Analyses of thermal conductivity from mineral composition and analyses by use of Thermal Conductivity Scanner: A study of thermal properties in Scanian rock types

Thomas Andolfsson

Dissertations in Geology at Lund University,
Master's thesis, no 361
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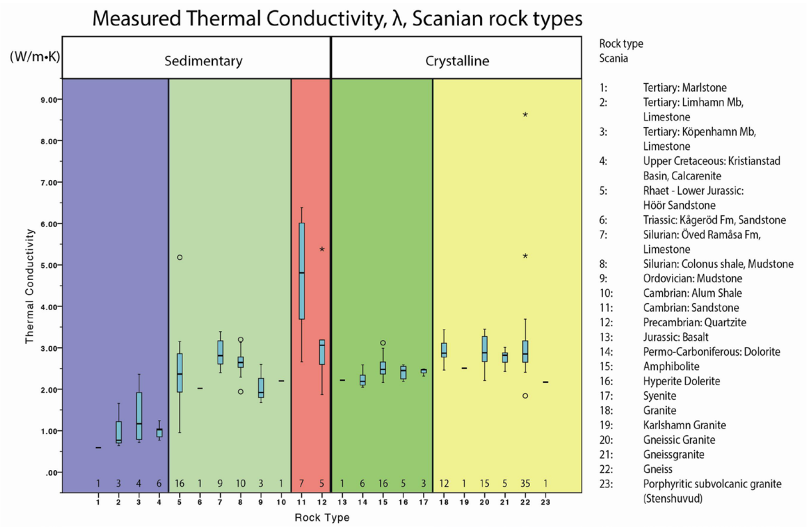

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Analyses of thermal conductivity from mineral composition and analyses by use of Thermal Conductivity Scanner

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Abstract: With an increase in demand for green energy the interest has grown in Geoenergy. The bedrock may function both as energy source and as energy storage, which makes it suitable for both heating and cooling. The thermal properties of the bedrock are essential when effectively planning and designing a geothermal energy well. This thesis focuses on research and study of the thermal properties of the Scanian bedrock, and on existing mineralogical data and samples accessible through Geological Survey of Sweden. Samples were chosen on the basis of the rock type and geographic location. Those rock units and areas that were not represented were sampled, if possible, during the summer of 2012. Sample preparation involved cutting them along several axes. Upon review of the results, they were then compared against the calculated values. The calculated values deviated slightly, but are considered representative for the thermal properties. The results show a grouping into 5 groups, 3 sedimentary and 2 crystalline. The amount of quartz content in the crystalline rock types defines the 2 different groups. High quartz content gives a conductivity of 3.0 W/mK, whereas the crystalline rock units that have a low quartz content, have a slightly lower thermal conductivity (2.5 W/m•k). The sedimentary rocks are divided by type and age. The youngest is limestone with a low thermal conductivity, 1 W/m•k. Following in age is a large span of rock types which have a midrange thermal conductivity around 3.0 W/m•k. The highest thermal conductivity, 6 W/m•k, are recorded in Cambrian quartzite and sandstone. With the database related to this project, makes it possible to develop an prognosis map of the thermal conductivity of Scanian rocks.

Keywords: Scania, Bedrock, Thermal conductivity, Geoenergy

Supervisors: Mikael Erlström, Leif Johansson

Subject: Bedrock Geology

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Analys av värmeledningsförmågan av den skånska berggrunden, genom mineralfördelningsdata och användandet av en TCS, Thermal Conductivity Scanner

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Sammanfattning: I ett ökat behov av grön energi, ökar även användadet av geoenergi. Berggrunden kan fungera som både energikälla och som energilager, vilket gör den passande för både värme- och kylanläggningar. Berggrundens termiska egenskaper är en av de viktigaste parametrarna vid planering av borrdjup och brunnsutformning för en optimal geotermisk anläggning. Detta mastersarbete innefattar en metodstudie och undersökning av olika bergarters termiska egenskaper. Arbetet utgår från befintliga mineralogiska data och prover från Skånes berggrund som finns tillgänglig via databaser vid Sveriges Geologiska Undersökning. Prover från databasen valdes efter typ och geografiskt läge. Kompletterande fältprovtagning genomfördes under sommaren 2012. Inför de termiska analyserna sågades proverna, beroende på lagring, skiktning etc. för att få plana ytor i olika riktningar. Resultaten av TCS analysen jämfördes mot beräknade teoretiska värden från mineralogiska analyser. Jämförelsen visade att de beräknade värdena är tillförlitliga vad avser värmeledningsförmågan på de skånska bergarterna. Resultaten visar på 5 olika värmeledningsgrupper, där 3 av dem är sedimentära och 2 kristallina. Kvartshalten i proven från de kristallina bergarterna påverkar tydligt värmeledningsförmågan. Hög kvartshalt ger en högre värmeledningsförmåga (3.0 W/m•K). De mindre kvartsrika ligger runt 2.5 W/m•K. Bland de sedimentära finns det tre grupper, en låg, 1 W/m•K, en mellan, 2.5 W/m•K, och en hög 6 W/m•K. Dessa grupper relaterar till ålder och bergart, där de mesozoiska och paleogena kalkstenarna har generellt låga värden, medan kambriska sandstenar och kvartsiter har de högsta värdena. Arbetet har resulterat i en stor mängd analysvärden och kunskap om den Skånska berggrundens värmeledande egenskaper som kan användas för att skapa prognoskartor över bergarternas värme-ledande egenskaper.

Nyckelord: Geoenergi, Geotermiska egenskaper, Skåne,

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1 Introduction

The worldwide energy consumption is rapidly growing. As to mitigate the climatic goals with decreasing emissions of greenhouse gases there has to be a significant component of renewable sources such as geothermal energy to comply this demand. Geothermal energy is a promising alternative and is a potential candidate to substitute conventional house heating alternatives. In Sweden, as well as in many of the Nordic countries, there has been a dramatic increase in the number of shallow geothermal wells used for heating.in 2008, Sweden had around 350 000 geothermal energy systems, roughly 9000 of them located in Scania. The total amount of energy produced from geothermal sources is roughly 12 TWh/y. To put this in perspective, this figure equals roughly to 10% of the total amount of the energy Sweden uses for heating purposes and is also comparable to two average nuclear reactors. In addition, if the households currently relying on electric heating would convert to geothermal energy, the need of electric power would be reduced by roughly 25 TWh/y. If a renewable source of energy, such as solar or hydropower, would run the geothermal energy pumps, the total energy reduction would be close to 30 TWh/y. This corresponds roughly to the energy that 5 average nuclear reactors produce.

The knowledge of the effective thermal conductivity has to increase as to achieve such an energy reduction. To achieve this goal, it is important to inform the public about the hidden geothermal potentials.

Shallow geothermal systems utilize heat that is absorbed from the sun and stored in the uppermost 200–500 m in the subsurface. The geothermal energy can be applied in various ways, either by active circulation of groundwater or by passive heat exchange systems in the soil and bedrock. Besides knowledge about the thickness of the Quaternary deposits, drillability of the rock and the groundwater conditions, it is essential to know the thermal properties of the rock as to assess drilling depth and thermal impacts in the surroundings of a geothermal system.

Estimation of the geothermal capacity in a specific rock block is difficult to assess due to mineralogical, structural and textural variations of the rock properties. The values used today are very general and commonly a geothermal system is based on a thermal conductivity around 3.0 W/m•K. However, as in Scania, with complicated bedrock geology, this value might be completely misleading resulting to either too deep or too shallow boreholes. More precise knowledge of the thermal properties is important as to be able to optimize the drilling operation, which is a major part of the costs of a geothermal system.

The need of information regarding the thermal properties of the Scanian rock types is essential as to make geothermal energy easier to optimize for the use of household heating. Thus, the aim of this project is to characterize the thermal properties of the various rock types in Scania. A second aim is to present a general prognosis map on a regional scale for the thermal properties of the bedrock types in Scania. This is the first step towards a more detailed description and presentation of the thermal properties that is undertaken by the Geological Survey of Sweden (SGU). Similar maps and guidelines for drilling depth for a standard 25 000 kWh/y heating, corresponding to the heating of a standard household, are present in e.g. Norway and Germany. In Germany there is regional thermal information on the soil and bedrock properties. In Norway there is a pilot project in the Oslo region focusing on the bedrock properties and drilling depth. That study is based on correlation of mineralogical and analytical data, in a similar fashion to what will be presented in this study.

The use of mineralogical data as an information source for the calculation of the thermal properties gives a possibility to achieve a better coverage and representation of data points. Data on the thermal conductivity of different Swedish rock types exists. However, the database is insufficient and incomplete; especially regarding information on sedimentary rocks such as those commonly found in Scania.

In Scania there is a large database of mineralogical analyses (n=827) performed during detailed bedrock mapping. Many of these rock samples are also accessible today from the SGU archive. As to be able to use this large database, the present study has performed a calibration of calculated values from these mineralogical analysis. This part of the work has been performed by the use of a Thermal Conductivity Scanner (TCS).

Another thing that makes Scania an interesting study area, beside the existence of a large database, is that it exhibits heterogeneous bedrock geology with a wide representation of various rock types. The heterogeneous geology, with its varying rock properties, creates local as well as regional differences in its geothermal potential. The region is also densely populated and there is great demand in accurate information about geothermal systems, including thermal properties.

1.1 Thermal properties

Thermal dynamics is a complicated science and the explanations presented below gives only a brief introduction and explanation to the terminology used in this study. For more detailed information see e.g. Sundén (2012).

It is important to understand what thermal conductivity (λ) really is. Thermal conductivity might be confusing as it is a value describing how well heat is conducted through a material, not how fast it passes through. The unit that describes how fast heat migrates through a material is called thermal diffusion (α).

Heat is a measure of how much the molecules in a material moves around. The thermal conductivity is the value of how well these vibrations are passed from one molecule to another. The definition of the coldest temperature, absolute zero, is when all mole-

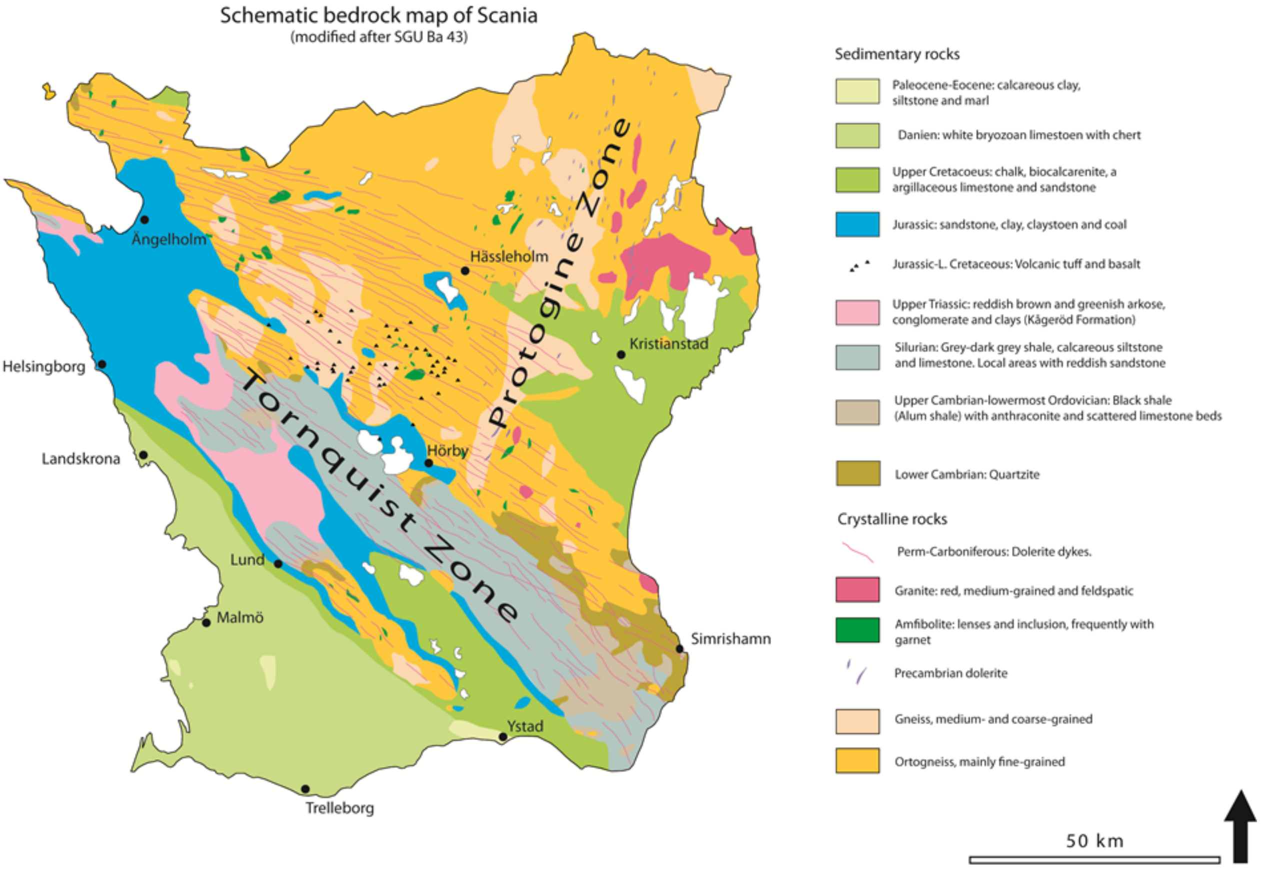


Figure 1. Schematic bedrock map of Scania (modified after SGU ser Ba 43)

cules in a material are stationary. Heat may be transported by vibrations or as transportation of electrons.

This means that there is a relation between the electric properties of a specific material and the thermal properties, i.e. thermal conductivity depends on the molecular arrangement and the amount of free electrons. This will give variable thermal conductivity in different directions of a heterogeneous material. In a mineral the molecular arrangement is the decisive factor. Similar in a strongly foliated rock (e.g. gneiss) it will have higher λ value parallel to the foliation, than perpendicular to it. In the case of an isotropic rock (e.g. granite), the value will be the same for any direction. In comparison, the thermal conductivity in metals is largely based on the ability to transport electrons.

Thermal diffusion on the other hand gives the actual value of how fast heat is transported. It is based on the thermal conductivity and the specific heat of the material. The definition of the specific heat is the amount of energy that is required to increase the temperature of a material, one degree Kelvin. The specific heat can be described as the willingness for the molecules and atoms of a material to start vibrate.

1.2 Overview of the investigated area

1.2.1 General description of the bedrock of Scania

An overview of the bedrock of Scania is given in SGU ser Ba 43 in the scale 1:250 000 (cf. fig 1). In addition, there are detailed bedrock maps with descriptions of Scania in SGU series Af, scale 1:50 000. The maps and associated descriptions have constituted the main source of information regarding composition and classification of the Scanian bedrock included in this study. Information on outcrops in the maps has been used for selection of reference sampling and complementary fieldwork.

The Scanian bedrock is represented by a wide variety of rock types, with sedimentary rocks constituting a significant part. Scania belongs to the southwestern part of the Fennoscandian Shield and has during Phanerozoic times acted as a transition zone between the stable shield area to the northeast and the more instable younger geological provinces to the south and southwest (Erlström et al., 1997). Due to these events, the Precambrian crystalline rocks are heavily fractured and weathered, which affects the thermal properties of these rocks.

The NW–SE trending Tornquist Zone, initiated during the Early Palaeozoic, is a significant tectonic zone in Scania which has been active during several periods. The latest activation during the Late Cretaceous Alpine orogeny resulted in a structural overprint of previous tectonic events. This, combined with a Permo-Carboniferous magmatic event, resulted in significant number of dolerite dykes in a characteristic pattern crossing Scania from the northwest to the southeast. These formed due to the intrusion of magma into cracks and faults that existed in the Scanian bedrock. According to (Erlström pers com), roughly 10% of the Scanian bedrock is composed of dolerite dykes.

Stretching from NNE to SSW is an older tectonic zone, the Protogine Zone. This zone splits the Precambrian into eastern and western parts. Banded gneiss dominates the western part while the eastern part includes more homogeneous gneiss and granite in various metamorphic stages. The Precambrian crystalline rocks constitute the bedrock in the central and north parts of Scania, while Phanerozoic sedimentary rocks of variable thickness are mainly found in other parts of Scania, especially in the southwest.

1.2.2 Sedimentary rocks

The sedimentary rocks in Scania are represented by a great variety of rock types with different properties, such as density, porosity, permeability and quartz content. The high variability in the properties allows for large difference in their thermal properties. The thickness of the sedimentary strata varies from a few meters to kilometers and covers the crystalline basement. The sedimentary strata are thickest in SW Scania and in the Colonus Shale Through (Larsson, 1984; Sivhed et al., 1999).

The majority of the Lower Palaeozoic rocks are composed of shaly lithologies, with the exception of the Lower Cambrian Hardeberga Sandstone, the Lower Ordovician Komstad Limstone and the Upper Silurian Övre Ramåsa Group with limestone and sandstone. The shale dominated strata constitutes the bedrock in a large area from SE Scania to the Söderåsen Ridge. This, more or less, corresponds to the extension of the Colonus Shale Through. There are also locations where the Palaeozoic strata underlies the Mesozoic deposits located in the Southwestern most parts of Scania, and in the Höganäs Basin, located in the NW (c.f. Larsson, 1984).

Due to intense erosion and continental environments, there are no strata from the uppermost Silurian to the Triassic preserved. The bedrock in large parts of NW Scania is from the Upper Triassic, such as the Kågeröd formation, which overlies Palaeozoic shale formations. (Norling et al., 1993). The 100–200 meter thick Kågeröd Formation is largely composed of arkose, with variably arenaceous clays and conglomerates.

The Jurassic deposits, in figure 1 displayed as blue, are composed of sequences of clay, sandstone, siltstone and coal. The petrophysical and mineralogy varies greatly as these different units frequently alternate and interbed each other. This provides highly variable prerequisites for the thermal properties. The Jurassic sandstone beds are mostly fine-grained, permeable and unconsolidated arenites. These are located in most of northwestern Scania, with the majority of the outcrops located in the Helsingborg area.

The Kristianstad Basin, southwest Scania and an area stretching NW from Ystad to Revinge (the Vomb Trough) is dominated by Upper Cretaceous and Paleogene limestone. In the SW, the bedrock is dominated by light grey, fine-grained biocalcarenite (Limhamn Member and Copenhagen Limestone), which have 10–40% of chert occurring as nodules and layers. This unit is in the range of 50–120 m thick and overlies a 1500 m thick carbonate sequence from the Upper Cretaceous period. The Vomb Formation, which is an up to 1000 m thick limestone sequence, found in the Vomb Trough is more quartz rich (Erlström et al., 1999). In the Kristianstad Basin the Upper Cretaceous bedrock is dominated by variably quartz rich biocalcarenite This Upper Cretaceous sequence is here up to c. 180 m thick (Nilsson, 1966).

1.2.3 Crystalline rocks

Various types of gneiss are the most common crystalline rock types in Scania. There are two main varieties, one fine-grained, mainly grey with faint foliation, located to the east of the Protogine Zone and a more foliated and banded variety to the west as a result of a higher degree of metamorphosis.

The gneiss dominated areas west of the Protogine Zone is also locally rich in amphibolites, which occur as irregular lenses, ribbons or as enclaves in the gneiss. These gneisses are considered as formed by metamorphic alteration of granites. Some, however, are likely of supracrustal origin (Wikman & Bergström, 1987). These supracrustal gneisses are distinguished as less banded and finer-grained than the granite derived equivalents. The Scanian gneisses have a quartz content of 15–30% and a plagioclase content of 25–45% (Wikman & Sivhed, 1992).

East of the Protogine Zone there are intrusive bodies of granite called Karlshamns granite. This reddish-grey granite is medium- to coarse-grained. Large alkali feldspar crystals with a matrix of quartz and plagioclase are the characteristics of Karlshamn granite. A significant amount of titanite is also typical. (Kornfält & Bergström, 1983)

Beside these main crystalline rock types there are dolerite dykes. These are of two generations, one Precambrian system located in the Protogine Zone, running along the strike of the zone, and another Permo-Carboniferous, running across Scania in a NW-SE direction. The NW-SE trending systems are characterized by a slightly higher silica content, up to a few percent quartz (Wikman et al., 1993).

2 Methods

The analytical work of this project is divided into three parts. The first part includes an inventory of available rock samples and rock data (mineralogical analyses) as well as identification of necessary complementary outcrops suitable for sampling. The second and main part involved sample preparation and collection of complementary samples in the field. The last part in-

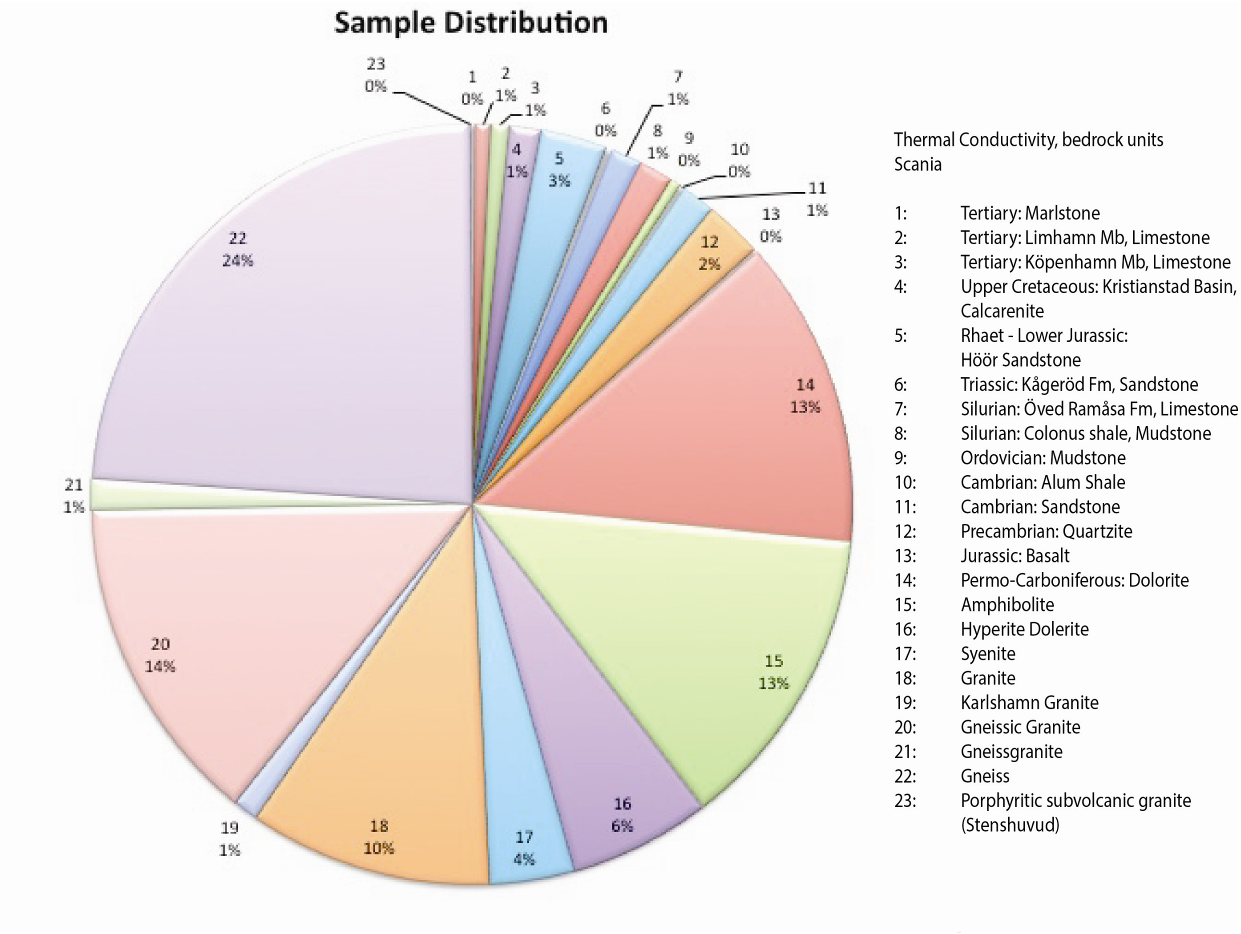


Figure 2. Circle diagram showing the distribution of the included rock types in the study.

volved analyses and laboratory works, as well as evaluation of the thermal properties based on both measured and calculated values.

2.1 Existing data on mineralogy

To create a geographic presentation of the thermal conductivity, as in all statistically based projects, a large amount of data is required. During the late half of the 20th century, SGU performed detailed bedrock mapping of Scania in the scale of 1:50 000. In connection to the bedrock mapping campaigns a large number of rock samples were analyzed regarding the mineralogical composition. These mineralogical analyses, so called modal analyses, as well as chemical investigations constitute the main database in this study.

