University of Stavanger

**Faculty of Science and Technology**

# MASTER'S THESIS

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| Study program/ Specialization:<br><br>**Petroleum Engineering / Petroleum Geosciences** | Spring semester, **2012**<br><br>Open access |
| Writer: **Sofia Kontou** | ………………………………………<br>(Writer's signature) |
| Faculty supervisor: **Dr. Udo Zimmermann** | |
| Title of thesis:<br><br>**Evaluating provenance techniques in the hydrocarbon industry:**<br>**Compositional quantification of modern sands from known tectonic settings as analog for the correlation of hydrocarbon bearing rocks in ancient geological settings.** | |
| Credits (ECTS): **30** | |
| Key words:<br><br>**Provenance**<br>**Paleotectonic setting**<br>**Petrography**<br>**Correlation of reservoir rocks**<br>**Karmøy**<br>**Randaberg**<br>**Santorini** | Pages: **56**<br><br>Stavanger, **June 15, 2012**. |

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# Abstract

Major and trace element analyses show different compositions between the sediments of the Karmøy southeast shoreline and the sediments of northern Randaberg. Also supported form petrographic analyses, the Karmøy samples indicate a mafic source with andesitic to sub-alkaline basalt composition, low to moderate content of $SiO_2$, enrichment in Cr, V, and Co and very low Y/Ni ratios. On the contrary, both petrographic and geochemical analyses of the Randaberg samples show a more felsic composition, similar to unrecycled UCC, with a rhyodacitic to dacitic composition and low concentrations of Cr, V, and Co. The sands from Santorini do not derive from the calcite-rich carboniferous basement that is exposed on the island; instead their source is the recent volcanic rocks with rhyodacitic/dacitic to andesitic composition typical of active subduction zones. The sediments from all three areas are only moderately to partly unweathered and show no significant recycling. Lithic-fragment and mineral compositions are closely related to the adjacent source rocks. The sediments from Santorini mirror the composition of the volcanic source rocks and the paleotectonic environment of continental arc is easily deduced from the geochemical results. In contrast, the sediments from southwest Norway do not reflect the proposed paleotectonic environment of passive margin. Both petrographic and geochemical analyses indicate an oceanic arc environment for the Karmøy sediments and an active continental margin for the Randaberg sediments. Therefore, provenance determination is not possible in southwest Norway and further analyses are needed. Correlation between the sediments of Karmøy and Randaberg is very difficult and should be done with great caution and further sampling. However, the provenance techniques can be used with accuracy in Santorini whilst the validity of the results could be explained by the much younger age of the source rocks.

## Introduction

The objective of this thesis is to determine the nature and origin of recent sediments deposited along the shoreline of southeastern Karmøy and northern Randaberg in Norway and to compare them with recent sediments deposited on the shoreline of the volcanic island Thera in the Santorini group of islands in Hellas. The methods and results are then discussed for their application as provenance techniques in the hydrocarbon industry.

The working hypothesis is that in both regions the modern tectonic setting is known. For Santorini a continental arc setting is envisaged and for the Norwegian region a passive margin. Provenance geochemistry should demonstrate if the tectonic setting can be easily reflected in the sediments of the area.

On the island of Karmøy the sampling areas are located within the geologic area of the Karmøy Ophiolite Complex and particularly the Karmøy Axis Sequence, dominated by gabbroic rocks, where a total of 15 sand samples were collected from 5 different outcrops, as well as 1 sample of the dominant gabbro (Foldout 1).

In the Randaberg area the sampling areas are located within the geologic area of the Middle Allochthon group, dominated by mica-schist and gneiss, where a total of 15 sand samples were collected from 2 different outcrops (Foldout 2).

On the island of Thera the sampling areas are located within the only volcanic center of the southern Aegean island arc that is active today. The island is dominated by the metamorphosed basement and various volcanic rocks, where a total of 27 sand samples were collected from 7 different outcrops, as well as 7 volcanic rock samples and 2 samples of the metamorphosed limestone basement (Foldout 3).

All the samples were analyzed macroscopically, microscopically and geochemically and the combined use of geologic observations and geochemical data was used to characterize the provenance and the plate tectonic environment.

## Geology of the Karmøy Area, Norway

The island of Karmøy is part of the Karmøy Ophiolite Complex of southwest Norway (Sturt and Thon, 1978; Sturt et al., 1979; Furnes et al., 1980) interpreted as ancient oceanic crust from the Iapetus Ocean that was formed when the continents of Baltica and Laurentia started drifting apart around 600Ma. The oceanic crust was then displaced on top of the thrust nappes during the formation of the Caledonian orogenic belt when the plate movement was reversed after Late Cambrian until the beginning of the collision of Laurentia and Baltica during the Silurian. The Karmøy Ophiolite Complex consists mainly of gabbro, chlorite-schist and ultramafic rocks, intruded by various younger mafic/silica-poor igneous rocks (Foldout 1). On the island of Karmøy the Ophiolite Complex is deformed, fragmented by faulting and underlie stratigraphically the metamorphosed deep-ocean chert and phyllite sediments that are found in the north of the island.

The major rock groups found on the island of Karmøy are in chronological order from old to young: the Karmøy Axis Sequence (dominated by layered gabbro), the West Karmøy Igneous

Complex (ranging from tonalites to granites), the Torvastad Group (volcano-sedimentary rocks in the northern part of the island) and the Skudeneset Group (sedimentary rocks in the southern part of the island) (Foldout 1).
Particularly at the southern part of the island, where the samples were collected, the geological situation is more complex with gabbros in the east (Axis Sequence), sedimentary rocks in southeast (Skudeneset Group) and tonalites, quartz-diorites, diorites, granodiorites and granites (West Karmøy Igneous Complex) towards the west (Foldout 1).

## Geology of the Randaberg Area, Norway

The area of Randaberg is situated 20 km south of the island of Karmøy and is characterized by the thrust geology of the southwest Norway resulting from the continent collision of Baltica and Laurentia. The rocks are quite metamorphosed and deformed suggesting a deep subduction zone where Laurentia is transported east-southeast over Baltica during the Caledonian orogeny. They belong to the Middle Allochthon group consisting of basement nappes of Baltic origin and late-precambrian deposits (Fossen et al., 2008). However, their detrital zircon population (youngest concordant grain 540Ma) is very unusual for Baltica with a large amount of zircons derived from an igneous event around 600Ma when Baltica was characterized on its western side by a passive margin (pers. com. U. Zimmermann).
The major rock groups found in the northern part of the Randaberg area, where the samples were collected, are mica-gneiss, mica-schist, meta-sandstones and amphibolites and belong to the Ryfylke Phyllite (Smit et al., 2011). In the southern part diorites, granodiorites, granites and migmatites are also exposed and represent part of the Jæren Nappe (Smit et al., 2011) (Foldout 2).

## Geology of the Santorini Area, Hellas

The group of volcanic islands of Santorini is part of the island arc of southern Aegean Sea produced by the continental convergence of the African and Eurasian plates (Foldout 3). Santorini is one of the five volcanic centers of the arc connected with tectonic zones of weakness of a northeast trend. It is the only volcanic center that is active today and is characterized by earthquakes, tsunamis and sulphurous gas escapes (Papazachos and Panagiotopoulos, 1993).
The Santorini group of islands used to form one single, round island ring with several volcanoes which since the Minoan eruption (3,6ka after Friedrich et al., 2006) has more or less its present form.
Thera is the largest island in the group and this is where the samples were collected (Foldout 3). The older core (basement) beneath the volcanic rocks consists of limestones that have been metamorphosed, deformed and uplifted. The basement can be seen forming the highest hills at the south part of the island (Perissa, Kamari, Vlychada) and as a single rock in the eastern part of the island (Monolithos). The basement is made of marine sedimentary rocks (mostly limestone, but also sandstones and clays) deposited in the Tethys Sea from the Triassic to the Tertiary. The

sedimentary rocks were metamorphosed during the Cenozoic to marble, quartzite and mica-schist.
The rest of the island is covered entirely of volcanic rocks of different phases, built from lava and pyroclastites (Foldout 3). The major volcanic rock groups are in chronological order from old to young: the updomed areas and early centers of Akrotiri (rhyodacites), the Peristeria (ranging from basalts to andesites), the Cinder Cones of Akrotiri (ranging from basalts to andesites), the pyroclastic deposits of Cycle 2 and Cycle 1 (ranging from rhyodacites to andesites), the Cinder Cones of northeast Thera (andesites), the Skaros Shield (ranging from basalts to andesites), and the Minoan Tuff (ranging from rhyodacites to andesites) (Druitt, 1998).

## Sampling of the Karmøy Area, Norway

Fifteen sand samples were collected from the shoreline at the southwest part of Karmøy within the geologic area of the Karmøy Axis Sequence interpreted as layered gabbroic complex with an age of 493+7/-4Ma (Pedersen and Malpas, 1984; Dunning and Petersen, 1988). The sampling area is characterized by a series of small bays with a steep topography and a short distance from the elevated cliff where the gabbroic rocks are prominent.
The most southern samples were collected from the outcrop A1 located north of the main fault that separates the gabbroic rocks from the sedimentary rocks of the Skudeneset Group (Foldout 1). One sample was collected from the beach at Litlehavnen (N59°10’21” - E05°18’38”), and one from the river 100m away from the shoreline Bekkjarvika (N59°10’17” - E05°18’29”). Heading north, three samples were collected from Norstø, outcrop A2 (N59°10’40” - E05°18’33”), four samples from Søra Børevika, outcrop A3 (N59°11’12” - E05°18’48”), two samples from Blikshavn Nord, outcrop A4 (N59°12’50” - E05°19’16”) and finally, four samples from Tømmervika, outcrop A5 (N59°13’05” - E05°19’16”). All the samples, with the exception of the river, were collected within one meter distance of the shoreline and 10-15cm deep in the sand. The sample from the river (A1P) was collected in a water depth of 25cm and 5cm deep in the sandy sediments (Appendix 2).
One rock sample was collected from the gabbro located at the eastern part of the road (N59°11’76” - E05°18’43”), near outcrop A3 and about 200m away from the shoreline (Appendix 2). The rock appears deformed and fragmented by faulting and represents the nearest source of the sandy sediments. The gabbro is cut by the Feøy dyke swarms which are more prominent in the north and have formed prior to, during and subsequent to crystallization of the underlying gabbro sequence (Pedersen, 1986) (Foldout 1).

## Sampling of the Randaberg Area, Norway

Fifteen sand samples were collected from the shoreline at the northern part of Randaberg within the geologic area of the Ryfylke Phyllite of unknown age, but assumed to be related to the Caledonian orogeny (Smit et al., 2011) (Foldout 2).

The area is characterized by a peninsula bordered by two bays with flat topography and long sandy beaches. Sandebukta, outcrop RS (N59°01’15” - E05°35’30”), is the largest bay at northwest, over 1km long, with a fine grained sandy beach and sand dunes at the innermost part of the bay. Seven samples were collected within 5m of the shoreline in a water depth of up to 40cm, as well as one sample was collected from the dunes (PB3). Six samples were collected within 3m of the shoreline in a water depth of up to 30cm at Randaberbukta, outcrop RM (N59°01’25” - E05°36’15”), the largest bay at northeast. Both bays have shallow waters and therefore significant effects of the tides (Appendix 2).

The rocks between the two bays have been interpreted as part of the Middle Allochthon group consisting of metamorphosed and deformed gneiss and mica-schist, but recent detrical zircon determination showed a Lower Palaeozoic depositional age and a very unusual detrital zircon population for Baltica (pers. com. U. Zimmermann).

## Sampling of the Santorini Area, Hellas

Twenty seven sandy samples were collected from the shoreline of the island of Thera, the largest island of the group of Santorini islands that are part of the volcanic arc of the southern Aegean (Foldout 3). The island is characterized by flat topography with the exception of the hills in the southeastern and western parts. The flat areas consist of about 80% of the island and are covered by Minoan Tuff. The Minoan Tuff was deposited during different phases, creating several tuff layers that have been eroded to various forms and contain xenoliths derived from older lavas of various ages (Appendix 2).

Profitis Elias, the highest hill in the southeastern part (565m) is located between Perissa and Kamari and consists of metamorphosed, deformed and uplifted basement rocks such as marble, quartzite and mica-schist of unknown age, interpreted as Triassic to Tertiary (Pichler et al., 1980; Heiken and McCoy, 1984; Druitt et al., 1989;). Two marble samples were collected from Profitis Elias, one from Perissa (RPEB) and one from Kamari (RKAB). Four sediment samples were collected from Perissa, outcrop PE (N36°21’27” – E25°28’36”), which is located SE and is characterized by a 4km long black sandy beach. Four sediment samples were collected from Kamari, outcrop KA (N36°22’09” – E25°28’51”), which is located NE of Profitis Elias and is characterized by a 2km black pebble beach (Appendix 2).

In the southern part of the island, where Gavrilos is located, another hill consisting of basement rocks crops out. Near Gavrilos, four sediment samples were collected from Vlychada, outcrop VL (N36°20’20” – E25°25’53”), as well as one rock sample of the Minoan Tuff (RVLT).

In Akrotiri, the southwestern part of the island, sediment samples were collected from two outcrops within a few hundred meters distance between them. Three samples were collected from outcrop BL (N36°20’56” – E25°23’54”), a small black pebble beach, and four samples from outcrop RE (N36°20’54” – E25°23’39”), a long red sandy beach. The area of Akrotiri forms a hill consisting of volcanic rocks of various cycles. Two rock samples were collected (RREBU-RRERP) from the Cinder Cones of Akrotiri of age 626 to 319ka (Druitt et al., 1998).

The western part of the island is located 200-400m above the sea level overlooking the caldera that was created during the Minoan eruption, and consists of various volcanic rocks. Two rock samples were collected from the northwest part of the island, one sample (RBMP) from outcrop

(BM) Mikro Profitis Ilias (N36°27'71" – E25°25'25") consisting of the Peristeria formation of age 536 to 425ka, and one sample (RRMC) from outcrop (RM) Kokkino Vouno (N36°27'48" – E25°24'52") of the Cinder Cones of northeast Thera of age 54±23ka (Druitt et al., 1998).
At Cape Kolumbo at the northeast part of the island, four sandy samples were collected from outcrop KO (N36°28'24" – E25°25'15"), as well as two volcanic rock samples from different layers of Minoan Tuff (RKOTB and RKOTR).
Finally, four sandy samples were collected from Monolithos, outcrop MO (N36°24'44" – E25°29'00"), at the eastern part of the island. Monolithos consists of a very flat area with shallow waters where a small piece of the basement is exposed at the northern part of the beach.
All the sandy samples were collected within one meter distance of the shoreline and 10-15cm deep in the sand.

## Methodology

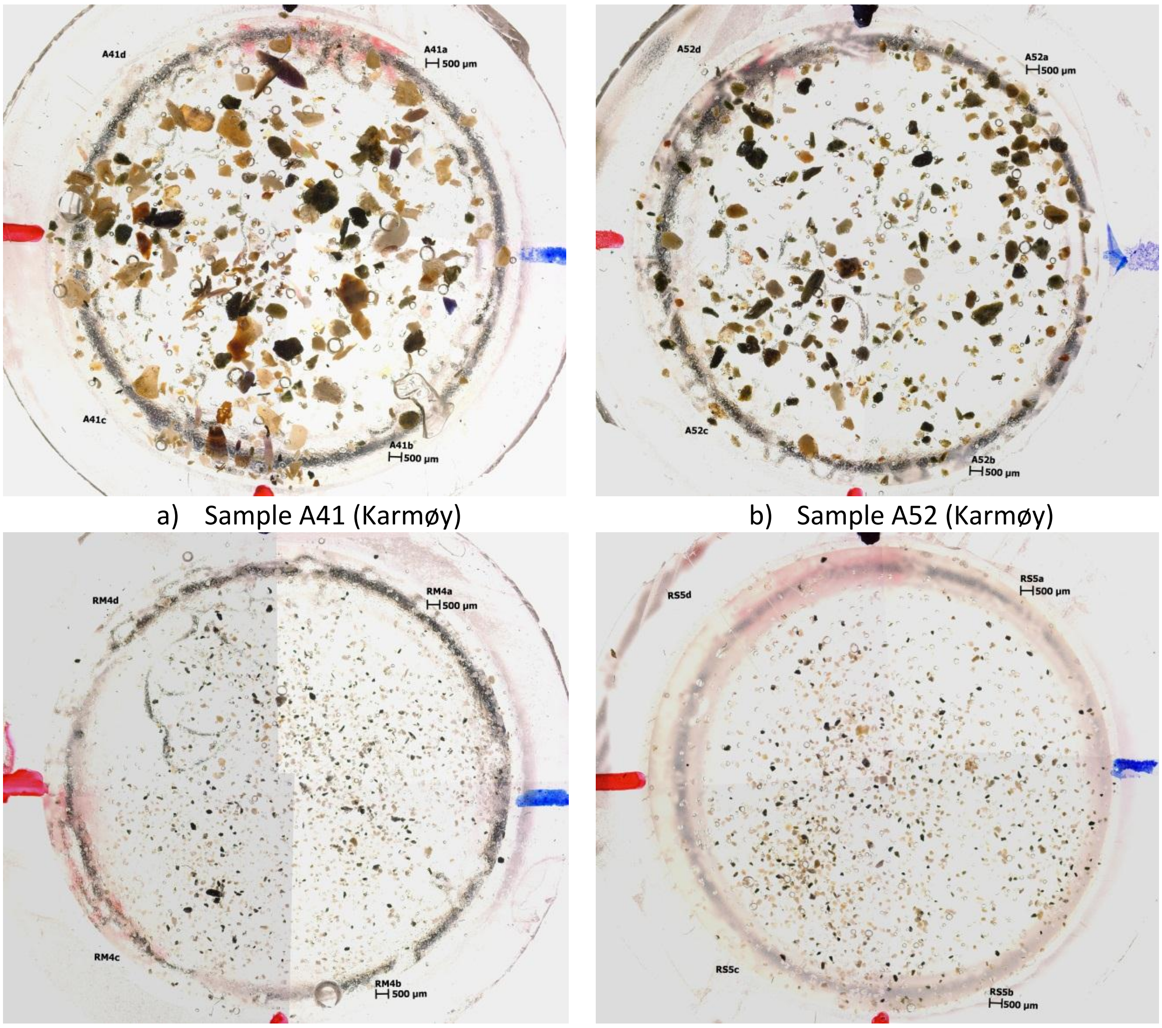
The sandy samples were dried and cleaned from anthropogenic materials such as glass, ceramic, metal and charcoal. The rock samples were dried and crushed. The samples were examined macroscopically and microscopically in order to separate the organic matter and the magnetic minerals, to observe size, color and shape of the grains, and to identify minerals and lithic fragments.
Studies have shown that the source for geochemical trends is best represented in the clay-sized fraction of the sediment (Cullers et al., 1987), so the samples were sieved and 50 gr from the finest grain sizes were milled in an agate swing mill to a very fine mesh for geochemical analyses. Geochemical analysis of major and trace elements was carried out in duplicate by Inductively Coupled Argon Plasma – Mass Spectrometry (ICP-MS) at ACME Laboratories (Vancouver, Canada). Analysis consisted of total extraction of the elements into a solution and element determination by instrumental analysis of the solution. ICP-MS measures the element concentrations by counting the atoms for each element present in the solution. More information about the method and the detection limits can be obtained from the homepage: www.acmelab.com. The results are shown at Appendix 1.

## Petrography of the sands of Karmøy Area, Norway

The sands collected from Karmøy range in size from coarse sand to coarse pebbles. Sorting is poor with a random size distribution on all the beaches and the grains have angular to sub-angular shape possibly indicating short transport (Fig.1). The lithic fragments observed are derived from gabbros, tonalites, chlorite-schists, gneiss, schists and sandstones. Some rock fragments have a three-faceted (triangular) shape, typical for glacial transport. Single minerals identified are pyrite, mica, feldspar, calcite, serpentine, amphibole, plagioclase, pyroxene, olivine and quartz. Organic matter occurs as shell fragments and only in the river section organic matter appears to be derived from plants. In the waters and sessile on algae, a number of shelled organisms, like foraminifers, have been identified and might be the source for the shell fragments in the sands.

## Petrography of the sands of Randaberg Area, Norway

The sands collected from Randaberg range in size from very fine to coarse grained sand. Sorting is moderate at both beaches and the grains are mostly sub-angular. Lithic fragments appear to be derived from phyllites and gneiss. Single minerals identified are pyrite, mica, feldspar, calcite, amphibole, plagioclase, pyroxene, muscovite, tourmaline, garnet and quartz. The organic derived matter is represented by shell fragments (Fig.1).




a) Sample A41 (Karmøy)

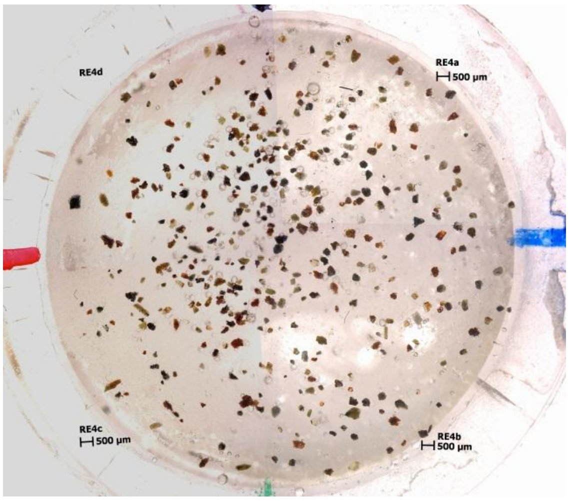
b) Sample A52 (Karmøy)

c) Sample RM4 (Randaberg)

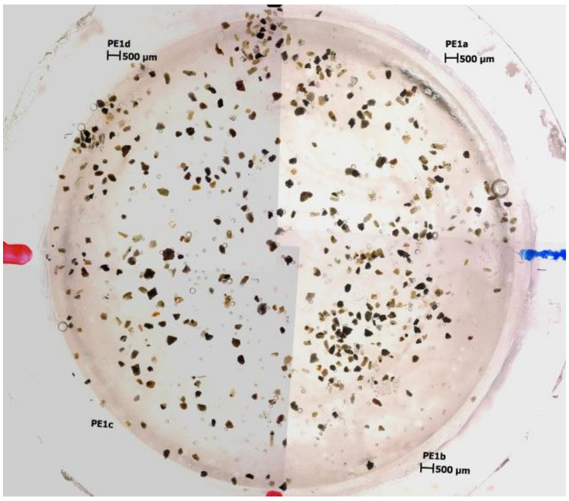
d) Sample RS5 (Randaberg)

**Figure 1** Images of sand grains (more images at Appendix 3). a) Sample A41 from Blikshavn Nord, Karmøy. b) Sample A52 from Tømmervika, Karmøy. c) Sample RM4 from Randaberbukta, Randaberg. d) Sample RS5 from Sandebukta, Randaberg.

