could had been occurring much before the put in use of the boulder, during the ice ages. In these the impacts of detached fragments caused by rock structure is higher compared to other materials, also because of the small dimension of the blocks, but the walls that are thick and composed by blocks connected with mortar minimize the structural problem of the event.

Figure 1. Detachment of a piece from boulder block in Olavinlinna

The results showed that the material had been affected by light surface weathering, visible from chemical and petrographic analysis and by visual inspection. From some places it had been possible to see through weathering indexes that there had been a surface weathering. The petrographical analysis had shown presence of mineral disintegration and surface cracking both in boulder blocks and in quarried blocks, as an example the images from Suomenlinna and the National Museum, Figure 2.

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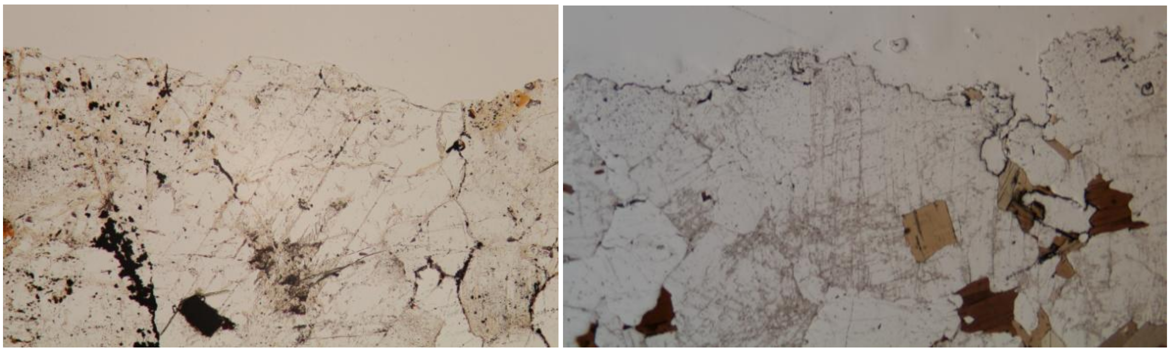

Figure 1. HAP$ 2012-12 Disintegration and breaking of the minerals on the top surface of the sample, visible from the fracturing (on the left). HAP$-2013-36 (on the right) weathered stone surface characterized by intensive fracture formation in feldspar grains.

While from visual analysis the main problems had been oxidation of minerals that determined local or diffused change of colours and in more serious cases fracturing in correspondence of the part and vegetative growth on wet and shadowed areas. Atmospheric particle deposition and fixation had affected the building exposed to traffic areas, but not always had been visible since building had undergone maintenance in recent years. Construction solutions had affected the durability of the material on site, as salt migration from sealing mortar had penetrated and stained the rock, or deposition of cupper and iron oxide had come from metal anchoring, roofing or pipes (Figure 2). Problems had also come from movement of the structure causing breaking in correspondence of the compressed block but fractures had also been caused by impacts.

Figure 2.Changes of colour determined by migration of the salts of the mortar (on the left), by leaching of elements (in the center) and by deposition of oxides (on the right)

Stones had also shown in few cases surface weathering as chipping, deepenings and cavities or roughening of the surfaces that sometimes could had been caused by mechanical cleaning actions.

The values of open porosity and water absorption in average are characteristic of the material and do not show high degree of weathering but present on some specimens differences between the top and bottom part of the sample.

In conclusion could be told that the material used on the site inspected - mainly granitic rock - has been under several kind of weathering actions, being the anthropogenic ones the worse ones. Even thought superficially had been noticed the impacts of the weathering, at deeper level the material had kept its characteristics, maintaining generally the material durable on the construction site.