A modal analysis is performed by a systematic microscopy investigation of thin sections. The mineralogy and classification of the rock is done by point counting. This method is highly dependent on the skills of the geologist performing the study and on the complexity of the mineralogy of the actual rock type. Most of the investigated crystalline rock samples from Scania does not show any complex mineralogy and are thus, dominated by variable amounts of quartz, feldspars and mica.

When comparing the 682 analyses in the existing database with information presented in the map descriptions (SGU series Af) it was found that there existed additional analyses that had to be manually included into the database. The final data set used, including the primary data from SGU and the added data, amounts to 827 analyses. These constitute the main database for the assessment of the thermal rock properties and measurements presented in this study. In total c. 40 minerals are identified in these rocks, however, individual analyses and rock types rarely include more than ten different minerals.

With the exception of the modal data, most of the data is associated with results from bulk chemical analyses. However, these data have not been used to any larger extent in this study. The locations of the individual modal analyses are given as X and Y coordinates in the Swedish national coordinate system, RT 90 2.5° gon W. The majority of these data represents investigations on Precambrian crystalline rocks from northern and central parts of Scania, with the exception of Romeleåsen.

It was also found that there was a discrepancy in some of the data regarding the total sum for each analysis presented in the existing data set of the 827 analyses. One or two minerals were frequently excluded, a problem since some of the excluded minerals may be important when calculating the λ-values. For

Figure 3. Photographs of different outcrop localities where complimentary samples were collected (Sample, Location name, N and E coordinates in SWEREF 99), **A**: TAN 20, Östra Sönnarslöv (6195150, 438221), **B**: TAN 8, Simrishamn (6158650, 457743), **C**: TAN 27, Sireköpinge (6200180, 374827), **D**: TAN 37, Västra Genastorp (6243486, 435454).Photos: T. Andolfsson.

example, the mineral kyanite was originally excluded from these data. Given that kvanite has a λ-value of 14 W/m•K and also is a mineral quite abundant in some samples, even a low amount of kyanite would significantly affect the λ-value of the rock type.

The modal data was used to theoretically calculate the thermal conductivity on each rock type. This was achieved by multiplying the thermal conductivity for each mineral with the mineral abundances and finally adding them up. The majority of the thermal conductivity values of the minerals were obtained from Sundberg et al. (1985). The thermal conductivity value on minerals not included in that report, e.g. kyanite, were taken from Clauser & Huenges (1995)

A schematic example: A rock with a mineral composition of 80% quartz and 20% clinopyroxene, will have the theoretically thermal conductivity of 7.0 W/m•K, based on a λ of 7.7 W/m•K for quartz and 4.3 W/m•K for clinopyroxene, i.e. 0.8x7.7+ 0.2x4.3= 7.0 W/m•K

2.2 Analytical work

The aim of this part of the study was to measure the thermal properties of a suite of rock samples by use of a Thermal Conductivity Scanner (TCS). The analyses were primarily performed on existing and saved rock samples, which also have been analyzed regarding the mineral composition, i.e. SGU modal database. The intention was to get a calibration and correlation of the modal data to actual measured data on the thermal properties on a selected number of rock samples and rock types. The establishment of a correlation factor between modal data and the thermal properties enables a better basis for the construction of a prognosis of the thermal properties in the bedrock. The used rock samples are stored at the Geological Survey in Lund. The samples were initially examined regarding primarily suitable size for a TCS analysis and rock type. A suitable sample must be at least 2x5x5 cm large for a reliable TCS analysis.

About 350 of the samples were large enough for the TCS. However, as it was not possible to measure all in this study, a second selection of 171 representative samples was done. A good geographical distribution of the selected samples was sought. Therefore, additional sampling had to be performed to cover poorly represented areas and rock types. Most of the additional sampling was performed on sedimentary rocks. As modal analyses does not exist on these it was important to get a good data from the measured TCS values. A problem with the sedimentary rocks is the fact that they are often poorly consolidated, which makes it hard to get samples that hold together and that are large enough for the TCS.

The sampling was performed during one week in July 2012. The selected localities, quarries, outcrops, road cuts and boulders were chosen from the bedrock maps of Scania. Field notes taken included information on rock unit on the map, identified rock unit, GPS Coordinates (RT90), strike & dip (if applicable) and sample location on the outcrop. A picture was also taken at each locality. A total of 55 comple-

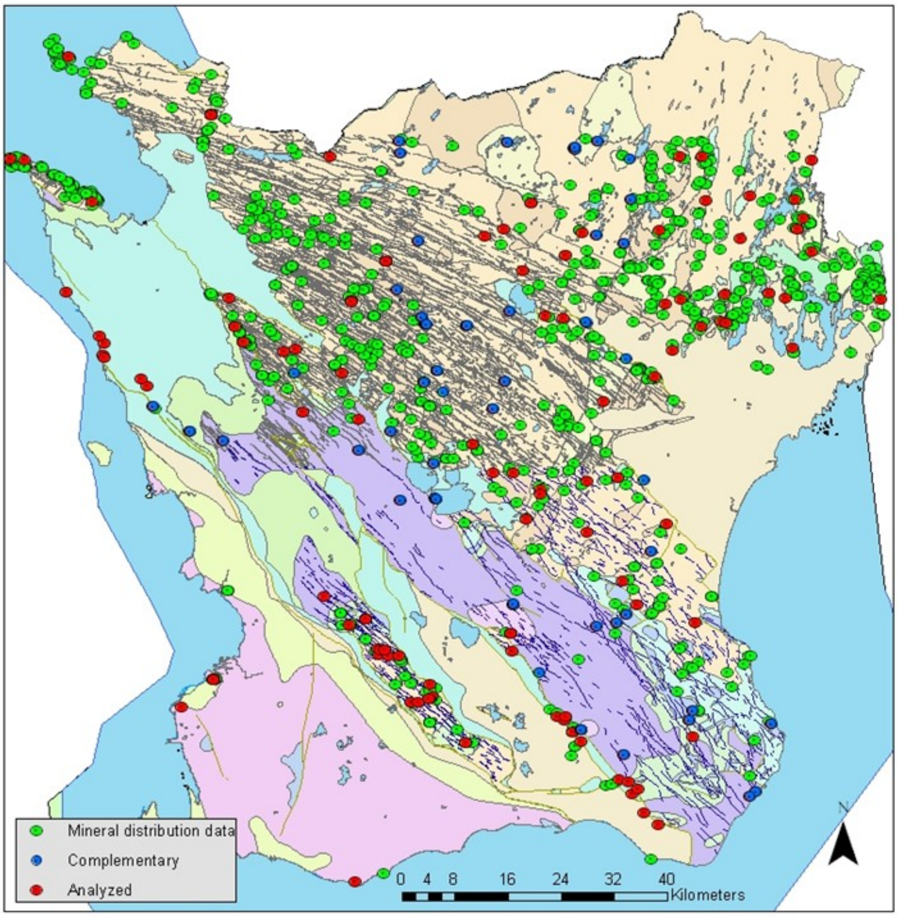


Figure 4. Schematic map of Scania showing the location of samples where the thermal conductivities were measured using the TCS equipment (red and blue). Red dots constitute archived rock samples at SGU with modal data and blue dots represent complimentary samples collected in this study. The green dots represent archived samples at SGU where the thermal conductivity has been calculated from the modal data. A larger version is presented in appendix II.

mentary samples were collected in the field. Some additional core material on sedimentary rocks was also collected from the archives at the Geological Survey.

All together the selected samples from the archive at SGU and field sampling for the TCS measurement amounted to 185 samples.

2.3 Sample preparation

The TSC analysis does not require a lot of sample preparation. It is, however, most important that the sample is big enough, at least 2 cm thick, and has a planar smooth surface, >5 cm in diameter, on which the measurement is performed.

The primary sample preparation involved reducing oversized samples and making a planar smooth surface with a rock saw. For many of the samples taken from the SGU archive there was already a smooth surface because the samples had been sawed for preparation of thin sections. Thus, this enables a good correlation between the measured thermal properties and the mineral composition in the thin section as it measures the same sample. The sedimentary rock samples were often sawed in two or three directions, depending on their stratification. This was done to measure if there were significant directional variations in the thermal properties related to the stratification. The drill cores were also prepared with a parallel and one perpendicular cut to the drill axis.

The flat surfaces on the samples were coated with a black acrylic paint. This was done as to get the same color based conditions for absorbing the heat from the TSC heat source. The painted area was at least 2 cm wide covering the analyzed surface.

2.4 TCS measurements

The analysis was performed on the TCS equipment at the Geological Survey in Uppsala. The scanner consists of a platform with a cm-wide slot. The thermal scanner unit is located below the platform and operates along the slot. The scanner unit consists of three aligned units; a cold temperature sensor, a heat source, and a hot temperature sensor. The used TCS model also has an extra sensor in the hot temperature unit, located on the side, 7 mm from the regular three units.

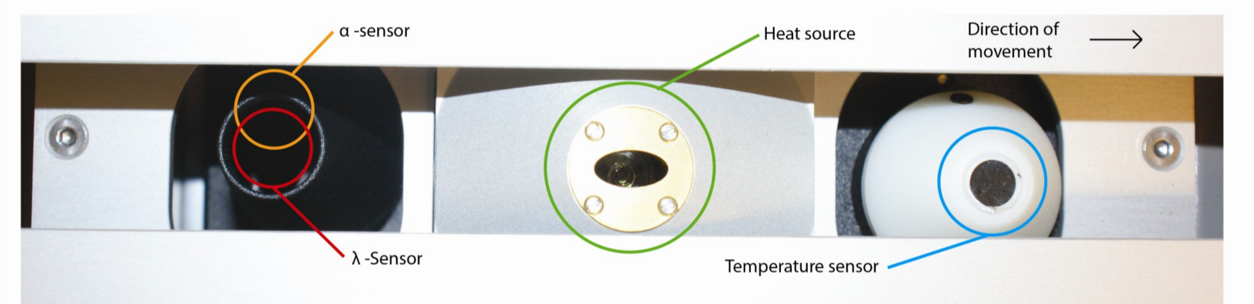


Figure 5. Photograph of the TCS sensor set up (vertical view from the top). From the right is following order to the left; a temperature sensor, (which measures the temperature of the sample before it gets exposed to the heat source), followed by the heat source, (which is adjustable accordingly to the type of sample that is analyzed). To the left are two temperature sensors that measure the thermal conductivity, λ, thermal diffusivity, α. Photo: T. Andolfsson.

Figure 6. Photo of a drill core sample prepared for measurement in the Thermal Conductivity Scanner. The surfaces which are to be analyzed are planar cut and painted black. Photo: T. Andolfsson.

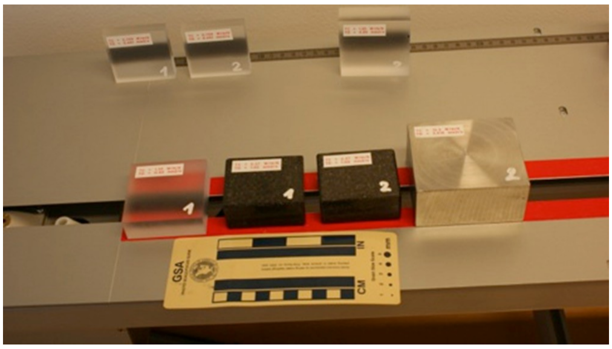


Figure 7. Photograph showing the set up during calibration performed before and after the measurement. The calibration here is using two sets of standards positioned over the measuring track visualized in figure 5. Photo: T. Andolfsson.

With this extra sensor, it is possible to also measure the thermal diffusion (α) of the sample. (c.f. Fig 5).

All measurements were calibrated against different standard materials, provided by the manufacturer of the instrument, with known thermal properties. (c.f. table 1). A main calibration of the instrument was performed at the start and end of each session. This calibration involved measurement of glass, gabbro and titanium standards. In addition, a second calibration was in addition performed in the beginning of each analysis. This involved individual calibration of the three temperature sensors, T (cold), T (hot) and T (diffusion), against each other. (c.f. Fig 5). It was performed by placing the first standard in the order over the sensors, and run for a few seconds.

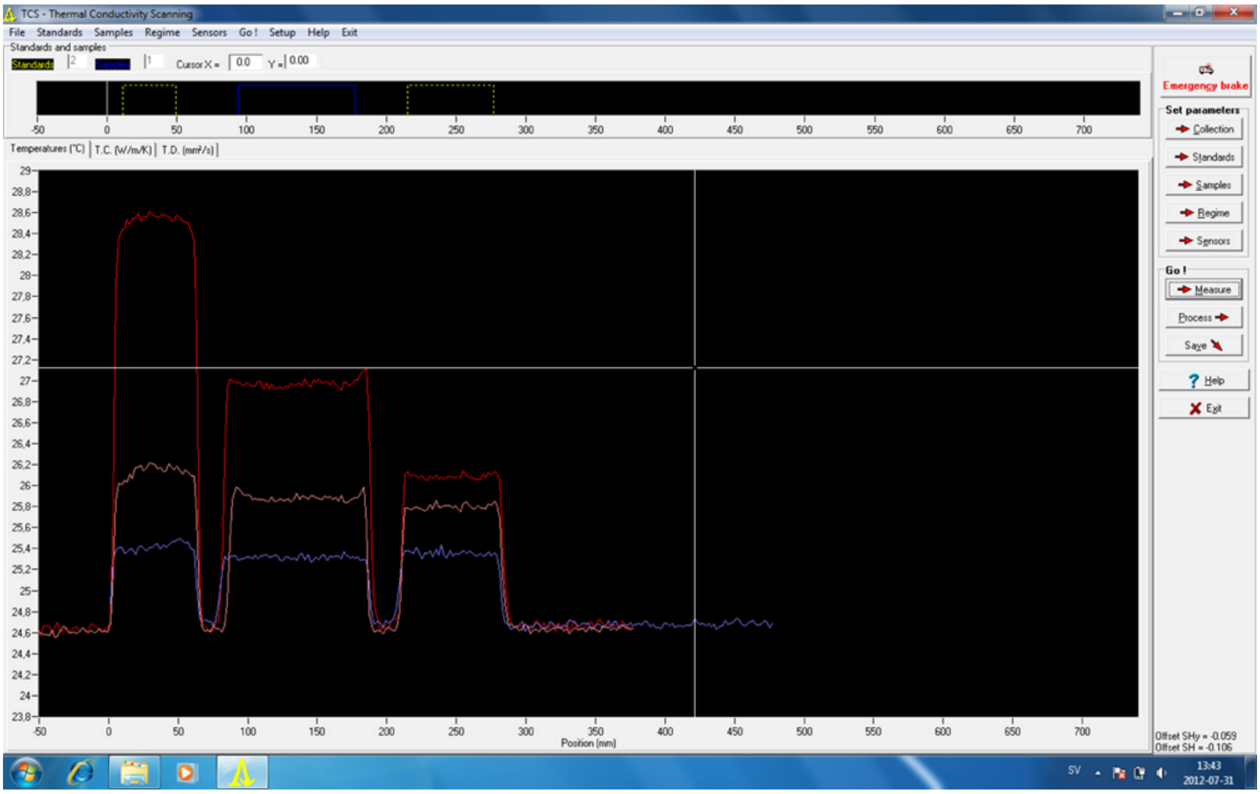
When using the standards, there are two alternative ways of using them. The first approach includes one standard material that is used in the beginning and at the end of the analysis. (c.f. fig 7). This setup is best suited for the basic analysis of the thermal conductivity. If the measurement includes the thermal diffusion, two different standard materials have to be used. When only analyzing the thermal conductivity a standard composed of gabbro can be used for most igneous and magmatic rock types with an expected λ-value between 2.5 and 4. However, in this study the analysis also involved measurement of the thermal diffusivity, which mean that there were two different standards used, glass with a low α value and titanium alloy with a high α value.(c.f. table 1). A few samples had, however, thermal properties that were higher than the used standards, which meant that a standard pair of steel and titanium alloy was used instead. For samples with low values two different glass standards were used.

Standard	**λ (W/m/K)**	**α (mm^2/s)**
Thin Glass	0.709	0.401
Thick Glass	1.35	0.85
Gabbro	2.37	1.02
Titanium alloy	5.94	2.685
Steel alloy	13.3	3.619

Table 1. Standards that is used together with the TCS.

The thermal scanner can work on with several samples along the 90 cm long measuring track. When working with several samples, each is placed over the slot with a big enough space in between. The space will be displayed as a distinct anomaly in the reading of the measurement, which makes it possible to separate the results from each other.

The measurements are displayed graphically (c.f. fig 8). For a homogeneous sample there will be three distinct temperature levels representing the two



TCS - Thermal Conductivity Scanning

Standards and samples

Standards 2 Samples 1 Cursor X = 0.0 Y = 0.00

Offset SHy = -0.059
Offset SH = -0.106

Figure 8. Example of a screen display of the curves from a TCS measurement. The red curve represents reading from the thermal conductivity sensor, the orange curve the readings from the thermal diffusion sensor and the cold temperature of the sample is represented by the blue curve. The three plateaus represent the sample set up with two standards and the rock to be measured in the middle.

standards in the beginning and the end and the rock sample in the middle. If the rock sample has a foliated and laminated texture or patchy mineral distribution the plateaus will be more irregular and then an average value has to be defined manually. The software gives a suggestion based on max/min and median values.

Three temperature curves are displayed for each sample. The blue curve shows the cold temperature that measures the sample temperature before the heat source, orange curve gives the hot temperature that is located (7 mm) to the side of the measuring track, and the red curve for the hot temperature sensor.

The thermal conductivity is calculated using the temperature difference between the red and blue curves. The thermal diffusion is determined by the thermal conductivity and a time factor, i.e. the time between heating and measurement. All data is saved as separate files that enable reinterpretation. The TCS software performs all the calculations based on chosen plateaus and intervals on the analyzed sample. The calculation of the conductivity and diffusivity is based on marked intervals corresponding to standard 1, sample/s and standard 2. When choosing these intervals, it is important that the used data are related to plateaus, so the magnitude of the data is as linear as possible. Data with a high level of "noise" was only used unless it was the only sample.

As the software runs calculations on these intervals, it also reports various types of information of the analysis. This is included in the data report file, which contains columns with the max/min and the mean of calculated thermal conductivity (λ) and diffusivity (α). Other data that is reported is homogeneity (calculated as max-min/mean) and standard deviation (G). There is an option to add other type of data, such as orientation, shape of measured object, wet or dry.

With the exception a few sandstone samples all the analyses were performed on dry rock samples. A couple of sandstone samples were, however, analyzed both in dry and water saturated conditions. This was done to see the effect on thermal properties in a saturated porous rock.

Table 2. Summary of median values of thermal conductivity and diffusivity on the investigated rock types in Scania. Data in the combined column refers to both measured and calculated values. Full statistics are located in appendix I.

ID Number	Rock Type	Measured λ Median Value (W/m•K)	Min-Max λ (W/m•K)	Measured α Median Value (mm^2/s)	Min-Max α (mm^2/s)	Calculated λ Median Value (W/m•K)	Min-Max λ (W/m•K)
1	Tertiary: Marlstone	0.59 (N=1)	-	0.39 (N=1)	-	-	-
2	Tertiary: Limhamn Mb, Limestone	0.77 (N=3)	0.64-1.66	0.52 (N=3)	0.51-1.39	-	-
3	Tertiary: Köpenhamn Mb, Limestone	1.17 (N=4)	0.72-2.36	0.83 (N=4)	0.53-1.13	-	-
4	Upper Cretaceous: Kristianstad Basin, Calcarenite	1.02 (N=6)	0.77-1.24	0.66 (N=6)	0.57-0.91	-	-
5	Rhaet - Lower Jurassic: Höör Sandstone.	2.37 (N=16)	0.95-5.18	1.31 (N=15)	0.46-2.00	-	-
6	Triassic: Kågeröd Fm, Sandstone	2.02 (N=1)	-	0.96 (N=1)	-	-	-
7	Silurian: Öved Ramsåsa Fm, Limestone	2.81 (N=9)	2.40-3.39	1.20 (N=8)	1.12-1.59	-	-
8	Silurian: Colonus shale, Mudstone	2.65 (N=10)	1.94-3.20	1.29 (N=9)	0.94-1.54	-	-
9	Ordovician: Mudstone	1.92 (N=3)	1.68-2.60	1.11 (N=3)	1.04-1.19	-	-
10	Cambrian: Alun Shale	2.20 (N=1)	-	0.98 (N=1)	-	-	-
11	Cambrian: Sandstone	4.81 (N=7)	2.66-6.38	2.63 (N=7)	1.13-3.85	6.84 (N=10)	6.44-7.58
12	Precambrian: Quartzite	3.06 (N=5)	1.87-5.38	1.65 (N=4)	1.08-2.10	6.04 (N=21)	4.15-7.68
13	Jurassic: Basalt	2.22 (N=1)	-	0.93 (N=1)	-	-	-
14	Permian-Carboniferous: Dolerite	2.19 (N=6)	2.05-2.59	0.96 (N=5)	0.94-1.03	2.19 (N=108)	1.76-2.74
15	Amphibolite	2.48 (N=15)	2.16-3.12	1.08 (N=13)	0.96-1.33	2.41 (N=111)	1.40-3.22
16	Hyperite Dolerite	2.45 (N=5)	2.19-2.59	1.01 (N=5)	0.97-1.06	2.10 (N=63)	1.45-2.80
17	Syenite	2.47 (N=3)	2.32-2.49	1.13 (N=3)	1.05-1.31	2.24 (N=32)	1.97-2.81
18	Granite	2.87 (N=12)	2.46-3.44	1.34 (N=12)	1.22-1.87	2.83 (N=88)	2.24-3.52
19	Karlshamn Granite	2.51 (N=1)	-	1.20 (N=1)	-	2.81 (N=10)	2.22-2.95
20	Gneissic Granite	2.88 (N=15)	2.21-3.45	1.31 (N=14)	1.06-1.65	2.69 (N=116)	1.96-3.29
21	Gneissgranite	2.82 (N=5)	2.43-3.01	1.33 (N=5)	1.16-1.37	2.79 (N=9)	2.53-7.21
22	Gneiss	2.85 (N=35)	1.84-8.63	1.35 (N=34)	0.94-6.80	2.79 (N=202)	1.96-8.45
23	Porphyritic subvolcanic granite (Stenshuvud)	2.17 (N=1)	-	0.92 (N=1)	-	2.67 (N=55)	1.79-5.45