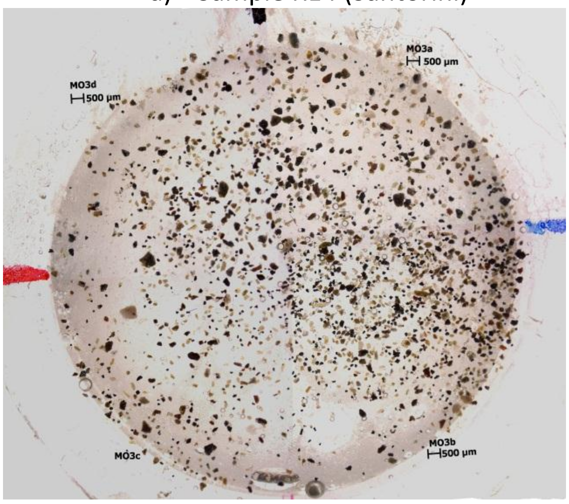
The sands collected from Santorini range in size from fine sand at Monolithos to coarse pebbles at Kamari. Sorting is moderate at all the beaches and the grains have mainly sub-angular shape indicating possibly short transport, suggesting that the main source of sediment are the adjacent cliffs. Lithic fragments are mainly of volcanic origin, such as lava, pumice and even preserved glass. Metamorphic grains have also been observed shed from marbles and phyllites. Most common minerals identified are plagioclase, clinopyroxene, orthopyroxene, amphibole, hornblende and quartz. Less common minerals are magnetite, orthoclase, zircon, zeolite, hematite, olivine, calcite and dolomite (Fig.2).



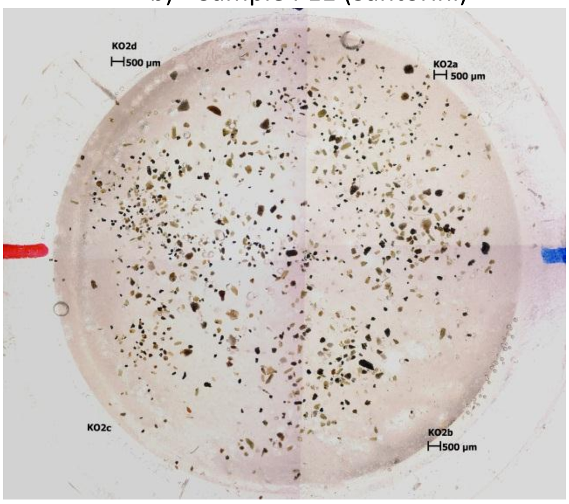

a) Sample RE4 (Santorini)




b) Sample PE1 (Santorini)




c) Sample MO3 (Santorini)




d) Sample KO2 (Santorini)

**Figure 2** Images of sand grains (more images at Appendix 3). a) Sample RE4 from Red Beach at Akrotiri, Santorini. b) Sample PE1 from Perissa, Santorini. c) Sample MO3 from Monolithos, Santorini. d) Sample KO2 from Kolumbo, Santorini.

## *Major Elements*

Most of the samples from Karmøy (including the rock sample) have low to moderate content of $SiO_2$ (from 46% to 57%) with the exception of outcrop A4 where the content of $SiO_2$ (from 34% to 41%) is even lower (Appendix 1). All the samples show higher values of $Fe_2O_3$ (5,72% - 12,07%) and MgO (4,40% - 7,58%) than the average upper continental crust (UCC), but there is a variation in the values of $Al_2O_3$ (10,60% - 20,23%). In addition all the samples show high CaO abundances (ranging from 6,92 to 22,71%) and low $K_2O$ (less than 1%). The highest values of CaO (22,71% and 16,48%) are shown in outcrop A4 indicating abundance of calcite shells as petrographic analyses can confirm.

The samples from Randaberg are moderately enriched in $SiO_2$ (from 73% to 78%) and depleted in all other major elements in comparison to UCC (Appendix 1). CaO % concentrations are between 1,36% and 2,44% and reflect the organism shells. Although the samples are collected from two different exposures they are geochemically in their major elements relatively homogeneous.

All the sand samples from Santorini have moderate content of $SiO_{2,}$ ranging from 53% to 61% (Appendix 1). Almost all the samples show enrichment in $Fe_2O_3$ (values vary between 4,33% and 10,64%) but only some in MgO (values vary between 1,45% and 10,21%). The values of $Al_2O_3$ vary from 12,35% to 18,90%. All the samples are depleted in $K_2O$ (0,90% - 2,15%) and enriched in $TiO_2$ (0,57% - 1,06%). In addition all the samples show slight enrichment in CaO (5,56 to 9,87%) indicating presence of calcite as petrographic analyses can confirm.

The volcanic rocks have low to moderate content of $SiO_{2,}$ ranging from 47% to 65% (Appendix 1). Most samples are enriched in $Fe_2O_3$ (values vary between 4,09% and 8,49%), but only a few in MgO (values vary between 1,34% and 7,78%). All the samples are depleted in $K_2O$ (0,68% - 2,57%), most are enriched in $TiO_2$ (values vary between 0,48% and 1,14%) and some show slight enrichment in CaO (values vary between 2,99 to 10,63%).

The two samples from the metamorphosed carbonate rocks (RPEB and RKAB) show expectedly high concentrations of CaO (55-56%) and depletion in all other major elements including MgO, supporting the existence of calcite as major carbonate mineral (Appendix 1).

## *Alteration*

The chemical index of alteration CIA is used to show the degree of chemical weathering (Nesbitt and Young, 1982) and was calculated using the molecular proportions by eq.1:

$CIA=(Al_2O_3/(Al_2O_3+CaO^*+Na_2O+K_2O))*100$ (eq.1)

Where CaO* represents the CaO associated with the silicate fraction of the sample and was calculated by eq.2:

$CaO^*=CaO-CO_2-(0.5*CO_2)-((10/3)*P_2O_5)$ (eq.2)

Unweathered igneous rocks have values of 50 or below, residual clays have values of near 100 and typical shales have average values 70 to 75.

The CIA is low in most of the Karmøy samples varying from 40 to 47 indicating no significant alteration (Appendix 1). Samples from outcrop A4 have particularly low values 25,04 and 33,73. The samples from Randaberg all have similar CIA values varying from 49 to 53 indicating slight weathering. The samples from Santorini have low CIA values varying from 35 to 48 indicating no significant weathering.

In addition, weathering trends are shown on the A-CN-K ($A=Al_2O_3$, C=CaO, $N=Na_2O$ and $K=K_2O$) triangular plot (Nesbitt and Young, 1984, 1989) where, the trends for increasing degrees of weathering for different rocks are illustrated (Fig. 3). Weathering involves the conversion of unstable minerals (mainly feldspars and mica) and volcanic rocks (glass), to clay. Deviations from the trends indicate chemical changes resulting from diagenesis or metasomatism. Compositions are plotted as molar proportions and the initial stages of weathering form a trend parallel to the CN-A side of the diagram. During weathering there is a substantial increase in $Al_2O_3$ and removal of alkalis and Ca, during the breakdown of plagioclase, then potassium feldspar and ferromagnesian silicates.

All the samples from Karmøy plot on or near the basaltic weathering trend line and have degree of weathering less than 50, characterized as unweathered. Most of the Randaberg samples follow a trend line between andesite and shale, but there are deviations towards both the A-K and the CN-A sides of the diagram. Most of the Santorini samples follow a basaltic-andesitic trend, but some of them deviate towards the A-K side of the diagram. All of the Santorini samples have degree of weathering less than 50, so they are characterized as unweathered.

Comparing K/Cs ratios to CIA (McLennan et al., 1993) can show if K-metasomatic effect is present, that would cause weathered compositions to plot closer to the K apex, thus lowering the CIA values. Both K and Cs are absorbed on clay minerals during weathering. Cs as a larger ion element, being preferred over K, thus the K/Cs ratio should decrease with increasing chemical weathering. A K-metasomatic effect is shown as a deviation from the negative correlation between the K/Cs ratio and CIA.

K/Cs ratios scatter for the Karmøy samples, indicating different influences of the detritus and/or different weathering influences. The K/Cs ratios of the samples from Randaberg are homogeneous and have higher values than UCC. The K/Cs ratios of the Santorini samples do not correlate with the CIA values, indicating a minor K-metasomatic influence (Fig. 3).
However, most of the samples can be described as only moderately to partly unweathered.

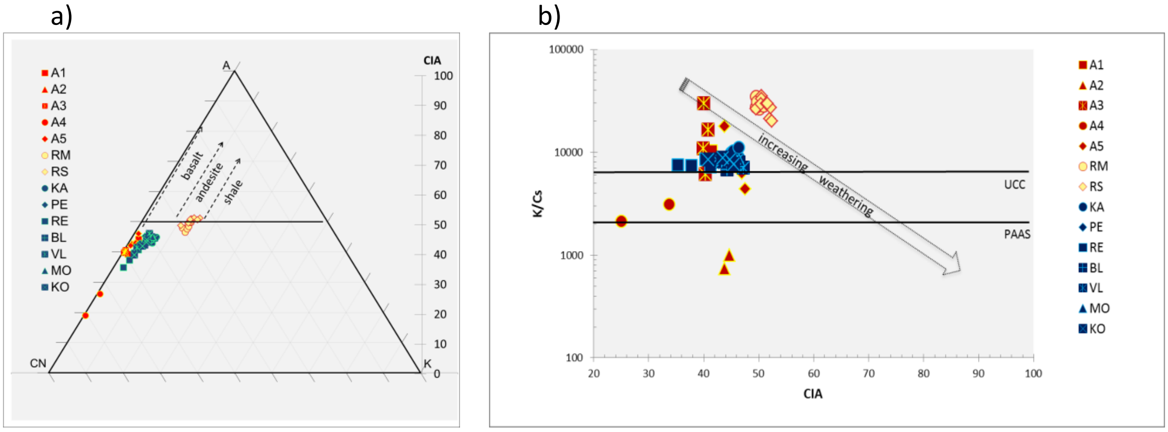



**Figure 3** a) CIA and ACNK trivalent diagram (Nesbitt and Young, 1984, 1989). b) K/Cs versus CIA diagram (McLennan et al., 1993).

## *Trace Elements*

Trace elements like rare earth elements (REE) and high field strength elements (HFSE) are usually immobile under surface conditions, preserving characteristics of the source rocks, and have been used to suggest the former tectonic environment.

All the Karmøy samples show enrichment in Cr (103 to 377 ppm), V (136 to 410 ppm) and Co (21,50 to 67,60), which are good indicators for a mafic source component. They are also characterized by low abundances of La, Th, U, Zr and Nb indicating a tectonic setting of oceanic arc. On the contrary, none of the Randaberg samples shows enrichment in Cr, V or Co. The only samples from Santorini that are enriched in Cr are the ones from outcrop RE (323 to 595 ppm). These samples are also enriched in Ni (73 to 164 ppm), with a ratio Cr/Ni between 3,6 and 4,5 (Appendix 1).

Classification of the volcanic and sedimentary rocks can be done with the plot Zr/Ti versus Nb/Y, a discrimination diagram relying on High-Field-Strength Elements (HFSE), where Nb/Y measures the degree of alkalinity and Zr/Ti is an index of fractionation (Fig. 4). The various fields are illustrated according to Winchester and Floyd (1977). These elements are stable under conditions of hydrothermal, sea-floor weathering and up to medium metamorphic grades (mid-amphibolites). Nb/Y is insensitive to fractionation in the shallow mantle and variations in these ratios may reflect heterogeneities in the mantle source. The behavior of Y, however, changes depending on the depth in the mantle. It is incompatible in the shallow mantle, but is compatible in the deep mantle, where it is retained in garnet during partial melting.

Most of the samples from Karmøy plot in the andesitic basalt field, while some plot in the sub-alkaline basalt field. It is interesting that the samples from outcrop A1 (the most southern outcrop) have higher Zr/Ti ratios and plot in the andesite field. All the samples from Randaberg plot in the rhyodacite/dacite field. The samples from Santorini plot between the rhyodacite/dacite and the andesite fields.

Rare earth elements (REE) are of special interest in sediments since they are considered representative of provenance. REE are amongst the least soluble trace elements and present in minute concentrations in water. They are also relatively immobile under surface conditions, so the concentration of REE in sediments reflects the chemistry of their source.

Values for concentration of REE (Rare Earth Elements) of the sediment samples were normalized to Chondrite after Taylor and McLennan (1985), Upper Continental Crust (UCC) after McLennan et al. (2006) and Post Archean Average Australian Shale (PAAS) after Nance and Taylor (1976), (Fig. 4). Post Archean shales normalized to Chondrite show typically patterns with light REE enrichment, flat heavy REE and negative Eu anomaly. The removal of feldspar by crystal fractionation or partial melting will result to Eu depletion. Strong positive enrichment in Eu results from plagioclase enrichments due to sedimentary sorting processes.

The Karmøy samples show a flat pattern slightly enriched in all the REE compared to chondrite, with a higher enrichment in Eu. The Randaberg samples follow more or less the pattern of UCC (except for Eu), showing light REE enrichment and flat heavy REE compared to chondrite. The samples from Santorini are also enriched in light REE but have higher values of the heavy REE compared to UCC and closer to the values of PAAS.

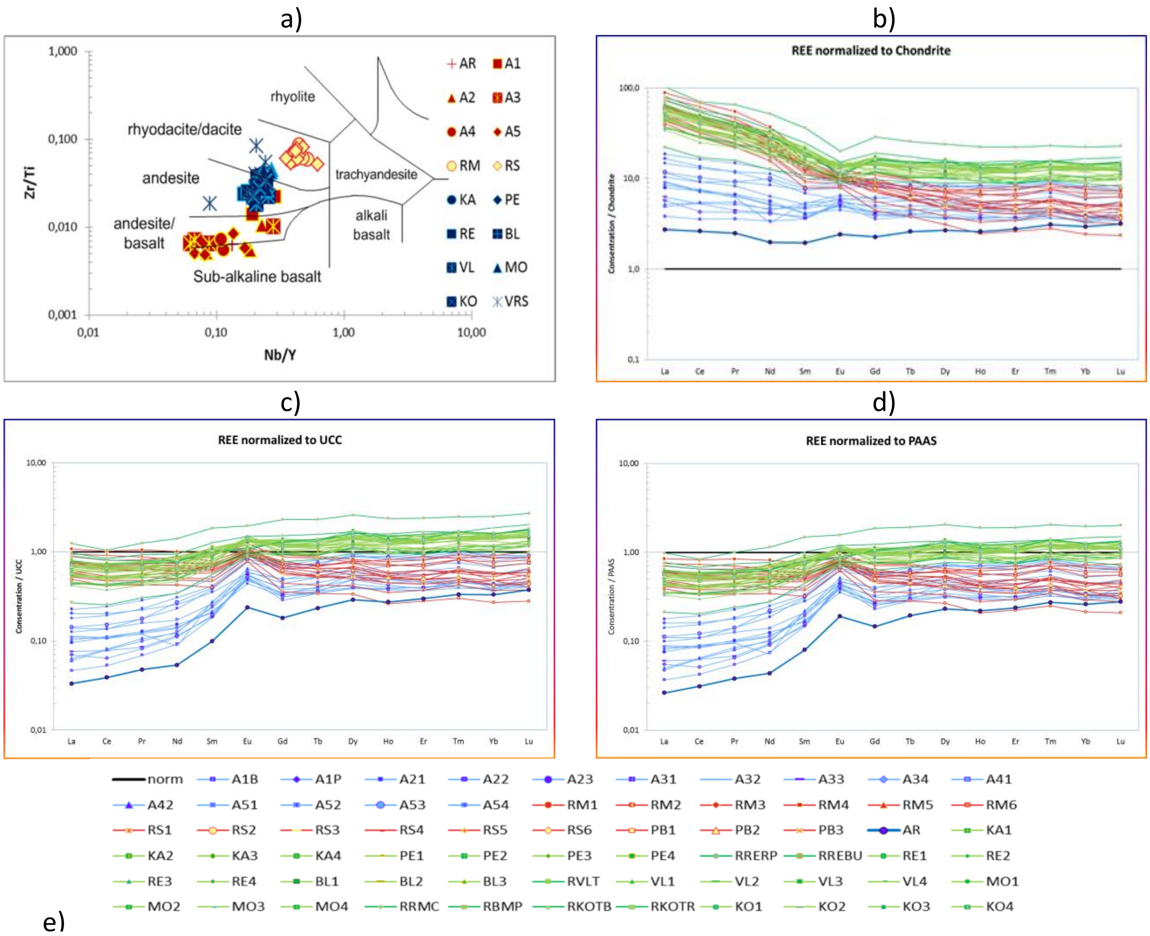



**Figure 4** a) Zr/Ti versus Nb/Y diagram (Winchester and Floyd, 1977). b) REE pattern normalized to chondrite after Taylor and McLennan (1985). c) REE pattern normalized to UCC after McLennan et al. (2006). d) REE pattern normalized to PAAS after Nance and Taylor (1976). e) Legend for figures 4. b,c and d.

Ratios of Th/Sc were plotted against Zr/Sc on the diagram after McLennan et al., (1993), a useful indicator of zircon enrichment that shows sediment reworking (Fig. 5). The Th/Sc ratio is a good measure of igneous chemical differentiation processes since Th is typically an incompatible element enriched in felsic rocks, whereas Sc is typically compatible indicating mafic source components. Both elements are transferred almost exclusively to the clastic sedimentary record during weathering, erosion and transport, and are not redistributed widely by secondary processes, such as diagenesis.

The Th/Sc ratios of the Karmøy samples vary, but are generally low and none of the samples show zircon enrichment, thus they have undergone no sediment recycling or the sediment derived from a mafic source. The samples from Randaberg show Zr addition and the Th/Sc ratios are similar to the UCC. All the samples from Santorini follow the composition line with Th/Sc ratios less than 1 and no zircon addition, which points to a mixing of different mafic and intermediate rock sources.

Cr is compatible in the minerals olivine, orthopyroxene, clinopyroxene and the spinels in a basaltic melt. The abundance of Cr and Ni in clastic sediments indicates an ultramafic source, where low concentrations of Cr are typical of a felsic provenance. The diagram Cr/V versus Y/Ni (Hiscott, 1984) shows the mixing curve model between granite and ultramafic end-members (Fig. 5). High Cr/V ratios and very low Y/Ni ratios indicate ultramafic sources. Homogeneous Cr/V ratios indicate a single mafic source, where variations can be caused by different processes and/or source mixing.

All the samples from Karmøy have very low Y/Ni ratios and varying Cr/V ratios indicating source mixing. None of the Randaberg samples, as well as most of the Santorini samples, show influence from an ultramafic source. Interesting though, the samples from outcrop RE (Akrotiri) have very high ratios of Cr/V and very low ratios of Y/Ni, plotting at the ultramafic end of the mixing curve model. Hence, they have to have a different sand composition which is also supported by petrography.

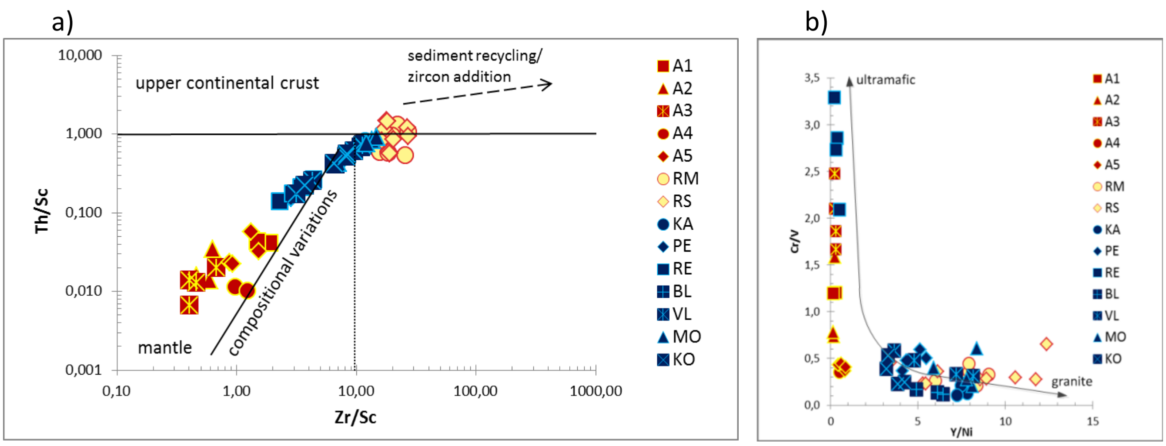



**Figure 5** a) Th/Sc versus Zr/Sc diagram (McLennan et al., 1993). b) Cr/V versus Y/Ni diagram (Hiscott, 1984).

The elements Rb, Nb, Y, Yb and Ta are used as discriminants between most types of ocean-ridge granites (ORG), within-plate granites (WPG), volcanic arc granites (VAG) and syn-collisional granites (syn-COLG), (Pearce et al., 1984), (Fig. 6). Elements Y and Yb are compatible, while Rb is highly incompatible in continental granites, but less abundant in oceanic granites. The elements Nb and Ta are incompatible in intra-plate magmas, but are compatible in subduction zones. Low Nb content is typical of subduction-related magmas.

In all the diagrams, the volcanic rock samples from Santorini plot in or near the volcanic-arc granite (VAG) field. As expected, the sampled rocks are related to a volcanic arc.

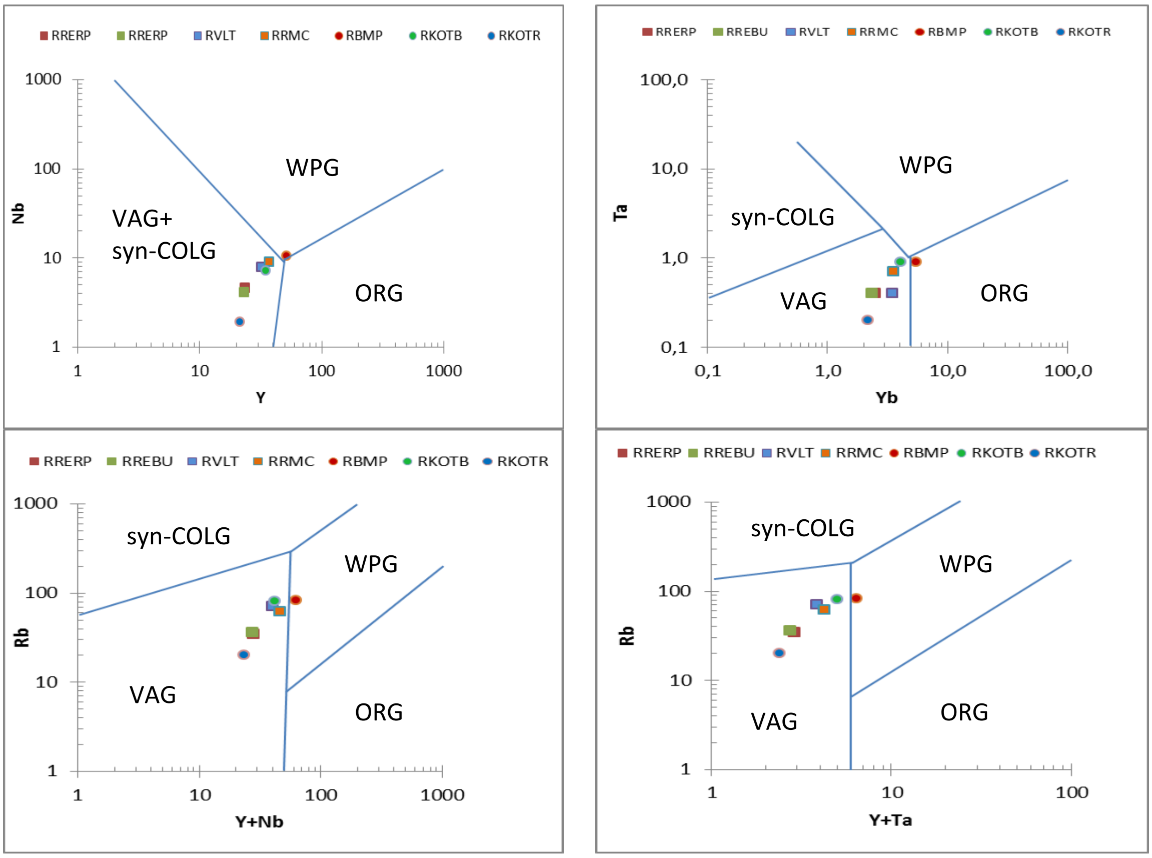



**Figure 6** Granite discrimination diagrams after Pearce et al. (1984). VAG=volcanic-arc granites, syn-COLG=syn-collisional granites, WPG=within-plate granites, ORG=ocean-ridge granites.

## Implication of the petrographic and geochemical data

The sediments from Karmøy are poorly sorted with angular to sub-angular shape and have not undergone significant weathering or sediment recycling. They are characterized by low to moderate content of $SiO_2$, enrichment in Cr, V, and Co and very low Y/Ni ratios. Their homogeneous andesitic to sub-alkaline basalt composition corresponds to the composition of the gabbroic rocks in the area and is reflected as well in the abundance of mafic lithoclasts. Hence, there has been no visible input of felsic detritus.

The sediments from Randaberg are moderately enriched in $SiO_2$ with low concentrations of Cr, V, and Co and their composition is rhyodacitic to dacitic. REE patterns are homogeneous for both outcrops and similar to unrecycled UCC. The sands are moderately sorted with sub-angular shape, but have not undergone significant weathering or sediment recycling. The phyllite rocks in the area are relatively soft, therefore quick erosion can be the cause of the rapid dismembering of the sediments. Petrographic data confirm this interpretation with a majority of lithoclasts derived from felsic rocks.

The grains in the sands from Santorini have sub-angular shape, moderate sorting and do not show significant weathering or sediment recycling. They are characterized by moderate content of $SiO_2$ and have no significant enrichment in CaO, thus the calcite-rich carboniferous basement rocks cannot be the main source of the sediments. The composition ranges between rhyodacitic/dacitic to andesitic corresponding to the composition of the adjacent volcanic rocks which have geochemical features typical of active subduction zones. The REE patterns are homogeneous for all the outcrops and similar to PAAS. The samples from outcrop RE are enriched in Cr and Ni resulting in very high ratios of Cr/V and very low ratios of Y/Ni, showing a more mafic composition of the volcanic source which is supported by previous geochemical studies of the magma. The Cinder Cones of Akrotiri, the source of the sediments in outcrop RE, comprise of andesitic-basaltic magma of age 626 to 319ka (Druitt et al., 1998). Therefore, Santorini is a perfect example for a recognizable short source to sink transport based on the identified petrographic and geochemical signatures.

To determine the provenance of the source rocks, the plot Ti/Zr versus La/Sc (after Bhatia and Crook, 1986) has been used as a good discriminator of the paleotectonic setting (Fig. 7). Zr is mainly transported by the ultra-stable heavy mineral zircon and Ti is fixed in rutile. Depletion of the high field strength elements Ti and Zr indicates an arc signature, whereas enrichment in Ti and Zr indicates intraplate setting. Oceanic island arc samples are characterized by Ti/Zr ratio more than 40 and La/Sc ratios less than 1. Continental island arc samples are characterized by Ti/Zr ratio between 10 and 35, and La/Sc ratio between 1 and 4. Active continental margins have Ti/Zr ratio between 10 and 25 and La/Sc ratio ranging from 3 to 7. Finally, passive margin samples are characterized by Ti/Zr ratio between 0 and 10, and La/Sc ratio between 4,5 and 11,5.

All samples from Karmøy plot in the oceanic island arc field with some extremely high values of Ti/Zr ratio (ranging from 45 to 207) and very low values of La/Sc ratio (less than 0,25). They even show higher values than the sampled gabbro (as well plotted in Fig. 7 for comparison). Almost all the samples from Randaberg plot in the active continental margin field. It is interesting that the samples from Santorini plot half in the continental island arc and half in the oceanic island arc. Hence, the amount of Ti-rich sources is significant higher than those related to felsic rocks.

Using the elements the elements Th, Sc and Zr on the triangular plot after Bhatia and Crook (1986) is another technique of paleotectonic environment discrimination (Fig. 7). On this diagram the Karmøy samples plot very close to the Sc apex, showing an extreme enrichment in Sc in comparison to Th and Zr. The Randaberg samples do not show a typical passive margin signature; instead they straddle the fields of active continental margin, passive margin and continental arc showing a typical unrecycled upper continental crust rock composition. This is in accordance with the petrography, as the rock debris is relatively angular and not well rounded or even sub-rounded as the main typical feature. Hence, sampling along the coastline of Karmøy reveals an oceanic island arc signature for the sediments, while the Randaberg samples reveal an unrecycled UCC composition, which implies that correlation along large basins need to be made with greatest caution. The samples from Santorini plot half in the continental island arc and half in the oceanic island arc just like the plot Ti/Zr versus La/Sc.

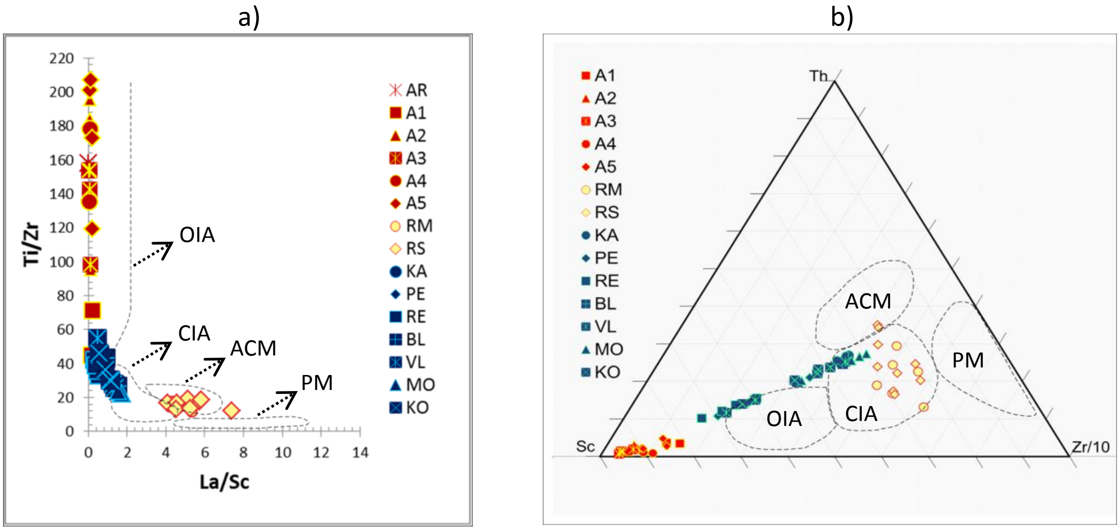



**Figure 7** a) Ti/Zr versus La/Sc diagram (Bhatia and Crook, 1986). b) Th, Sc, Zr trivalent diagram (Bhatia and Crook, 1986). OIA=oceanic island arc, CIA=continental island arc, ACM=active continental margin, PM=passive margin.

The paleotectonic environment of Santorini is a continental arc and it is reflected in the geochemistry, as expected. The differences in some samples that show a stronger mafic signature can be explained by the different compositions of the volcanic magmas. In Randaberg, the paleotectonic environment is proposed to be a passive margin but it is not reflected in the geochemistry. The Karmøy sediments do not reflect the paleotectonic environment either, as the geochemistry and petrography show quartz-poor sediments with a geochemical signature of oceanic arc. The samples have not been transported far and they hold the mafic signature of the adjacent gabbroic rocks that belong to the Karmøy Axis Sequence and are from the oldest on the island. Sands from other parts of Karmøy, where younger rocks are exposed (e.g. from the southwest, where the dominant rocks are of quartz-dioritic, dioritic, granodioritic and granitic composition), might show different geochemical and petrographic results and further studies are needed in order to establish the paleotectonic environment. The sands from Randaberg in turn show an unrecycled UCC signature, which cannot be expected at a typical passive margin. In combination with the findings of similar aged sediments from Karmøy, a tectonic setting of the sediments cannot be deduced by provenance techniques. Santorini, as shown, reflects and mirrors within the sink sediments the composition (and the tectonic setting) of the source rocks. These sediments are actually supporting the provenance techniques as proposed (references see above in Introduction), which is also deciphered in Lower Palaeozoic rocks in the Central Andes (Zimmermann et al., 2010).

Moreover, applying Ce/Y ratios in basalts has been used as a quantitative estimate of crustal thickness during the evolution of an orogeny (Mantle and Collins, 2008). The volcanic rocks in Santorini have Ce/Y ratios between 1 and 1,5 (except sample RKOTR that has a ratio of 0,76) indicating a Moho depth of 20-30km which is also supported by recent geophysical studies (Li et al., 2003; Sodoudi et al., 2006; Karagianni and Papazachos, 2007). The sediments have also Ce/Y ratios between 1 and 1,5 supporting the theory that they derive from the adjacent volcanic rocks and that the depositional setting is a continental arc. This supports the interpretation of 100% recycling.

## Consequences for the hydrocarbon industry

Correlation is an often used tool in the oil industry to gain information about basin extension and to trace down hydrocarbon-rich layers or successions. Understanding of the provenance of hydrocarbon-rich sedimentary rocks and their depositional system, should aid in regional mapping correlation of potential reservoirs. This implies the validity of provenance models and quantitative analytical techniques. Here, as shown this cannot be applied to western Norway. The petrographic and geochemical analyses do not suggest a passive margin as a paleotectonic environment. Instead the Karmøy sediments indicate an oceanic arc and the Randaberg sediments an active continental margin. Correlation between the two locations is very difficult and further sampling is required. Since the samples show no significant weathering or recycling and their petrography indicates possible short transport, it is suggested that the characteristics of the sediments are biased by the adjacent source rocks. In contrast, Santorini reflects the paleotectonic environment accurately as the sediments carry the signature of the volcanic source rocks, typical of continental arc. Hence, greatest caution is needed when applying provenance techniques to correlate sedimentary layers and detailed studies should be carried in order to check the validity of the results.

## Conclusion

Petrography and geochemistry of the sediments of southwest Karmøy revealed detrital material deriving mainly from the adjacent gabbroic rocks belonging to the Karmøy Axis Sequence of the Karmøy Ophiolite Complex. Trace element geochemistry and petrographic features exclude a reworking of the sediments and indicate a possibly short transport. The sediments show a strong quartz-poor mafic precursor with no visible felsic input and provenance studies indicate a paleotectonic environment of an oceanic island arc which does not come in accordance with the proposed paleotectonic environment of passive margin.

In turn, the petrography and geochemistry of the moderately sorted sub-angular sediment grains of Randaberg reveals a source rock composition similar to unrecycled UCC, implying a paleotectonic environment of active continental margin and not of passive margin either.

However, the sands from Santorini mirror both the composition and the tectonic environment of the volcanic source rocks with geochemical features typical of active subduction zones. Texture and composition show local variations which reflect differences in magma composition.

The study demonstrates that although provenance studies can reveal important information about the source rocks, greatest caution is needed when their validity is applied as indicators of the paleotectonic environment. The geochemical results can reflect local variations in geology that would make correlation between different layers very difficult. Further detailed studies are needed and in order to successfully correlate sedimentary layers extended sampling is suggested.

## Acknowledgements

It gives me great pleasure to acknowledge Dr. Udo Zimmermann for his guidance, contribution, inspiration and sharing of his knowledge, not only during this study, but throughout the whole two years of the Master's degree education.

I also would like to thank Angeliki Kreona and Nieve El Souki for their assistance with sampling in Norway, as well as Eva Kontou and Christina Vasilaki for their assistance with sampling in Hellas.

Finally, this thesis would not have been possible without the patience, spousal encouragement and technical support at every step of the process, given unconditionally by Atle J. Sørhus to whom I am deeply grateful.

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## Appendix 1 – Geochemical data

Major and trace element abundances and ratios for rocks and sediments of Karmøy, Randaberg and Santorini.

Oxide concentrations, LOI, TOT/C and TOT/S are given in wt%.
Single trace element concentrations are given in ppm.

| Sample | Outcrop | Rock type | CIA | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MgO | CaO | $Na_2O$ | $K_2O$ | $TiO_2$ | $P_2O_5$ | MnO | $Cr_2O_3$ | LOI | Sum | TOT/C | TOT/S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AR | A3 | Gabbroic | 40,49 | 52,49 | 14,76 | 10,47 | 6,69 | 9,02 | 3,37 | 0,04 | 0,29 | 0,02 | 0,16 | 0,032 | 2,50 | 99,83 | 0,07 | 0,08 |
| A11 | A1 | Sand | 41,39 | 54,02 | 15,81 | 6,10 | 5,42 | 11,25 | 1,99 | 0,62 | 0,34 | 0,07 | 0,10 | 0,028 | 4,10 | 99,85 | 0,53 | 0,02 |
| A1P | A1 | Sand | 45,77 | 51,56 | 16,19 | 8,68 | 7,03 | 9,39 | 1,58 | 0,72 | 0,56 | 0,08 | 0,28 | 0,040 | 3,70 | 99,78 | 0,31 | <0,02 |
| A21 | A2 | Sand | 40,23 | 48,59 | 19,29 | 6,54 | 5,81 | 14,33 | 1,66 | 0,35 | 0,29 | 0,02 | 0,11 | 0,035 | 2,80 | 99,83 | 0,13 | <0,02 |
| A22 | A2 | Sand | 44,68 | 46,51 | 18,02 | 8,91 | 7,58 | 11,30 | 1,89 | 0,41 | 0,65 | 0,02 | 0,13 | 0,030 | 4,30 | 99,79 | 0,50 | <0,02 |
| A23 | A2 | Sand | 43,84 | 46,91 | 18,02 | 8,36 | 7,34 | 11,15 | 1,93 | 0,63 | 0,57 | 0,03 | 0,12 | 0,031 | 4,70 | 99,80 | 0,28 | <0,02 |
| A31 | A3 | Sand | 40,34 | 48,66 | 19,80 | 5,91 | 5,92 | 13,81 | 2,49 | 0,22 | 0,31 | 0,01 | 0,10 | 0,042 | 2,60 | 99,85 | 0,04 | <0,02 |
| A32 | A3 | Sand | 39,98 | 50,06 | 18,85 | 5,75 | 6,09 | 13,30 | 2,57 | 0,26 | 0,33 | 0,02 | 0,10 | 0,037 | 2,50 | 99,88 | 0,10 | <0,02 |
| A33 | A3 | Sand | 40,82 | 48,24 | 20,23 | 5,72 | 5,83 | 14,05 | 2,32 | 0,20 | 0,30 | <0,01 | 0,10 | 0,035 | 2,80 | 99,85 | 0,07 | <0,02 |
| A34 | A3 | Sand | 40,08 | 47,61 | 19,36 | 6,26 | 6,76 | 14,09 | 2,10 | 0,18 | 0,34 | 0,02 | 0,11 | 0,055 | 2,90 | 99,86 | 0,08 | <0,02 |
| A41 | A4 | Sand | 25,04 | 34,21 | 10,60 | 8,37 | 4,78 | 22,71 | 2,34 | 0,23 | 0,75 | 0,04 | 0,13 | 0,015 | 15,60 | 99,77 | 3,90 | 0,09 |
| A42 | A4 | Sand | 33,73 | 40,78 | 12,19 | 9,32 | 5,34 | 16,48 | 2,53 | 0,34 | 0,80 | 0,08 | 0,17 | 0,019 | 11,70 | 99,78 | 2,98 | 0,07 |
| A51 | A5 | Sand | 46,91 | 50,61 | 13,84 | 12,07 | 6,08 | 7,62 | 2,94 | 0,30 | 1,11 | 0,08 | 0,17 | 0,026 | 5,00 | 99,81 | 0,91 | 0,03 |
| A52 | A5 | Sand | 44,50 | 55,39 | 14,83 | 9,15 | 4,55 | 7,55 | 3,20 | 0,64 | 1,14 | 0,06 | 0,16 | 0,015 | 3,10 | 99,83 | 0,30 | <0,02 |
| A53 | A5 | Sand | 47,52 | 52,82 | 15,29 | 10,54 | 5,80 | 6,92 | 2,99 | 0,37 | 1,15 | 0,06 | 0,16 | 0,020 | 3,70 | 99,83 | 0,25 | 0,03 |
| A54 | A5 | Sand | 43,82 | 57,08 | 14,64 | 8,38 | 4,40 | 7,26 | 3,38 | 0,86 | 0,85 | 0,05 | 0,17 | 0,015 | 2,80 | 99,86 | 0,23 | <0,02 |
| RM1 | RM | Sand | 50,10 | 73,09 | 12,41 | 1,99 | 0,63 | 2,44 | 3,61 | 2,88 | 0,37 | 0,08 | 0,11 | 0,002 | 2,30 | 99,89 | 0,27 | <0,02 |
| RM2 | RM | Sand | 50,59 | 75,95 | 11,58 | 1,45 | 0,54 | 1,90 | 3,37 | 2,87 | 0,23 | 0,10 | 0,05 | <0,002 | 1,90 | 99,91 | 0,16 | 0,02 |
| RM3 | RM | Sand | 49,53 | 75,72 | 11,12 | 1,15 | 0,45 | 2,34 | 3,23 | 2,98 | 0,20 | 0,06 | 0,04 | <0,002 | 2,60 | 99,90 | 0,38 | 0,02 |
| RM4 | RM | Sand | 49,48 | 75,69 | 11,29 | 1,50 | 0,52 | 2,07 | 3,31 | 2,94 | 0,31 | 0,07 | 0,06 | <0,002 | 2,20 | 99,91 | 0,20 | 0,03 |
| RM5 | RM | Sand | 49,68 | 75,94 | 11,63 | 1,37 | 0,51 | 1,85 | 3,52 | 3,00 | 0,23 | 0,07 | 0,04 | 0,002 | 1,70 | 99,90 | 0,13 | 0,02 |
| RM6 | RM | Sand | 50,87 | 75,23 | 12,23 | 1,54 | 0,51 | 1,85 | 3,47 | 3,05 | 0,26 | 0,09 | 0,07 | <0,002 | 1,60 | 99,90 | 0,10 | <0,02 |
| RS1 | RS | Sand | 50,51 | 76,31 | 11,94 | 1,39 | 0,49 | 1,61 | 3,60 | 2,96 | 0,20 | 0,06 | 0,05 | <0,002 | 1,30 | 99,92 | 0,06 | 0,03 |
| RS2 | RS | Sand | 51,98 | 74,89 | 13,00 | 1,59 | 0,52 | 1,63 | 3,79 | 3,06 | 0,21 | 0,05 | 0,06 | <0,002 | 1,10 | 99,90 | 0,11 | 0,02 |
| RS3 | RS | Sand | 50,55 | 76,67 | 11,82 | 1,35 | 0,44 | 1,65 | 3,61 | 2,78 | 0,19 | 0,06 | 0,06 | <0,002 | 1,30 | 99,92 | 0,07 | <0,02 |
| RS4 | RS | Sand | 52,34 | 75,06 | 12,91 | 1,62 | 0,46 | 1,47 | 3,76 | 3,14 | 0,22 | 0,05 | 0,09 | <0,002 | 1,10 | 99,89 | 0,11 | <0,02 |
| RS5 | RS | Sand | 49,53 | 75,05 | 11,99 | 2,08 | 0,66 | 2,12 | 3,64 | 2,54 | 0,37 | 0,07 | 0,12 | 0,002 | 1,30 | 99,91 | 0,06 | <0,02 |
| RS6 | RS | Sand | 50,42 | 76,14 | 11,82 | 1,62 | 0,49 | 1,75 | 3,52 | 2,84 | 0,25 | 0,06 | 0,09 | <0,002 | 1,30 | 99,91 | 0,08 | <0,02 |
| PB1 | RS | Sand | 52,20 | 77,37 | 11,99 | 0,90 | 0,30 | 1,36 | 3,29 | 3,28 | 0,11 | <0,01 | 0,02 | <0,002 | 1,30 | 99,91 | 0,13 | <0,02 |
| PB2 | RS | Sand | 51,45 | 76,31 | 12,33 | 1,69 | 0,45 | 1,79 | 3,42 | 2,86 | 0,29 | 0,04 | 0,11 | <0,002 | 0,60 | 99,89 | 0,07 | <0,02 |
| PB3 | RS | Sand | 51,62 | 77,19 | 12,03 | 1,04 | 0,32 | 1,42 | 3,42 | 3,23 | 0,14 | 0,02 | 0,03 | <0,002 | 1,10 | 99,90 | 0,11 | <0,02 |