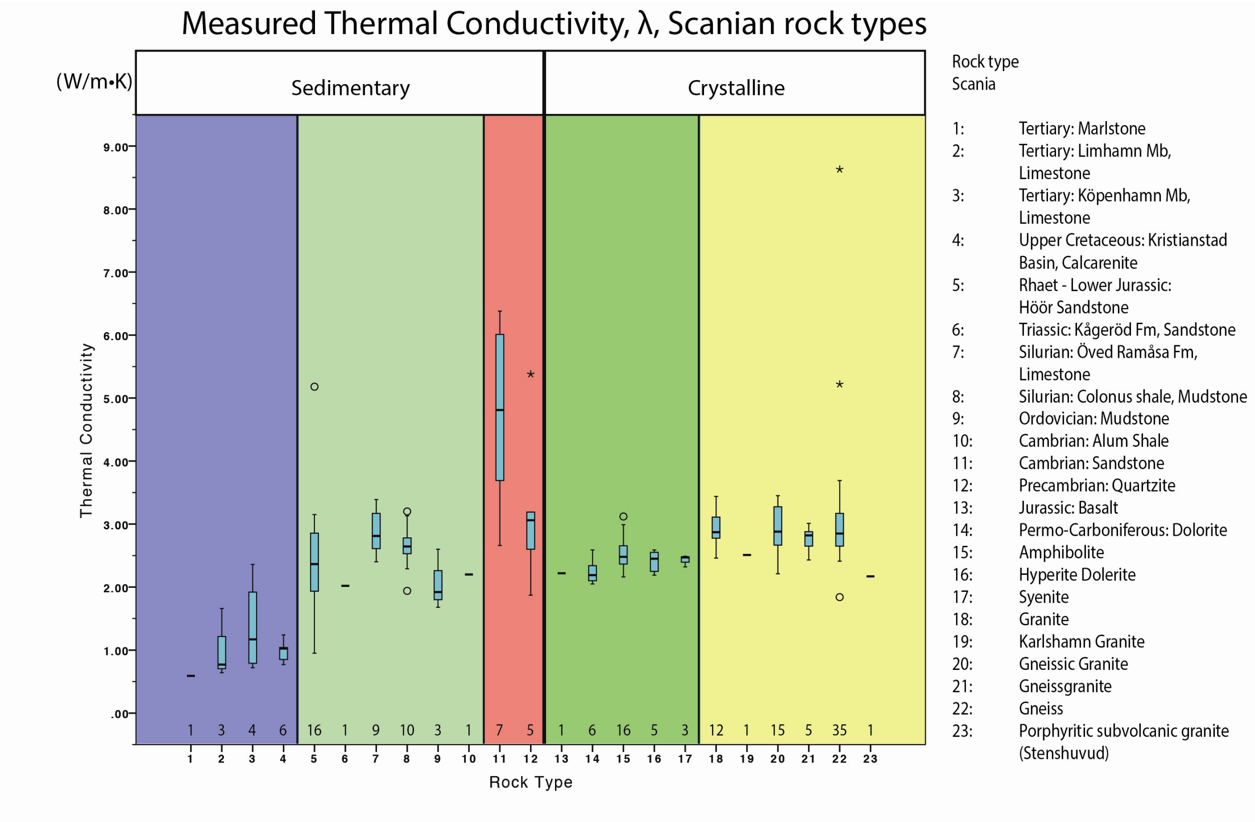


Figure 9a

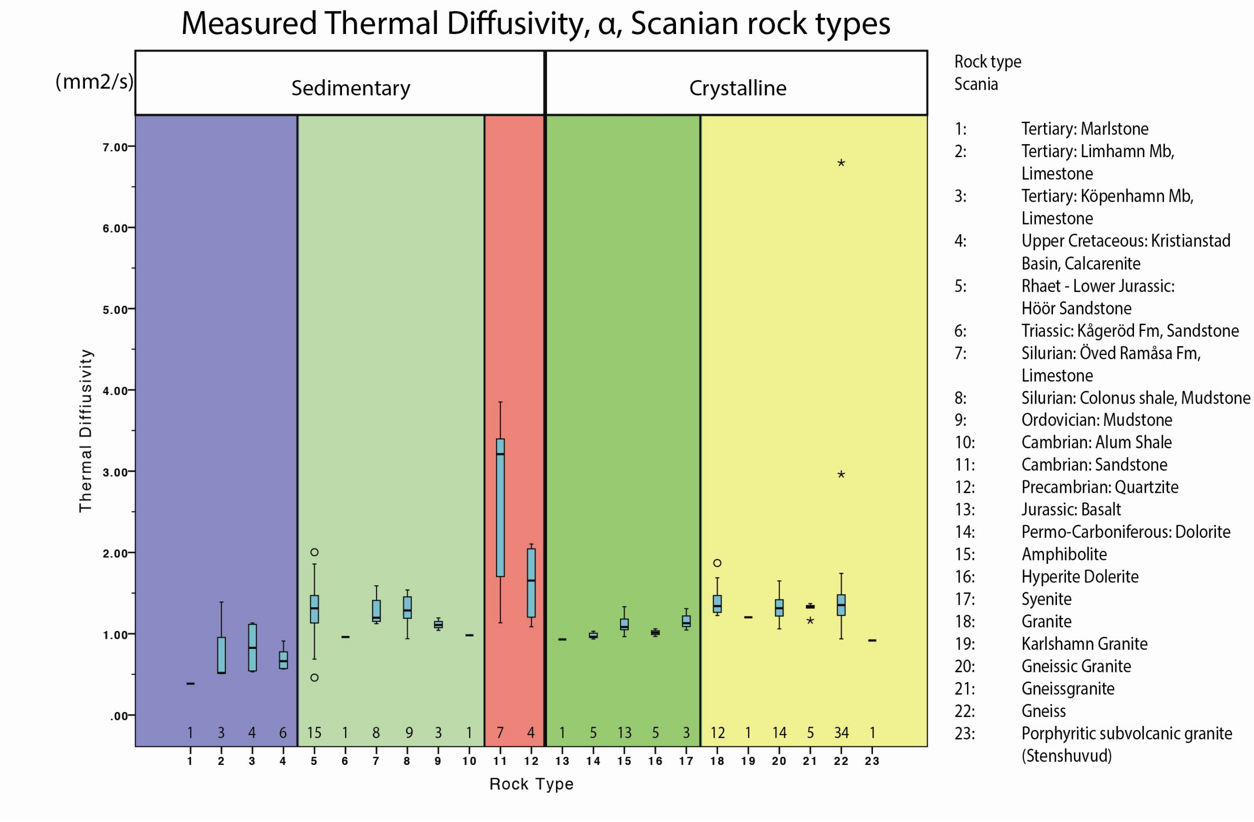


Figure 9b

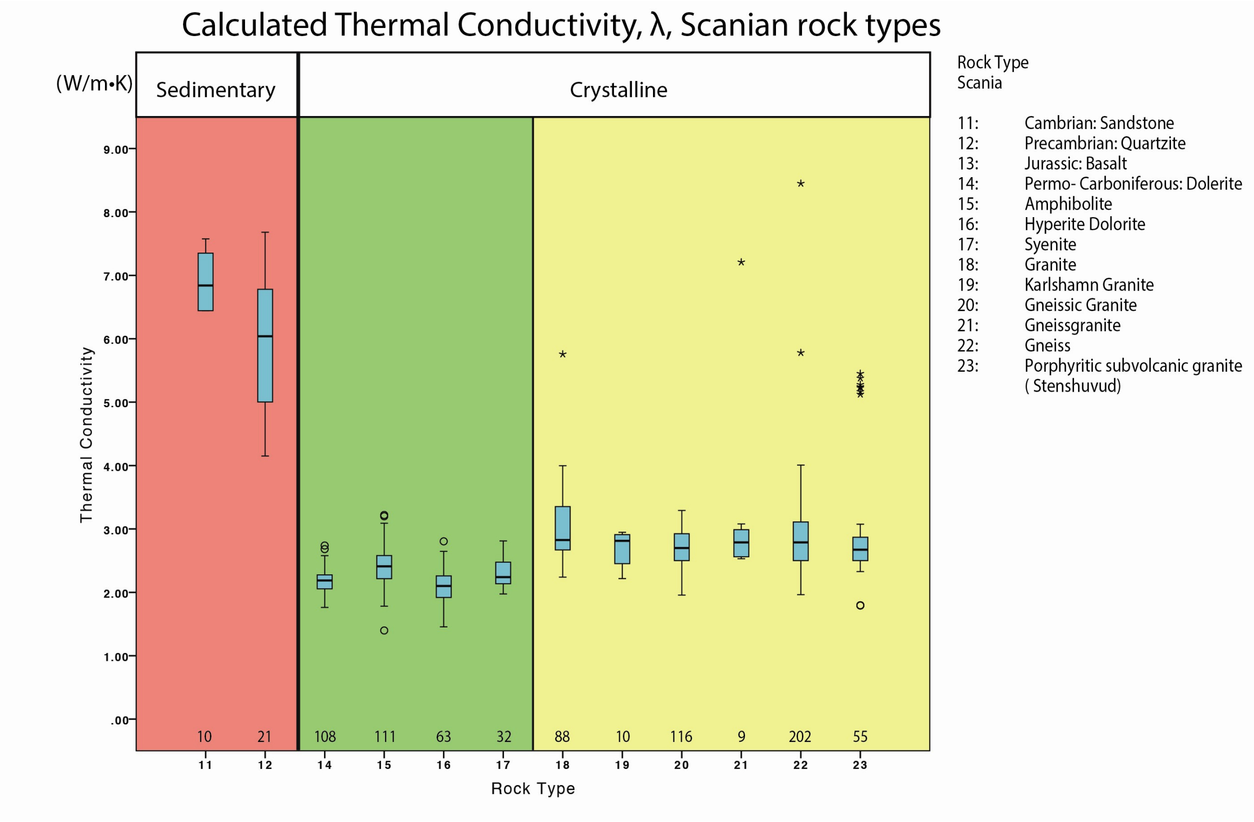


Figure 9c

Figure 9a-c. Boxplots showing the results of the TCS measurements and calculations of the thermal conductivity (λ), a/c, and the calculated values, b. The diagram is split into sedimentary rocks to the left and crystalline rocks to the right. Above the rock type is the number of values. The boxes are showing max, 1st quarter, median, 3rd quarter, minimum. The colored backgrounds seperate the units into 5 groups, 3 sedimentary and 2 crystalline. Boxplots are plotted with SPSS, IBM. Version 2.0 for Mac.

3 Results

3.1 Measured vs. calculated values on thermal conductivity

The results from the TCS measurements on 185 samples gave a data set with a wide range of values on the thermal conductivity. These TCS measurements of the thermal conductivity (λ) and the thermal diffusion (α) are presented in box diagrams (figs. 9a-c). The display of values in the diagrams shows that there is a relation between the two parameters. A high value of thermal conductivity is most commonly accompanied by a high value on the thermal diffusion.

When comparing the different rock types, the youngest sedimentary (groups 1–4) have the lowest λ-values. Some of the Mesozoic limestone samples display values around 1.0 W/m•K as they do not contain any quartz. However, Cretaceous and Paleogene limestone with chert have significantly higher values because of their chert content. The limestone is a poor thermal conductor, as it is porous, and consists of poorly heat conducting minerals and as many other rocks, they are poorly consolidated with high porosity and poorly developed grain boundaries.

Looking at the slightly older rocks, rock type group 5–10 (Fig. 9a), there is a slightly greater range of values. These range from 1.92–2.81 W/m•K as expected since they represent a wide variety of sandstones, shales and claystones. By default sedimentary rocks will have a greater spread in the thermal conductivity, compared to an large crystalline body, as well as deposition origin. Local diagenetic alterations due to tectonic events can also result in a variation in heat properties.

The next group of rock types, 11 and 12, are Cambrian sandstones and Precambrian quartzite . Samples of the Cambrian sandstone display some of the highest measured values in this study, >6.00 W/m•K. The Precambrian quartzite samples don’t have as high values, which might be caused by a significant mount of mica in the rock..

Measurements were made on several different axes of the drill core samples, two parallel to bedding and one perpendicular. The parallel were perpendicular to each other, but there was no geographic direction marked on the core samples. The results were inconclusive, mostly as only a few were core samples. There was a trend of slightly lower thermal conductivity perpendicular to the bedding, though an average of all

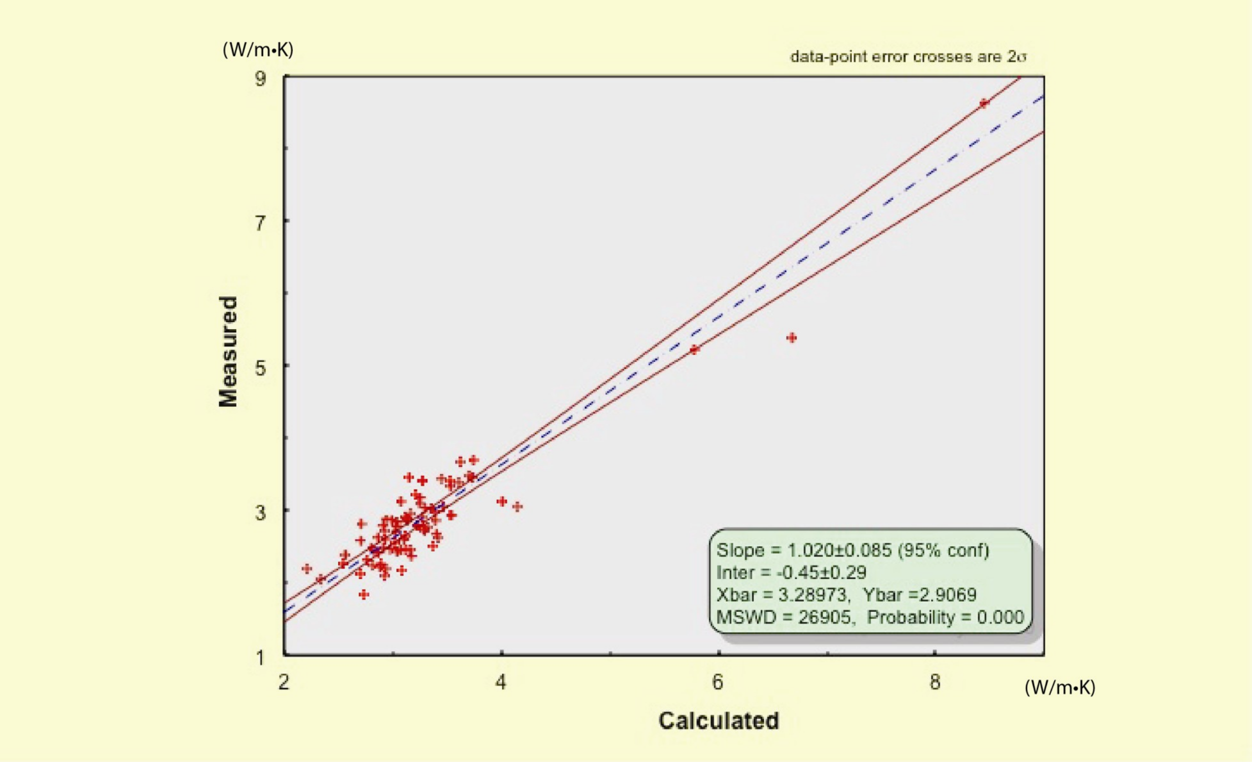


Figure 10. A correlation of the 95 percentile of the samples between calculated and measured. An best fit line is drawn for all different cases of 95% of the values. The red lines outlines the max and min, while the dashed is the average best fitted line.

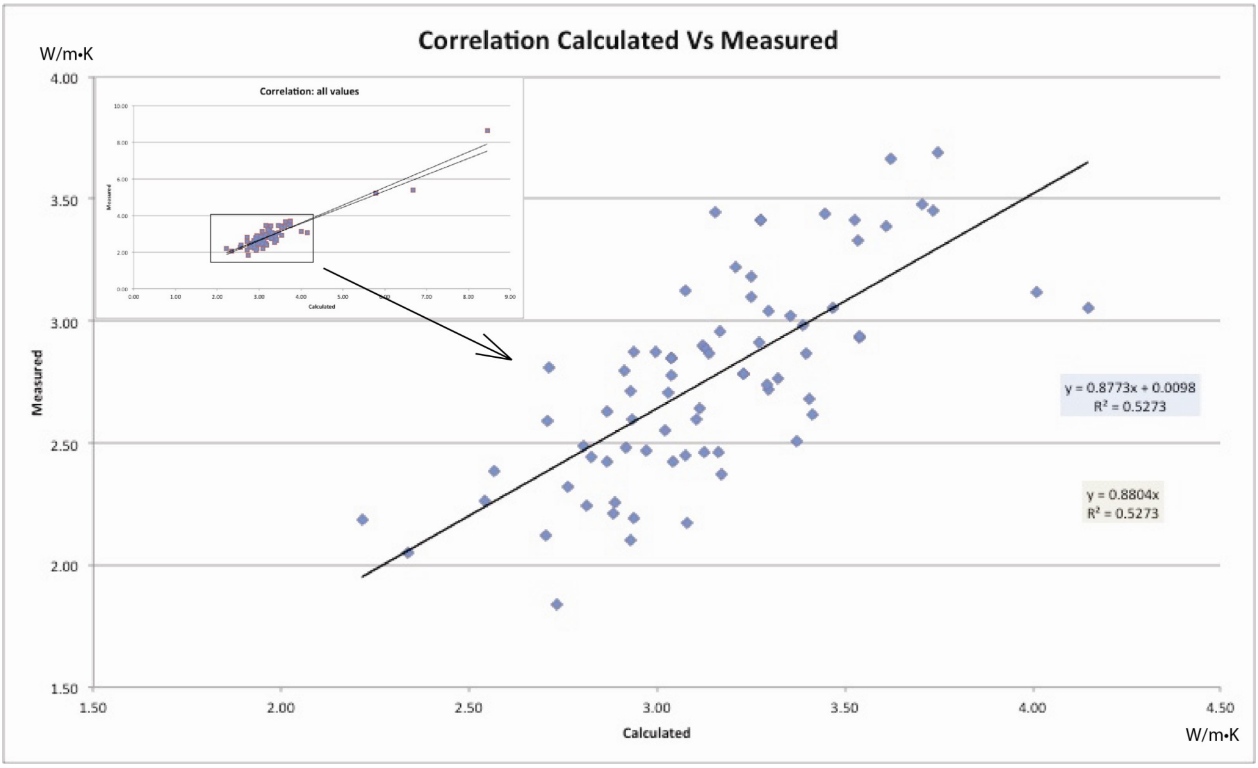


Figure 11. This is a similar correlation, as seen in fig 10, but with only values located in the cluster. A perfect correlation would be if the line has a slope of 1, and intercepts the Y axis at origo. the different equations is for a fully floating best fit line, and one that is forced to intercept at 0. As the floating is close to the fixed, it looks like just one line.

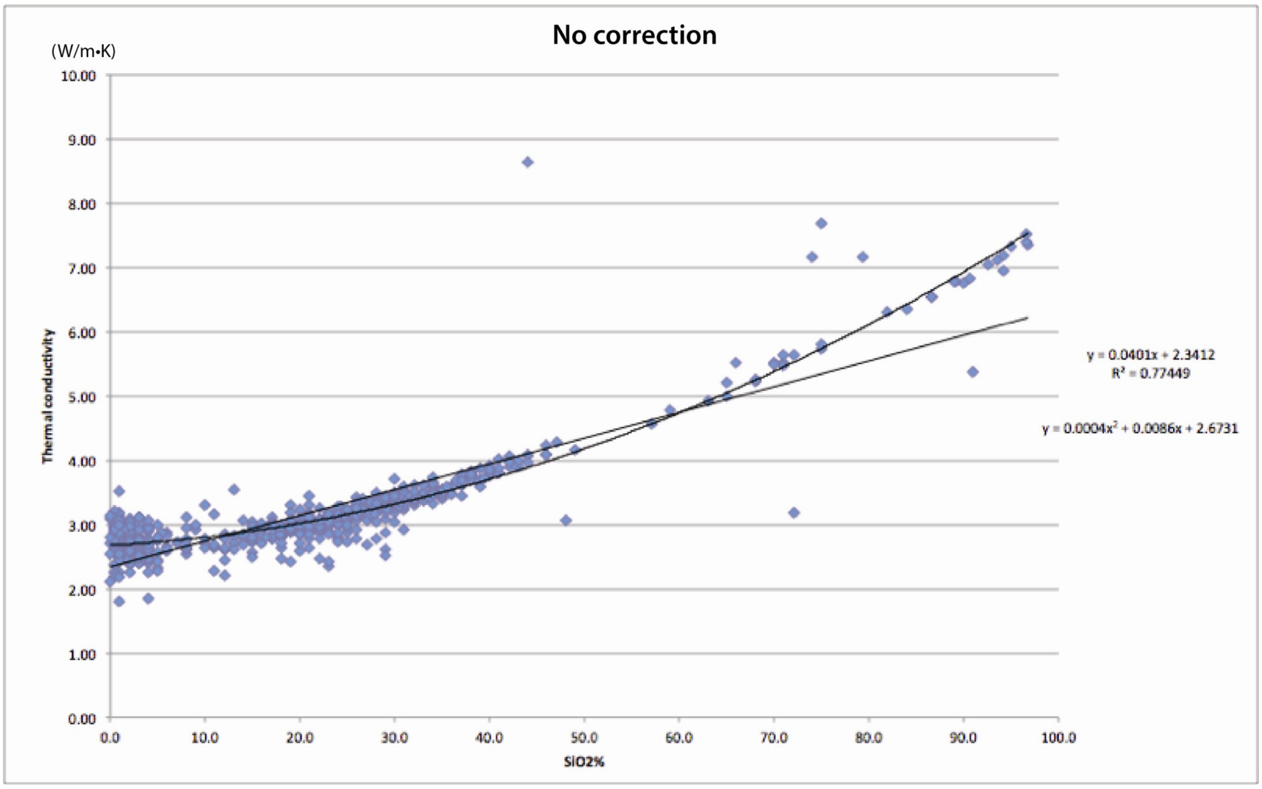


Figure 12. This shows a correlation between quartz content and thermal conductivity. Quartz is the most common mineral in a rock and has the highest thermal conductivity. This can be used to loosely calculate the thermal conductivity from the quartz content. This is based on the λ of both analyzed and calculated values.

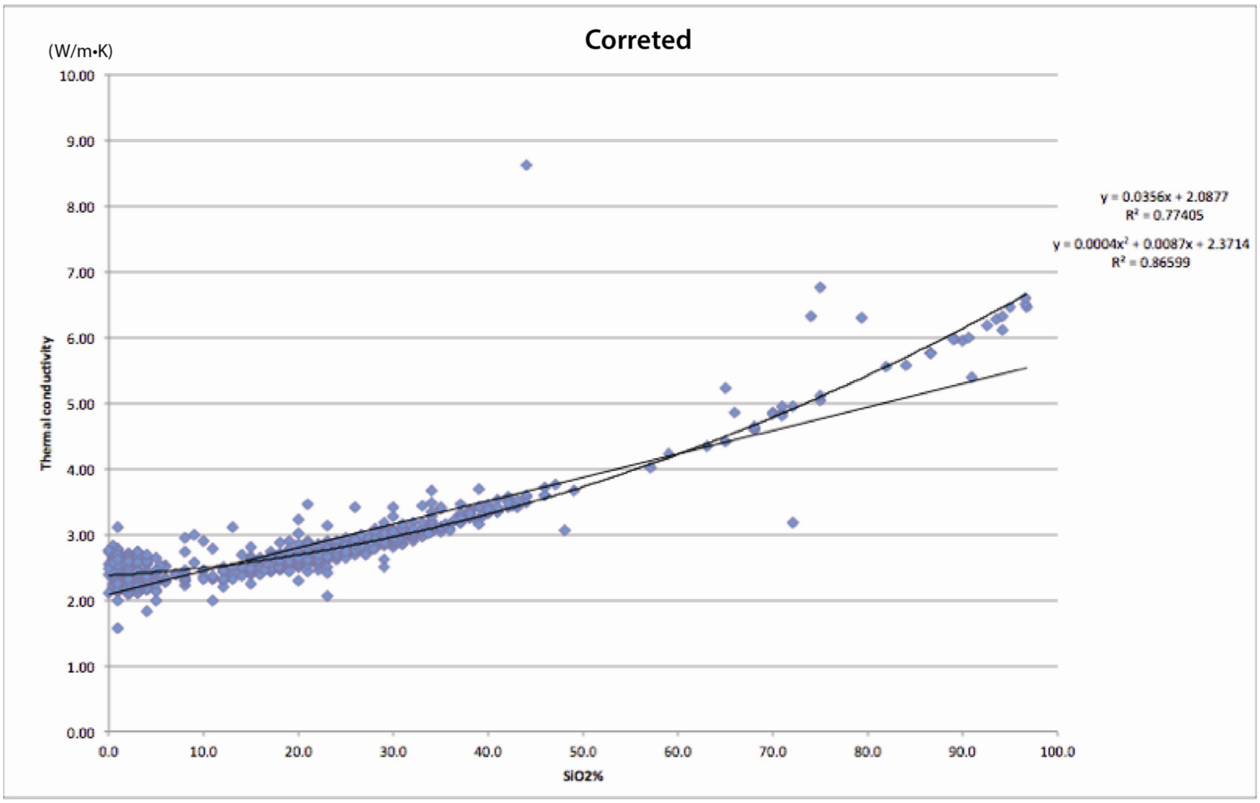


Figure 13. In a similar fashion as figure 12, though here with the calculated values are corrected by using a correlation factor found in the correlation in fig 11. Notice that the grouping is slightly tighter.

different directions were made for those samples as there was a larger difference within units.

The crystalline rocks tend to have a narrower span in values compared to the sedimentary. There is a clear grouping, which can be described by the quartz content; Quartz poor, rock types 13–17, and quartz rich, rock type 18–23. Due to the lower quartz content, the quartz poor units tend to have a lower thermal conductivity, around 2.5 W/m•K, compared to the quartz rich units.

The second crystalline group, rock type 18–23, does not only have a higher thermal conductivity but represent the most common value for Scanina rock-types. Different types of gneisses and granites represent this group. These do have a higher value than the quartz poor, just below 3.0 W/m•K.

Few values are extremely high in some of the rock types. This is due to local abnormal mineral composition. In, some of these cases, an occurrence of kyanite has raised the value. It has a really high thermal conductivity, 14 W/m•K, and a small amount can significantly increase the λ of the rock.

When it comes to thermal diffusion there was no theoretical database, so all the diffusion data was obtained from TCS measurements. This means that the amount of data is limited and is somewhat unreliable. The results follow a similar pattern to the thermal conductivity, with a diffusion value (mm^2/s) that is roughly half of the conductivity. The exception is the young tertiary limestone which has a significantly higher thermal diffusion rate that the rest of the tested rock types.

The relationship between the thermal conductivity and the amount of quartz in a rock follows an exponential trend, cf. figures 12 & 13.

When the relationship is known a rough estimation of the thermal conductivity can be calculated from the quartz content. This means that if the mineralogy is known in a rock the thermal conductivity can be estimated.

4 Discussion

The practical use of the values on the thermal conductivity and thermal diffusion of the bedrock is not a straightforward procedure. One has to remember that the presented results here describe the thermal properties on individual rock samples representing typical rock types in Scania. When transferring these results to a geothermal borehole it is important to also consider many other parameters in the subsurface such as bedding, layering, porosity, groundwater conditions, relative occurrence of different rock types etc. Below follows some considerations regarding these use of the thermal properties of rock.