| Sample | Outcrop | Rock type | CIA | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MgO | CaO | $Na_2O$ | $K_2O$ | $TiO_2$ | $P_2O_5$ | MnO | $Cr_2O_3$ | LOI | Sum | TOT/C | TOT/S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RKAB | KA | Sand | 0,11 | 0,39 | 0,06 | <0,04 | 0,57 | 55,07 | 0,01 | <0,01 | <0,01 | 0,02 | <0,01 | <0,002 | 43,80 | 99,95 | 13,04 | 0,05 |
| RPEB | PE | Sand | 0,26 | 0,51 | 0,15 | 0,06 | 0,15 | 55,77 | 0,02 | 0,03 | <0,01 | 0,25 | <0,01 | <0,002 | 43,00 | 99,98 | 12,67 | <0,02 |
| KA1 | KA | Sand | 45,00 | 59,42 | 15,61 | 5,87 | 2,07 | 6,29 | 4,26 | 2,15 | 0,82 | 0,17 | 0,11 | 0,002 | 3,10 | 99,84 | 0,37 | <0,02 |
| KA2 | KA | Sand | 46,33 | 60,67 | 15,84 | 5,97 | 2,15 | 5,56 | 4,26 | 2,15 | 0,85 | 0,18 | 0,12 | 0,004 | 2,10 | 99,84 | 0,19 | 0,08 |
| KA3 | KA | Sand | 45,36 | 59,16 | 15,72 | 6,24 | 2,36 | 6,65 | 3,91 | 2,10 | 0,86 | 0,18 | 0,12 | 0,004 | 2,50 | 99,82 | 0,41 | <0,02 |
| KA4 | KA | Sand | 46,32 | 59,67 | 16,10 | 6,22 | 2,24 | 6,18 | 4,00 | 2,14 | 0,86 | 0,18 | 0,12 | 0,002 | 2,10 | 99,84 | 0,30 | <0,02 |
| PE1 | PE | Sand | 44,00 | 55,70 | 16,76 | 6,94 | 4,14 | 7,84 | 4,15 | 1,14 | 0,69 | 0,15 | 0,18 | 0,008 | 2,10 | 99,84 | 0,18 | 0,08 |
| PE2 | PE | Sand | 42,79 | 55,20 | 15,47 | 8,07 | 4,86 | 7,83 | 3,82 | 1,15 | 0,85 | 0,16 | 0,21 | 0,009 | 2,20 | 99,81 | 0,20 | 0,08 |
| PE3 | PE | Sand | 46,23 | 57,39 | 18,90 | 4,72 | 2,23 | 7,53 | 4,74 | 1,29 | 0,57 | 0,13 | 0,10 | 0,005 | 2,30 | 99,86 | 0,17 | 0,09 |
| PE4 | PE | Sand | 41,65 | 53,65 | 13,75 | 10,64 | 6,55 | 7,57 | 3,33 | 1,00 | 0,95 | 0,21 | 0,30 | 0,008 | 1,80 | 99,79 | 0,16 | 0,07 |
| RE1 | RE | Sand | 41,22 | 55,81 | 15,20 | 7,00 | 6,16 | 8,41 | 3,33 | 1,30 | 0,72 | 0,12 | 0,13 | 0,048 | 1,60 | 99,79 | 0,06 | 0,10 |
| RE2 | RE | Sand | 40,37 | 54,76 | 15,13 | 6,85 | 6,79 | 8,92 | 3,35 | 1,14 | 0,65 | 0,11 | 0,14 | 0,058 | 1,90 | 99,80 | 0,10 | 0,05 |
| RE3 | RE | Sand | 35,25 | 53,19 | 12,35 | 8,39 | 10,21 | 9,87 | 2,56 | 0,90 | 0,65 | 0,10 | 0,17 | 0,087 | 1,30 | 99,75 | 0,06 | <0,02 |
| RE4 | RE | Sand | 37,72 | 54,01 | 14,01 | 7,51 | 8,23 | 9,58 | 3,02 | 1,07 | 0,68 | 0,10 | 0,15 | 0,072 | 1,30 | 99,77 | 0,05 | <0,02 |
| BL1 | BL | Sand | 46,44 | 58,78 | 16,84 | 5,08 | 1,78 | 6,18 | 4,51 | 1,81 | 0,72 | 0,15 | 0,10 | 0,002 | 3,90 | 99,87 | 0,24 | 0,03 |
| BL2 | BL | Sand | 44,29 | 55,69 | 15,18 | 8,38 | 3,36 | 7,03 | 3,79 | 1,54 | 1,06 | 0,20 | 0,18 | 0,004 | 3,40 | 99,83 | 0,32 | <0,02 |
| BL3 | BL | Sand | 45,36 | 58,72 | 15,91 | 5,98 | 2,12 | 6,51 | 4,15 | 2,03 | 0,85 | 0,17 | 0,11 | 0,002 | 3,30 | 99,83 | 0,37 | <0,02 |
| VL1 | VL | Sand | 42,43 | 54,71 | 14,80 | 9,39 | 5,54 | 7,62 | 3,65 | 1,02 | 0,95 | 0,18 | 0,24 | 0,012 | 1,70 | 99,81 | 0,13 | 0,09 |
| VL2 | VL | Sand | 47,26 | 58,46 | 18,21 | 5,08 | 2,04 | 6,61 | 4,69 | 1,53 | 0,66 | 0,14 | 0,10 | 0,004 | 2,30 | 99,86 | 0,21 | 0,09 |
| VL3 | VL | Sand | 46,04 | 60,17 | 16,13 | 5,64 | 2,02 | 5,87 | 4,30 | 2,08 | 0,82 | 0,18 | 0,11 | 0,005 | 2,50 | 99,85 | 0,19 | 0,08 |
| VL4 | VL | Sand | 43,31 | 55,84 | 14,88 | 8,75 | 4,83 | 7,03 | 3,85 | 1,28 | 0,94 | 0,21 | 0,23 | 0,009 | 2,00 | 99,82 | 0,15 | 0,09 |
| MO1 | MO | Sand | 45,89 | 59,82 | 16,68 | 4,55 | 1,61 | 6,10 | 4,80 | 1,87 | 0,65 | 0,14 | 0,09 | 0,006 | 3,50 | 99,86 | 0,29 | 0,08 |
| MO2 | MO | Sand | 46,48 | 60,23 | 16,80 | 4,33 | 1,45 | 5,87 | 4,80 | 1,90 | 0,65 | 0,13 | 0,08 | 0,002 | 3,60 | 99,87 | 0,28 | 0,10 |
| MO3 | MO | Sand | 45,75 | 56,40 | 17,63 | 6,14 | 2,61 | 7,31 | 4,46 | 1,37 | 0,79 | 0,14 | 0,13 | 0,006 | 2,90 | 99,85 | 0,25 | 0,08 |
| MO4 | MO | Sand | 45,69 | 59,36 | 16,95 | 4,55 | 1,66 | 6,49 | 4,77 | 1,80 | 0,67 | 0,14 | 0,09 | 0,003 | 3,40 | 99,86 | 0,32 | 0,10 |
| KO1 | KO | Sand | 40,85 | 53,81 | 13,31 | 10,33 | 6,29 | 7,85 | 3,23 | 1,12 | 0,91 | 0,23 | 0,29 | 0,008 | 2,40 | 99,75 | 0,28 | 0,07 |
| KO2 | KO | Sand | 43,50 | 56,27 | 15,46 | 7,94 | 3,90 | 7,44 | 3,85 | 1,49 | 0,90 | 0,19 | 0,18 | 0,011 | 2,20 | 99,82 | 0,27 | 0,04 |
| KO3 | KO | Sand | 44,76 | 57,55 | 16,11 | 6,73 | 2,99 | 6,94 | 4,14 | 1,63 | 0,79 | 0,17 | 0,15 | 0,004 | 2,70 | 99,84 | 0,26 | 0,03 |
| KO4 | KO | Sand | 45,43 | 57,84 | 16,86 | 6,18 | 2,76 | 7,01 | 4,29 | 1,56 | 0,74 | 0,17 | 0,13 | 0,004 | 2,30 | 99,85 | 0,24 | <0,02 |
| RRERP | RE | Volcanic | 42,01 | 53,41 | 15,76 | 8,49 | 7,78 | 9,03 | 2,82 | 0,94 | 0,79 | 0,12 | 0,15 | 0,051 | 0,40 | 99,77 | <0,02 | 0,06 |
| RREBU | RE | Volcanic | 41,08 | 52,99 | 15,20 | 7,87 | 7,71 | 8,85 | 2,96 | 1,05 | 0,75 | 0,11 | 0,14 | 0,047 | 2,10 | 99,76 | <0,02 | 0,10 |
| RVLT | VL | Volcanic | 48,72 | 62,35 | 15,10 | 5,19 | 1,69 | 4,10 | 4,02 | 2,24 | 0,65 | 0,12 | 0,11 | <0,002 | 4,20 | 99,82 | 0,09 | 0,03 |
| RRMC | RM | Volcanic | 47,84 | 58,95 | 17,03 | 7,19 | 2,11 | 5,55 | 4,23 | 2,08 | 0,99 | 0,19 | 0,14 | <0,002 | 1,30 | 99,81 | 0,08 | 0,03 |
| RBMP | BM | Volcanic | 48,08 | 61,04 | 15,79 | 8,27 | 1,49 | 4,27 | 4,43 | 2,52 | 1,14 | 0,29 | 0,16 | <0,002 | 0,40 | 99,83 | <0,02 | <0,02 |
| RKOTB | KO | Volcanic | 48,14 | 64,67 | 14,34 | 4,09 | 1,34 | 2,99 | 4,59 | 2,57 | 0,48 | 0,09 | 0,10 | <0,002 | 4,60 | 99,86 | 0,03 | 0,03 |
| RKOTR | KO | Volcanic | 38,67 | 47,82 | 16,33 | 7,74 | 5,14 | 10,63 | 3,99 | 0,68 | 0,71 | 0,10 | 0,13 | 0,009 | 6,50 | 99,82 | 0,14 | 0,48 |

| Sample | Outcrop | Rock type | Ni | Sc | Ba | Be | Co | Cs | Ga | Hf | Nb | Rb | Sn | Sr | Ta | Th | U | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AR | A3 | Gabbroic | 33,00 | 43,00 | 4,00 | <1 | 21,50 | <0,10 | 11,60 | 0,30 | 0,80 | 0,40 | <1 | 70,40 | <0,10 | 0,30 | <0,10 | 261,00 |
| A11 | A1 | Sand | 61,00 | 24,00 | 119,00 | <1 | 21,90 | 0,50 | 12,50 | 1,20 | 2,50 | 21,30 | <1 | 194,50 | 0,20 | 1,00 | 0,50 | 159,00 |
| A1P | A1 | Sand | 123,00 | 32,00 | 156,00 | <1 | 67,60 | 0,80 | 13,70 | 1,20 | 2,30 | 26,00 | 1,00 | 161,90 | 0,20 | 1,40 | 0,60 | 229,00 |
| A21 | A2 | Sand | 65,00 | 29,00 | 66,00 | <1 | 21,70 | 0,40 | 13,60 | 0,50 | 1,80 | 12,30 | 3,00 | 186,10 | <0,10 | 1,00 | 0,30 | 151,00 |
| A22 | A2 | Sand | 99,00 | 36,00 | 53,00 | <1 | 41,30 | 3,40 | 15,80 | 0,70 | 1,90 | 28,00 | 5,00 | 154,60 | 0,20 | 0,50 | 0,30 | 279,00 |
| A23 | A2 | Sand | 111,00 | 38,00 | 51,00 | <1 | 44,00 | 7,10 | 16,30 | 0,40 | 0,80 | 55,40 | <1 | 175,70 | 0,10 | 0,60 | 0,30 | 272,00 |
| A31 | A3 | Sand | 77,00 | 30,00 | 46,00 | <1 | 21,50 | 0,30 | 14,70 | 0,40 | 0,50 | 6,20 | <1 | 187,80 | <0,10 | 0,20 | 0,10 | 137,00 |
| A32 | A3 | Sand | 93,00 | 30,00 | 47,00 | <1 | 24,60 | 0,20 | 14,40 | 0,50 | 2,70 | 8,10 | <1 | 206,60 | 0,30 | 0,60 | 0,20 | 136,00 |
| A33 | A3 | Sand | 72,00 | 29,00 | 44,00 | <1 | 23,00 | 0,10 | 15,80 | 0,50 | 0,80 | 5,90 | <1 | 203,30 | <0,10 | 0,40 | 0,10 | 144,00 |
| A34 | A3 | Sand | 83,00 | 31,00 | 37,00 | <1 | 26,10 | <0,10 | 15,70 | 0,50 | 0,60 | 5,80 | <1 | 204,70 | <0,10 | 0,40 | 0,20 | 152,00 |
| A41 | A4 | Sand | 41,00 | 26,00 | 37,00 | <1 | 26,00 | 0,90 | 13,10 | 0,60 | 1,50 | 10,70 | 4,00 | 782,00 | <0,10 | 0,30 | 0,20 | 292,00 |
| A42 | A4 | Sand | 58,00 | 29,00 | 61,00 | <1 | 47,50 | 0,90 | 12,90 | 1,00 | 1,50 | 15,10 | 2,00 | 432,00 | 0,10 | 0,30 | 0,20 | 300,00 |
| A51 | A5 | Sand | 72,00 | 38,00 | 51,00 | <1 | 36,00 | 0,40 | 16,30 | 1,20 | 1,20 | 9,90 | 1,00 | 145,20 | 0,10 | 0,90 | 0,40 | 410,00 |
| A52 | A5 | Sand | 40,00 | 30,00 | 129,00 | 1,00 | 26,10 | 0,60 | 16,20 | 1,30 | 3,20 | 21,80 | 3,00 | 188,30 | 0,20 | 1,70 | 0,60 | 279,00 |
| A53 | A5 | Sand | 56,00 | 36,00 | 64,00 | <1 | 31,70 | 0,70 | 16,50 | 1,00 | 1,60 | 12,90 | <1 | 154,10 | 0,20 | 0,80 | 0,40 | 308,00 |
| A54 | A5 | Sand | 46,00 | 28,00 | 156,00 | <1 | 26,50 | 0,40 | 15,50 | 1,30 | 2,40 | 24,70 | <1 | 170,30 | 0,30 | 0,90 | 0,50 | 252,00 |
| RM1 | RM | Sand | 68,00 | 6,00 | 543,00 | 2,00 | 2,60 | 0,90 | 15,40 | 3,30 | 9,40 | 99,90 | <1 | 313,00 | 0,60 | 8,00 | 1,60 | 38,00 |
| RM2 | RM | Sand | <20 | 5,00 | 562,00 | 5,00 | 2,80 | 0,80 | 14,20 | 1,90 | 5,10 | 104,00 | <1 | 286,60 | 0,40 | 3,00 | 1,00 | 32,00 |
| RM3 | RM | Sand | <20 | 4,00 | 562,00 | 1,00 | 1,90 | 0,90 | 13,50 | 2,00 | 4,80 | 106,60 | <1 | 299,00 | 0,40 | 2,30 | 1,00 | 26,00 |
| RM4 | RM | Sand | <20 | 5,00 | 577,00 | <1 | 2,20 | 0,70 | 12,70 | 3,50 | 5,40 | 104,40 | 1,00 | 300,50 | 0,40 | 2,70 | 1,00 | 21,00 |
| RM5 | RM | Sand | <20 | 5,00 | 616,00 | 3,00 | 2,80 | 0,80 | 14,40 | 2,70 | 5,20 | 103,30 | <1 | 286,10 | 0,50 | 4,80 | 1,10 | 31,00 |
| RM6 | RM | Sand | <20 | 5,00 | 612,00 | 1,00 | 2,10 | 0,90 | 13,50 | 3,70 | 6,00 | 104,20 | <1 | 288,00 | 0,50 | 5,40 | 1,20 | 27,00 |
| RS1 | RS | Sand | <20 | 4,00 | 577,00 | <1 | 2,10 | 0,70 | 15,40 | 2,10 | 4,20 | 105,90 | <1 | 287,80 | 0,30 | 4,60 | 0,90 | 25,00 |
| RS2 | RS | Sand | <20 | 4,00 | 618,00 | 2,00 | 2,70 | 1,20 | 15,60 | 1,80 | 6,60 | 109,60 | <1 | 288,00 | 0,50 | 3,30 | 1,20 | 30,00 |
| RS3 | RS | Sand | <20 | 4,00 | 500,00 | 2,00 | 2,00 | 0,70 | 14,70 | 1,90 | 4,80 | 102,90 | <1 | 273,30 | 0,40 | 2,40 | 1,30 | 24,00 |
| RS4 | RS | Sand | <20 | 4,00 | 661,00 | 3,00 | 2,10 | 1,30 | 15,90 | 2,00 | 4,60 | 114,50 | <1 | 277,60 | 0,40 | 6,00 | 1,10 | 30,00 |
| RS5 | RS | Sand | <20 | 7,00 | 478,00 | <1 | 2,80 | 0,80 | 15,40 | 4,20 | 8,60 | 91,20 | 1,00 | 299,50 | 0,80 | 4,00 | 1,10 | 21,00 |
| RS6 | RS | Sand | <20 | 5,00 | 516,00 | 1,00 | 2,50 | 0,80 | 15,40 | 2,50 | 5,40 | 100,30 | <1 | 266,10 | 0,40 | 7,30 | 1,40 | 25,00 |
| PB1 | RS | Sand | <20 | 2,00 | 674,00 | 2,00 | 1,50 | 1,00 | 15,00 | 1,50 | 3,10 | 120,90 | <1 | 263,50 | 0,20 | 2,40 | 0,80 | 15,00 |
| PB2 | RS | Sand | <20 | 5,00 | 550,00 | 2,00 | 2,30 | 0,80 | 15,30 | 3,60 | 6,70 | 106,90 | <1 | 283,20 | 0,50 | 4,70 | 1,20 | 23,00 |
| PB3 | RS | Sand | <20 | 3,00 | 637,00 | 2,00 | 1,60 | 0,90 | 14,30 | 1,80 | 3,60 | 120,70 | <1 | 270,10 | 0,30 | 2,60 | 0,90 | 19,00 |

| Sample | Outcrop | Rock type | W | Zr | Y | La | Ce | Pr | Nd | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AR | A3 | Gabbroic | <0,50 | 11,00 | 6,00 | 1,00 | 2,50 | 0,34 | 1,40 | 0,45 | 0,21 | 0,69 | 0,15 | 1,02 | 0,22 | 0,69 | 0,11 | 0,73 |
| A11 | A1 | Sand | <0,50 | 45,30 | 8,70 | 4,20 | 8,80 | 1,13 | 4,50 | 1,19 | 0,42 | 1,33 | 0,24 | 1,52 | 0,32 | 0,92 | 0,15 | 0,95 |
| A1P | A1 | Sand | <0,50 | 47,20 | 12,00 | 6,10 | 13,00 | 1,60 | 6,70 | 1,59 | 0,51 | 1,90 | 0,33 | 2,03 | 0,44 | 1,25 | 0,20 | 1,25 |
| A21 | A2 | Sand | <0,50 | 18,30 | 7,90 | 3,10 | 7,20 | 0,90 | 3,70 | 0,97 | 0,39 | 1,20 | 0,22 | 1,37 | 0,30 | 0,85 | 0,13 | 0,84 |
| A22 | A2 | Sand | <0,50 | 21,20 | 10,30 | 3,30 | 6,80 | 0,87 | 3,60 | 1,07 | 0,47 | 1,53 | 0,29 | 1,89 | 0,39 | 1,06 | 0,17 | 0,85 |
| A23 | A2 | Sand | <0,50 | 17,50 | 9,50 | 2,90 | 7,00 | 0,91 | 4,00 | 0,93 | 0,43 | 1,29 | 0,26 | 1,71 | 0,40 | 1,05 | 0,16 | 0,97 |
| A31 | A3 | Sand | <0,50 | 12,10 | 8,00 | 1,40 | 3,40 | 0,49 | 2,40 | 0,83 | 0,45 | 1,09 | 0,22 | 1,38 | 0,30 | 0,86 | 0,15 | 0,92 |
| A32 | A3 | Sand | <0,50 | 20,20 | 9,70 | 3,40 | 7,00 | 0,85 | 2,30 | 1,25 | 0,49 | 1,45 | 0,25 | 1,96 | 0,36 | 1,09 | 0,13 | 0,87 |
| A33 | A3 | Sand | <0,50 | 11,70 | 9,10 | 2,30 | 5,00 | 0,61 | 3,00 | 0,84 | 0,49 | 1,25 | 0,23 | 1,41 | 0,31 | 0,93 | 0,14 | 0,80 |
| A34 | A3 | Sand | <0,50 | 14,30 | 8,90 | 2,10 | 4,10 | 0,58 | 2,90 | 0,88 | 0,46 | 1,19 | 0,23 | 1,71 | 0,34 | 0,89 | 0,16 | 0,92 |
| A41 | A4 | Sand | <0,50 | 25,20 | 13,20 | 1,80 | 5,10 | 0,71 | 3,30 | 1,11 | 0,53 | 1,68 | 0,33 | 2,28 | 0,46 | 1,43 | 0,22 | 1,23 |
| A42 | A4 | Sand | <0,50 | 35,40 | 13,80 | 1,90 | 5,20 | 0,76 | 3,20 | 1,23 | 0,57 | 1,86 | 0,38 | 2,14 | 0,56 | 1,66 | 0,25 | 1,49 |
| A51 | A5 | Sand | <0,50 | 33,10 | 17,70 | 3,80 | 8,70 | 1,27 | 6,00 | 1,73 | 0,68 | 2,51 | 0,48 | 3,10 | 0,67 | 1,85 | 0,30 | 1,75 |
| A52 | A5 | Sand | <0,50 | 39,60 | 19,20 | 6,80 | 15,60 | 2,03 | 9,00 | 2,28 | 0,80 | 2,67 | 0,52 | 3,13 | 0,71 | 2,16 | 0,34 | 1,93 |
| A53 | A5 | Sand | <0,50 | 33,30 | 19,60 | 4,30 | 9,80 | 1,26 | 7,10 | 1,79 | 0,73 | 2,64 | 0,48 | 3,15 | 0,70 | 2,04 | 0,33 | 2,04 |
| A54 | A5 | Sand | <0,50 | 42,80 | 17,60 | 5,40 | 12,40 | 1,64 | 8,00 | 1,87 | 0,79 | 2,41 | 0,45 | 3,33 | 0,66 | 1,92 | 0,32 | 1,90 |
| RM1 | RM | Sand | <0,50 | 132,00 | 18,20 | 32,40 | 65,60 | 7,51 | 26,20 | 4,29 | 0,98 | 3,50 | 0,57 | 2,91 | 0,62 | 1,87 | 0,31 | 1,87 |
| RM2 | RM | Sand | <0,50 | 78,60 | 13,40 | 21,50 | 41,20 | 4,67 | 15,90 | 3,14 | 0,88 | 2,66 | 0,42 | 2,34 | 0,41 | 1,25 | 0,21 | 1,05 |
| RM3 | RM | Sand | <0,50 | 73,50 | 10,20 | 18,50 | 34,20 | 3,98 | 14,90 | 2,61 | 0,81 | 2,23 | 0,34 | 1,75 | 0,36 | 1,00 | 0,16 | 0,92 |
| RM4 | RM | Sand | <0,50 | 127,80 | 13,60 | 21,30 | 40,70 | 4,81 | 16,80 | 3,09 | 0,84 | 2,52 | 0,42 | 2,30 | 0,43 | 1,44 | 0,19 | 1,16 |
| RM5 | RM | Sand | <0,50 | 98,70 | 12,70 | 23,30 | 46,00 | 5,16 | 20,00 | 3,22 | 0,94 | 2,68 | 0,41 | 1,92 | 0,43 | 1,10 | 0,21 | 1,30 |
| RM6 | RM | Sand | <0,50 | 134,70 | 13,60 | 26,70 | 51,80 | 5,76 | 22,90 | 3,58 | 0,96 | 2,86 | 0,45 | 2,66 | 0,47 | 1,44 | 0,20 | 1,28 |
| RS1 | RS | Sand | <0,50 | 68,60 | 10,30 | 23,00 | 41,60 | 4,70 | 15,90 | 2,74 | 0,81 | 2,23 | 0,33 | 1,84 | 0,36 | 1,01 | 0,15 | 1,05 |
| RS2 | RS | Sand | <0,50 | 65,40 | 10,60 | 20,60 | 39,60 | 4,50 | 15,80 | 2,95 | 0,91 | 2,35 | 0,35 | 2,16 | 0,41 | 1,15 | 0,17 | 0,93 |
| RS3 | RS | Sand | <0,50 | 74,70 | 10,70 | 17,80 | 32,60 | 3,71 | 13,20 | 2,27 | 0,89 | 2,12 | 0,35 | 1,82 | 0,40 | 1,12 | 0,17 | 1,04 |
| RS4 | RS | Sand | <0,50 | 71,30 | 12,00 | 23,30 | 43,90 | 4,68 | 17,50 | 2,85 | 0,83 | 2,50 | 0,38 | 2,39 | 0,46 | 1,28 | 0,20 | 1,24 |
| RS5 | RS | Sand | <0,50 | 132,40 | 19,80 | 28,60 | 58,70 | 6,27 | 21,00 | 4,17 | 1,09 | 3,33 | 0,55 | 2,71 | 0,66 | 2,04 | 0,28 | 2,01 |
| RS6 | RS | Sand | <0,50 | 90,50 | 15,30 | 22,90 | 44,30 | 5,01 | 18,10 | 3,10 | 0,88 | 3,02 | 0,44 | 2,79 | 0,58 | 1,57 | 0,27 | 1,52 |
| PB1 | RS | Sand | <0,50 | 53,50 | 6,50 | 14,80 | 26,80 | 3,03 | 11,10 | 1,80 | 0,69 | 1,35 | 0,22 | 1,18 | 0,21 | 0,65 | 0,10 | 0,60 |
| PB2 | RS | Sand | <0,50 | 135,00 | 15,90 | 22,60 | 45,90 | 5,30 | 19,60 | 3,36 | 0,91 | 2,79 | 0,46 | 2,66 | 0,56 | 1,69 | 0,27 | 1,69 |
| PB3 | RS | Sand | <0,50 | 61,50 | 8,60 | 15,80 | 30,30 | 3,37 | 12,60 | 2,11 | 0,76 | 1,70 | 0,27 | 1,46 | 0,28 | 0,86 | 0,14 | 0,82 |

| Sample | Outcrop | Rock type | Lu | Mo | Cu | Pb | Zn | Ni | As | Cd | Sb | Bi | Ag | Au | Hg | Tl | Se |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AR | A3 | Gabbroic | 0,12 | 0,30 | 40,60 | 2,20 | 26,00 | 10,30 | <0,50 | <0,10 | <0,10 | <0,10 | <0,10 | 2,00 | <0,01 | <0,10 | <0,50 |
| A11 | A1 | Sand | 0,14 | 0,20 | 14,30 | 2,90 | 28,00 | 28,60 | 3,70 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| A1P | A1 | Sand | 0,20 | 0,40 | 22,00 | 18,90 | 102,00 | 76,70 | 11,70 | 0,30 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| A21 | A2 | Sand | 0,13 | 0,70 | 12,60 | 12,40 | 50,00 | 30,70 | 2,50 | <0,10 | 0,20 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| A22 | A2 | Sand | 0,17 | 0,20 | 120,80 | 11,70 | 135,00 | 55,30 | 3,80 | <0,10 | 0,10 | <0,10 | <0,10 | 18,40 | 0,01 | <0,10 | <0,50 |
| A23 | A2 | Sand | 0,15 | 0,20 | 99,70 | 4,80 | 45,00 | 65,70 | 1,80 | <0,10 | <0,10 | <0,10 | <0,10 | 3,70 | 0,02 | <0,10 | <0,50 |
| A31 | A3 | Sand | 0,13 | 0,50 | 15,30 | 2,90 | 22,00 | 30,20 | 1,20 | <0,10 | <0,10 | <0,10 | <0,10 | 9,50 | <0,01 | <0,10 | <0,50 |
| A32 | A3 | Sand | 0,14 | <0,10 | 19,60 | 3,90 | 21,00 | 29,80 | 0,90 | <0,10 | <0,10 | <0,10 | <0,10 | 1,10 | <0,01 | <0,10 | <0,50 |
| A33 | A3 | Sand | 0,15 | <0,10 | 19,40 | 3,60 | 24,00 | 29,60 | 1,40 | <0,10 | <0,10 | <0,10 | <0,10 | 0,70 | <0,01 | <0,10 | <0,50 |
| A34 | A3 | Sand | 0,14 | <0,10 | 21,50 | 2,40 | 24,00 | 36,20 | 1,20 | <0,10 | <0,10 | <0,10 | <0,10 | 1,20 | <0,01 | <0,10 | <0,50 |
| A41 | A4 | Sand | 0,21 | 0,60 | 40,40 | 6,30 | 74,00 | 25,90 | 6,10 | 0,10 | 0,30 | <0,10 | <0,10 | 0,70 | <0,01 | <0,10 | <0,50 |
| A42 | A4 | Sand | 0,24 | 0,50 | 54,50 | 11,10 | 135,00 | 24,80 | 7,60 | 0,30 | 0,20 | 0,10 | <0,10 | 2,30 | 0,03 | <0,10 | <0,50 |
| A51 | A5 | Sand | 0,28 | 0,40 | 32,50 | 53,50 | 98,00 | 40,90 | 6,30 | <0,10 | 0,30 | <0,10 | <0,10 | 1,80 | <0,01 | <0,10 | <0,50 |
| A52 | A5 | Sand | 0,29 | 0,50 | 33,40 | 17,90 | 96,00 | 23,10 | 4,40 | <0,10 | 0,30 | <0,10 | <0,10 | 0,50 | 0,02 | <0,10 | <0,50 |
| A53 | A5 | Sand | 0,29 | 0,20 | 26,70 | 6,00 | 58,00 | 32,00 | 2,70 | <0,10 | 0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| A54 | A5 | Sand | 0,27 | 0,40 | 20,30 | 6,70 | 59,00 | 20,50 | 5,50 | 0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| RM1 | RM | Sand | 0,28 | 0,30 | 2,10 | 2,10 | 14,00 | 2,30 | 1,00 | <0,10 | <0,10 | <0,10 | <0,10 | 2,10 | <0,01 | <0,10 | <0,50 |
| RM2 | RM | Sand | 0,18 | 0,20 | 2,30 | 1,30 | 12,00 | 1,60 | <0,50 | <0,10 | <0,10 | <0,10 | <0,10 | 0,90 | <0,01 | <0,10 | <0,50 |
| RM3 | RM | Sand | 0,15 | 0,20 | 3,50 | 6,40 | 11,00 | 1,70 | 0,60 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| RM4 | RM | Sand | 0,21 | 0,10 | 2,50 | 1,50 | 11,00 | 1,50 | <0,50 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| RM5 | RM | Sand | 0,17 | 0,10 | 1,90 | 1,00 | 10,00 | 1,60 | <0,50 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| RM6 | RM | Sand | 0,19 | 0,20 | 2,50 | 1,50 | 11,00 | 1,80 | 0,50 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| RS1 | RS | Sand | 0,13 | 0,10 | 0,90 | 1,10 | 9,00 | 1,20 | 0,60 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| RS2 | RS | Sand | 0,14 | 0,30 | 1,40 | 2,20 | 13,00 | 2,00 | 1,00 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| RS3 | RS | Sand | 0,16 | 0,10 | 0,60 | 1,20 | 9,00 | 1,20 | <0,50 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| RS4 | RS | Sand | 0,19 | 0,30 | 1,60 | 2,30 | 16,00 | 2,20 | 0,90 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| RS5 | RS | Sand | 0,32 | 0,20 | 1,10 | 2,10 | 11,00 | 1,60 | 0,70 | <0,10 | <0,10 | <0,10 | <0,10 | 0,70 | <0,01 | <0,10 | <0,50 |
| RS6 | RS | Sand | 0,24 | 0,10 | 0,90 | 1,60 | 10,00 | 1,30 | <0,50 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| PB1 | RS | Sand | 0,09 | 0,20 | 1,60 | 3,50 | 12,00 | 1,90 | <0,50 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | 0,10 | <0,50 |
| PB2 | RS | Sand | 0,26 | <0,10 | 1,20 | 3,30 | 12,00 | 1,50 | <0,50 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | 0,10 | <0,50 |
| PB3 | RS | Sand | 0,12 | 0,20 | 1,60 | 3,20 | 12,00 | 1,40 | <0,50 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | 0,10 | <0,50 |

| Sample | Outcrop | Rock type | Ni | Sc | Ba | Be | Co | Cs | Ga | Hf | Nb | Rb | Sn | Sr | Ta | Th | U | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RKAB | KA | Sand | <20 | <1 | 13,00 | <1 | 0,60 | <0,10 | <0,50 | <0,10 | <0,10 | 0,30 | <1 | 150,40 | <0,10 | <0,20 | <0,10 | <8 |
| RPEB | PE | Sand | <20 | <1 | 12,00 | <1 | 0,40 | 0,30 | <0,50 | <0,10 | <0,10 | 1,30 | <1 | 122,60 | <0,10 | <0,20 | 0,20 | <8 |
| KA1 | KA | Sand | <20 | 16,00 | 412,00 | 4,00 | 10,90 | 1,80 | 15,20 | 5,10 | 8,00 | 68,10 | 2,00 | 204,30 | 0,70 | 13,00 | 3,90 | 110,00 |
| KA2 | KA | Sand | <20 | 17,00 | 401,00 | <1 | 11,90 | 2,00 | 15,50 | 5,20 | 7,90 | 69,00 | 1,00 | 196,40 | 0,80 | 13,30 | 3,70 | 119,00 |
| KA3 | KA | Sand | <20 | 18,00 | 418,00 | 2,00 | 11,90 | 1,70 | 14,60 | 5,00 | 7,80 | 67,20 | 2,00 | 205,20 | 0,70 | 12,10 | 4,00 | 130,00 |
| KA4 | KA | Sand | <20 | 18,00 | 400,00 | <1 | 12,40 | 1,60 | 14,20 | 4,70 | 7,80 | 65,20 | 2,00 | 197,30 | 0,60 | 12,50 | 3,70 | 127,00 |
| PE1 | PE | Sand | <20 | 25,00 | 258,00 | <1 | 15,80 | 1,20 | 15,40 | 2,70 | 4,70 | 35,30 | <1 | 264,30 | 0,30 | 6,30 | 2,00 | 92,00 |
| PE2 | PE | Sand | <20 | 29,00 | 264,00 | <1 | 19,20 | 1,20 | 15,30 | 2,70 | 5,80 | 37,50 | 1,00 | 244,80 | 0,40 | 6,80 | 2,10 | 130,00 |
| PE3 | PE | Sand | <20 | 15,00 | 295,00 | <1 | 9,80 | 1,50 | 16,60 | 2,50 | 5,30 | 40,20 | <1 | 287,40 | 0,30 | 7,00 | 2,20 | 68,00 |
| PE4 | PE | Sand | <20 | 37,00 | 228,00 | <1 | 24,50 | 1,00 | 13,50 | 3,00 | 5,90 | 32,10 | <1 | 202,50 | 0,30 | 5,70 | 1,80 | 149,00 |
| RE1 | RE | Sand | 73,00 | 30,00 | 264,00 | 1,00 | 24,30 | 1,50 | 13,40 | 3,10 | 5,20 | 42,60 | 1,00 | 178,40 | 0,40 | 7,90 | 2,40 | 157,00 |
| RE2 | RE | Sand | 91,00 | 32,00 | 223,00 | <1 | 25,40 | 1,10 | 13,70 | 3,10 | 4,90 | 36,70 | 1,00 | 195,20 | 0,30 | 6,80 | 2,00 | 139,00 |
| RE3 | RE | Sand | 164,00 | 41,00 | 181,00 | <1 | 36,80 | 1,00 | 11,20 | 2,50 | 3,90 | 28,80 | <1 | 151,60 | 0,40 | 5,70 | 1,50 | 181,00 |
| RE4 | RE | Sand | 112,00 | 36,00 | 209,00 | <1 | 28,90 | 1,20 | 11,40 | 2,90 | 4,10 | 35,40 | <1 | 166,70 | 0,40 | 6,40 | 2,10 | 180,00 |
| BL1 | BL | Sand | <20 | 14,00 | 366,00 | <1 | 10,10 | 1,90 | 15,50 | 4,30 | 7,00 | 57,90 | 1,00 | 242,80 | 0,50 | 10,70 | 3,10 | 104,00 |
| BL2 | BL | Sand | <20 | 22,00 | 312,00 | <1 | 17,70 | 1,90 | 13,80 | 3,90 | 7,00 | 49,40 | 1,00 | 209,00 | 0,70 | 9,00 | 2,80 | 165,00 |
| BL3 | BL | Sand | <20 | 17,00 | 396,00 | <1 | 12,40 | 2,30 | 15,10 | 4,30 | 7,20 | 65,20 | 1,00 | 211,40 | 0,70 | 11,60 | 3,50 | 120,00 |
| VL1 | VL | Sand | <20 | 33,00 | 241,00 | 2,00 | 21,20 | 1,00 | 14,90 | 2,60 | 5,50 | 32,80 | <1 | 219,40 | 0,40 | 5,70 | 1,80 | 141,00 |
| VL2 | VL | Sand | <20 | 15,00 | 338,00 | <1 | 9,20 | 1,80 | 16,80 | 3,90 | 6,20 | 50,30 | 1,00 | 269,60 | 0,50 | 9,10 | 2,70 | 84,00 |
| VL3 | VL | Sand | <20 | 17,00 | 408,00 | <1 | 10,90 | 2,10 | 15,80 | 5,00 | 8,40 | 68,20 | 2,00 | 219,60 | 0,60 | 12,20 | 3,40 | 110,00 |
| VL4 | VL | Sand | <20 | 29,00 | 273,00 | 3,00 | 19,70 | 1,30 | 14,90 | 3,60 | 6,90 | 40,90 | <1 | 215,00 | 0,50 | 7,30 | 2,30 | 129,00 |
| MO1 | MO | Sand | <20 | 13,00 | 391,00 | 1,00 | 8,40 | 2,10 | 16,20 | 4,50 | 6,70 | 61,40 | 2,00 | 238,30 | 0,50 | 11,00 | 3,40 | 68,00 |
| MO2 | MO | Sand | <20 | 12,00 | 361,00 | 1,00 | 7,80 | 1,90 | 16,50 | 4,40 | 7,70 | 63,70 | 1,00 | 232,80 | 0,60 | 11,10 | 3,20 | 67,00 |
| MO3 | MO | Sand | <20 | 18,00 | 292,00 | <1 | 11,80 | 1,50 | 17,40 | 2,80 | 5,80 | 44,00 | <1 | 257,10 | 0,40 | 7,70 | 2,50 | 103,00 |
| MO4 | MO | Sand | <20 | 14,00 | 365,00 | 1,00 | 8,60 | 1,70 | 15,80 | 4,30 | 7,50 | 59,40 | 2,00 | 249,90 | 0,50 | 10,60 | 3,20 | 74,00 |
| KO1 | KO | Sand | <20 | 32,00 | 234,00 | <1 | 23,90 | 1,10 | 13,30 | 3,20 | 6,00 | 35,90 | <1 | 204,20 | 0,40 | 7,10 | 2,20 | 142,00 |
| KO2 | KO | Sand | 25,00 | 23,00 | 305,00 | <1 | 17,70 | 1,40 | 15,40 | 4,50 | 6,60 | 47,90 | <1 | 227,90 | 0,50 | 9,60 | 2,60 | 142,00 |
| KO3 | KO | Sand | <20 | 19,00 | 329,00 | <1 | 14,60 | 1,60 | 15,40 | 4,50 | 7,10 | 52,40 | 2,00 | 245,00 | 0,60 | 9,80 | 2,80 | 124,00 |
| KO4 | KO | Sand | <20 | 18,00 | 329,00 | <1 | 12,30 | 1,70 | 15,40 | 4,40 | 6,80 | 49,20 | 1,00 | 260,20 | 0,60 | 9,90 | 2,60 | 112,00 |
| RRERP | RE | Volcanic | 110,00 | 31,00 | 200,00 | <1 | 32,50 | 1,10 | 14,10 | 3,20 | 4,60 | 34,40 | 1,00 | 170,40 | 0,40 | 6,20 | 1,90 | 193,00 |
| RREBU | RE | Volcanic | 104,00 | 30,00 | 186,00 | <1 | 30,20 | 1,10 | 14,80 | 3,00 | 4,10 | 35,90 | 2,00 | 164,50 | 0,40 | 5,80 | 1,80 | 178,00 |
| RVLT | VL | Volcanic | <20 | 14,00 | 408,00 | <1 | 10,20 | 3,10 | 13,70 | 5,30 | 7,80 | 70,30 | 1,00 | 165,70 | 0,40 | 13,70 | 3,90 | 86,00 |
| RRMC | RM | Volcanic | <20 | 15,00 | 394,00 | <1 | 13,70 | 2,10 | 16,70 | 5,00 | 9,10 | 61,50 | 3,00 | 230,70 | 0,70 | 12,40 | 3,40 | 124,00 |
| RBMP | BM | Volcanic | <20 | 16,00 | 412,00 | <1 | 11,90 | 2,30 | 17,10 | 6,70 | 10,50 | 82,20 | 3,00 | 190,80 | 0,90 | 15,40 | 4,50 | 69,00 |
| RKOTB | KO | Volcanic | <20 | 10,00 | 458,00 | <1 | 7,40 | 3,00 | 14,40 | 6,50 | 7,20 | 80,80 | 2,00 | 130,10 | 0,90 | 15,40 | 4,70 | 49,00 |
| RKOTR | KO | Volcanic | 32,00 | 28,00 | 110,00 | <1 | 25,10 | 0,50 | 13,80 | 2,10 | 1,90 | 20,10 | <1 | 237,50 | 0,20 | 4,10 | 1,30 | 188,00 |