4.1 Application of thermal conductivity and diffusivity

Thermal conductivity (λ) is the most important parameter when planning a small-scale geothermal energy plant, such as one for residential use. With a uniform subsurface geology the thermal conductivity largely controls the drilling depth for a standard well. The measured range of λ values on rock types in Scania (0.7–6.3 W/m•K) give quite different required drilling depths for the same energy output. This could result in a difference in drilling depth, between 90 and 210 m depending on the thermal conductivity values presented in figure 14. Thus, there is a strong economic reason for optimizing the drilling, as it is a large part of

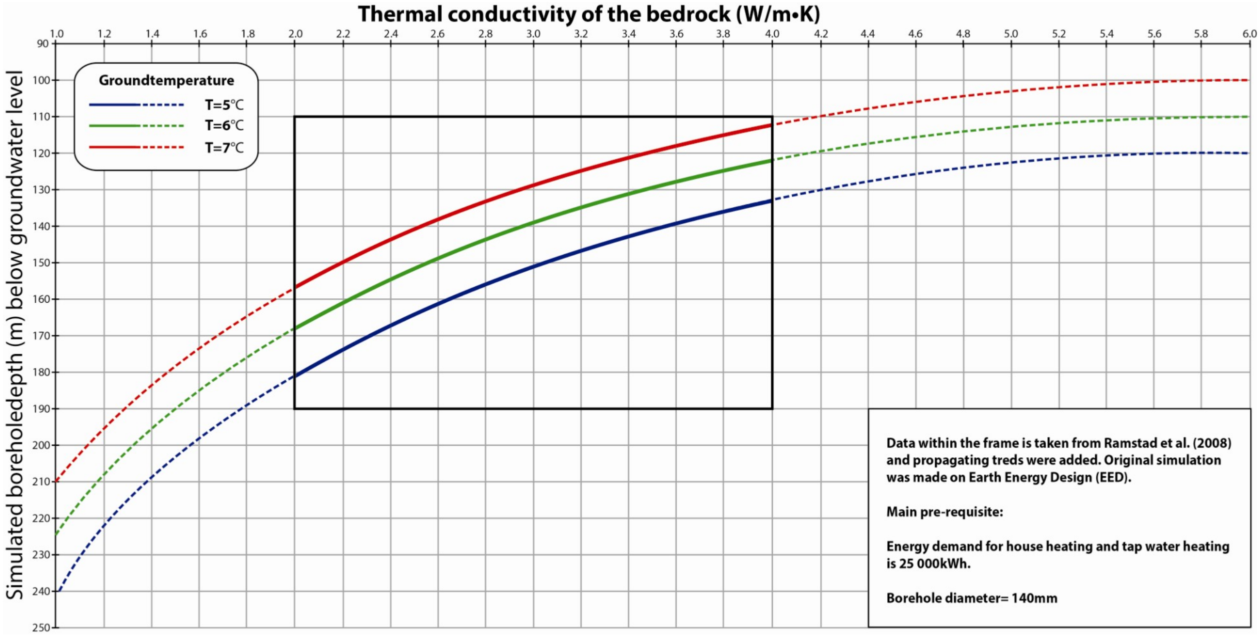


Figure 14. Simulated depth needed, for a 25’000 kWh/year, depending on the ambient ground temperature and the thermal conductivity of the bedrock. The middle box is taken from Ramstad et al. (2008) and propagating trends were added to illustrate the larger spread that is represented in Scania.

the costs for a geothermal system.

By looking at fig. 14 that is a simulated drill depth chart for different Thermal properties, is it easy to see the differences. For example, in the Simrishamn area where the bedrock is dominated by the Cambrian sandstone ($\lambda \sim 6$ W/m•K) a well depth can be 90 m deep in contrary to a well in a gneiss ($\lambda \sim 3.0$ W/m•K) which has to be over 130 m deep. These are readouts from extension of the graph that Ramstad (2008) produced. A more accurate value can be derived from the formulas in Eskilson (1987), where a further understanding on how the thermal properties affects the depth also can be found.

To achieve the same energy output in an area with a low thermal conductivity e.g. as in the limestone in SW Scania ($\lambda \approx 1.0$ W/m•K), the depth would have to be roughly 210 m. This depth estimate, however, is only based on the thermal conductivity of the rock, and not the system. When adding all the different factors that affect the effective thermal conductivity, λ_{eff}, such as texture, groundwater flow, ground temperature and relative occurrence of rock types, it is likely that the effective thermal conductivity is higher than the thermal conductivity of the rock. This is further explained in the following chapters.

Considering that costs are significantly increasing with increasing drilling depth, it can be expected that a 300 m deep well will be more than 3–4 times as expensive in comparison to a 100 m deep well. This is partly due to the requirement of stronger drilling equipment when drilling deeper wells. In this case it can be an alternative to drill several shallower wells in the same system. There has also during the last decade been an increasing amount of so called a multi-well systems for heating of apartment buildings, industries, offices etc. This is where the thermal diffusivity factor (α) becomes an important parameter as to assess the thermal impact of the surroundings. If wells are placed too close to each other there's a risk for permafrost, which significantly decreases the efficiency of the system. So α is an important parameter in the design of multi-well systems, particularly in determining and optimizing the distance between the individual boreholes.

4.2 Other parameters that effect the efficiency of a geothermal energy well

Previous chapter discussed the impact of the thermal conductivity on the theoretical drilling depth if λ was the only controlling factor. However, as mentioned there are several other factors that influence the efficiency of a geothermal well. These are the groundwater conditions, porosity, texture, homogeneity and structure, and the temperature gradient of the bedrock.

These have to be assessed together with the thermal conductivity of the rock as to get a better value on the required drilling depth. Therefore the effective thermal conductivity (λ_{eff}) is the actual value that has to be used. It is, thus, the sum of all the different factors that affects the amount of heat that can be extracted from a system. As the λ_{eff} is based on factors which are either dimensionless, or cancels out to become W/m•K, the units are the same for both λ and λ_{eff}. This can be confusing if the wrong denotation is used.

4.2.1 Groundwater conditions

The groundwater level and mobility of the groundwater are essential properties in a geothermal well. The mobility of groundwater can result in considerable changes in the thermal properties of a well. Stagnant groundwater condition does not affect the effective thermal conductivity. The temperature difference will propagate in a radial manor from the well bore and will not change the footprint the well have on the bedrock. On the contrary mobile groundwater conditions will considerably affect both the effective thermal conductivity and the temperature spreading in the surrounding to the well.

The degree of influence depends on flow rate and flow pattern in the well. When wells are closely spaced, it may affect the wells placed perpendicular to a hydraulic gradient. As water cooled down by the first well reaches the second well the amount of energy that can be withdrawn decreases considerably from the first to the last well down stream in a multi well system. This makes the downstream well less efficient than the first. However, it may still be more effective than if the water had been stagnant.

This will only be the case of a highly fractured rock or in a high-flow aquifer and if the area is not already geothermal exploited. If this is the case, then the λ / α will determine how much efficiency is lost by groundwater temperature loss from upstream geothermal wells. To truly get an understanding on these different scenarios, a further understanding of advanced geohydrology and thermodynamics is needed. Applying models of groundwater flow, thermal properties and geology can give valuable input to the design of systems in mobile groundwater settings.

4.2.2 Porosity

Porosity is another important factor. This is because it affects the λ, both in the fact that it allows fluids to move and that it affects the thermal conductivity of the rock. Groundwater has a λ value of roughly 0.6 W/m•K, and a high porosity with water-filled pores will reduce the bulk λ value of the rock. For example, a pure quartz sandstone, where the quartz has a λ of 7.7 W/m•K, and has a 20% porosity, the actual λ of the rock unit will be: $0.8 \times 7.7 + 0.2 \times 0.6 = 6.28$ W/m•K.

This is a simplified linear estimation; whereas there are more complex and correct calculations to use. (cf. Quali, 2003).

If the fluids occupying the pores are brine, the effective thermal conductivity will increase slightly in comparison to pores filled with fresh groundwater. The thermal properties presented in this study is based

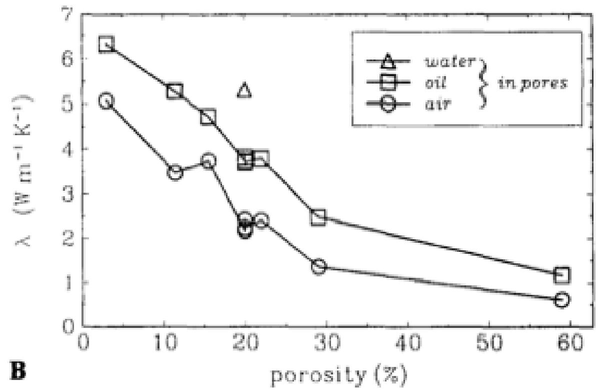


Figure 15. The diagram is illustrating the influence that different fluids, and the porosity, has on the thermal conductivity. Fig, 4B from Clauser & Huenges (1995, p.113).

on measurements on dry samples, thus the pores are filled with air with a λ-value of 0.025 W/m•K. This means that the actual thermal conductivity is expected to be considerably higher in porous samples where the pores are filled with water. This is especially the case for sedimentary rocks such as porous sandstone and limestone.

Porosity is also one of the few properties that can be assessed and easily calculated from theoretical data. However, the correct in situ value does also depend on the water saturation of the rock. The saturation can be <100% when there is natural gas in a sedimentary rock. Shallow biogenic gas in sedimentary rocks is locally found in Sweden, i.e. Östergötland and in Skåne. More information on the effect of porosity is described in several publications, such as Clauser & Huenges (1995).

4.2.3 Texture and crystallinity of the rock

The grain boundaries and crystallinity of a rock depends mainly on how much pressure and heat it has been exposed to. High amount of integrated grain boundaries significantly increases the λ-value. This is because heat is more easily transferred between the grains in a dense grain texture than in a loosely packed one. This means that not only the mineral composition of the rock determines the thermal conductivity, but also the grain size and texture of the rock is important.

4.2.4 Homogeneity and bedding

The estimated drilling depth of a geothermal well is based on a λ-value that represent the rock distribution over the whole length of the borehole (Eskilson, 1987). This can be applied if you consider that the bedrock is uniform and horizontally bedded. But when it comes to the volume/area that is affected by the well, the understanding of subsurface bedding conditions and structure of the rock is very important. Figure 16 exemplifies in a schematic way some typical different scenarios of thermal influences (A-D) along the borehole and perpendicular to the well bore.

In homogenous bedrock conditions the thermally affected rock volume will display as a spherical cylinder (fig. 16A). But in the case of bedded sedimentary bedrock, the pattern will be more complex related to the orientation and frequency of alternating bed units with different thermal properties in the sedimentary sequence. A simple stratigraphic order with two alternating bed units is illustrated in figure 16B. It is unlikely that both units will have the same thermal properties, and thus one of them will likely transport heat more effectively than the other. This gives a profile of thermal influence that has an undulating pattern along the borehole. As the bedding is considered horizontal the influence will radiate in the same manner as in the last case, however the radius of influence varies between the different bed units. Individual beds in such an example could yield far extended thermal impact on the surroundings if they have high values of thermal diffusivity. This could result in significant thermal impact on other neighboring wells.

In tectonically disturbed areas, such as fault zones, the bedding is commonly tilted or even overturned (cf. Sivhed el al., 1999; Erlström et al., 2004). A schematic example of this case is shown in figure 16C where a bedding sequence with varying thermal properties is steeply dipping. This will result in an undulating shape and elliptic shape in the perpendicular planar section. The shape of the ellipse is controlled by the λ, α values and the temperature difference between the well and surrounding rock. Depending on the difference in thermal properties between the higher and lower conducting layers, the minimal area can have a less elliptic shape.

With increasing dip angle of the bedding the minimum zone of thermal influence will gradually coincide with the maximum one. When the bedding is more or less vertical the shape of influence zone will depend on the thickness of the bed in which the well is located. Thicker beds will yield less elliptical shapes in contrary to thinner beds (fig. 16D).

The illustrated and described cases in figure 16 show that the thermal influence could differ considerably depending on the bedding and structure of the bedrock, especially if there are considerable differences in the thermal properties of the different bed units. Thus, the knowledge of bedding and structure of the rock volume in which a thermal system is operating is important especially when assessing the thermal influences on the surrounding.

4.2.5 Ground temperature

Sweden has a stable bedrock temperature of 6–8°C in the upper 100–200 meters. When the surface temperature is higher it is possible to withdraw more energy. In the north of Sweden, the average ground temperature is around 6°C and in Scania around 8°C. The ground ambient temperature is mainly controlled by the groundwater. In areas where the groundwater is replenished by a slightly warmer source, there will be a higher groundwater temperature and then allow for

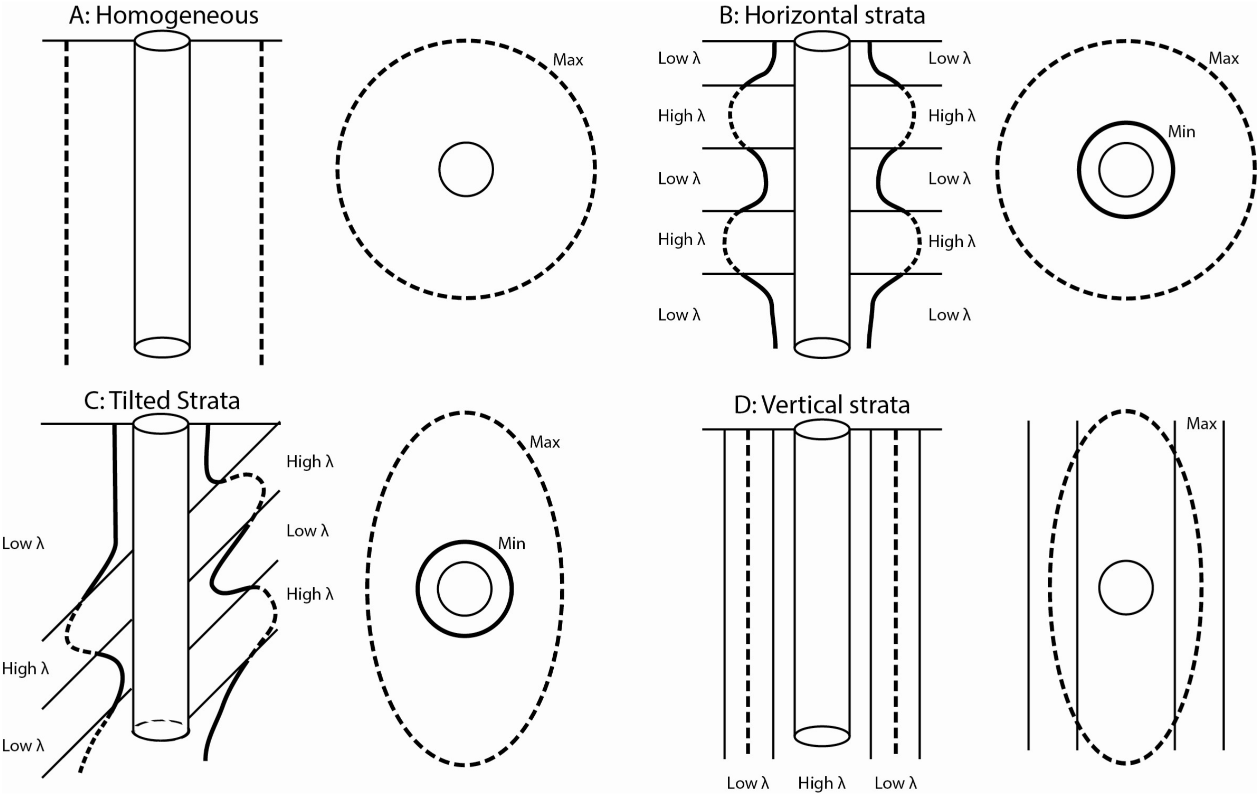


Figure 16 A-D. Schematic illustrations of how the affected volume around a energy well changes depending on the structure. **A**: when the bedrock is homogenous, the affected volume will take the shape of an standing cylinder. **B:** if the bedrock is layered, such in a sedimentary rock, the affected volume will be different for each layer. An layer with larger thermal conductivity will have an larger affected volume. **C**: if the strata is tilted, the area affected around the well will be of an elliptic shape. D: In cases of vertical layering, the affected volume will in the shape of a elliptic cylinder.

an increased energy withdrawal. Such sources could be lakes, rivers and seas. This means that the surface temperature will decrease with the distance to these types of waters. At depths below a couple of hundred meters the effect of solar heat decreases significantly and the temperature is instead controlled by the geothermal effect from the crust which results from decay of radioactive elements in the rock, i.e. uranium, potassium and thorium. The geothermal gradient between 200 and 7000 meters depth in Swedish bedrock ranges between 1.6 to 4.0°C/100 m. Higher gradient are found in areas with sedimentary strata which also in general have lower thermal conductivity than crystalline rocks. Thus, thick sedimentary cover strata on top of crystalline basement rocks do not allow heat from the deeper crust to be as easily transferred to the surface. This is exemplified on Gotland where a steep gradient of 3.8–4.0°C/100m in the subsurface Palaeozoic sequence, largely composed of marlstone, shale and argillaceous limestone with poor thermal properties is observed (Karlquist et al. 1982). In comparison the geothermal gradient in the 6–7 km deep boreholes in the Siljan district (Gravberg-1 and Stenberg-1) has a value ranging between 1.6 and 1.8°C/100m for the granitic and gneissic bedrock (M. Erlström, *pers. com*). In conclusion the effect of solar heat and surface waters affecting the upper part of the ground plays the most important role in assessing the temperature conditions for most geothermal systems. However, when drilling deeper wells other sources of heat influences, which varies considerably from place to place on the earth, has to be considered.

4.3 Other ways of determining the thermal rock properties

Using modal data is one of the easier and more direct ways to calculate the thermal conductivity of rocks. Modal data with determination of the mineralogy of rocks is most commonly applied on crystalline rocks as it is one of the most important ways in the classification of rocks. The technique is, however, generally not performed on sedimentary rocks where other schemes of classification apply. This is partly also due to the fact that a large part of many sedimentary rock types, such as shale, mudstone, marlstone, consist of very fine-grained clastic material which is not possible to classify in thin sections under a polarizing microscope. There are, however, other ways of determining the thermal conductivity of sedimentary rocks beside laboratory TCS measurements. By using i.e. wire line logging data it is possible to calculate the thermal properties of the rocks in a well.

4.3.1 Well log data - Resistivity & Gamma ray logs

The resistivity of the rock type is related to the thermal conductivity, this is because the free electron in the atoms of the minerals that is “carrying” the heat. This allows for determination of the λ for several different layers in a succession of strata. Using geophysical wire line log data would also give a better average value for the rock type. In comparison, the gamma log data gives valuable information on the lithological composition of the succession related to differences such shale, sandstone etc. The gamma ray log shows the natural radiation in the different lithologies. This means that in sedimentary rocks this is indirect more or less a log which can relate to the quartz content. High readings give shale formations and low readings give sandy quartz rich formations, with the exception of limestone which also shows low values. As the thermal conductivity, as mentioned in previous chapter, is strongly depending on the porosity the gamma ray data has to be calibrated with a porosity log. For example pure quartz sandstone will have a very low reading in the Gamma ray log, so will also a pure quartzite. Both these will appear similar on the gamma ray log, but are in fact very different. Depending on the porosity which can be 30% or higher in a quartz sandstone while being only a few percent in the quartzite. In a quartzite with barely no porosity the thermal conductivity could be as high as 7 W/m•K, measured in this study. Comparing this to the quartz sandstone, that is more likely to be 5–7 W/m•K depending on porosity (theoretical: 5.5 W/m•K, 30% porosity filled with water, quartz sandstone).

Combining the Gamma Ray Log with a porosity log will give a rough estimate that is more or less based on the quartz content. The logging methods are considered applicable in deeper wells or in areas with a heterogeneous bedding sequence of sedimentary rocks.

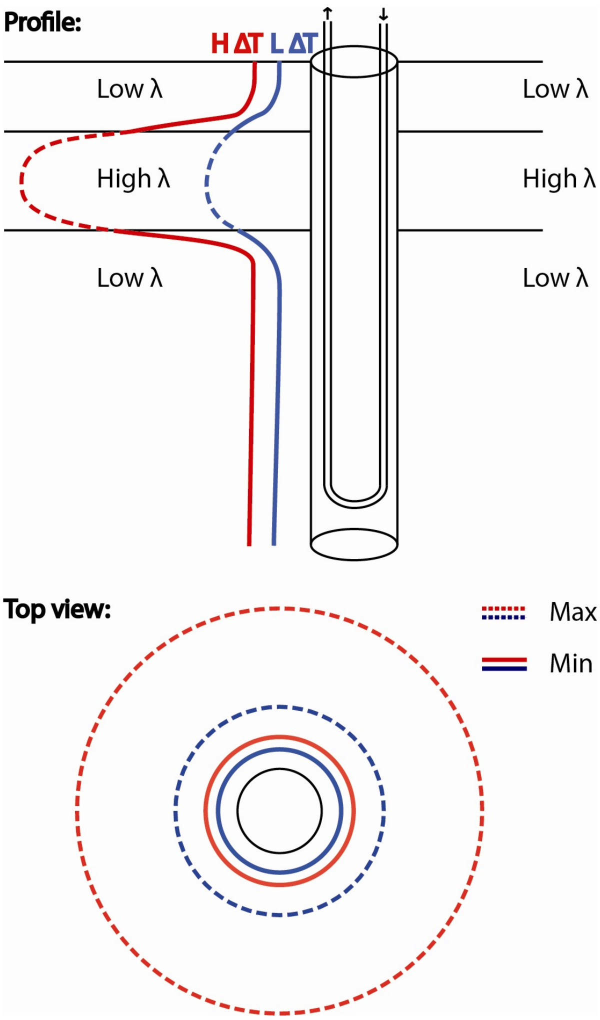


Figure 17. A schematic illustration of the problem of using TRT measurements as the thermal conductivity of the rock in layered rock. As a higher thermally conducting layer will be overrepresented. This is problem can be reduced if the difference in heat decreases.

4.3.2 Thermal Response Test (TRT- in situ measurement of boreholes

A commonly applied method in the industry is the Thermal Response Test, which is primarily applied when designing multi-well systems. The method is used worldwide but with some slight differences in performance and applications between nations. The method is based on the idea to test the effective thermal properties of a specific location, usually in relation to a large geothermal project. The test is performed in a pilot well before starting the complete drilling operation. The data is used to define the distances between wells and the necessary drilling depth.

The TRT test is basically carried out using a pump that circulates hot fluid in a closed tube that is extended into the well. The temperature is recorded before and after the fluid is passed through the tubing placed in the well. The difference between in and outgoing temperatures is related to the amount of energy that has been transferred into the rock during a measured time interval.

In the heat exchanger the heat is drawn from the rock while the TRT ads heat. The system works the same for either way, but it is much easier and cheaper to heat the fluid. A different advantage in circulating hot fluids, rather than cold, is that a greater difference in temperature can be achieved. This also allows for a larger affected volume without the risk of obtaining a frost plug in the system as the groundwater temperature is normally around 6–8°C. With a larger difference in temperature, the larger volume will be affected and therefore increase validity for the calculated thermal conductivity for the area.