| Sample | Outcrop | Rock type | W | Zr | Y | La | Ce | Pr | Nd | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RKAB | KA | Sand | <0,50 | 2,00 | 2,00 | 1,40 | 0,90 | 0,13 | 0,40 | 0,13 | <0,02 | 0,24 | <0,01 | 0,08 | 0,03 | 0,10 | <0,01 | 0,07 |
| RPEB | PE | Sand | <0,50 | 3,80 | 9,90 | 5,40 | 1,10 | 0,76 | 3,30 | 0,62 | 0,15 | 0,73 | 0,10 | 0,94 | 0,18 | 0,59 | 0,05 | 0,41 |
| KA1 | KA | Sand | <0,50 | 189,60 | 32,90 | 24,00 | 44,70 | 5,34 | 20,40 | 4,44 | 1,14 | 5,06 | 0,87 | 5,36 | 1,19 | 3,63 | 0,49 | 3,50 |
| KA2 | KA | Sand | 0,60 | 193,60 | 34,70 | 24,20 | 46,00 | 5,53 | 21,70 | 5,10 | 1,17 | 4,97 | 0,88 | 5,11 | 1,22 | 3,38 | 0,52 | 3,55 |
| KA3 | KA | Sand | 0,60 | 192,10 | 33,60 | 23,70 | 45,20 | 5,37 | 21,50 | 4,74 | 1,20 | 5,14 | 0,89 | 5,32 | 1,24 | 3,37 | 0,55 | 3,59 |
| KA4 | KA | Sand | 1,30 | 184,80 | 33,30 | 23,40 | 46,20 | 5,42 | 21,40 | 4,91 | 1,12 | 4,85 | 0,88 | 5,35 | 1,10 | 3,51 | 0,47 | 3,37 |
| PE1 | PE | Sand | 0,50 | 107,30 | 24,60 | 16,60 | 30,70 | 3,62 | 14,70 | 3,53 | 1,16 | 3,93 | 0,66 | 4,30 | 0,91 | 2,45 | 0,39 | 2,62 |
| PE2 | PE | Sand | <0,50 | 116,80 | 26,60 | 17,30 | 33,20 | 4,02 | 17,10 | 3,70 | 1,21 | 4,22 | 0,75 | 4,30 | 1,00 | 2,84 | 0,45 | 3,10 |
| PE3 | PE | Sand | 0,50 | 114,50 | 20,80 | 17,00 | 31,40 | 3,79 | 15,70 | 3,33 | 1,27 | 3,62 | 0,58 | 4,34 | 0,86 | 2,43 | 0,35 | 2,27 |
| PE4 | PE | Sand | <0,50 | 105,70 | 28,10 | 16,60 | 34,10 | 4,10 | 17,40 | 4,22 | 1,19 | 4,63 | 0,76 | 5,36 | 1,09 | 3,05 | 0,47 | 3,23 |
| RE1 | RE | Sand | 1,10 | 130,40 | 24,90 | 16,30 | 32,90 | 3,69 | 14,10 | 3,58 | 0,93 | 3,98 | 0,70 | 4,06 | 0,96 | 2,47 | 0,41 | 2,55 |
| RE2 | RE | Sand | 0,50 | 109,70 | 24,20 | 13,80 | 27,80 | 3,22 | 13,30 | 3,31 | 0,90 | 3,69 | 0,60 | 3,99 | 0,77 | 2,56 | 0,36 | 2,62 |
| RE3 | RE | Sand | <0,50 | 92,90 | 23,80 | 12,60 | 23,90 | 3,00 | 12,10 | 3,02 | 0,83 | 3,67 | 0,63 | 3,95 | 0,87 | 2,58 | 0,34 | 2,37 |
| RE4 | RE | Sand | <0,50 | 105,30 | 23,40 | 13,40 | 26,70 | 3,13 | 12,90 | 3,17 | 0,78 | 3,48 | 0,62 | 4,30 | 0,79 | 2,57 | 0,36 | 2,36 |
| BL1 | BL | Sand | 0,70 | 164,10 | 30,00 | 21,60 | 43,00 | 4,79 | 19,30 | 4,18 | 1,15 | 4,41 | 0,76 | 4,53 | 1,04 | 2,96 | 0,44 | 3,21 |
| BL2 | BL | Sand | 0,50 | 147,60 | 32,10 | 20,40 | 39,80 | 4,66 | 19,10 | 4,45 | 1,17 | 4,67 | 0,81 | 5,20 | 1,07 | 3,22 | 0,49 | 3,43 |
| BL3 | BL | Sand | 0,80 | 186,70 | 34,20 | 23,30 | 44,70 | 5,34 | 22,70 | 4,86 | 1,19 | 5,05 | 0,88 | 5,44 | 1,16 | 3,59 | 0,54 | 3,33 |
| VL1 | VL | Sand | 0,60 | 104,10 | 26,80 | 15,90 | 32,70 | 3,89 | 15,90 | 3,73 | 1,18 | 4,40 | 0,72 | 4,82 | 1,02 | 2,86 | 0,44 | 3,08 |
| VL2 | VL | Sand | 0,70 | 143,10 | 25,90 | 19,60 | 38,10 | 4,41 | 16,60 | 3,97 | 1,32 | 4,36 | 0,70 | 4,19 | 0,96 | 2,90 | 0,44 | 2,90 |
| VL3 | VL | Sand | 1,10 | 192,30 | 34,40 | 23,20 | 47,70 | 5,50 | 23,40 | 4,89 | 1,18 | 5,34 | 0,86 | 6,14 | 1,16 | 3,22 | 0,54 | 3,54 |
| VL4 | VL | Sand | 0,60 | 124,90 | 26,90 | 18,20 | 37,90 | 4,38 | 17,50 | 4,63 | 1,16 | 4,73 | 0,78 | 5,00 | 1,05 | 3,27 | 0,46 | 3,13 |
| MO1 | MO | Sand | 0,80 | 174,40 | 28,50 | 21,90 | 43,60 | 4,96 | 19,10 | 4,35 | 1,18 | 4,54 | 0,78 | 5,04 | 1,04 | 2,89 | 0,50 | 3,29 |
| MO2 | MO | Sand | 1,00 | 175,50 | 28,40 | 21,00 | 42,10 | 4,77 | 19,40 | 4,04 | 1,16 | 4,33 | 0,76 | 4,32 | 1,09 | 3,10 | 0,48 | 3,07 |
| MO3 | MO | Sand | <0,50 | 126,40 | 23,00 | 17,00 | 34,10 | 3,83 | 16,30 | 3,54 | 1,21 | 3,91 | 0,62 | 3,72 | 0,81 | 2,30 | 0,38 | 2,61 |
| MO4 | MO | Sand | 1,00 | 169,90 | 28,10 | 21,40 | 40,70 | 4,71 | 19,40 | 4,21 | 1,27 | 4,52 | 0,77 | 5,07 | 1,04 | 3,02 | 0,48 | 3,22 |
| KO1 | KO | Sand | <0,50 | 119,50 | 30,70 | 18,90 | 37,40 | 4,53 | 19,50 | 4,34 | 1,05 | 4,56 | 0,83 | 5,41 | 1,07 | 3,26 | 0,48 | 3,32 |
| KO2 | KO | Sand | 0,60 | 149,70 | 30,40 | 20,20 | 41,50 | 4,76 | 21,10 | 4,58 | 1,07 | 4,47 | 0,82 | 4,90 | 1,01 | 3,15 | 0,50 | 2,95 |
| KO3 | KO | Sand | 0,60 | 157,30 | 29,00 | 21,40 | 42,10 | 4,68 | 17,30 | 4,25 | 1,20 | 4,33 | 0,78 | 5,18 | 0,98 | 3,03 | 0,50 | 3,20 |
| KO4 | KO | Sand | 0,60 | 150,30 | 28,10 | 21,40 | 40,90 | 4,75 | 17,10 | 4,21 | 1,24 | 4,35 | 0,78 | 4,92 | 1,06 | 3,09 | 0,47 | 3,13 |
| RRERP | RE | Volcanic | <0,50 | 113,70 | 23,60 | 13,10 | 28,20 | 3,32 | 14,40 | 3,17 | 0,85 | 3,62 | 0,60 | 3,90 | 0,87 | 2,21 | 0,38 | 2,51 |
| RREBU | RE | Volcanic | <0,50 | 109,40 | 23,30 | 13,70 | 27,10 | 3,23 | 13,10 | 3,17 | 0,86 | 3,55 | 0,59 | 3,83 | 0,81 | 2,15 | 0,36 | 2,36 |
| RVLT | VL | Volcanic | 0,70 | 211,30 | 32,30 | 23,70 | 47,20 | 5,22 | 20,30 | 4,63 | 0,98 | 4,88 | 0,85 | 5,79 | 1,11 | 3,26 | 0,56 | 3,49 |
| RRMC | RM | Volcanic | <0,50 | 192,40 | 37,00 | 29,30 | 54,20 | 6,64 | 24,80 | 5,69 | 1,32 | 5,81 | 1,01 | 5,88 | 1,21 | 3,64 | 0,56 | 3,55 |
| RBMP | BM | Volcanic | 0,70 | 272,30 | 51,80 | 37,50 | 67,00 | 8,93 | 36,70 | 8,34 | 1,73 | 8,79 | 1,48 | 9,07 | 1,90 | 5,52 | 0,82 | 5,51 |
| RKOTB | KO | Volcanic | 1,00 | 243,10 | 35,00 | 27,10 | 52,00 | 5,62 | 20,80 | 4,54 | 0,93 | 5,04 | 0,89 | 5,65 | 1,28 | 3,89 | 0,55 | 4,11 |
| RKOTR | KO | Volcanic | <0,50 | 78,90 | 21,40 | 8,10 | 16,30 | 2,16 | 8,90 | 2,53 | 0,78 | 2,96 | 0,53 | 3,39 | 0,76 | 2,22 | 0,34 | 2,18 |

| Sample | Outcrop | Rock type | Lu | Mo | Cu | Pb | Zn | Ni | As | Cd | Sb | Bi | Ag | Au | Hg | Tl | Se |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RKAB | KA | Sand | <0,01 | <0,10 | 3,40 | 2,00 | 3,00 | 0,10 | 1,10 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| RPEB | PE | Sand | 0,05 | <0,10 | 1,80 | 4,30 | 27,00 | 2,40 | 5,10 | 0,80 | 0,30 | <0,10 | <0,10 | 0,80 | 0,01 | 0,10 | <0,50 |
| KA1 | KA | Sand | 0,54 | 0,60 | 14,10 | 4,60 | 35,00 | 4,20 | 3,50 | <0,10 | 0,20 | <0,10 | <0,10 | 0,50 | <0,01 | <0,10 | <0,50 |
| KA2 | KA | Sand | 0,56 | 0,50 | 15,90 | 4,80 | 33,00 | 4,60 | 3,00 | <0,10 | 0,20 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| KA3 | KA | Sand | 0,53 | 0,60 | 15,00 | 5,00 | 37,00 | 4,50 | 3,00 | <0,10 | 0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| KA4 | KA | Sand | 0,57 | 0,50 | 14,90 | 5,00 | 35,00 | 4,60 | 2,30 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| PE1 | PE | Sand | 0,43 | 0,20 | 6,40 | 4,40 | 23,00 | 4,80 | 6,80 | <0,10 | <0,10 | <0,10 | <0,10 | 2,10 | <0,01 | <0,10 | <0,50 |
| PE2 | PE | Sand | 0,46 | 0,20 | 7,20 | 4,60 | 30,00 | 6,10 | 6,10 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| PE3 | PE | Sand | 0,37 | 0,30 | 6,40 | 5,00 | 23,00 | 3,80 | 7,90 | <0,10 | <0,10 | <0,10 | <0,10 | 0,90 | <0,01 | <0,10 | <0,50 |
| PE4 | PE | Sand | 0,47 | 0,30 | 6,90 | 4,20 | 32,00 | 6,80 | 5,70 | <0,10 | <0,10 | <0,10 | <0,10 | 1,40 | <0,01 | <0,10 | <0,50 |
| RE1 | RE | Sand | 0,42 | 0,20 | 12,00 | 2,20 | 20,00 | 50,00 | 1,90 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| RE2 | RE | Sand | 0,40 | 0,10 | 8,60 | 2,00 | 18,00 | 62,60 | 2,50 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | 0,01 | <0,10 | <0,50 |
| RE3 | RE | Sand | 0,39 | 0,40 | 10,80 | 1,20 | 20,00 | 112,10 | 1,40 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| RE4 | RE | Sand | 0,37 | 0,30 | 10,40 | 1,70 | 19,00 | 76,60 | 1,70 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| BL1 | BL | Sand | 0,46 | 0,40 | 14,60 | 6,00 | 31,00 | 4,90 | 3,30 | <0,10 | 0,10 | <0,10 | <0,10 | <0,50 | 0,02 | <0,10 | <0,50 |
| BL2 | BL | Sand | 0,48 | 0,50 | 17,00 | 5,00 | 42,00 | 6,50 | 5,10 | <0,10 | 0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| BL3 | BL | Sand | 0,52 | 0,50 | 14,50 | 5,50 | 37,00 | 5,30 | 3,30 | <0,10 | 0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| VL1 | VL | Sand | 0,47 | 0,20 | 6,60 | 4,10 | 31,00 | 7,30 | 4,70 | <0,10 | <0,10 | <0,10 | <0,10 | 1,60 | <0,01 | <0,10 | <0,50 |
| VL2 | VL | Sand | 0,39 | 0,30 | 8,30 | 4,70 | 25,00 | 3,60 | 4,90 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| VL3 | VL | Sand | 0,54 | 0,30 | 13,80 | 5,50 | 35,00 | 4,20 | 3,50 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| VL4 | VL | Sand | 0,47 | 0,30 | 8,80 | 4,20 | 30,00 | 5,60 | 3,80 | <0,10 | <0,10 | <0,10 | <0,10 | 1,90 | 0,01 | <0,10 | <0,50 |
| MO1 | MO | Sand | 0,49 | 0,30 | 7,90 | 6,00 | 29,00 | 3,40 | 5,20 | <0,10 | <0,10 | <0,10 | <0,10 | 1,40 | <0,01 | <0,10 | <0,50 |
| MO2 | MO | Sand | 0,47 | 0,20 | 8,50 | 6,00 | 27,00 | 3,50 | 5,30 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| MO3 | MO | Sand | 0,40 | 0,20 | 7,20 | 4,70 | 32,00 | 3,90 | 4,30 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| MO4 | MO | Sand | 0,48 | 0,40 | 9,10 | 5,80 | 29,00 | 3,60 | 5,10 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| KO1 | KO | Sand | 0,52 | 0,80 | 11,90 | 4,40 | 36,00 | 9,60 | 3,00 | <0,10 | 1,40 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| KO2 | KO | Sand | 0,49 | 0,90 | 16,70 | 5,30 | 38,00 | 9,20 | 3,40 | <0,10 | 1,30 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| KO3 | KO | Sand | 0,51 | 0,80 | 15,40 | 5,20 | 35,00 | 7,50 | 3,80 | <0,10 | 1,20 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| KO4 | KO | Sand | 0,47 | 0,70 | 13,50 | 4,70 | 32,00 | 6,60 | 3,50 | <0,10 | 1,00 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| RRERP | RE | Volcanic | 0,37 | 0,60 | 14,30 | 2,30 | 22,00 | 85,80 | <0,50 | <0,10 | 2,00 | <0,10 | <0,10 | 1,40 | <0,01 | <0,10 | <0,50 |
| RREBU | RE | Volcanic | 0,39 | <0,10 | 60,70 | 0,80 | 17,00 | 80,60 | <0,50 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| RVLT | VL | Volcanic | 0,57 | 0,60 | 16,10 | 6,00 | 28,00 | 5,00 | 2,70 | <0,10 | 1,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| RRMC | RM | Volcanic | 0,58 | 0,10 | 13,30 | 2,00 | 18,00 | 1,70 | <0,50 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| RBMP | BM | Volcanic | 0,87 | 1,50 | 54,40 | 6,00 | 61,00 | 0,30 | 0,90 | <0,10 | <0,10 | <0,10 | <0,10 | <0,50 | 0,02 | <0,10 | <0,50 |
| RKOTB | KO | Volcanic | 0,65 | 0,50 | 11,10 | 4,20 | 21,00 | 2,90 | 5,60 | <0,10 | 1,20 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |
| RKOTR | KO | Volcanic | 0,31 | 0,40 | 15,50 | 1,60 | 15,00 | 23,10 | 0,60 | <0,10 | 0,90 | <0,10 | <0,10 | <0,50 | <0,01 | <0,10 | <0,50 |

| Sample | Outcrop | Rock type | K/Cs | Zr/Ti | Nb/Y | Th/Sc | Zr/Sc | Cr/Ni | Cr/V | Y/Ni | Ti/Zr | La/Sc | Ce/Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AR | A3 | Gabbroic | 6641 | 0,006 | 0,13 | 0,01 | 0,26 | 6,63 | 0,84 | 0,58 | 158,05 | 0,02 | 0,42 |
| A11 | A1 | Sand | 10293 | 0,022 | 0,29 | 0,04 | 1,89 | 3,14 | 1,20 | 0,30 | 45,00 | 0,18 | 1,01 |
| A1P | A1 | Sand | 7471 | 0,014 | 0,19 | 0,04 | 1,48 | 2,23 | 1,20 | 0,16 | 71,13 | 0,19 | 1,08 |
| A21 | A2 | Sand | 7263 | 0,011 | 0,23 | 0,03 | 0,63 | 3,68 | 1,59 | 0,26 | 95,00 | 0,11 | 0,91 |
| A22 | A2 | Sand | 1001 | 0,005 | 0,18 | 0,01 | 0,59 | 2,07 | 0,74 | 0,19 | 183,81 | 0,09 | 0,66 |
| A23 | A2 | Sand | 737 | 0,005 | 0,08 | 0,02 | 0,46 | 1,91 | 0,78 | 0,14 | 195,27 | 0,08 | 0,74 |
| A31 | A3 | Sand | 6087 | 0,007 | 0,06 | 0,01 | 0,40 | 3,73 | 2,10 | 0,26 | 153,59 | 0,05 | 0,43 |
| A32 | A3 | Sand | 10791 | 0,010 | 0,28 | 0,02 | 0,67 | 2,72 | 1,86 | 0,33 | 97,94 | 0,11 | 0,72 |
| A33 | A3 | Sand | 16602 | 0,007 | 0,09 | 0,01 | 0,40 | 3,33 | 1,66 | 0,31 | 153,72 | 0,08 | 0,55 |
| A34 | A3 | Sand | 29884 | 0,007 | 0,07 | 0,01 | 0,46 | 4,53 | 2,48 | 0,25 | 142,54 | 0,07 | 0,46 |
| A41 | A4 | Sand | 2121 | 0,006 | 0,11 | 0,01 | 0,97 | 2,50 | 0,35 | 0,51 | 178,42 | 0,07 | 0,39 |
| A42 | A4 | Sand | 3136 | 0,007 | 0,11 | 0,01 | 1,22 | 2,24 | 0,43 | 0,56 | 135,48 | 0,07 | 0,38 |
| A51 | A5 | Sand | 6226 | 0,005 | 0,07 | 0,02 | 0,87 | 2,47 | 0,43 | 0,43 | 201,04 | 0,10 | 0,49 |
| A52 | A5 | Sand | 8854 | 0,006 | 0,17 | 0,06 | 1,32 | 2,57 | 0,37 | 0,83 | 172,58 | 0,23 | 0,81 |
| A53 | A5 | Sand | 4388 | 0,005 | 0,08 | 0,02 | 0,93 | 2,44 | 0,44 | 0,61 | 207,03 | 0,12 | 0,50 |
| A54 | A5 | Sand | 17847 | 0,008 | 0,14 | 0,03 | 1,53 | 2,23 | 0,41 | 0,86 | 119,06 | 0,19 | 0,70 |
| RM1 | RM | Sand | 26563 | 0,060 | 0,52 | 1,33 | 22,00 | 0,20 | 0,36 | 7,91 | 16,80 | 5,40 | 3,60 |
| RM2 | RM | Sand | 29780 | 0,057 | 0,38 | 0,60 | 15,72 | 0,68 | 0,21 | 8,38 | 17,54 | 4,30 | 3,07 |
| RM3 | RM | Sand | 27486 | 0,061 | 0,47 | 0,58 | 18,38 | 0,68 | 0,26 | 6,00 | 16,31 | 4,63 | 3,35 |
| RM4 | RM | Sand | 34864 | 0,069 | 0,40 | 0,54 | 25,56 | 0,68 | 0,33 | 9,07 | 14,54 | 4,26 | 2,99 |
| RM5 | RM | Sand | 31129 | 0,072 | 0,41 | 0,96 | 19,74 | 1,37 | 0,44 | 7,94 | 13,97 | 4,66 | 3,62 |
| RM6 | RM | Sand | 28131 | 0,086 | 0,44 | 1,08 | 26,94 | 0,68 | 0,25 | 7,56 | 11,57 | 5,34 | 3,81 |
| RS1 | RS | Sand | 35101 | 0,057 | 0,41 | 1,15 | 17,15 | 0,68 | 0,27 | 8,58 | 17,48 | 5,75 | 4,04 |
| RS2 | RS | Sand | 21168 | 0,052 | 0,62 | 0,83 | 16,35 | 0,68 | 0,23 | 5,30 | 19,25 | 5,15 | 3,74 |
| RS3 | RS | Sand | 32967 | 0,066 | 0,45 | 0,60 | 18,68 | 0,68 | 0,29 | 8,92 | 15,25 | 4,45 | 3,05 |
| RS4 | RS | Sand | 20050 | 0,054 | 0,38 | 1,50 | 17,83 | 0,68 | 0,23 | 5,45 | 18,50 | 5,83 | 3,66 |
| RS5 | RS | Sand | 26356 | 0,060 | 0,43 | 0,57 | 18,91 | 1,37 | 0,65 | 12,38 | 16,75 | 4,09 | 2,96 |
| RS6 | RS | Sand | 29469 | 0,060 | 0,35 | 1,46 | 18,10 | 0,68 | 0,27 | 11,77 | 16,56 | 4,58 | 2,90 |
| PB1 | RS | Sand | 27227 | 0,081 | 0,48 | 1,20 | 26,75 | 0,68 | 0,46 | 3,42 | 12,33 | 7,40 | 4,12 |
| PB2 | RS | Sand | 29676 | 0,078 | 0,42 | 0,94 | 27,00 | 0,68 | 0,30 | 10,60 | 12,88 | 4,52 | 2,89 |
| PB3 | RS | Sand | 29791 | 0,073 | 0,42 | 0,87 | 20,50 | 0,68 | 0,36 | 6,14 | 13,65 | 5,27 | 3,52 |

| Sample | Outcrop | Rock type | K/Cs | Zr/Ti | Nb/Y | Th/Sc | Zr/Sc | Cr/Ni | Cr/V | Y/Ni | Ti/Zr | La/Sc | Ce/Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RKAB | KA | Sand | 830 | 0,067 | 0,00 | 0,11 | 2,22 | 0,68 | 0,98 | 40,00 | 14,99 | 1,56 | 0,45 |
| RPEB | PE | Sand | 830 | 0,127 | 0,00 | 0,11 | 4,22 | 0,68 | 0,98 | 4,13 | 7,89 | 6,00 | 0,11 |
| KA1 | KA | Sand | 9915 | 0,039 | 0,24 | 0,81 | 11,85 | 1,37 | 0,12 | 7,83 | 25,93 | 1,50 | 1,36 |
| KA2 | KA | Sand | 8924 | 0,038 | 0,23 | 0,78 | 11,39 | 2,74 | 0,23 | 7,54 | 26,32 | 1,42 | 1,33 |
| KA3 | KA | Sand | 10254 | 0,037 | 0,23 | 0,67 | 10,67 | 2,74 | 0,21 | 7,47 | 26,84 | 1,32 | 1,35 |
| KA4 | KA | Sand | 11103 | 0,036 | 0,23 | 0,69 | 10,27 | 1,37 | 0,11 | 7,24 | 27,90 | 1,30 | 1,39 |
| PE1 | PE | Sand | 7886 | 0,026 | 0,19 | 0,25 | 4,29 | 5,47 | 0,59 | 5,13 | 38,55 | 0,66 | 1,25 |
| PE2 | PE | Sand | 7955 | 0,023 | 0,22 | 0,23 | 4,03 | 6,16 | 0,47 | 4,36 | 43,63 | 0,60 | 1,25 |
| PE3 | PE | Sand | 7139 | 0,034 | 0,25 | 0,47 | 7,63 | 3,42 | 0,50 | 5,47 | 29,84 | 1,13 | 1,51 |
| PE4 | PE | Sand | 8301 | 0,019 | 0,21 | 0,15 | 2,86 | 5,47 | 0,37 | 4,13 | 53,88 | 0,45 | 1,21 |
| RE1 | RE | Sand | 7194 | 0,030 | 0,21 | 0,26 | 4,35 | 4,50 | 2,09 | 0,50 | 33,10 | 0,54 | 1,32 |
| RE2 | RE | Sand | 8603 | 0,028 | 0,20 | 0,21 | 3,43 | 4,36 | 2,85 | 0,39 | 35,52 | 0,43 | 1,15 |
| RE3 | RE | Sand | 7471 | 0,024 | 0,16 | 0,14 | 2,27 | 3,63 | 3,29 | 0,21 | 41,95 | 0,31 | 1,00 |
| RE4 | RE | Sand | 7402 | 0,026 | 0,18 | 0,18 | 2,93 | 4,40 | 2,74 | 0,31 | 38,71 | 0,37 | 1,14 |
| BL1 | BL | Sand | 7908 | 0,038 | 0,23 | 0,76 | 11,72 | 1,37 | 0,13 | 6,12 | 26,30 | 1,54 | 1,43 |
| BL2 | BL | Sand | 6728 | 0,023 | 0,22 | 0,41 | 6,71 | 2,74 | 0,17 | 4,94 | 43,05 | 0,93 | 1,24 |
| BL3 | BL | Sand | 7327 | 0,037 | 0,21 | 0,68 | 10,98 | 1,37 | 0,11 | 6,45 | 27,29 | 1,37 | 1,31 |
| VL1 | VL | Sand | 8467 | 0,018 | 0,21 | 0,17 | 3,15 | 8,21 | 0,58 | 3,67 | 54,71 | 0,48 | 1,22 |
| VL2 | VL | Sand | 7056 | 0,036 | 0,24 | 0,61 | 9,54 | 2,74 | 0,33 | 7,19 | 27,65 | 1,31 | 1,47 |
| VL3 | VL | Sand | 8222 | 0,039 | 0,24 | 0,72 | 11,31 | 3,42 | 0,31 | 8,19 | 25,56 | 1,36 | 1,39 |
| VL4 | VL | Sand | 8173 | 0,022 | 0,26 | 0,25 | 4,31 | 6,16 | 0,48 | 4,80 | 45,12 | 0,63 | 1,41 |
| MO1 | MO | Sand | 7392 | 0,045 | 0,24 | 0,85 | 13,42 | 4,11 | 0,60 | 8,38 | 22,34 | 1,68 | 1,53 |
| MO2 | MO | Sand | 8301 | 0,045 | 0,27 | 0,93 | 14,63 | 1,37 | 0,20 | 8,11 | 22,20 | 1,75 | 1,48 |
| MO3 | MO | Sand | 7582 | 0,027 | 0,25 | 0,43 | 7,02 | 4,11 | 0,40 | 5,90 | 37,47 | 0,94 | 1,48 |
| MO4 | MO | Sand | 8789 | 0,042 | 0,27 | 0,76 | 12,14 | 2,05 | 0,28 | 7,81 | 23,64 | 1,53 | 1,45 |
| KO1 | KO | Sand | 8452 | 0,022 | 0,20 | 0,22 | 3,73 | 5,47 | 0,39 | 3,20 | 45,65 | 0,59 | 1,22 |
| KO2 | KO | Sand | 8835 | 0,028 | 0,22 | 0,42 | 6,51 | 3,01 | 0,53 | 3,30 | 36,04 | 0,88 | 1,37 |
| KO3 | KO | Sand | 8457 | 0,033 | 0,24 | 0,52 | 8,28 | 2,74 | 0,22 | 3,87 | 30,11 | 1,13 | 1,45 |
| KO4 | KO | Sand | 7617 | 0,034 | 0,24 | 0,55 | 8,35 | 2,74 | 0,24 | 4,26 | 29,52 | 1,19 | 1,46 |
| RRERP | RE | Volcanic | 7094 | 0,024 | 0,19 | 0,20 | 3,67 | 3,17 | 1,81 | 0,28 | 41,65 | 0,42 | 1,19 |
| RREBU | RE | Volcanic | 7924 | 0,024 | 0,18 | 0,19 | 3,65 | 3,09 | 1,81 | 0,29 | 41,10 | 0,46 | 1,16 |
| RVLT | VL | Volcanic | 5998 | 0,054 | 0,24 | 0,98 | 15,09 | 0,68 | 0,08 | 6,46 | 18,44 | 1,69 | 1,46 |
| RRMC | RM | Volcanic | 8222 | 0,032 | 0,25 | 0,83 | 12,83 | 0,68 | 0,06 | 21,76 | 30,85 | 1,95 | 1,46 |
| RBMP | BM | Volcanic | 9095 | 0,040 | 0,20 | 0,96 | 17,02 | 0,68 | 0,10 | 172,67 | 25,10 | 2,34 | 1,29 |
| RKOTB | KO | Volcanic | 7111 | 0,084 | 0,21 | 1,54 | 24,31 | 0,68 | 0,14 | 12,07 | 11,84 | 2,71 | 1,49 |
| RKOTR | KO | Volcanic | 11289 | 0,019 | 0,09 | 0,15 | 2,82 | 1,92 | 0,33 | 0,93 | 53,95 | 0,29 | 0,76 |

## Appendix 2 – Sampling pictures

1-20. Karmøy localities and representative samples.

21-32. Randaberg localities and representative samples.

33-70. Santorini localities and representative samples.

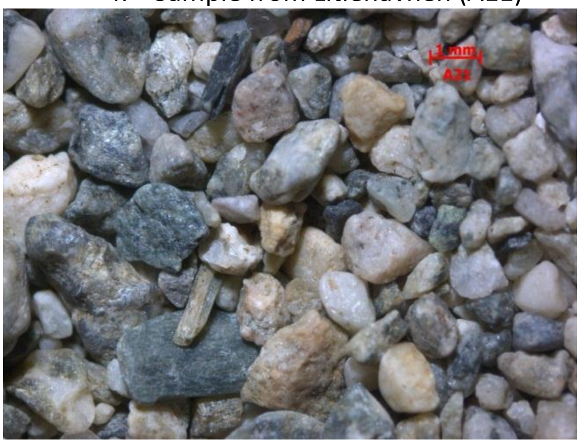
1. River at Bekkjarvika (A1)

2. Sample from River (A1P)

3. Litlehavnen (A1)

4. Sample from Litlehavnen (A11)

5. Norstø (A2)



6. Sample from Norstø (A21)

7. Søra Børevika (A3)


8. Sample from Søra Børevika (A31)

9. Blikshavn Nord (A4)


10. Sample from Blikshavn Nord (A41)

11. Tømmervika (A5)

12. Sample from Tømmervika (A54)

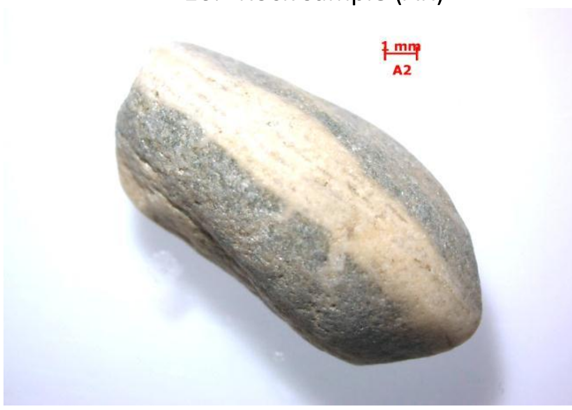

13. Gabbro sampled (A3)


14. Gabbro sampled (A3)


15. Gabbro sampled (AR)


16. Rock sample (AR)


17. Layered gabbroic rocks at A2



18. Lithic fragment at A2

19. Lithic fragments at A3

20. Lithic fragments indicating glacial transport (A1)

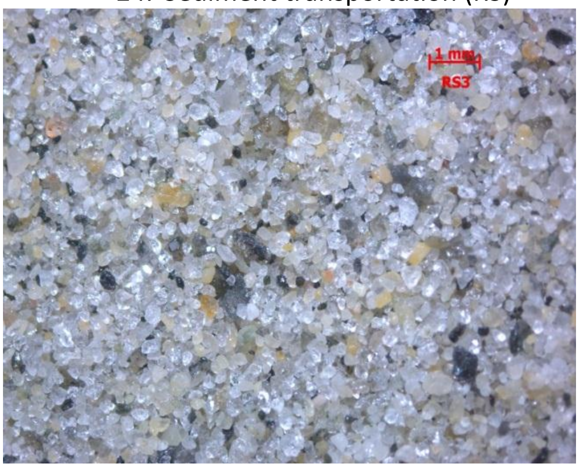
21. Sandebukta (RS) south view

22. Sandebukta (RS) north view

23. Sediment transportation (RS)

24. Sediment transportation (RS)

25. Sand dunes (RS)




26. Sample from Sandebukta (RS3)

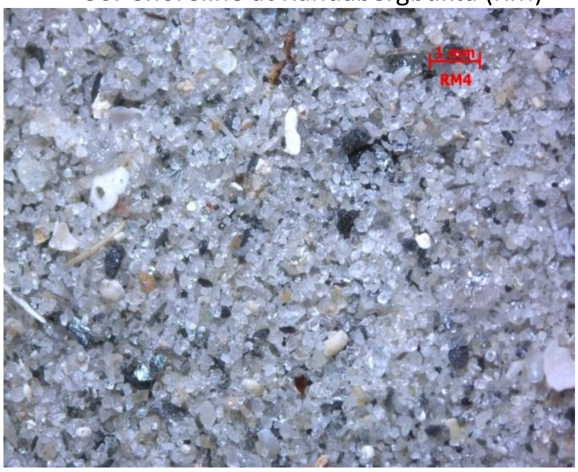
27. Randabergbukta (RM) north view

28. Randabergbukta (RM) south view

29. Sediment transportation (RM)

30. Shoreline at Randabergbukta (RM)

31. Rock between outcrops RS and RM




32. Sample from Randabergbukta (RM4)

33. Red Beach at Akrotiri (RE)


34. Sample from Red Beach (RE4)

35. Red Beach (RREBU) Cinder cones

36. Sample from Cinder cones (RREBU)

37. Red Beach (RRERP) Cinder cones

38. Sample from Cinder cones (RRERP)

39. Black Beach at Akrotiri (BL)

40. Sample from Black Beach (BL3)

41. Vlyhada (VL)

42. Sample from Vlyhada (VL1)

43. Tuff erosion at Vlyhada (VL)

44. Tuff erosion at Vlyhada (VL)

45. Vlyhada (RVLT) Tuff breccia


46. Sample from Tuff breccia at Vlyhada (RVLT)

47. Perissa (PE)

48. Sample from Perissa (PE1)

49. Marble basement (RPEB) at Perissa

50. Sample from basement at Perissa (RPEB)

51. Kamari (KA)

52. Sample from Kamari (KA1)

53. Marble basement (RKAB) at Kamari

54. Sample from basement at Kamari (RKAB)

55. Mikro Profitis Ilias (RBMP) Peristeria

56. Mikro Profitis Ilias (RBMP) Peristeria

57. Mikro Profitis Ilias (RBMP) Peristeria

58. Sample from Peristeria (RBMP)

59. Kokkino Vouno (RRMC) Cinder cones

60. Kokkino Vouno (RRMC) Cinder cones

61. Kokkino Vouno (RRMC) Cinder cones

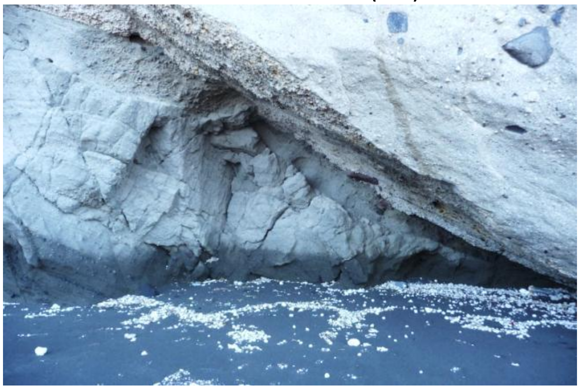
62. Sample from Cinder cones (RRMC)

63. Monolithos (MO)

64. Sample from Monolithos (MO)

65. Kolumbo (KO)

66. Sample from Kolumbo (KO3)

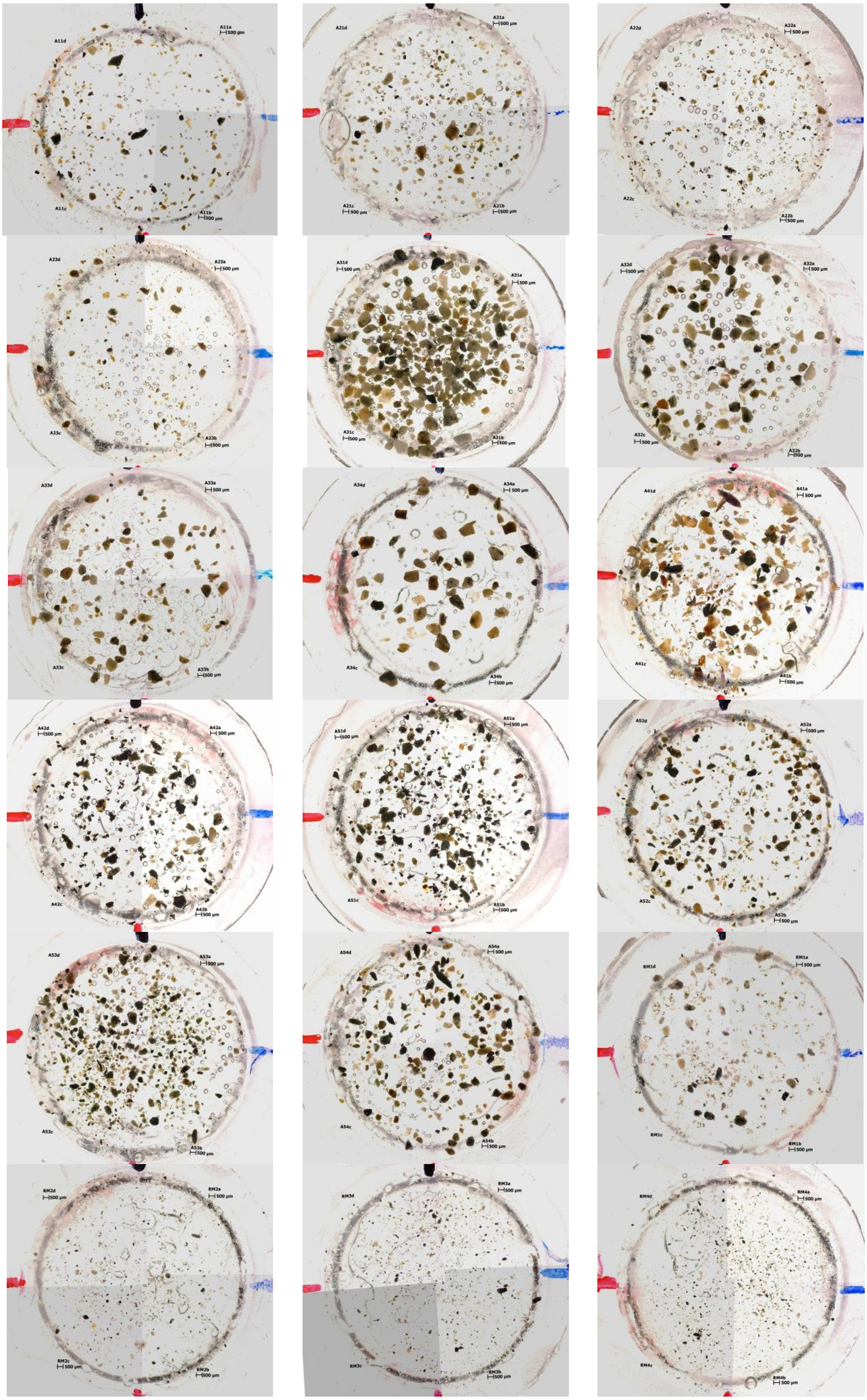


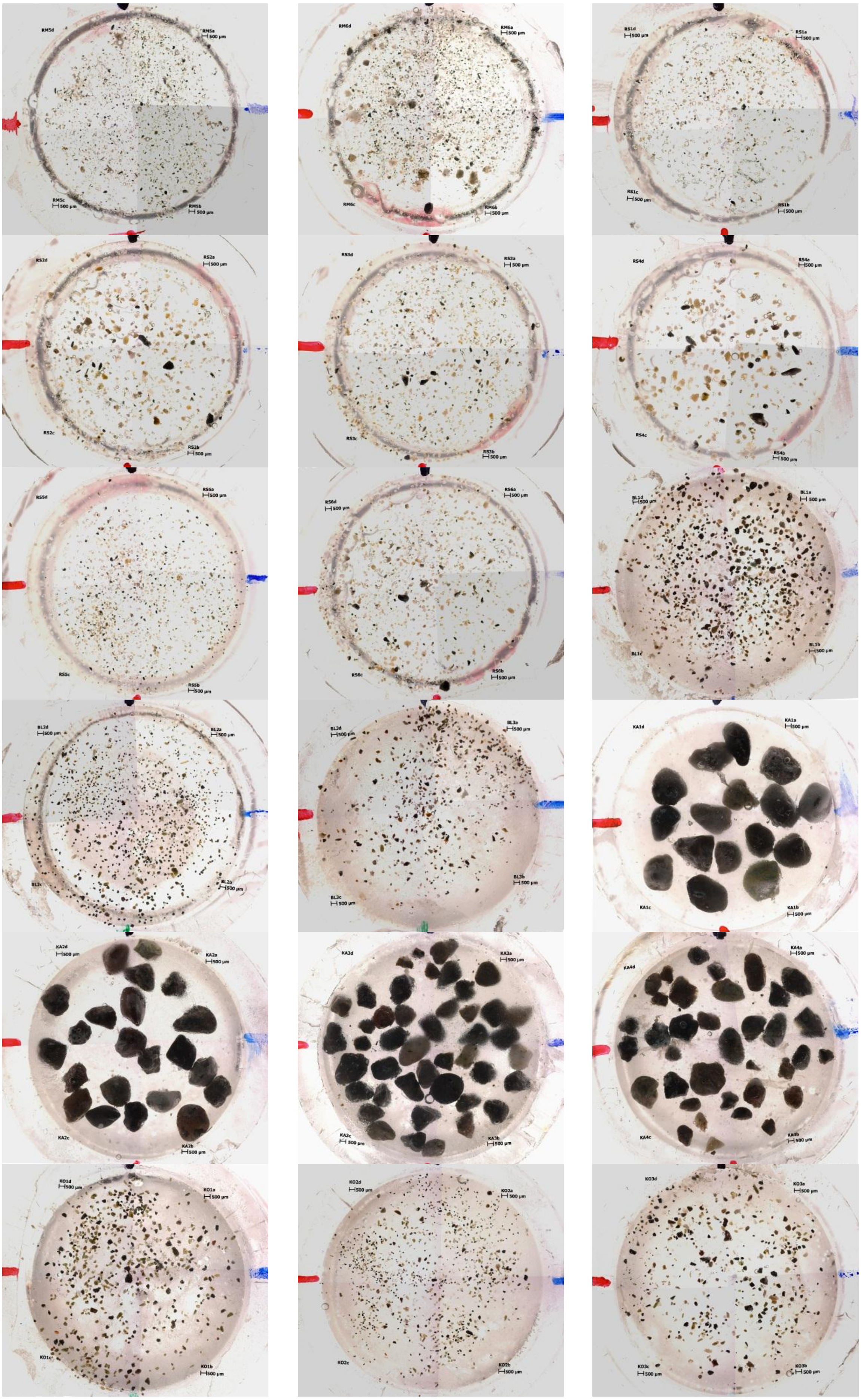
67. Tuff layers at Kolumbo (RKOTR and RKOTB)

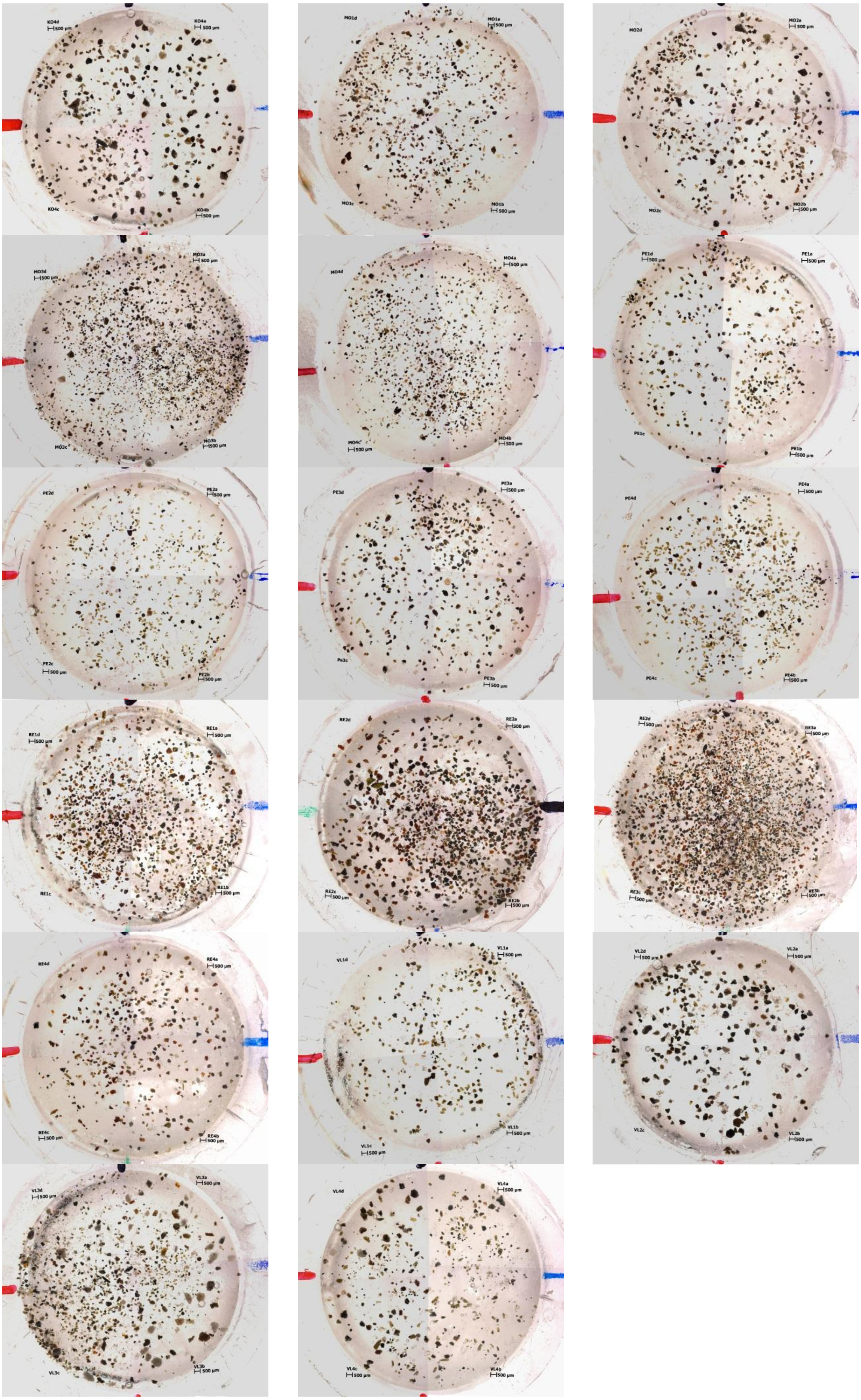
68. Sample from Tuff at Kolumbo (RKOTR)

69. Kolumbo Tuff breccia (RKOTB)


70. Sample from Tuff breccia (RKOTB)







1) Karmøy

A. Geological map of the Karmøy Ophiolite Complex and associated rocks (Pedersen and Hertogen (1990).

B. Block diagram summarizing the magmatic evolution as displayed on Feøy. Numbers in boxes are U-Pb ages determined on zircons (Pedersen and Hertogen (1990).