The TRT method gives, in general, very good estimates of the thermal properties of a specific site especially in areas with homogeneous bedrock such as granite. Though in less homogenous rock, like a layered sedimentary rock, the obtained value on the ther-

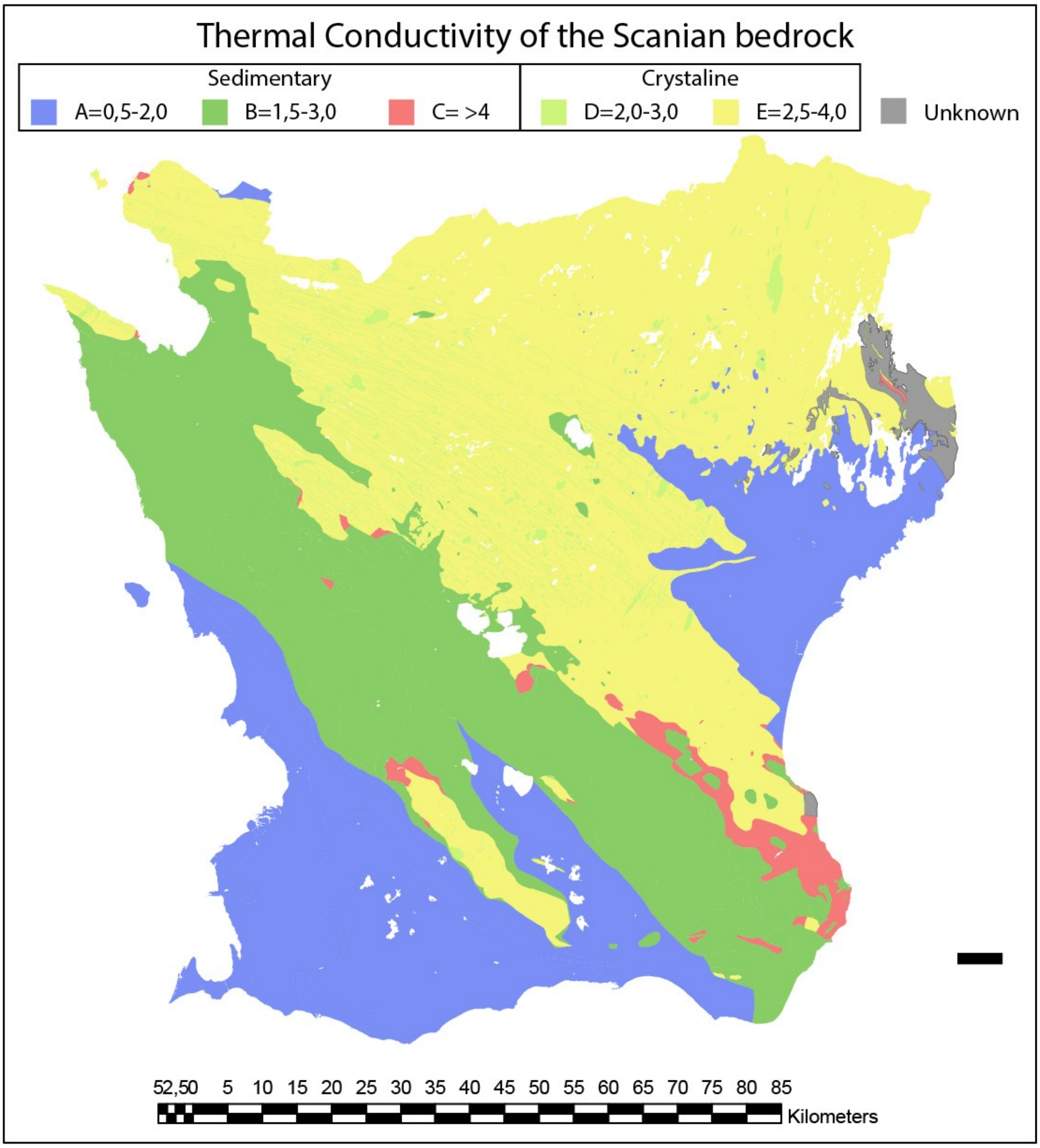


Figure 18. An example of a prognosis map of the thermal conductivity of rock types in Scania. It is based on the boxplots in figure 13, and plotted out over the SGU bedrock map. The warmer color, the higher thermal conductivity. The unknown areas, marked as grey, are areas of rock that has no calculated nor measured values. Example of that is the Kaolin deposits in the N-E. it is easy to see where the bedrock has low thermal conductivity, such as in Malmö and in the Kristianstads Basin. It is important to recognize that this is a prognosis map of the thermal conductivity of the bedrock, and shall not be confused with the effective thermal conductivity , λ_{eff}. A larger version is found in appendix III.

mal conductivity may be misleading due to various geological parameters.

In Scania, there are a few particularly interesting sedimentary units that exemplifies this. The Limhamn and Köpenhamn limestone units contain variable amount chert nodules, chert layers and silicified beds. The amount of chert varies locally from a few to tens of percent. The chert and silicified layers, compared to the pure limestone, are highly thermally conductive. These will therefore be more affected by the input heat from a TRT measurement. Even though the chert ratio might only be a few percent of the total well length, the affected chert volume ratio is higher due to the high conductivity. If the difference in the temperature between the hole and the surrounding rock is higher, the chert volume ratio will increase even further. This means that a result from a TRT measurement in bedrock with several layers and units with different thermal conductivity will end up showing a result that represents more of the higher thermal conducting units, than are found in the bedrock. Thus, TRT result will generally give a site-specific value of the effective thermal conductivity, which not always corresponds to the thermal properties of the major rock type in the area. Applying TRT measurements will give the best value for a specific site as it represents the sum of all the factors that affects the thermal efficiency of a well, such as the thermal conductivity of the pure bed rock, the water flow rate, porosity etc. Although the difference between a TRT and TCS value is in most cases fairly consistent. There are, however, certain discrepancies in areas which are related to specific geological conditions such as the case of chert occurring in limestone with overall low thermal conductivity.

Another example is when a pure limestone with a low thermal conductivity is fractured, and there is mobile groundwater conditions in the vicinity of the well, the water will bring new water that effectively increase the efficiency of a well and therefor give a higher TRT measure.

This means that TRT measures are suitable for getting data on a local scale, where the conditions are presumed to be uniform. But as it is a combined value of several factors, it does not give the specific thermal properties of the bedrock. The TCS data and usage of modal data for definition of the thermal properties of the different rock types is one of several parameters that can be used as input information in assessing an average drilling depth for a specific well. Most probably it will be possible, at least in Scania, to define areas where the other parameters such as heterogeneity, porosity and groundwater flow will considerably affect the thermal properties in a specific area.

4.4 Outreach of this study

The performed investigation and achieved results have given a wider understanding of the thermal properties of various rock types in Scania. The study has been directed towards getting a database on the thermal properties of the rock types. These properties are perhaps one of the most important factors behind optimizing and designing shallow geothermal wells for heating and cooling purposes. As pointed out in the discussion, however, there are several other factors that affects the efficiency of a geothermal system that has to be considered, such as groundwater conditions, bedrock heterogeneity, porosity and bedding. The data of the thermal properties of the rocks are an important complement in assessing the basic prerequisites in the design of geothermal systems. As shown there is a good possibility to extend the predictability for drilling depth and well distance if there is a good data base to relate to. This could include TCS measurements, calculated values based on modal analyses, TRT measurements performed by the industry and geological maps with areas of complex bedding and faulting. The geological information is especially important in some of the areas with sedimentary bedrock as it includes commonly complex bedding, layering and variations in lithology which affects the design. If this is done there is a good possibility to make prediction models of drilling depth and thermal influence with good confidence. This, however, requires a collaboration between several stakeholders and organizations, e.g. SGU, Universities, trade associations etc.

Another important outreach from this study is that there is now, with the TCS equipment at SGU, a possibility to assess the thermal influence better by measuring the thermal diffusion. These data are important parameters in modeling the thermal impact and defining the minimum distances between geothermal wells without disturbing each other.

4.5 Suggestions for further studies

The performed study primarily presents information on one of the main parameters that influences the design of a geothermal system. As pointed out there is a great need to combine and validate different techniques of measurement concerning assessment of the thermal properties at a specific location. It is also important that the thermal properties are related to geological conditions, which as in Scania varies greatly between different locations. Today there are no best adapted methodology and recommendations available for the public and authorities concerning design and feasibility of geothermal energy. Comprehensive information regarding geology, thermal properties and recommendations for a geothermal system in a specific location is today not available in an integrated manner by a single organization. If available data both from stakeholders, trade associations, universities and authorities (SGU) were combined it would be possible by joint research to provide a much better knowledge about the geothermal potential and prognosis of the recommended depth of a geothermal well and in addition provide guidelines regarding thermal influence and well design.

Regarding improvement of data concerning the thermal conductivity on the sedimentary rock in Scania one way would be to calibrate data from performed wire line logs, such as Gamma Ray and resistivity. There are today in some areas a large amount of data available from various infrastructure projects that could give valuable input, e.g. from the Citytunnel project in Malmö and the H+ project in Helsingborg. Both projects are localized in areas with complex sedimentary bedrock and difficulties in predicting the subsurface thermal properties.

These suggestions don’t involve obtaining new data but utilizing existing data. In the case of sedimentary sections, there is a high demand for obtaining more data, either analysis data, or theoretical, that can complement and shed light over the large spread in the existing data. The increase of data may show geographical trends that can be used.

Modeling of thermal influence in various geological settings is another way to increase the knowledge about design and optimization of geothermal energy. Especially involvement of the thermal diffusivity in the models would significantly improve the understanding of thermal migration and influence radius.

5 Conclusions

- 867 values on thermal conductivity and diffusivity on Scanian rock types have been determined either by TCS measurement or by calculations from existing modal analyses. The study has shown that there is a good correlation between quartz content and thermal properties the crystalline rocks. The study has given a valuable input to the correlation and use of modal data regarding thermal properties of rocks. The results constitute an important data base and will be available in the SGU databases.
- The measured thermal properties of the sedimentary rocks show a wide range of thermal values related to their physical properties. Important factors are texture, groundwater conditions, bedding and porosity. Thermal conductivities ranging between 0.7 and 8.8 W/m•K have been measured. The lowest representing limestone from SW Scania and the highest value dense quartzitic Cambrian sandstone from southeast Scania.
- The data is grouped into three sedimentary rock classes according to their thermal conductivity, low (0.5–1.5 W/m•K), moderate (2.5–3.5 W/m•K) and high (5–7 W/m•K). The low values represent young limestone units, which covers large parts of southwest Scania and the Kristianstad Basin. The high values derive from Cambrian sandstone and quartzite, which are found primarily in the SE corner of Scania, with a trend towards NW. The moderate value represents primarily Paleozoic shale and mudstone, sandstone and limestone which are found in zone crossing Scania in a NW–SE direction.
- The crystalline rocks, have measured and calculated values close to what is seen in the moderate class for the sedimentary rocks. The values do not show such a wide range of values as for the sedimentary rock types. The crystalline rocks are divided into 2 classes, quartz poor (2.5 W/m•K) and quartz rich (2.9 W/m•K). The majority of the Scanian bedrock belongs to the quartz rich class, which includes primarily granite and gneiss. Rock units that are quartz poor are e.g. dolerite and amphibolite.
- Overall the thermal properties of the Scanian rock types are around 3.0 W/m•K.
- The study has also identified a need to combine various data sets as to assess the thermal properties of specific location. The thermal property of the rock type itself is only one of several other parameters that control the design and optimization of a geothermal well. Beside lithology, porosity, ground water conditions, bedding and thickness of the Quaternary deposits play an important role in the planning of a geothermal well.
- Thermal diffusivity is shown to be a very important parameter in assessing the thermal influence from a geothermal well.

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Case Processing Summary

		Cases					
		Valid		Missing		Total	
	GROUP	N	Percent	N	Percent	N	Percent
TCS	1.00	1	100.0%	0	0.0%	1	100.0%
	2.00	3	100.0%	0	0.0%	3	100.0%
	3.00	4	100.0%	0	0.0%	4	100.0%
	4.00	6	100.0%	0	0.0%	6	100.0%
	5.00	16	100.0%	0	0.0%	16	100.0%
	6.00	1	100.0%	0	0.0%	1	100.0%
	7.00	9	100.0%	0	0.0%	9	100.0%
	8.00	10	100.0%	0	0.0%	10	100.0%
	9.00	3	100.0%	0	0.0%	3	100.0%
	10.00	1	100.0%	0	0.0%	1	100.0%
	11.00	7	41.2%	10	58.8%	17	100.0%
	12.00	5	21.7%	18	78.3%	23	100.0%
	13.00	1	100.0%	0	0.0%	1	100.0%
	14.00	6	5.4%	105	94.6%	111	100.0%
	15.00	15	12.9%	101	87.1%	116	100.0%
	16.00	5	7.9%	58	92.1%	63	100.0%
	17.00	3	9.4%	29	90.6%	32	100.0%
	18.00	12	13.6%	76	86.4%	88	100.0%
	19.00	1	10.0%	9	90.0%	10	100.0%
	20.00	15	12.5%	105	87.5%	120	100.0%
	21.00	5	41.7%	7	58.3%	12	100.0%
	22.00	35	16.6%	176	83.4%	211	100.0%
	23.00	1	1.8%	54	98.2%	55	100.0%

Descriptives[a,b,c,d,e,f]

	GROUP			Statistic	Std. Error
TCS	2.00	Mean		1.0233	.32054
		95% Confidence Interval for Mean	Lower Bound	-.3558	
			Upper Bound	2.4025	
		5% Trimmed Mean		.	
		Median		.7700	
		Variance		.308	
		Std. Deviation		.55519	
		Minimum		.64	
		Maximum		1.66	
		Range		1.02	
		Interquartile Range		.	
		Skewness		1.626	1.225
		Kurtosis		.	.
	3.00	Mean		1.3550	.37349
		95% Confidence Interval for Mean	Lower Bound	.1664	
			Upper Bound	2.5436	
		5% Trimmed Mean		1.3344	
		Median		1.1700	
		Variance		.558	
		Std. Deviation		.74697	
		Minimum		.72	
		Maximum		2.36	
		Range		1.64	
		Interquartile Range		1.38	
		Skewness		1.023	1.014
		Kurtosis		-.191	2.619
	4.00	Mean		.9917	.06720
		95% Confidence Interval for Mean	Lower Bound	.8189	
			Upper Bound	1.1644	
		5% Trimmed Mean		.9902	
		Median		1.0250	
		Variance		.027	
		Std. Deviation		.16461	
		Minimum		.77	
		Maximum		1.24	
		Range		.47	
		Interquartile Range		.26	
		Skewness		.119	.845
		Kurtosis		.070	1.741
	5.00	Mean		2.4381	.24595
		95% Confidence Interval for Mean	Lower Bound	1.9139	
			Upper Bound	2.9624	
		5% Trimmed Mean		2.3685	
		Median		2.3650	
		Variance		.968	
		Std. Deviation		.98382	
		Minimum		.95	
		Maximum		5.18	
		Range		4.23	
		Interquartile Range		1.08	
		Skewness		1.158	.564

Descriptives[a,b,c,d,e,f]

GROUP			Statistic	Std. Error
	Kurtosis		3.312	1.091
7.00	**Mean**		2.8356	.11528
	95% Confidence Interval for Mean	**Lower Bound**	2.5697	
		Upper Bound	3.1014	
	5% Trimmed Mean		2.8290	
	Median		2.8100	
	Variance		.120	
	Std. Deviation		.34584	
	Minimum		2.40	
	Maximum		3.39	
	Range		.99	
	Interquartile Range		.65	
	Skewness		.348	.717
	Kurtosis		-1.115	1.400
8.00	**Mean**		2.6460	.11603
	95% Confidence Interval for Mean	**Lower Bound**	2.3835	
		Upper Bound	2.9085	
	5% Trimmed Mean		2.6544	
	Median		2.6450	
	Variance		.135	
	Std. Deviation		.36692	
	Minimum		1.94	
	Maximum		3.20	
	Range		1.26	
	Interquartile Range		.40	
	Skewness		-.317	.687
	Kurtosis		.648	1.334
9.00	**Mean**		2.0667	.27552
	95% Confidence Interval for Mean	**Lower Bound**	.8812	
		Upper Bound	3.2521	
	5% Trimmed Mean		.	
	Median		1.9200	
	Variance		.228	
	Std. Deviation		.47721	
	Minimum		1.68	
	Maximum		2.60	
	Range		.92	
	Interquartile Range		.	
	Skewness		1.252	1.225
	Kurtosis		.	.
11.00	**Mean**		4.7500	.54672
	95% Confidence Interval for Mean	**Lower Bound**	3.4122	
		Upper Bound	6.0878	
	5% Trimmed Mean		4.7756	
	Median		4.8100	
	Variance		2.092	
	Std. Deviation		1.44648	
	Minimum		2.66	
	Maximum		6.38	
	Range		3.72	
	Interquartile Range		2.64	

Descriptives[a,b,c,d,e,f]

GROUP			Statistic	Std. Error
	Skewness		-.239	.794
	Kurtosis		-1.716	1.587
12.00	**Mean**		3.2200	.58732
	95% Confidence Interval for Mean	**Lower Bound**	1.5893	
		Upper Bound	4.8507	
	5% Trimmed Mean		3.1750	
	Median		3.0600	
	Variance		1.725	
	Std. Deviation		1.31330	
	Minimum		1.87	
	Maximum		5.38	
	Range		3.51	
	Interquartile Range		2.05	
	Skewness		1.357	.913
	Kurtosis		2.605	2.000
14.00	**Mean**		2.2433	.08225
	95% Confidence Interval for Mean	**Lower Bound**	2.0319	
		Upper Bound	2.4548	
	5% Trimmed Mean		2.2348	
	Median		2.1900	
	Variance		.041	
	Std. Deviation		.20146	
	Minimum		2.05	
	Maximum		2.59	
	Range		.54	
	Interquartile Range		.31	
	Skewness		1.120	.845
	Kurtosis		.796	1.741
15.00	**Mean**		2.5433	.07463
	95% Confidence Interval for Mean	**Lower Bound**	2.3833	
		Upper Bound	2.7034	
	5% Trimmed Mean		2.5326	
	Median		2.4800	
	Variance		.084	
	Std. Deviation		.28903	
	Minimum		2.16	
	Maximum		3.12	
	Range		.96	
	Interquartile Range		.32	
	Skewness		.709	.580
	Kurtosis		-.276	1.121
16.00	**Mean**		2.4060	.07985
	95% Confidence Interval for Mean	**Lower Bound**	2.1843	
		Upper Bound	2.6277	
	5% Trimmed Mean		2.4078	
	Median		2.4500	
	Variance		.032	
	Std. Deviation		.17855	
	Minimum		2.19	
	Maximum		2.59	
	Range		.40	

Descriptives^{a,b,c,d,e,f}

GROUP			Statistic	Std. Error
	Interquartile Range		.35	
	Skewness		-.335	.913
	Kurtosis		-2.651	2.000
17.00	Mean		2.4267	.05364
	95% Confidence Interval for Mean	Lower Bound	2.1959	
		Upper Bound	2.6575	
	5% Trimmed Mean		.	
	Median		2.4700	
	Variance		.009	
	Std. Deviation		.09292	
	Minimum		2.32	
	Maximum		2.49	
	Range		.17	
	Interquartile Range		.	
	Skewness		-1.642	1.225
	Kurtosis		.	.
18.00	Mean		2.9433	.08335
	95% Confidence Interval for Mean	Lower Bound	2.7599	
		Upper Bound	3.1268	
	5% Trimmed Mean		2.9426	
	Median		2.8700	
	Variance		.083	
	Std. Deviation		.28874	
	Minimum		2.46	
	Maximum		3.44	
	Range		.98	
	Interquartile Range		.34	
	Skewness		.406	.637
	Kurtosis		-.148	1.232
20.00	Mean		2.9167	.10543
	95% Confidence Interval for Mean	Lower Bound	2.6905	
		Upper Bound	3.1428	
	5% Trimmed Mean		2.9263	
	Median		2.8800	
	Variance		.167	
	Std. Deviation		.40834	
	Minimum		2.21	
	Maximum		3.45	
	Range		1.24	
	Interquartile Range		.71	
	Skewness		-.274	.580
	Kurtosis		-1.224	1.121
21.00	Mean		2.7580	.10037
	95% Confidence Interval for Mean	Lower Bound	2.4793	
		Upper Bound	3.0367	
	5% Trimmed Mean		2.7622	
	Median		2.8200	
	Variance		.050	
	Std. Deviation		.22443	
	Minimum		2.43	
	Maximum		3.01	

Descriptives[a,b,c,d,e,f]

GROUP			Statistic	Std. Error
	Range		.58	
	Interquartile Range		.40	
	Skewness		-.682	.913
	Kurtosis		-.127	2.000
22.00	**Mean**		3.1171	.18677
	95% Confidence Interval for Mean	**Lower Bound**	2.7376	
		Upper Bound	3.4967	
	5% Trimmed Mean		2.9494	
	Median		2.8500	
	Variance		1.221	
	Std. Deviation		1.10496	
	Minimum		1.84	
	Maximum		8.63	
	Range		6.79	
	Interquartile Range		.58	
	Skewness		4.004	.398
	Kurtosis		19.017	.778

a. TCS is constant when GROUP = 1.00. It has been omitted.

b. TCS is constant when GROUP = 6.00. It has been omitted.

c. TCS is constant when GROUP = 10.00. It has been omitted.

d. TCS is constant when GROUP = 13.00. It has been omitted.

e. TCS is constant when GROUP = 19.00. It has been omitted.

f. TCS is constant when GROUP = 23.00. It has been omitted.

M-Estimators[a,f,g,h,i,j]

	GROUP	Huber's M-Estimator[b]	Tukey's Biweight[c]	Hampel's M-Estimator[d]	Andrews' Wave[e]
TCS	2.00	.7919	.7051	.7353	.7051
	3.00	1.1893	1.1555	1.2351	1.1570
	4.00	.9898	.9913	.9858	.9914
	5.00	2.4110	2.3453	2.3567	2.3446
	7.00	2.8264	2.8269	2.8356	2.8268
	8.00	2.6491	2.6347	2.6530	2.6324
	9.00	1.9591	1.9603	2.0028	1.9616
	11.00	4.8143	4.7871	4.7500	4.7872
	12.00	2.9510	2.7328	2.8442	2.7328
	14.00	2.2047	2.1903	2.2129	2.1902
	15.00	2.4975	2.4592	2.4924	2.4576
	16.00	2.4145	2.4142	2.4060	2.4143
	17.00	2.4669	2.4795	2.4765	2.4795
	18.00	2.9142	2.8976	2.9207	2.8978
	20.00	2.9405	2.9288	2.9267	2.9287
	21.00	2.7837	2.7765	2.7692	2.7765
	22.00	2.8765	2.8461	2.8584	2.8458

a. TCS is constant when GROUP = 1.00. It has been omitted.

b. The weighting constant is 1.339.

c. The weighting constant is 4.685.

d. The weighting constants are 1.700, 3.400, and 8.500

e. The weighting constant is 1.340*pi.

f. TCS is constant when GROUP = 6.00. It has been omitted.

g. TCS is constant when GROUP = 10.00. It has been omitted.

h. TCS is constant when GROUP = 13.00. It has been omitted.

i. TCS is constant when GROUP = 19.00. It has been omitted.

j. TCS is constant when GROUP = 23.00. It has been omitted.

Percentiles[a,b,c,d,e,f]

			Percentiles						
		GROUP	5	10	25	50	75	90	95
Weighted Average (Definition 1)	**TCS**	2.00	.6400	.6400	.6400	.7700	.	.	.
		3.00	.7200	.7200	.7550	1.1700	2.1400	.	.
		4.00	.7700	.7700	.8300	1.0250	1.0900	.	.
		5.00	.9500	1.0970	1.8125	2.3650	2.8875	3.7590	.
		7.00	2.4000	2.4000	2.5250	2.8100	3.1750	.	.
		8.00	1.9400	1.9750	2.4700	2.6450	2.8675	3.1930	.
		9.00	1.6800	1.6800	1.6800	1.9200	.	.	.
		11.00	2.6600	2.6600	3.5400	4.8100	6.1800	.	.
		12.00	1.8700	1.8700	2.2350	3.0600	4.2850	.	.
		14.00	2.0500	2.0500	2.0875	2.1900	2.4025	.	.
		15.00	2.1600	2.1780	2.3600	2.4800	2.6800	3.0420	.
		16.00	2.1900	2.1900	2.2200	2.4500	2.5700	.	.
		17.00	2.3200	2.3200	2.3200	2.4700	.	.	.
		18.00	2.4600	2.5260	2.7725	2.8700	3.1150	3.4310	.
		20.00	2.2100	2.2820	2.6200	2.8800	3.3300	3.4140	.
		21.00	2.4300	2.4300	2.5400	2.8200	2.9450	.	.
		22.00	2.2960	2.4620	2.6400	2.8500	3.2200	3.6720	5.9020
Tukey's Hinges	**TCS**	2.00			.7050	.7700	1.2150		
		3.00			.7900	1.1700	1.9200		
		4.00			.8500	1.0250	1.0400		
		5.00			1.9350	2.3650	2.8550		
		7.00			2.6100	2.8100	3.1700		
		8.00			2.5300	2.6450	2.7800		
		9.00			1.8000	1.9200	2.2600		
		11.00			3.6900	4.8100	6.0100		
		12.00			2.6000	3.0600	3.1900		
		14.00			2.1000	2.1900	2.3400		
		15.00			2.3650	2.4800	2.6550		
		16.00			2.2500	2.4500	2.5500		
		17.00			2.3950	2.4700	2.4800		
		18.00			2.7750	2.8700	3.1100		
		20.00			2.6650	2.8800	3.2750		
		21.00			2.6500	2.8200	2.8800		
		22.00			2.6500	2.8500	3.1700		

a. TCS is constant when GROUP = 1.00. It has been omitted.

b. TCS is constant when GROUP = 6.00. It has been omitted.

c. TCS is constant when GROUP = 10.00. It has been omitted.

d. TCS is constant when GROUP = 13.00. It has been omitted.

e. TCS is constant when GROUP = 19.00. It has been omitted.

f. TCS is constant when GROUP = 23.00. It has been omitted.

Extreme Values[a,b,c,d,e,f,g]

GROUP				Case Number	Value
TCS	2.00	Highest	1	913	1.66
		Lowest	1	911	.64
	3.00	Highest	1	842	2.36
			2	905	1.48
		Lowest	1	843	.72
			2	844	.86
	4.00	Highest	1	838	1.24
			2	876	1.04
			3	875	1.03
		Lowest	1	874	.77
			2	836	.85
			3	877	1.02
	5.00	Highest	1	893	5.18
			2	847	3.15
			3	837	3.06
			4	907	2.92
			5	840	2.79
		Lowest	1	829	.95
			2	879	1.16
			3	830	1.41
			4	908	1.69
			5	846	2.18
	7.00	Highest	1	835	3.39
			2	870	3.18
			3	853	3.17
			4	859	2.83
		Lowest	1	854	2.40
			2	871	2.44
			3	858	2.61
			4	860	2.69
	8.00	Highest	1	863	3.20
			2	862	3.13
			3	851	2.78
			4	850	2.72
			5	833	2.69
		Lowest	1	881	1.94
			2	868	2.29
			3	869	2.53
			4	861	2.58
			5	849	2.60
	9.00	Highest	1	866	2.60
		Lowest	1	839	1.68
	11.00	Highest	1	865	6.38
			2	856	6.18
			3	864	5.84
		Lowest	1	841	2.66
			2	857	3.54
			3	834	3.84
	12.00	Highest	1	365	5.38
			2	375	3.19

Extreme Values[a,b,c,d,e,f,g]

GROUP			Case Number	Value
	Lowest	1	894	1.87
		2	867	2.60
14.00	Highest	1	750	2.59
		2	250	2.34
		3	636	2.26
	Lowest	1	615	2.05
		2	735	2.10
		3	620	2.12
15.00	Highest	1	325	3.12
		2	796	2.99
		3	627	2.94
		4	896	2.68
		5	890	2.63
	Lowest	1	892	2.16
		2	580	2.19
		3	329	2.26
		4	898	2.36
		5	719	2.37
16.00	Highest	1	778	2.59
		2	727	2.55
	Lowest	1	138	2.19
		2	556	2.25
17.00	Highest	1	749	2.49
	Lowest	1	39	2.32
18.00	Highest	1	90	3.44
		2	105	3.41
		3	548	3.12
		4	307	3.10
		5	761	3.02
	Lowest	1	23	2.46
		2	724	2.68
		3	403	2.77
		4	106	2.78
		5	25	2.80
20.00	Highest	1	598	3.45
		2	21	3.39
		3	882	3.37
		4	587	3.33
		5	891	3.22
	Lowest	1	442	2.21
		2	900	2.33
		3	458	2.45
		4	603	2.62
		5	595	2.71
21.00	Highest	1	888	3.01
		2	93	2.88
	Lowest	1	631	2.43
		2	886	2.65
22.00	Highest	1	378	8.63
		2	817	5.22

Extreme Values[a,b,c,d,e,f,g]

GROUP		Case Number	Value
	3	8	3.69
	4	815	3.66
	5	738	3.47
Lowest	1	176	1.84
	2	897	2.41
	3	820	2.42
	4	884	2.49
	5	895	2.52

a. TCS is constant when GROUP = 1.00. It has been omitted.

b. The requested number of extreme values exceeds the number of data points. A smaller number of extremes is displayed.

c. TCS is constant when GROUP = 6.00. It has been omitted.

d. TCS is constant when GROUP = 10.00. It has been omitted.

e. TCS is constant when GROUP = 13.00. It has been omitted.

f. TCS is constant when GROUP = 19.00. It has been omitted.

g. TCS is constant when GROUP = 23.00. It has been omitted.

Extreme Values[a,b,c,d,e,f,g]

GROUP				Case Number	Value
TCS	2.00	Highest	1	913	1.66
		Lowest	1	911	.64
	3.00	Highest	1	842	2.36
			2	905	1.48
		Lowest	1	843	.72
			2	844	.86
	4.00	Highest	1	838	1.24
			2	876	1.04
			3	875	1.03
		Lowest	1	874	.77
			2	836	.85
			3	877	1.02
	5.00	Highest	1	893	5.18
			2	847	3.15
			3	837	3.06
			4	907	2.92
			5	840	2.79
		Lowest	1	829	.95
			2	879	1.16
			3	830	1.41
			4	908	1.69
			5	846	2.18
	7.00	Highest	1	835	3.39
			2	870	3.18
			3	853	3.17
			4	859	2.83
		Lowest	1	854	2.40
			2	871	2.44
			3	858	2.61
			4	860	2.69
	8.00	Highest	1	863	3.20
			2	862	3.13
			3	851	2.78
			4	850	2.72
			5	833	2.69
		Lowest	1	881	1.94
			2	868	2.29
			3	869	2.53
			4	861	2.58
			5	849	2.60
	9.00	Highest	1	866	2.60
		Lowest	1	839	1.68
	11.00	Highest	1	865	6.38
			2	856	6.18
			3	864	5.84
		Lowest	1	841	2.66
			2	857	3.54
			3	834	3.84
	12.00	Highest	1	365	5.38
			2	375	3.19

Extreme Values[a,b,c,d,e,f,g]

GROUP			Case Number	Value
	Lowest	1	894	1.87
		2	867	2.60
14.00	Highest	1	750	2.59
		2	250	2.34
		3	636	2.26
	Lowest	1	615	2.05
		2	735	2.10
		3	620	2.12
15.00	Highest	1	325	3.12
		2	796	2.99
		3	627	2.94
		4	896	2.68
		5	890	2.63
	Lowest	1	892	2.16
		2	580	2.19
		3	329	2.26
		4	898	2.36
		5	719	2.37
16.00	Highest	1	778	2.59
		2	727	2.55
	Lowest	1	138	2.19
		2	556	2.25
17.00	Highest	1	749	2.49
	Lowest	1	39	2.32
18.00	Highest	1	90	3.44
		2	105	3.41
		3	548	3.12
		4	307	3.10
		5	761	3.02
	Lowest	1	23	2.46
		2	724	2.68
		3	403	2.77
		4	106	2.78
		5	25	2.80
20.00	Highest	1	598	3.45
		2	21	3.39
		3	882	3.37
		4	587	3.33
		5	891	3.22
	Lowest	1	442	2.21
		2	900	2.33
		3	458	2.45
		4	603	2.62
		5	595	2.71
21.00	Highest	1	888	3.01
		2	93	2.88
	Lowest	1	631	2.43
		2	886	2.65
22.00	Highest	1	378	8.63
		2	817	5.22

Extreme Values[a,b,c,d,e,f,g]

GROUP		Case Number	Value
	3	8	3.69
	4	815	3.66
	5	738	3.47
Lowest	1	176	1.84
	2	897	2.41
	3	820	2.42
	4	884	2.49
	5	895	2.52

a. TCS is constant when GROUP = 1.00. It has been omitted.

b. The requested number of extreme values exceeds the number of data points. A smaller number of extremes is displayed.

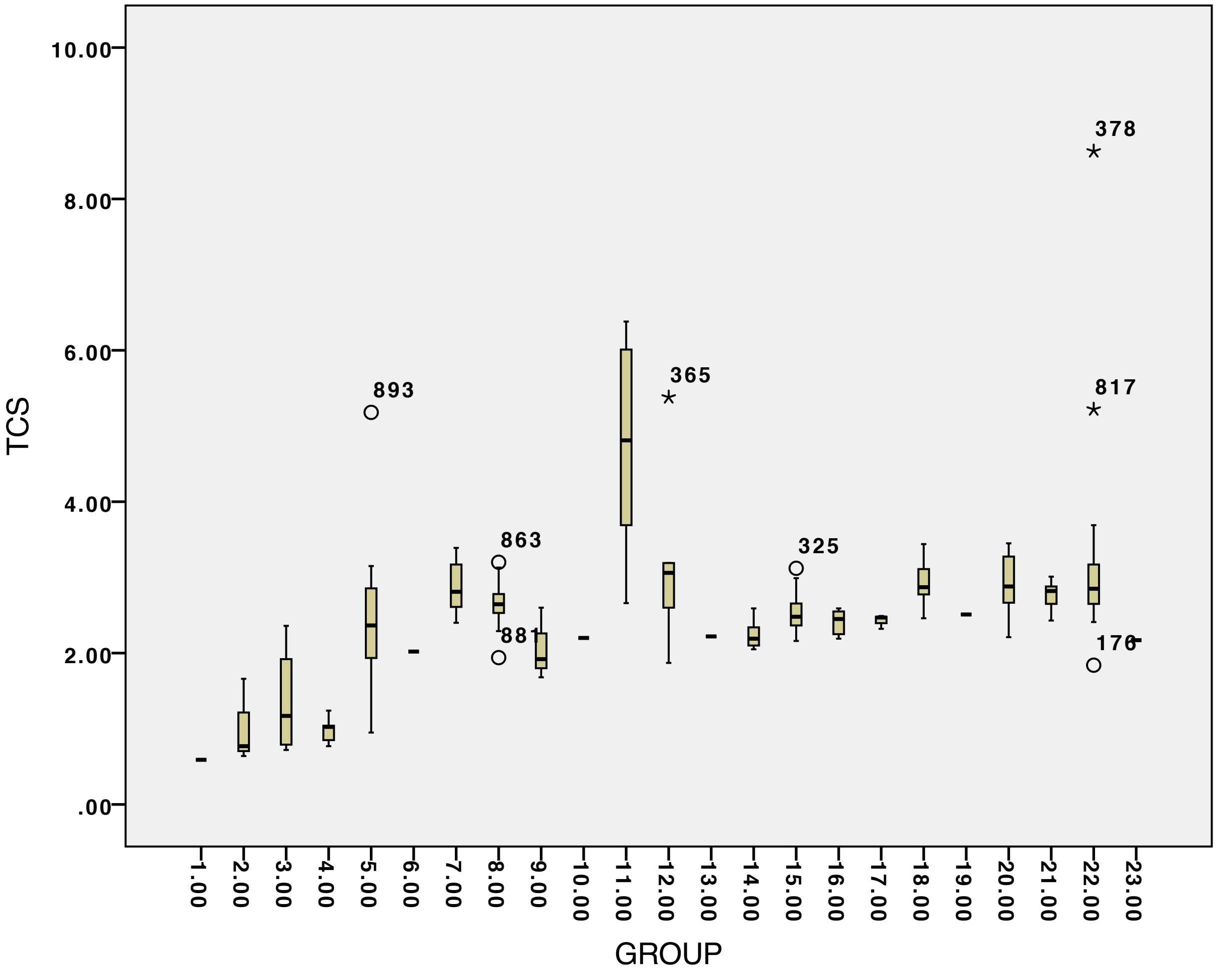
c. TCS is constant when GROUP = 6.00. It has been omitted.

d. TCS is constant when GROUP = 10.00. It has been omitted.

e. TCS is constant when GROUP = 13.00. It has been omitted.

f. TCS is constant when GROUP = 19.00. It has been omitted.

g. TCS is constant when GROUP = 23.00. It has been omitted.


TCS
10.00
8.00
6.00
4.00
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893
365
378
817
863
881
325
176
1.00
2.00
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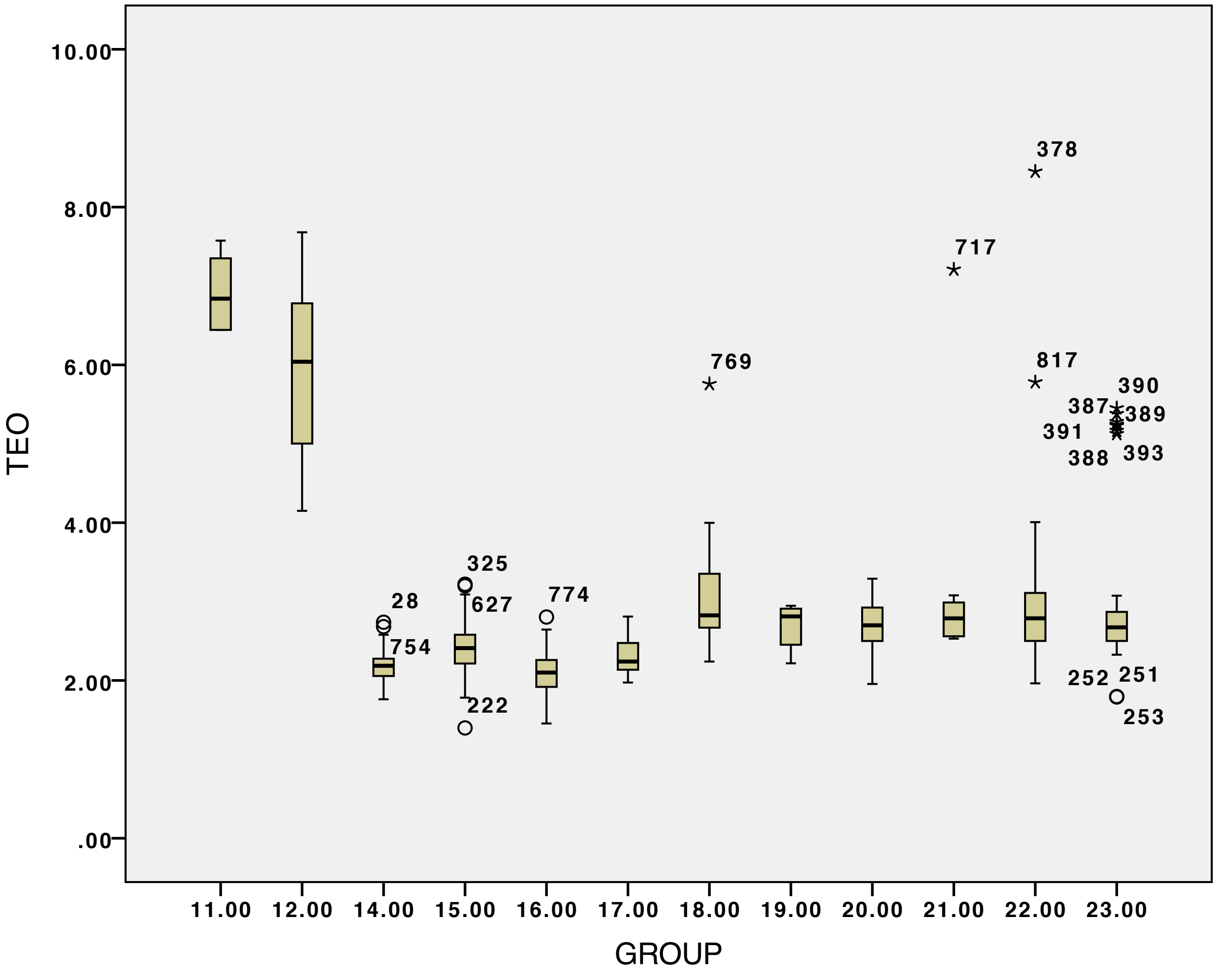
GROUP



10.00
8.00
6.00
4.00
2.00
.00
TEO
378
717
769
817
390
387
389
391
393
388
325
28
627
774
754
222
252
251
253
11.00
12.00
14.00
15.00
16.00
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18.00
19.00
20.00
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22.00
23.00
GROUP

M-Estimators[a]

	GROUP	Huber's M-Estimator[b]	Tukey's Biweight[c]	Hampel's M-Estimator[d]	Andrews' Wave[e]
TEO	11.00	6.8858	6.8872	6.9014	6.8872
	12.00	5.9563	5.9482	5.9340	5.9483
	14.00	2.1823	2.1821	2.1798	2.1822
	15.00	2.4031	2.4003	2.3991	2.3997
	16.00	2.0992	2.0969	2.1007	2.0969
	17.00	2.2768	2.2736	2.2853	2.2736
	18.00	2.8933	2.8298	2.9017	2.8274
	19.00	2.8007	2.8454	2.7934	2.8470
	20.00	2.7063	2.7060	2.7050	2.7059
	21.00	2.8103	2.7702	2.7723	2.7702
	22.00	2.7936	2.7849	2.7925	2.7846
	23.00	2.6803	2.6551	2.6388	2.6551

a. There are no valid cases for TEO when GROUP = 1.000. Statistics cannot be computed for this level.

b. The weighting constant is 1.339.

c. The weighting constant is 4.685.

d. The weighting constants are 1.700, 3.400, and 8.500

e. The weighting constant is 1.340*pi.

Extreme Values[a,b]

GROUP				Case Number	Value
TEO	11.00	Highest	1	691	7.58
			2	688	7.37
			3	684	7.35
			4	687	7.27
			5	683	6.88
		Lowest	1	671	6.44
			2	642	6.44
			3	641	6.44
			4	637	6.44
			5	694	6.80
	12.00	Highest	1	385	7.68
			2	367	7.33
			3	383	7.17
			4	707	7.05
			5	685	7.04
		Lowest	1	381	4.15
			2	373	4.16
			3	382	4.56
			4	376	4.79
			5	377	4.92
	14.00	Highest	1	28	2.74
			2	754	2.68
			3	239	2.58
			4	33	2.53
			5	616	2.51
		Lowest	1	244	1.76
			2	245	1.78
			3	238	1.82
			4	246	1.82
			5	34	1.84
	15.00	Highest	1	627	3.22
			2	325	3.20
			3	796	3.09
			4	719	2.95
			5	333	2.82
		Lowest	1	222	1.40
			2	215	1.78
			3	224	1.81
			4	223	1.89
			5	330	1.91
	16.00	Highest	1	774	2.80
			2	780	2.65
			3	778	2.64
			4	773	2.55
			5	664	2.50
		Lowest	1	135	1.45
			2	145	1.62
			3	138	1.69
			4	147	1.70
			5	144	1.72

Extreme Values[a,b]

GROUP			Case Number	Value
17.00	Highest	1	46	2.81
		2	41	2.71
		3	45	2.61
		4	746	2.58
		5	40	2.53
	Lowest	1	156	1.97
		2	748	2.04
		3	152	2.04
		4	157	2.05
		5	155	2.06
18.00	Highest	1	769	5.76
		2	394	4.00
		3	396	3.99
		4	398	3.92
		5	407	3.92
	Lowest	1	14	2.24
		2	94	2.42
		3	20	2.45
		4	25	2.47
		5	26	2.48
19.00	Highest	1	312	2.95
		2	310	2.93
		3	756	2.91
		4	315	2.90
		5	314	2.86
	Lowest	1	542	2.22
		2	309	2.40
		3	757	2.45
		4	313	2.72
		5	308	2.77
20.00	Highest	1	587	3.29
		2	21	3.28
		3	639	3.25
		4	608	3.22
		5	604	3.20
	Lowest	1	457	1.96
		2	292	2.12
		3	464	2.13
		4	293	2.16
		5	462	2.18
21.00	Highest	1	717	7.21
		2	103	3.08
		3	117	2.99
		4	589	2.94
	Lowest	1	440	2.53
		2	453	2.56
		3	93	2.56
		4	631	2.74
22.00	Highest	1	378	8.45
		2	817	5.78

Extreme Values[a,b]

GROUP			Case Number	Value
		3	804	4.01
		4	201	3.93
		5	808	3.83
	Lowest	1	187	1.96
		2	487	1.99
		3	176	2.01
		4	178	2.02
		5	188	2.03
23.00	Highest	1	390	5.45
		2	389	5.38
		3	392	5.28
		4	387	5.24
		5	388	5.23
	Lowest	1	251	1.79
		2	252	1.80
		3	253	1.80
		4	336	2.33
		5	369	2.34

a. There are no valid cases for TEO when GROUP = 1.000. Statistics cannot be computed for this level.

b. The requested number of extreme values exceeds the number of data points. A smaller number of extremes is displayed.

Percentiles[a]

			Percentiles						
		GROUP	5	10	25	50	75	90	95
Weighted Average (Definition 1)	**TEO**	11.00	6.4435	6.4435	6.4435	6.8396	7.3559	7.5549	.
		12.00	4.1509	4.2391	4.9634	6.0400	6.9113	7.3021	7.6464
		14.00	1.8470	1.9183	2.0551	2.1863	2.2781	2.3623	2.4943
		15.00	1.9193	2.0205	2.2128	2.4100	2.5904	2.7117	2.8196
		16.00	1.6919	1.7557	1.9000	2.1006	2.2609	2.4422	2.6220
		17.00	2.0140	2.0417	2.1345	2.2400	2.4804	2.5964	2.7429
		18.00	2.4747	2.5168	2.6689	2.8252	3.3575	3.8559	3.9199
		19.00	2.2175	2.2353	2.4385	2.8120	2.9162	2.9454	.
		20.00	2.1791	2.3217	2.4908	2.6989	2.9244	3.0798	3.1855
		21.00	2.5301	2.5301	2.5577	2.7869	3.0336	.	.
		22.00	2.1126	2.3294	2.4999	2.7875	3.1096	3.3364	3.5311
		23.00	1.7958	2.3505	2.4898	2.6733	2.8778	5.1892	5.2969
Tukey's Hinges	**TEO**	11.00			6.4435	6.8396	7.3510		
		12.00			5.0027	6.0400	6.7801		
		14.00			2.0565	2.1863	2.2761		
		15.00			2.2149	2.4100	2.5796		
		16.00			1.9188	2.1006	2.2592		
		17.00			2.1359	2.2400	2.4752		
		18.00			2.6693	2.8252	3.3525		
		19.00			2.4529	2.8120	2.9100		
		20.00			2.5006	2.6989	2.9243		
		21.00			2.5600	2.7869	2.9882		
		22.00			2.5012	2.7875	3.1095		
		23.00			2.5009	2.6733	2.8690		

a. There are no valid cases for TEO when GROUP = 1.000. Statistics cannot be computed for this level.