C. Geological map of Karmøy downloaded from www.ngu.no.

2) Randaberg

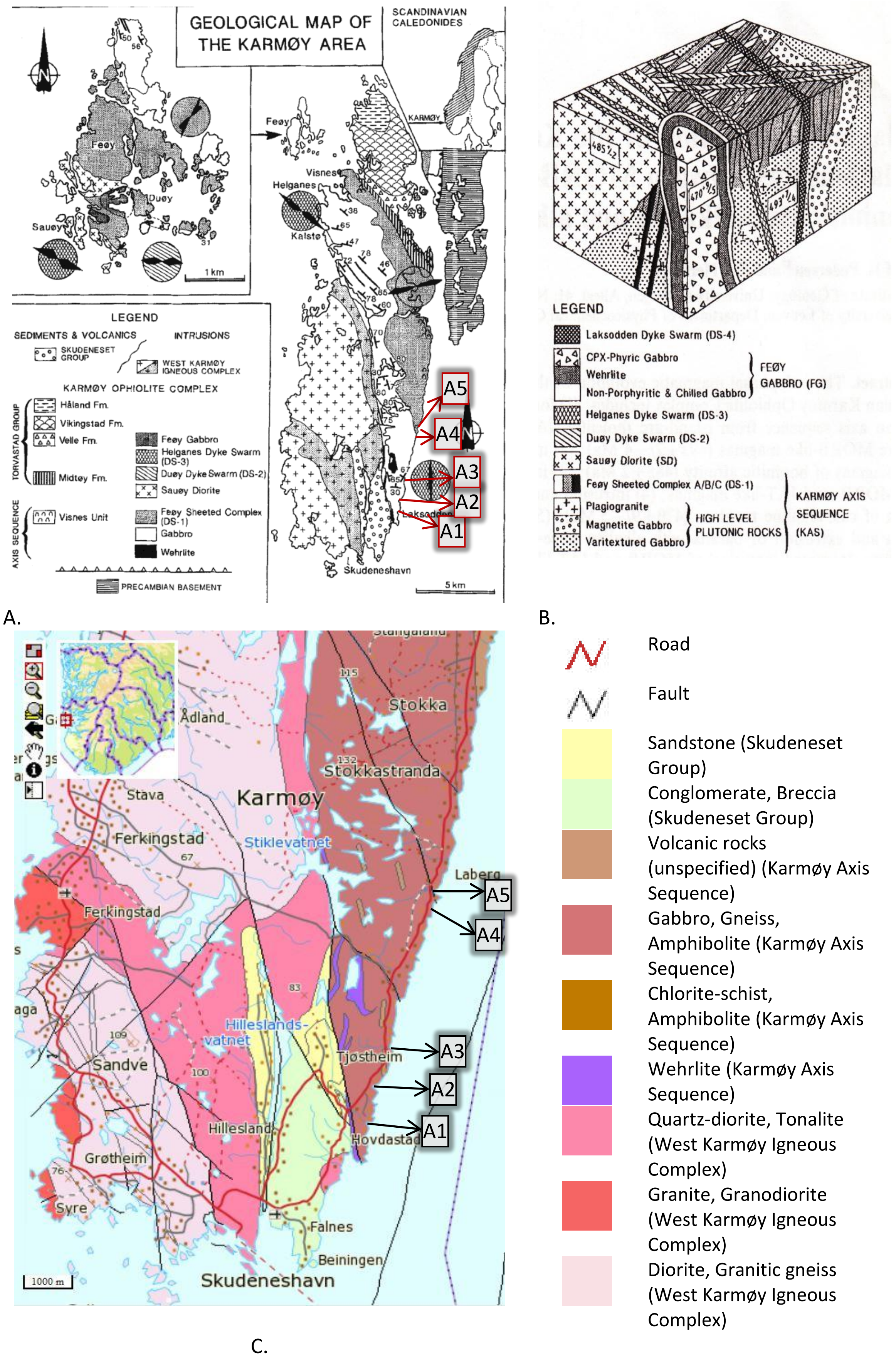
Geological map of Randaberg downloaded from www.ngu.no.

3) Santorini

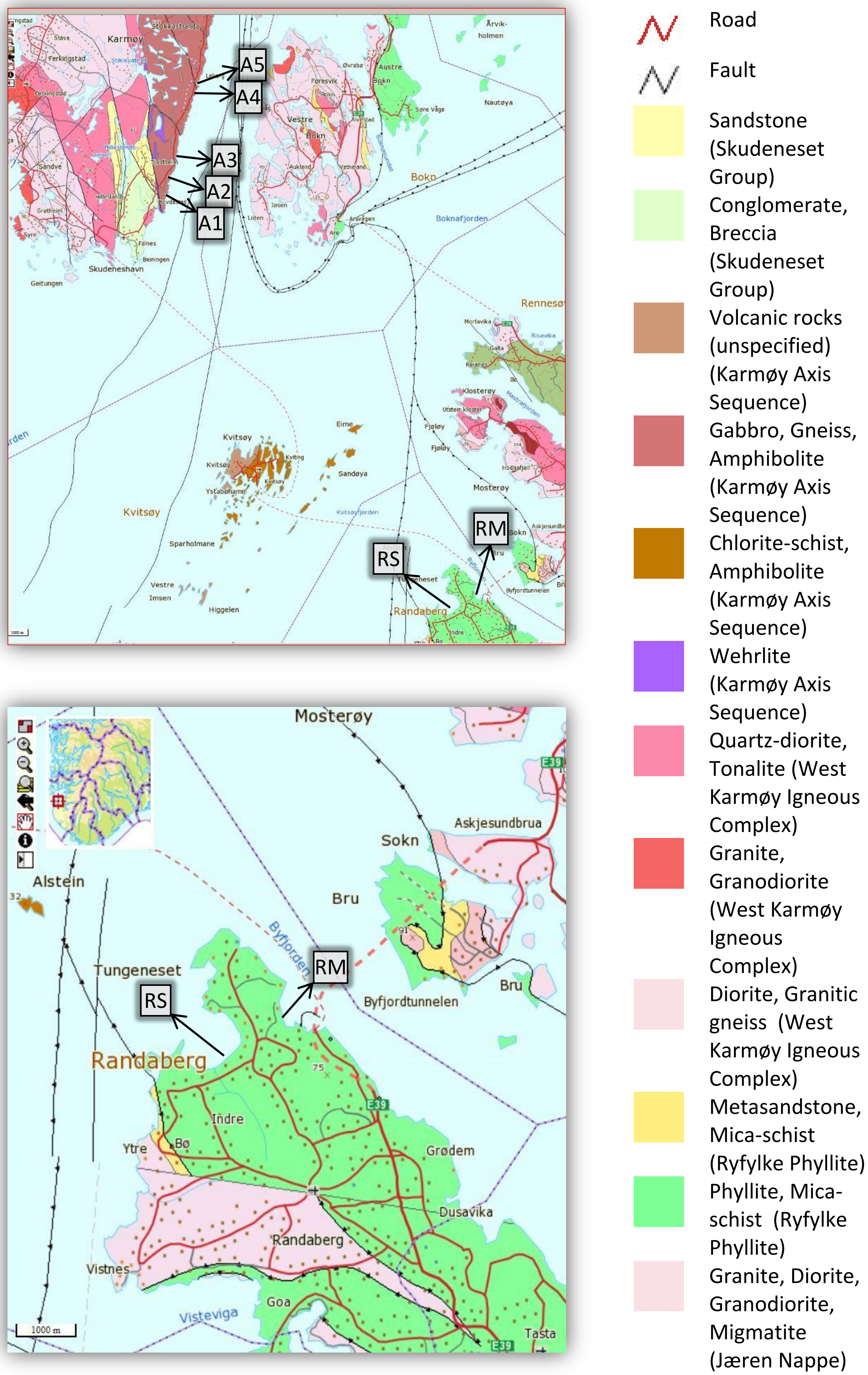
A. Island arc of southern Aegean Sea showing the volcanic centers (Papazachos and Panagiotopoulos, 1993).

B. Summarized stratigraphic section of Santorini after Druitt et al., 1989.

C. Simplified geological map of Santorini after Druitt et al., 1998.

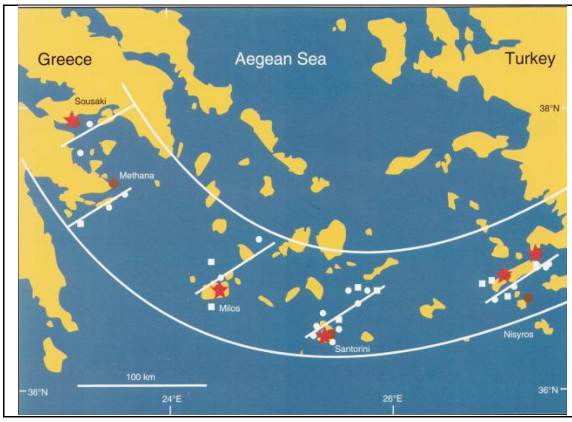

GEOLOGICAL MAP OF THE KARMØY AREA
SCANDINAVIAN CALEDONIDES
KARMØY
Feøy
Duøy
Sauøy
Visnes
Helganes
Kalstø
Laksodden
Skudeneshavn
1 km
5 km
LEGEND
SEDIMENTS & VOLCANICS
INTRUSIONS
SKUDENESET GROUP
WEST KARMØY IGNEOUS COMPLEX
KARMØY OPHIOLITE COMPLEX
TORVASTAD GROUP
Håland Fm.
Vikingstad Fm.
Velle Fm.
Midtøy Fm.
Feøy Gabbro
Helganes Dyke Swarm (DS-3)
Duøy Dyke Swarm (DS-2)
Sauøy Diorite
AXIS SEQUENCE
Visnes Unit
Feøy Sheeted Complex (DS-1)
Gabbro
Wehrlite
PRECAMBIAN BASEMENT
A5
A4
A3
A2
A1
A.
LEGEND
Laksodden Dyke Swarm (DS-4)
CPX-Phyric Gabbro
Wehrlite
Non-Porphyritic & Chilled Gabbro
FEØY GABBRO (FG)
Helganes Dyke Swarm (DS-3)
Duøy Dyke Swarm (DS-2)
Sauøy Diorite (SD)
Feøy Sheeted Complex A/B/C (DS-1)
Plagiogranite
Magnetite Gabbro
Varitextured Gabbro
HIGH LEVEL PLUTONIC ROCKS
KARMØY AXIS SEQUENCE (KAS)
B.
Stokka
Stokkastranda
Ådland
Karmøy
Stava
Ferkingstad
Stiklevatnet
Laberg
Hilleslands-vatnet
Tjøstheim
Sandve
Hillesland
Hovdastad
Grøtheim
Syre
Falnes
Beiningen
Skudeneshavn
1000 m
Road
Fault
Sandstone (Skudeneset Group)
Conglomerate, Breccia (Skudeneset Group)
Volcanic rocks (unspecified) (Karmøy Axis Sequence)
Gabbro, Gneiss, Amphibolite (Karmøy Axis Sequence)
Chlorite-schist, Amphibolite (Karmøy Axis Sequence)
Wehrlite (Karmøy Axis Sequence)
Quartz-diorite, Tonalite (West Karmøy Igneous Complex)
Granite, Granodiorite (West Karmøy Igneous Complex)
Diorite, Granitic gneiss (West Karmøy Igneous Complex)
C.

i)

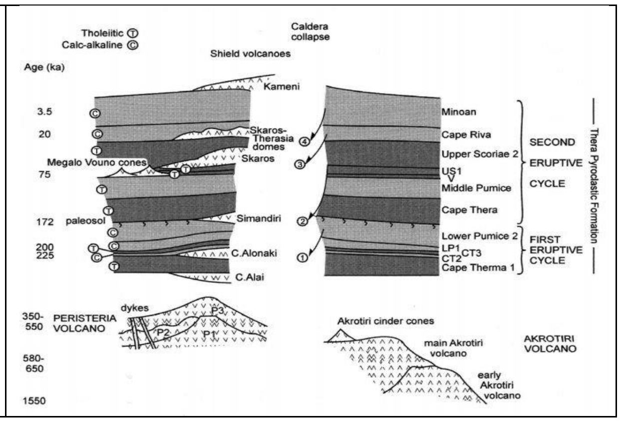


A5
A4
A3
A2
A1
Karmøy
Skudeneshavn
Bokn
Boknafjorden
Kvitsøy
Sandøya
Mosterøy
RM
RS
Randaberg
Mosterøy
Askjesundbrua
Sokn
Bru
Alstein
Tungeneset
Byfjorden
Byfjordtunnelen
Bru
RS
RM
Randaberg
Indre
Ytre
Bø
Grødem
Dusavika
Randaberg
Vistnes
Goa
Visteviga
Tasta
1000 m
Road
Fault
Sandstone (Skudeneset Group)
Conglomerate, Breccia (Skudeneset Group)
Volcanic rocks (unspecified) (Karmøy Axis Sequence)
Gabbro, Gneiss, Amphibolite (Karmøy Axis Sequence)
Chlorite-schist, Amphibolite (Karmøy Axis Sequence)
Wehrlite (Karmøy Axis Sequence)
Quartz-diorite, Tonalite (West Karmøy Igneous Complex)
Granite, Granodiorite (West Karmøy Igneous Complex)
Diorite, Granitic gneiss (West Karmøy Igneous Complex)
Metasandstone, Mica-schist (Ryfylke Phyllite)
Phyllite, Mica-schist (Ryfylke Phyllite)
Granite, Diorite, Granodiorite, Migmatite (Jæren Nappe)

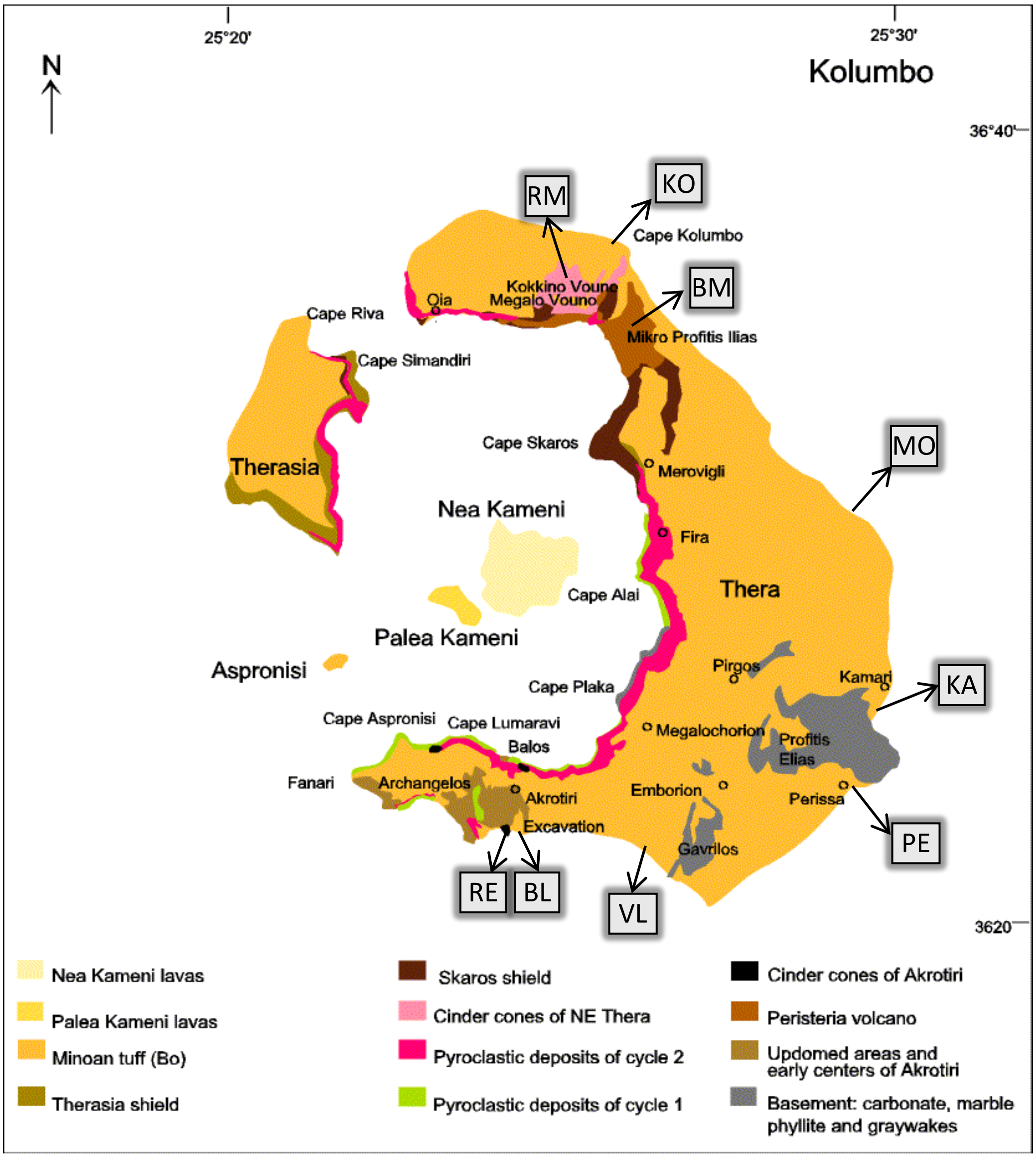

2)


Greece
Aegean Sea
Turkey
Sousaki
Methana
Milos
Santorini
Nisyros
100 km
38°N
36°N
24°E
26°E

A.


Tholeiitic
Calc-alkaline
Caldera collapse
Shield volcanoes
Age (ka)
Kameni
Minoan
Cape Riva
Upper Scoriae 2
US1
Middle Pumice
Cape Thera
Lower Pumice 2
LP1
CT3
CT2
Cape Therma 1
SECOND ERUPTIVE CYCLE
FIRST ERUPTIVE CYCLE
Thera Pyroclastic Formation
Skaros-Therasia domes
Skaros
Megalo Vouno cones
paleosol
Simandiri
C.Alonaki
C.Alai
3.5
20
75
172
200
225
350-550
580-650
1550
PERISTERIA VOLCANO
dykes
Akrotiri cinder cones
main Akrotiri volcano
early Akrotiri volcano
AKROTIRI VOLCANO

B.


25°20'
25°30'
N
Kolumbo
36°40'
RM
KO
Cape Kolumbo
BM
Kokkino Vouno
Megalo Vouno
Oia
Cape Riva
Mikro Profitis Ilias
Cape Simandiri
MO
Cape Skaros
Merovigli
Therasia
Nea Kameni
Fira
Cape Alai
Thera
Palea Kameni
Aspronisi
Pirgos
Cape Plaka
Kamari
KA
Cape Aspronisi
Cape Lumaravi
Megalochorion
Balos
Profitis Elias
Fanari
Archangelos
Akrotiri
Emborion
Perissa
Excavation
Gavrilos
PE
RE
BL
VL
3620
Nea Kameni lavas
Palea Kameni lavas
Minoan tuff (Bo)
Therasia shield
Skaros shield
Cinder cones of NE Thera
Pyroclastic deposits of cycle 2
Pyroclastic deposits of cycle 1
Cinder cones of Akrotiri
Peristeria volcano
Updomed areas and early centers of Akrotiri
Basement: carbonate, marble phyllite and graywakes

C.

3)