Descriptives[a]

	GROUP			Statistic	Std. Error
TEO	11.00	Mean		6.9020	.14381
		95% Confidence Interval for Mean	Lower Bound	6.5766	
			Upper Bound	7.2273	
		5% Trimmed Mean		6.8900	
		Median		6.8396	
		Variance		.207	
		Std. Deviation		.45477	
		Minimum		6.44	
		Maximum		7.58	
		Range		1.13	
		Interquartile Range		.91	
		Skewness		.239	.687
		Kurtosis		-1.842	1.334
	12.00	Mean		5.9275	.23873
		95% Confidence Interval for Mean	Lower Bound	5.4295	
			Upper Bound	6.4255	
		5% Trimmed Mean		5.9297	
		Median		6.0400	
		Variance		1.197	
		Std. Deviation		1.09400	
		Minimum		4.15	
		Maximum		7.68	
		Range		3.53	
		Interquartile Range		1.95	
		Skewness		-.129	.501
		Kurtosis		-1.269	.972
	14.00	Mean		2.1786	.01729
		95% Confidence Interval for Mean	Lower Bound	2.1443	
			Upper Bound	2.2129	
		5% Trimmed Mean		2.1758	
		Median		2.1863	
		Variance		.032	
		Std. Deviation		.17967	
		Minimum		1.76	
		Maximum		2.74	
		Range		.98	
		Interquartile Range		.22	
		Skewness		.185	.233
		Kurtosis		.734	.461
	15.00	Mean		2.3939	.02817
		95% Confidence Interval for Mean	Lower Bound	2.3381	
			Upper Bound	2.4497	
		5% Trimmed Mean		2.3928	
		Median		2.4100	
		Variance		.088	
		Std. Deviation		.29678	
		Minimum		1.40	
		Maximum		3.22	
		Range		1.82	
		Interquartile Range		.38	
		Skewness		-.068	.229

Descriptives[a]

GROUP				Statistic	Std. Error
		Kurtosis		.849	.455
	16.00	Mean		2.1076	.03399
		95% Confidence Interval for Mean	Lower Bound	2.0397	
			Upper Bound	2.1756	
		5% Trimmed Mean		2.1037	
		Median		2.1006	
		Variance		.073	
		Std. Deviation		.26978	
		Minimum		1.45	
		Maximum		2.80	
		Range		1.35	
		Interquartile Range		.36	
		Skewness		.171	.302
		Kurtosis		-.030	.595
	17.00	Mean		2.2990	.03808
		95% Confidence Interval for Mean	Lower Bound	2.2213	
			Upper Bound	2.3767	
		5% Trimmed Mean		2.2895	
		Median		2.2400	
		Variance		.046	
		Std. Deviation		.21542	
		Minimum		1.97	
		Maximum		2.81	
		Range		.84	
		Interquartile Range		.35	
		Skewness		.560	.414
		Kurtosis		-.521	.809
	18.00	Mean		3.0254	.05731
		95% Confidence Interval for Mean	Lower Bound	2.9115	
			Upper Bound	3.1394	
		5% Trimmed Mean		2.9852	
		Median		2.8252	
		Variance		.289	
		Std. Deviation		.53764	
		Minimum		2.24	
		Maximum		5.76	
		Range		3.52	
		Interquartile Range		.69	
		Skewness		1.893	.257
		Kurtosis		6.308	.508
	19.00	Mean		2.7102	.08266
		95% Confidence Interval for Mean	Lower Bound	2.5233	
			Upper Bound	2.8972	
		5% Trimmed Mean		2.7245	
		Median		2.8120	
		Variance		.068	
		Std. Deviation		.26138	
		Minimum		2.22	
		Maximum		2.95	
		Range		.73	
		Interquartile Range		.48	

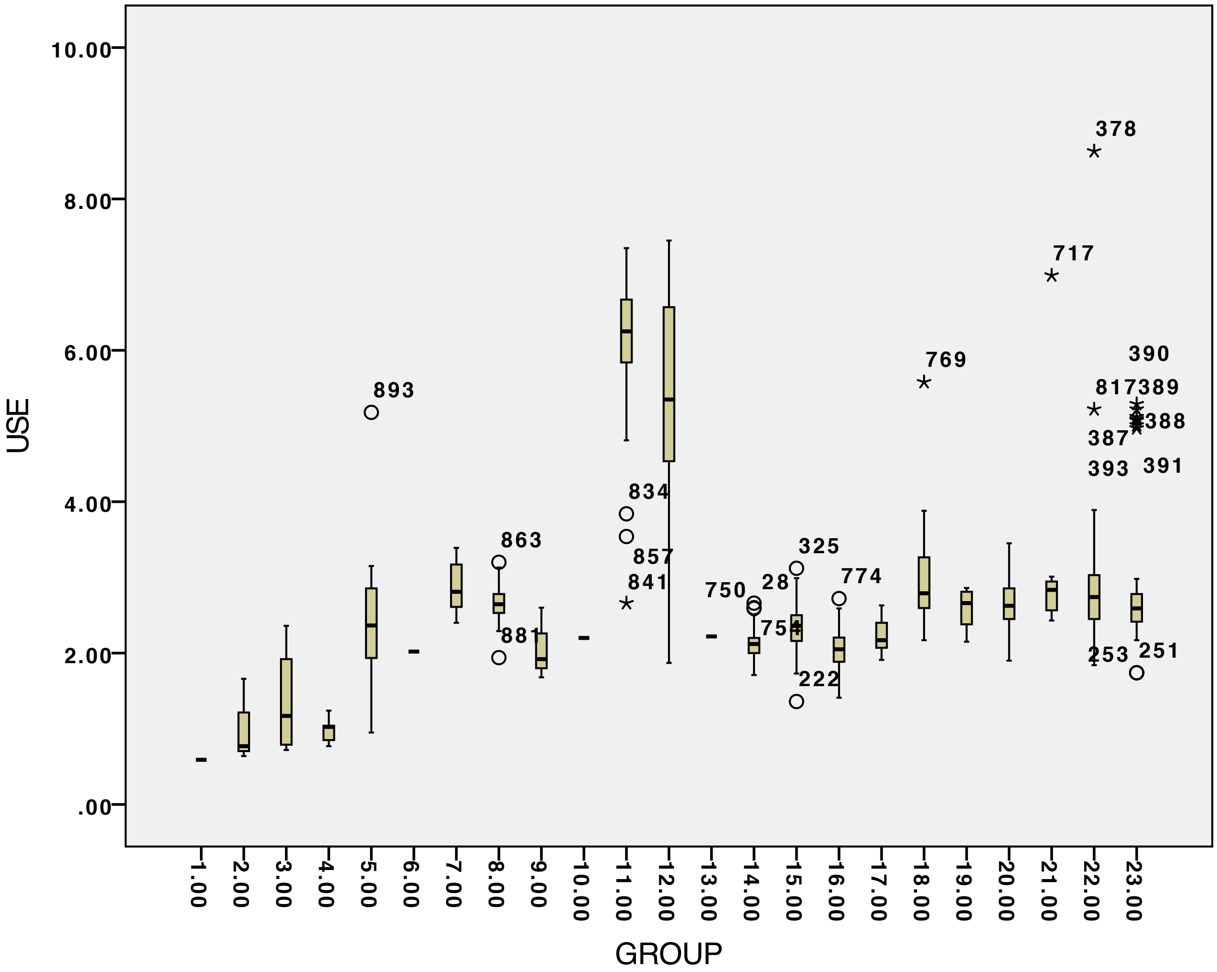
Descriptives[a]

GROUP			Statistic	Std. Error
	Skewness		-.975	.687
	Kurtosis		-.497	1.334
20.00	Mean		2.7002	.02725
	95% Confidence Interval for Mean	Lower Bound	2.6463	
		Upper Bound	2.7542	
	5% Trimmed Mean		2.7028	
	Median		2.6989	
	Variance		.086	
	Std. Deviation		.29355	
	Minimum		1.96	
	Maximum		3.29	
	Range		1.33	
	Interquartile Range		.43	
	Skewness		-.158	.225
	Kurtosis		-.579	.446
21.00	Mean		3.2653	.49744
	95% Confidence Interval for Mean	Lower Bound	2.1182	
		Upper Bound	4.4124	
	5% Trimmed Mean		3.0870	
	Median		2.7869	
	Variance		2.227	
	Std. Deviation		1.49233	
	Minimum		2.53	
	Maximum		7.21	
	Range		4.68	
	Interquartile Range		.48	
	Skewness		2.897	.717
	Kurtosis		8.541	1.400
22.00	Mean		2.8463	.04258
	95% Confidence Interval for Mean	Lower Bound	2.7623	
		Upper Bound	2.9303	
	5% Trimmed Mean		2.8034	
	Median		2.7875	
	Variance		.366	
	Std. Deviation		.60524	
	Minimum		1.96	
	Maximum		8.45	
	Range		6.49	
	Interquartile Range		.61	
	Skewness		4.549	.171
	Kurtosis		38.036	.341
23.00	Mean		2.9432	.12580
	95% Confidence Interval for Mean	Lower Bound	2.6910	
		Upper Bound	3.1954	
	5% Trimmed Mean		2.8718	
	Median		2.6733	
	Variance		.870	
	Std. Deviation		.93292	
	Minimum		1.79	
	Maximum		5.45	
	Range		3.66	

Descriptives[a]

GROUP		Statistic	Std. Error
	Interquartile Range	.39	
	Skewness	1.928	.322
	Kurtosis	2.640	.634

a. There are no valid cases for TEO when GROUP = 1.000. Statistics cannot be computed for this level.


USE
10.00
8.00
6.00
4.00
2.00
.00
378
717
390
769
817389
893
388
387
393
391
834
863
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841
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21.00
22.00
23.00
GROUP

Extreme Values[a,b,c,d,e]

GROUP				Case Number	Value
USE	2.00	Highest	1	913	1.66
		Lowest	1	911	.64
	3.00	Highest	1	842	2.36
			2	905	1.48
		Lowest	1	843	.72
			2	844	.86
	4.00	Highest	1	838	1.24
			2	876	1.04
			3	875	1.03
		Lowest	1	874	.77
			2	836	.85
			3	877	1.02
	5.00	Highest	1	893	5.18
			2	847	3.15
			3	837	3.06
			4	907	2.92
			5	840	2.79
		Lowest	1	829	.95
			2	879	1.16
			3	830	1.41
			4	908	1.69
			5	846	2.18
	7.00	Highest	1	835	3.39
			2	870	3.18
			3	853	3.17
			4	859	2.83
		Lowest	1	854	2.40
			2	871	2.44
			3	858	2.61
			4	860	2.69
	8.00	Highest	1	863	3.20
			2	862	3.13
			3	851	2.78
			4	850	2.72
			5	833	2.69
		Lowest	1	881	1.94
			2	868	2.29
			3	869	2.53
			4	861	2.58
			5	849	2.60
	9.00	Highest	1	866	2.60
		Lowest	1	839	1.68
	11.00	Highest	1	691	7.35
			2	688	7.15
			3	684	7.13
			4	687	7.05
			5	683	6.67
		Lowest	1	841	2.66
			2	857	3.54
			3	834	3.84

Extreme Values[a,b,c,d,e]

GROUP			Case Number	Value
		4	855	4.81
		5	864	5.84
12.00	Highest	1	385	7.45
		2	367	7.11
		3	383	6.96
		4	707	6.84
		5	685	6.83
	Lowest	1	894	1.87
		2	867	2.60
		3	381	3.06
		4	375	3.19
		5	373	4.03
14.00	Highest	1	28	2.66
		2	754	2.60
		3	750	2.59
		4	239	2.50
		5	33	2.45
	Lowest	1	244	1.71
		2	245	1.73
		3	246	1.77
		4	238	1.77
		5	34	1.78
15.00	Highest	1	325	3.12
		2	796	2.99
		3	627	2.94
		4	333	2.74
		5	578	2.73
	Lowest	1	222	1.36
		2	215	1.73
		3	224	1.75
		4	223	1.83
		5	330	1.85
16.00	Highest	1	774	2.72
		2	778	2.59
		3	780	2.57
		4	727	2.55
		5	773	2.45
	Lowest	1	135	1.41
		2	145	1.58
		3	147	1.65
		4	144	1.67
		5	128	1.69
17.00	Highest	1	41	2.63
		2	45	2.53
		3	746	2.50
		4	749	2.49
		5	46	2.47
	Lowest	1	156	1.91
		2	748	1.97
		3	152	1.98

Extreme Values[a,b,c,d,e]

GROUP			Case Number	Value
		4	157	1.99
		5	155	2.00
18.00	Highest	1	769	5.58
		2	394	3.88
		3	396	3.87
		4	398	3.81
		5	407	3.80
	Lowest	1	14	2.17
		2	94	2.35
		3	20	2.38
		4	26	2.41
		5	13	2.41
19.00	Highest	1	312	2.86
		2	310	2.85
		3	315	2.81
		4	314	2.77
		5	308	2.68
	Lowest	1	542	2.15
		2	309	2.32
		3	757	2.38
		4	756	2.51
		5	313	2.64
20.00	Highest	1	598	3.45
		2	21	3.39
		3	882	3.37
		4	587	3.33
		5	891	3.22
	Lowest	1	457	1.90
		2	292	2.05
		3	464	2.06
		4	293	2.09
		5	462	2.11[f]
21.00	Highest	1	717	6.99
		2	888	3.01
		3	103	2.99
		4	117	2.90
		5	93	2.88
	Lowest	1	631	2.43
		2	440	2.45
		3	453	2.48
		4	886	2.65
		5	109	2.70
22.00	Highest	1	378	8.63
		2	817	5.22
		3	804	3.89
		4	201	3.81
		5	808	3.71
	Lowest	1	176	1.84
		2	187	1.90
		3	487	1.93

Extreme Values[a,b,c,d,e]

GROUP			Case Number	Value
		4	178	1.96
		5	188	1.97
23.00	Highest	1	390	5.29
		2	389	5.22
		3	392	5.12
		4	387	5.09
		5	388	5.07
	Lowest	1	253	1.74
		2	252	1.74
		3	251	1.74
		4	753	2.17
		5	336	2.26

a. USE is constant when GROUP = 1.00. It has been omitted.

b. The requested number of extreme values exceeds the number of data points. A smaller number of extremes is displayed.

c. USE is constant when GROUP = 6.00. It has been omitted.

d. USE is constant when GROUP = 10.00. It has been omitted.

e. USE is constant when GROUP = 13.00. It has been omitted.

f. Only a partial list of cases with the value 2.11 are shown in the table of lower extremes.

Percentiles[a,b,c,d]

			Percentiles						
		GROUP	5	10	25	50	75	90	95
Weighted Average (Definition 1)	**USE**	2.00	.6400	.6400	.6400	.7700	.	.	.
		3.00	.7200	.7200	.7550	1.1700	2.1400	.	.
		4.00	.7700	.7700	.8300	1.0250	1.0900	.	.
		5.00	.9500	1.0970	1.8125	2.3650	2.8875	3.7590	.
		7.00	2.4000	2.4000	2.5250	2.8100	3.1750	.	.
		8.00	1.9400	1.9750	2.4700	2.6450	2.8675	3.1930	.
		9.00	1.6800	1.6800	1.6800	1.9200	.	.	.
		11.00	2.6600	3.3640	5.3250	6.2500	6.8600	7.1900	.
		12.00	2.0160	2.7840	4.4200	5.3500	6.5800	7.0500	7.3820
		14.00	1.7900	1.8600	1.9950	2.1200	2.2150	2.3400	2.4450
		15.00	1.8670	1.9880	2.1600	2.3600	2.5050	2.6300	2.7130
		16.00	1.6540	1.7340	1.8800	2.0500	2.2200	2.4060	2.5660
		17.00	1.9490	1.9830	2.0700	2.1700	2.4050	2.4970	2.5650
		18.00	2.4100	2.4580	2.5925	2.7900	3.2675	3.7410	3.8055
		19.00	2.1500	2.1670	2.3650	2.6600	2.8200	2.8590	.
		20.00	2.1105	2.2330	2.4500	2.6250	2.8575	3.0660	3.1785
		21.00	2.4300	2.4360	2.5225	2.8350	2.9675	5.7960	.
		22.00	2.0500	2.2620	2.4500	2.7400	3.0300	3.2500	3.4780
		23.00	1.7400	2.2660	2.4100	2.5900	2.7900	5.0340	5.1400
Tukey's Hinges	**USE**	2.00			.7050	.7700	1.2150		
		3.00			.7900	1.1700	1.9200		
		4.00			.8500	1.0250	1.0400		
		5.00			1.9350	2.3650	2.8550		
		7.00			2.6100	2.8100	3.1700		
		8.00			2.5300	2.6450	2.7800		
		9.00			1.8000	1.9200	2.2600		
		11.00			5.8400	6.2500	6.6700		
		12.00			4.5350	5.3500	6.5700		
		14.00			2.0000	2.1200	2.2000		
		15.00			2.1600	2.3600	2.5000		
		16.00			1.8850	2.0500	2.2050		
		17.00			2.0700	2.1700	2.4000		
		18.00			2.5950	2.7900	3.2650		
		19.00			2.3800	2.6600	2.8100		
		20.00			2.4500	2.6250	2.8550		
		21.00			2.5650	2.8350	2.9450		
		22.00			2.4500	2.7400	3.0300		
		23.00			2.4150	2.5900	2.7800		

a. USE is constant when GROUP = 1.00. It has been omitted.

b. USE is constant when GROUP = 6.00. It has been omitted.

c. USE is constant when GROUP = 10.00. It has been omitted.

d. USE is constant when GROUP = 13.00. It has been omitted.

M-Estimators[a,f,g,h]

	GROUP	Huber's M-Estimator[b]	Tukey's Biweight[c]	Hampel's M-Estimator[d]	Andrews' Wave[e]
USE	2.00	.7919	.7051	.7353	.7051
	3.00	1.1893	1.1555	1.2351	1.1570
	4.00	.9898	.9913	.9858	.9914
	5.00	2.4110	2.3453	2.3567	2.3446
	7.00	2.8264	2.8269	2.8356	2.8268
	8.00	2.6491	2.6347	2.6530	2.6324
	9.00	1.9591	1.9603	2.0028	1.9616
	11.00	6.2930	6.5280	6.4591	6.5322
	12.00	5.4065	5.3703	5.3423	5.3694
	14.00	2.1155	2.1125	2.1134	2.1122
	15.00	2.3382	2.3375	2.3333	2.3370
	16.00	2.0524	2.0502	2.0539	2.0502
	17.00	2.2037	2.2053	2.2144	2.2054
	18.00	2.8482	2.8003	2.8610	2.7983
	19.00	2.6352	2.6331	2.6164	2.6328
	20.00	2.6441	2.6339	2.6410	2.6337
	21.00	2.7962	2.7572	2.7471	2.7572
	22.00	2.7353	2.7276	2.7317	2.7275
	23.00	2.5973	2.5722	2.5553	2.5722

a. USE is constant when GROUP = 1.00. It has been omitted.

b. The weighting constant is 1.339.

c. The weighting constant is 4.685.

d. The weighting constants are 1.700, 3.400, and 8.500

e. The weighting constant is 1.340*pi.

f. USE is constant when GROUP = 6.00. It has been omitted.

g. USE is constant when GROUP = 10.00. It has been omitted.

h. USE is constant when GROUP = 13.00. It has been omitted.

Descriptives[a,b,c,d]

	GROUP			Statistic	Std. Error
USE	2.00	Mean		1.0233	.32054
		95% Confidence Interval for Mean	Lower Bound	-.3558	
			Upper Bound	2.4025	
		5% Trimmed Mean		.	
		Median		.7700	
		Variance		.308	
		Std. Deviation		.55519	
		Minimum		.64	
		Maximum		1.66	
		Range		1.02	
		Interquartile Range		.	
		Skewness		1.626	1.225
		Kurtosis		.	.
	3.00	Mean		1.3550	.37349
		95% Confidence Interval for Mean	Lower Bound	.1664	
			Upper Bound	2.5436	
		5% Trimmed Mean		1.3344	
		Median		1.1700	
		Variance		.558	
		Std. Deviation		.74697	
		Minimum		.72	
		Maximum		2.36	
		Range		1.64	
		Interquartile Range		1.38	
		Skewness		1.023	1.014
		Kurtosis		-.191	2.619
	4.00	Mean		.9917	.06720
		95% Confidence Interval for Mean	Lower Bound	.8189	
			Upper Bound	1.1644	
		5% Trimmed Mean		.9902	
		Median		1.0250	
		Variance		.027	
		Std. Deviation		.16461	
		Minimum		.77	
		Maximum		1.24	
		Range		.47	
		Interquartile Range		.26	
		Skewness		.119	.845
		Kurtosis		.070	1.741
	5.00	Mean		2.4381	.24595
		95% Confidence Interval for Mean	Lower Bound	1.9139	
			Upper Bound	2.9624	
		5% Trimmed Mean		2.3685	
		Median		2.3650	
		Variance		.968	
		Std. Deviation		.98382	
		Minimum		.95	
		Maximum		5.18	
		Range		4.23	
		Interquartile Range		1.08	
		Skewness		1.158	.564

Descriptives[a,b,c,d]

GROUP			Statistic	Std. Error
	Kurtosis		3.312	1.091
7.00	**Mean**		2.8356	.11528
	95% Confidence Interval for Mean	**Lower Bound**	2.5697	
		Upper Bound	3.1014	
	5% Trimmed Mean		2.8290	
	Median		2.8100	
	Variance		.120	
	Std. Deviation		.34584	
	Minimum		2.40	
	Maximum		3.39	
	Range		.99	
	Interquartile Range		.65	
	Skewness		.348	.717
	Kurtosis		-1.115	1.400
8.00	**Mean**		2.6460	.11603
	95% Confidence Interval for Mean	**Lower Bound**	2.3835	
		Upper Bound	2.9085	
	5% Trimmed Mean		2.6544	
	Median		2.6450	
	Variance		.135	
	Std. Deviation		.36692	
	Minimum		1.94	
	Maximum		3.20	
	Range		1.26	
	Interquartile Range		.40	
	Skewness		-.317	.687
	Kurtosis		.648	1.334
9.00	**Mean**		2.0667	.27552
	95% Confidence Interval for Mean	**Lower Bound**	.8812	
		Upper Bound	3.2521	
	5% Trimmed Mean		.	
	Median		1.9200	
	Variance		.228	
	Std. Deviation		.47721	
	Minimum		1.68	
	Maximum		2.60	
	Range		.92	
	Interquartile Range		.	
	Skewness		1.252	1.225
	Kurtosis		.	.
11.00	**Mean**		5.8941	.33146
	95% Confidence Interval for Mean	**Lower Bound**	5.1914	
		Upper Bound	6.5968	
	5% Trimmed Mean		5.9929	
	Median		6.2500	
	Variance		1.868	
	Std. Deviation		1.36666	
	Minimum		2.66	
	Maximum		7.35	
	Range		4.69	
	Interquartile Range		1.54	

Descriptives[a,b,c,d]

GROUP			Statistic	Std. Error
	Skewness		-1.309	.550
	Kurtosis		.811	1.063
12.00	**Mean**		5.2378	.32021
	95% Confidence Interval for Mean	**Lower Bound**	4.5737	
		Upper Bound	5.9019	
	5% Trimmed Mean		5.2992	
	Median		5.3500	
	Variance		2.358	
	Std. Deviation		1.53570	
	Minimum		1.87	
	Maximum		7.45	
	Range		5.58	
	Interquartile Range		2.16	
	Skewness		-.568	.481
	Kurtosis		-.390	.935
14.00	**Mean**		2.1164	.01723
	95% Confidence Interval for Mean	**Lower Bound**	2.0823	
		Upper Bound	2.1506	
	5% Trimmed Mean		2.1124	
	Median		2.1200	
	Variance		.032	
	Std. Deviation		.17991	
	Minimum		1.71	
	Maximum		2.66	
	Range		.95	
	Interquartile Range		.22	
	Skewness		.305	.231
	Kurtosis		.722	.459
15.00	**Mean**		2.3248	.02542
	95% Confidence Interval for Mean	**Lower Bound**	2.2745	
		Upper Bound	2.3752	
	5% Trimmed Mean		2.3274	
	Median		2.3600	
	Variance		.075	
	Std. Deviation		.27383	
	Minimum		1.36	
	Maximum		3.12	
	Range		1.76	
	Interquartile Range		.34	
	Skewness		-.255	.225
	Kurtosis		.936	.446
16.00	**Mean**		2.0617	.03325
	95% Confidence Interval for Mean	**Lower Bound**	1.9953	
		Upper Bound	2.1282	
	5% Trimmed Mean		2.0589	
	Median		2.0500	
	Variance		.070	
	Std. Deviation		.26391	
	Minimum		1.41	
	Maximum		2.72	
	Range		1.31	

Descriptives[a,b,c,d]

GROUP			Statistic	Std. Error
	Interquartile Range		.34	
	Skewness		.154	.302
	Kurtosis		-.027	.595
17.00	Mean		2.2225	.03472
	95% Confidence Interval for Mean	Lower Bound	2.1517	
		Upper Bound	2.2933	
	5% Trimmed Mean		2.2181	
	Median		2.1700	
	Variance		.039	
	Std. Deviation		.19640	
	Minimum		1.91	
	Maximum		2.63	
	Range		.72	
	Interquartile Range		.34	
	Skewness		.355	.414
	Kurtosis		-1.052	.809
18.00	Mean		2.9631	.05556
	95% Confidence Interval for Mean	Lower Bound	2.8526	
		Upper Bound	3.0735	
	5% Trimmed Mean		2.9270	
	Median		2.7900	
	Variance		.272	
	Std. Deviation		.52122	
	Minimum		2.17	
	Maximum		5.58	
	Range		3.41	
	Interquartile Range		.68	
	Skewness		1.757	.257
	Kurtosis		5.861	.508
19.00	Mean		2.5970	.07806
	95% Confidence Interval for Mean	Lower Bound	2.4204	
		Upper Bound	2.7736	
	5% Trimmed Mean		2.6072	
	Median		2.6600	
	Variance		.061	
	Std. Deviation		.24685	
	Minimum		2.15	
	Maximum		2.86	
	Range		.71	
	Interquartile Range		.46	
	Skewness		-.661	.687
	Kurtosis		-.814	1.334
20.00	Mean		2.6462	.02866
	95% Confidence Interval for Mean	Lower Bound	2.5894	
		Upper Bound	2.7029	
	5% Trimmed Mean		2.6415	
	Median		2.6250	
	Variance		.099	
	Std. Deviation		.31392	
	Minimum		1.90	
	Maximum		3.45	

Descriptives[a,b,c,d]

GROUP			Statistic	Std. Error
	Range		1.55	
	Interquartile Range		.41	
	Skewness		.133	.221
	Kurtosis		-.185	.438
21.00	**Mean**		3.0958	.35887
	95% Confidence Interval for Mean	**Lower Bound**	2.3060	
		Upper Bound	3.8857	
	5% Trimmed Mean		2.9165	
	Median		2.8350	
	Variance		1.545	
	Std. Deviation		1.24315	
	Minimum		2.43	
	Maximum		6.99	
	Range		4.56	
	Interquartile Range		.45	
	Skewness		3.296	.637
	Kurtosis		11.178	1.232
22.00	**Mean**		2.7803	.04092
	95% Confidence Interval for Mean	**Lower Bound**	2.6996	
		Upper Bound	2.8609	
	5% Trimmed Mean		2.7411	
	Median		2.7400	
	Variance		.353	
	Std. Deviation		.59436	
	Minimum		1.84	
	Maximum		8.63	
	Range		6.79	
	Interquartile Range		.58	
	Skewness		4.901	.167
	Kurtosis		44.925	.333
23.00	**Mean**		2.8502	.12249
	95% Confidence Interval for Mean	**Lower Bound**	2.6046	
		Upper Bound	3.0958	
	5% Trimmed Mean		2.7803	
	Median		2.5900	
	Variance		.825	
	Std. Deviation		.90842	
	Minimum		1.74	
	Maximum		5.29	
	Range		3.55	
	Interquartile Range		.38	
	Skewness		1.921	.322
	Kurtosis		2.618	.634

a. USE is constant when GROUP = 1.00. It has been omitted.

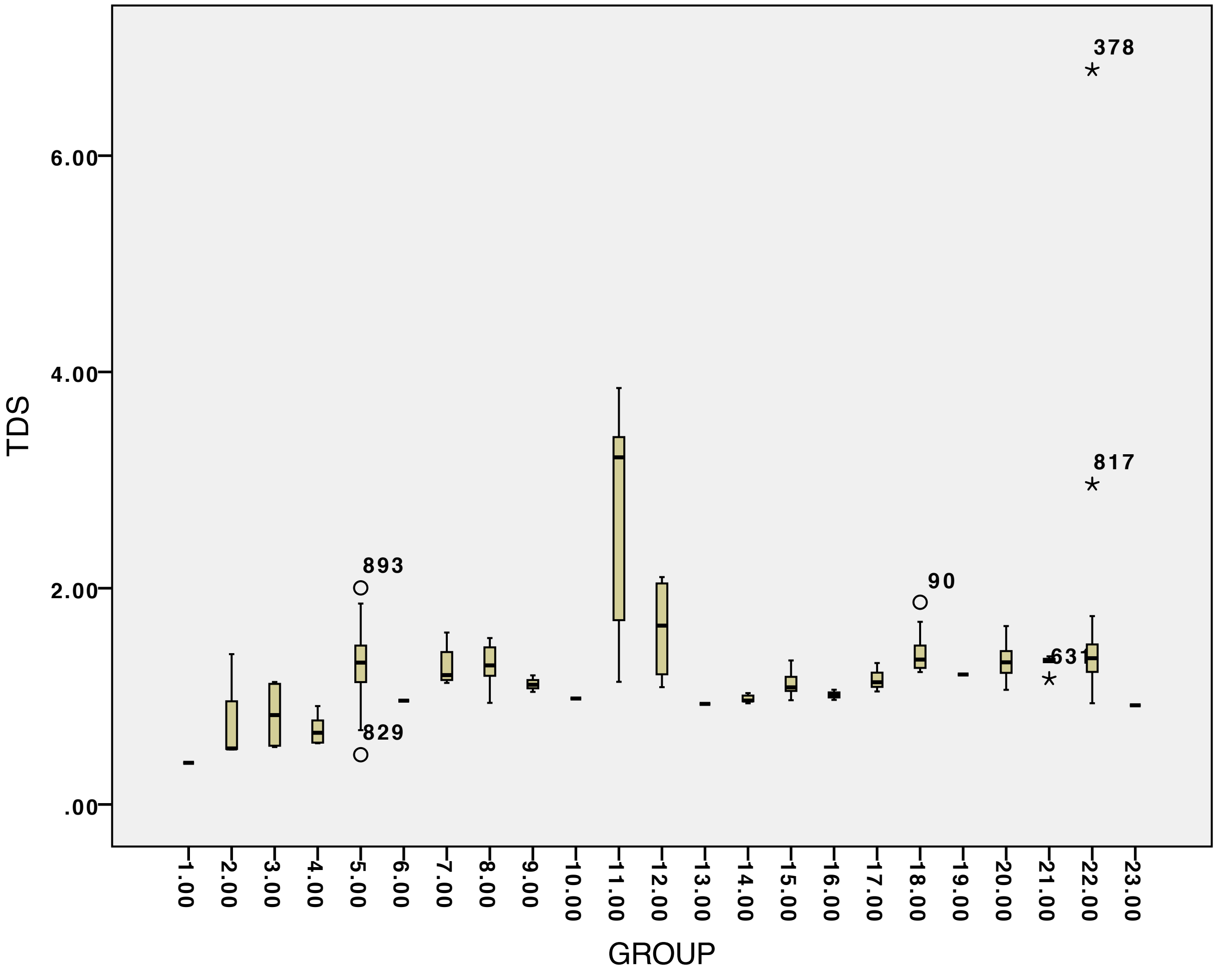
b. USE is constant when GROUP = 6.00. It has been omitted.

c. USE is constant when GROUP = 10.00. It has been omitted.

d. USE is constant when GROUP = 13.00. It has been omitted.

Case Processing Summary

	GROUP	Cases					
		Valid		Missing		Total	
		N	Percent	N	Percent	N	Percent
USE	1.00	1	100.0%	0	0.0%	1	100.0%
	2.00	3	100.0%	0	0.0%	3	100.0%
	3.00	4	100.0%	0	0.0%	4	100.0%
	4.00	6	100.0%	0	0.0%	6	100.0%
	5.00	16	100.0%	0	0.0%	16	100.0%
	6.00	1	100.0%	0	0.0%	1	100.0%
	7.00	9	100.0%	0	0.0%	9	100.0%
	8.00	10	100.0%	0	0.0%	10	100.0%
	9.00	3	100.0%	0	0.0%	3	100.0%
	10.00	1	100.0%	0	0.0%	1	100.0%
	11.00	17	100.0%	0	0.0%	17	100.0%
	12.00	23	100.0%	0	0.0%	23	100.0%
	13.00	1	100.0%	0	0.0%	1	100.0%
	14.00	109	98.2%	2	1.8%	111	100.0%
	15.00	116	100.0%	0	0.0%	116	100.0%
	16.00	63	100.0%	0	0.0%	63	100.0%
	17.00	32	100.0%	0	0.0%	32	100.0%
	18.00	88	100.0%	0	0.0%	88	100.0%
	19.00	10	100.0%	0	0.0%	10	100.0%
	20.00	120	100.0%	0	0.0%	120	100.0%
	21.00	12	100.0%	0	0.0%	12	100.0%
	22.00	211	100.0%	0	0.0%	211	100.0%
	23.00	55	100.0%	0	0.0%	55	100.0%


TDS
6.00
4.00
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21.00
22.00
23.00
GROUP

Extreme Values[a,b,c,d,e,f,g]

GROUP				Case Number	Value
TDS	2.00	Highest	1	913	1.39
		Lowest	1	912	.51
	3.00	Highest	1	842	1.13
			2	905	1.10
		Lowest	1	843	.53
			2	844	.56
	4.00	Highest	1	838	.91
			2	876	.78
			3	875	.67
		Lowest	1	874	.57
			2	836	.57
			3	877	.66
	5.00	Highest	1	893	2.00
			2	907	1.86
			3	847	1.82
			4	878	1.48
			5	837	1.46
		Lowest	1	829	.46
			2	830	.69
			3	879	.90
			4	908	1.07
			5	846	1.19
	7.00	Highest	1	835	1.59
			2	870	1.48
			3	853	1.34
			4	859	1.22
		Lowest	1	858	1.12
			2	831	1.15
			3	871	1.16
			4	860	1.18
	8.00	Highest	1	833	1.54
			2	863	1.50
			3	849	1.45
			4	861	1.37
		Lowest	1	881	.94
			2	869	1.12
			3	851	1.19
			4	850	1.25
	9.00	Highest	1	866	1.19
		Lowest	1	839	1.04
	11.00	Highest	1	865	3.85
			2	864	3.52
			3	855	3.28
		Lowest	1	841	1.13
			2	857	1.56
			3	834	1.85
	12.00	Highest	1	365	2.10
			2	381	1.99
		Lowest	1	894	1.08
			2	867	1.32

Extreme Values[a,b,c,d,e,f,g]

GROUP			Case Number	Value
14.00	Highest	1	636	1.03
		2	250	1.01
	Lowest	1	735	.94
		2	620	.95
15.00	Highest	1	325	1.33
		2	796	1.29
		3	627	1.25
		4	899	1.18
		5	431	1.14
	Lowest	1	719	.96
		2	580	1.01
		3	898	1.02
		4	12	1.05
		5	890	1.06
16.00	Highest	1	773	1.06
		2	727	1.04
	Lowest	1	138	.97
		2	778	.99
17.00	Highest	1	749	1.31
	Lowest	1	39	1.05
18.00	Highest	1	90	1.87
		2	105	1.69
		3	548	1.53
		4	755	1.41
		5	767	1.37
	Lowest	1	106	1.22
		2	23	1.23
		3	724	1.26
		4	403	1.27
		5	25	1.31
20.00	Highest	1	21	1.65
		2	587	1.55
		3	882	1.53
		4	598	1.42
		5	632	1.40
	Lowest	1	442	1.06
		2	458	1.08
		3	900	1.15
		4	506	1.22
		5	597	1.26
21.00	Highest	1	885	1.37
		2	93	1.35
	Lowest	1	631	1.16
		2	888	1.32
22.00	Highest	1	378	6.80
		2	817	2.96
		3	815	1.74
		4	57	1.74
		5	738	1.70

Extreme Values[a,b,c,d,e,f,g]

GROUP			Case Number	Value
	Lowest	1	176	.94
		2	897	1.06
		3	902	1.11
		4	883	1.13
		5	256	1.14

a. TDS is constant when GROUP = 1.00. It has been omitted.

b. The requested number of extreme values exceeds the number of data points. A smaller number of extremes is displayed.

c. TDS is constant when GROUP = 6.00. It has been omitted.

d. TDS is constant when GROUP = 10.00. It has been omitted.

e. TDS is constant when GROUP = 13.00. It has been omitted.

f. TDS is constant when GROUP = 19.00. It has been omitted.

g. TDS is constant when GROUP = 23.00. It has been omitted.

Percentiles[a,b,c,d,e,f]

			Percentiles						
		GROUP	5	10	25	50	75	90	95
Weighted Average (Definition 1)	**TDS**	2.00	.5090	.5090	.5090	.5180	.	.	.
		3.00	.5310	.5310	.5370	.8265	1.1239	.	.
		4.00	.5660	.5660	.5705	.6630	.8103	.	.
		5.00	.4600	.5962	1.0720	1.3120	1.4800	1.9160	.
		7.00	1.1240	1.1240	1.1490	1.1964	1.4463	.	.
		8.00	.9395	.9395	1.1555	1.2860	1.4773	.	.
		9.00	1.0410	1.0410	1.0410	1.1070	.	.	.
		11.00	1.1340	1.1340	1.5556	3.2100	3.5193	.	.
		12.00	1.0847	1.0847	1.1442	1.6540	2.0735	.	.
		14.00	.9355	.9355	.9448	.9610	1.0185	.	.
		15.00	.9640	.9808	1.0370	1.0830	1.2155	1.3140	.
		16.00	.9670	.9670	.9785	1.0120	1.0485	.	.
		17.00	1.0450	1.0450	1.0450	1.1300	.	.	.
		18.00	1.2245	1.2261	1.2615	1.3400	1.4981	1.8157	.
		20.00	1.0600	1.0720	1.1993	1.3145	1.4455	1.6000	.
		21.00	1.1630	1.1630	1.2395	1.3290	1.3585	.	.
		22.00	1.0320	1.1195	1.2243	1.3525	1.5038	1.7410	3.9203
Tukey's Hinges	**TDS**	2.00			.5135	.5180	.9540		
		3.00			.5430	.8265	1.1153		
		4.00			.5720	.6630	.7770		
		5.00			1.1317	1.3120	1.4695		
		7.00			1.1510	1.1964	1.4095		
		8.00			1.1900	1.2860	1.4530		
		9.00			1.0740	1.1070	1.1505		
		11.00			1.7043	3.2100	3.3974		
		12.00			1.2038	1.6540	2.0440		
		14.00			.9540	.9610	1.0070		
		15.00			1.0500	1.0830	1.1800		
		16.00			.9900	1.0120	1.0360		
		17.00			1.0875	1.1300	1.2190		
		18.00			1.2630	1.3400	1.4698		
		20.00			1.2170	1.3145	1.4185		
		21.00			1.3160	1.3290	1.3470		
		22.00			1.2260	1.3525	1.4800		

a. TDS is constant when GROUP = 1.00. It has been omitted.

b. TDS is constant when GROUP = 6.00. It has been omitted.

c. TDS is constant when GROUP = 10.00. It has been omitted.

d. TDS is constant when GROUP = 13.00. It has been omitted.

e. TDS is constant when GROUP = 19.00. It has been omitted.

f. TDS is constant when GROUP = 23.00. It has been omitted.

M-Estimators[a,f,g,h,i,j]

	GROUP	Huber's M-Estimator[b]	Tukey's Biweight[c]	Hampel's M-Estimator[d]	Andrews' Wave[e]
TDS	2.00	.5195	.5135	.5135	.5135
	3.00	.8291	.8285	.8291	.8285
	4.00	.6733	.6739	.6799	.6741
	5.00	1.3182	1.3356	1.3261	1.3343
	7.00	1.2128	1.1807	1.2087	1.1807
	8.00	1.3093	1.3038	1.3035	1.3037
	9.00	1.1140	1.1119	1.1140	1.1119
	11.00	2.7723	2.7676	2.6986	2.7664
	12.00	1.6310	1.6306	1.6239	1.6306
	14.00	.9718	.9723	.9748	.9723
	15.00	1.1013	1.0878	1.1043	1.0872
	16.00	1.0125	1.0125	1.0124	1.0125
	17.00	1.1435	1.1488	1.1589	1.1488
	18.00	1.3413	1.3173	1.3359	1.3173
	20.00	1.3178	1.3139	1.3178	1.3139
	21.00	1.3303	1.3390	1.3403	1.3390
	22.00	1.3625	1.3480	1.3498	1.3482

a. TDS is constant when GROUP = 1.00. It has been omitted.

b. The weighting constant is 1.339.

c. The weighting constant is 4.685.

d. The weighting constants are 1.700, 3.400, and 8.500

e. The weighting constant is 1.340*pi.

f. TDS is constant when GROUP = 6.00. It has been omitted.

g. TDS is constant when GROUP = 10.00. It has been omitted.

h. TDS is constant when GROUP = 13.00. It has been omitted.

i. TDS is constant when GROUP = 19.00. It has been omitted.

j. TDS is constant when GROUP = 23.00. It has been omitted.

Descriptives^{a,b,c,d,e,f}

	GROUP			Statistic	Std. Error
TDS	2.00	Mean		.8057	.29218
		95% Confidence Interval for Mean	Lower Bound	-.4515	
			Upper Bound	2.0628	
		5% Trimmed Mean		.	
		Median		.5180	
		Variance		.256	
		Std. Deviation		.50607	
		Minimum		.51	
		Maximum		1.39	
		Range		.88	
		Interquartile Range		.	
		Skewness		1.731	1.225
		Kurtosis		.	.
	3.00	Mean		.8291	.16542
		95% Confidence Interval for Mean	Lower Bound	.3027	
			Upper Bound	1.3556	
		5% Trimmed Mean		.8288	
		Median		.8265	
		Variance		.109	
		Std. Deviation		.33083	
		Minimum		.53	
		Maximum		1.13	
		Range		.60	
		Interquartile Range		.59	
		Skewness		.005	1.014
		Kurtosis		-5.920	2.619
	4.00	Mean		.6918	.05376
		95% Confidence Interval for Mean	Lower Bound	.5536	
			Upper Bound	.8300	
		5% Trimmed Mean		.6867	
		Median		.6630	
		Variance		.017	
		Std. Deviation		.13169	
		Minimum		.57	
		Maximum		.91	
		Range		.34	
		Interquartile Range		.24	
		Skewness		.951	.845
		Kurtosis		.212	1.741
	5.00	Mean		1.3058	.10874
		95% Confidence Interval for Mean	Lower Bound	1.0726	
			Upper Bound	1.5391	
		5% Trimmed Mean		1.3141	
		Median		1.3120	
		Variance		.177	
		Std. Deviation		.42115	
		Minimum		.46	
		Maximum		2.00	
		Range		1.54	
		Interquartile Range		.41	
		Skewness		-.298	.580

Descriptives[a,b,c,d,e,f]

GROUP			Statistic	Std. Error
	Kurtosis		.041	1.121
7.00	**Mean**		1.2785	.06165
	95% Confidence Interval for Mean	**Lower Bound**	1.1327	
		Upper Bound	1.4242	
	5% Trimmed Mean		1.2697	
	Median		1.1964	
	Variance		.030	
	Std. Deviation		.17436	
	Minimum		1.12	
	Maximum		1.59	
	Range		.47	
	Interquartile Range		.30	
	Skewness		1.073	.752
	Kurtosis		-.300	1.481
8.00	**Mean**		1.2943	.06481
	95% Confidence Interval for Mean	**Lower Bound**	1.1449	
		Upper Bound	1.4438	
	5% Trimmed Mean		1.3005	
	Median		1.2860	
	Variance		.038	
	Std. Deviation		.19442	
	Minimum		.94	
	Maximum		1.54	
	Range		.60	
	Interquartile Range		.32	
	Skewness		-.506	.717
	Kurtosis		-.266	1.400
9.00	**Mean**		1.1140	.04431
	95% Confidence Interval for Mean	**Lower Bound**	.9234	
		Upper Bound	1.3046	
	5% Trimmed Mean		.	
	Median		1.1070	
	Variance		.006	
	Std. Deviation		.07674	
	Minimum		1.04	
	Maximum		1.19	
	Range		.15	
	Interquartile Range		.	
	Skewness		.407	1.225
	Kurtosis		.	.
11.00	**Mean**		2.6284	.40917
	95% Confidence Interval for Mean	**Lower Bound**	1.6272	
		Upper Bound	3.6296	
	5% Trimmed Mean		2.6435	
	Median		3.2100	
	Variance		1.172	
	Std. Deviation		1.08255	
	Minimum		1.13	
	Maximum		3.85	
	Range		2.72	
	Interquartile Range		1.96	

Descriptives[a,b,c,d,e,f]

GROUP			Statistic	Std. Error
	Skewness		-.374	.794
	Kurtosis		-2.060	1.587
12.00	Mean		1.6239	.24854
	95% Confidence Interval for Mean	Lower Bound	.8330	
		Upper Bound	2.4149	
	5% Trimmed Mean		1.6273	
	Median		1.6540	
	Variance		.247	
	Std. Deviation		.49707	
	Minimum		1.08	
	Maximum		2.10	
	Range		1.02	
	Interquartile Range		.93	
	Skewness		-.147	1.014
	Kurtosis		-4.631	2.619
14.00	Mean		.9775	.01763
	95% Confidence Interval for Mean	Lower Bound	.9286	
		Upper Bound	1.0264	
	5% Trimmed Mean		.9769	
	Median		.9610	
	Variance		.002	
	Std. Deviation		.03942	
	Minimum		.94	
	Maximum		1.03	
	Range		.09	
	Interquartile Range		.07	
	Skewness		.536	.913
	Kurtosis		-1.867	2.000
15.00	Mean		1.1216	.03127
	95% Confidence Interval for Mean	Lower Bound	1.0535	
		Upper Bound	1.1898	
	5% Trimmed Mean		1.1187	
	Median		1.0830	
	Variance		.013	
	Std. Deviation		.11274	
	Minimum		.96	
	Maximum		1.33	
	Range		.37	
	Interquartile Range		.18	
	Skewness		.623	.616
	Kurtosis		-.571	1.191
16.00	Mean		1.0132	.01655
	95% Confidence Interval for Mean	Lower Bound	.9672	
		Upper Bound	1.0592	
	5% Trimmed Mean		1.0131	
	Median		1.0120	
	Variance		.001	
	Std. Deviation		.03701	
	Minimum		.97	
	Maximum		1.06	
	Range		.09	

Descriptives[a,b,c,d,e,f]

GROUP			Statistic	Std. Error
	Interquartile Range		.07	
	Skewness		.082	.913
	Kurtosis		-1.113	2.000
17.00	Mean		1.1610	.07749
	95% Confidence Interval for Mean	Lower Bound	.8276	
		Upper Bound	1.4944	
	5% Trimmed Mean		.	
	Median		1.1300	
	Variance		.018	
	Std. Deviation		.13421	
	Minimum		1.05	
	Maximum		1.31	
	Range		.26	
	Interquartile Range		.	
	Skewness		.984	1.225
	Kurtosis		.	.
18.00	Mean		1.4025	.05748
	95% Confidence Interval for Mean	Lower Bound	1.2760	
		Upper Bound	1.5290	
	5% Trimmed Mean		1.3864	
	Median		1.3400	
	Variance		.040	
	Std. Deviation		.19913	
	Minimum		1.22	
	Maximum		1.87	
	Range		.65	
	Interquartile Range		.24	
	Skewness		1.516	.637
	Kurtosis		1.733	1.232
20.00	Mean		1.3265	.04640
	95% Confidence Interval for Mean	Lower Bound	1.2263	
		Upper Bound	1.4267	
	5% Trimmed Mean		1.3233	
	Median		1.3145	
	Variance		.030	
	Std. Deviation		.17362	
	Minimum		1.06	
	Maximum		1.65	
	Range		.59	
	Interquartile Range		.25	
	Skewness		.229	.597
	Kurtosis		-.490	1.154
21.00	Mean		1.3050	.03664
	95% Confidence Interval for Mean	Lower Bound	1.2033	
		Upper Bound	1.4067	
	5% Trimmed Mean		1.3093	
	Median		1.3290	
	Variance		.007	
	Std. Deviation		.08193	
	Minimum		1.16	
	Maximum		1.37	

Descriptives[a,b,c,d,e,f]

GROUP			Statistic	Std. Error
	Range		.21	
	Interquartile Range		.12	
	Skewness		-1.894	.913
	Kurtosis		3.871	2.000
22.00	**Mean**		1.5653	.16854
	95% Confidence Interval for Mean	**Lower Bound**	1.2224	
		Upper Bound	1.9082	
	5% Trimmed Mean		1.3944	
	Median		1.3525	
	Variance		.966	
	Std. Deviation		.98272	
	Minimum		.94	
	Maximum		6.80	
	Range		5.86	
	Interquartile Range		.28	
	Skewness		4.912	.403
	Kurtosis		26.028	.788

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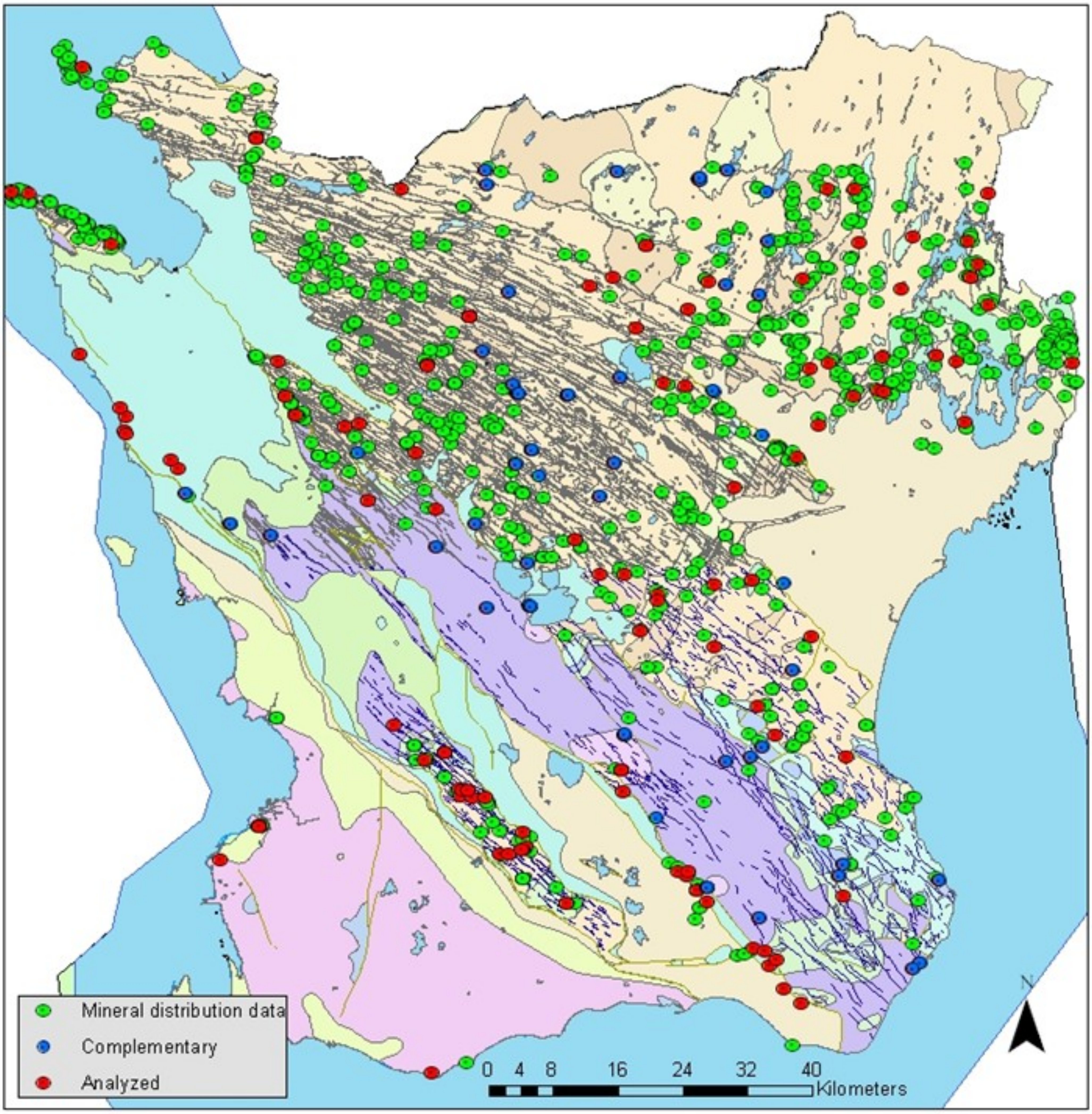
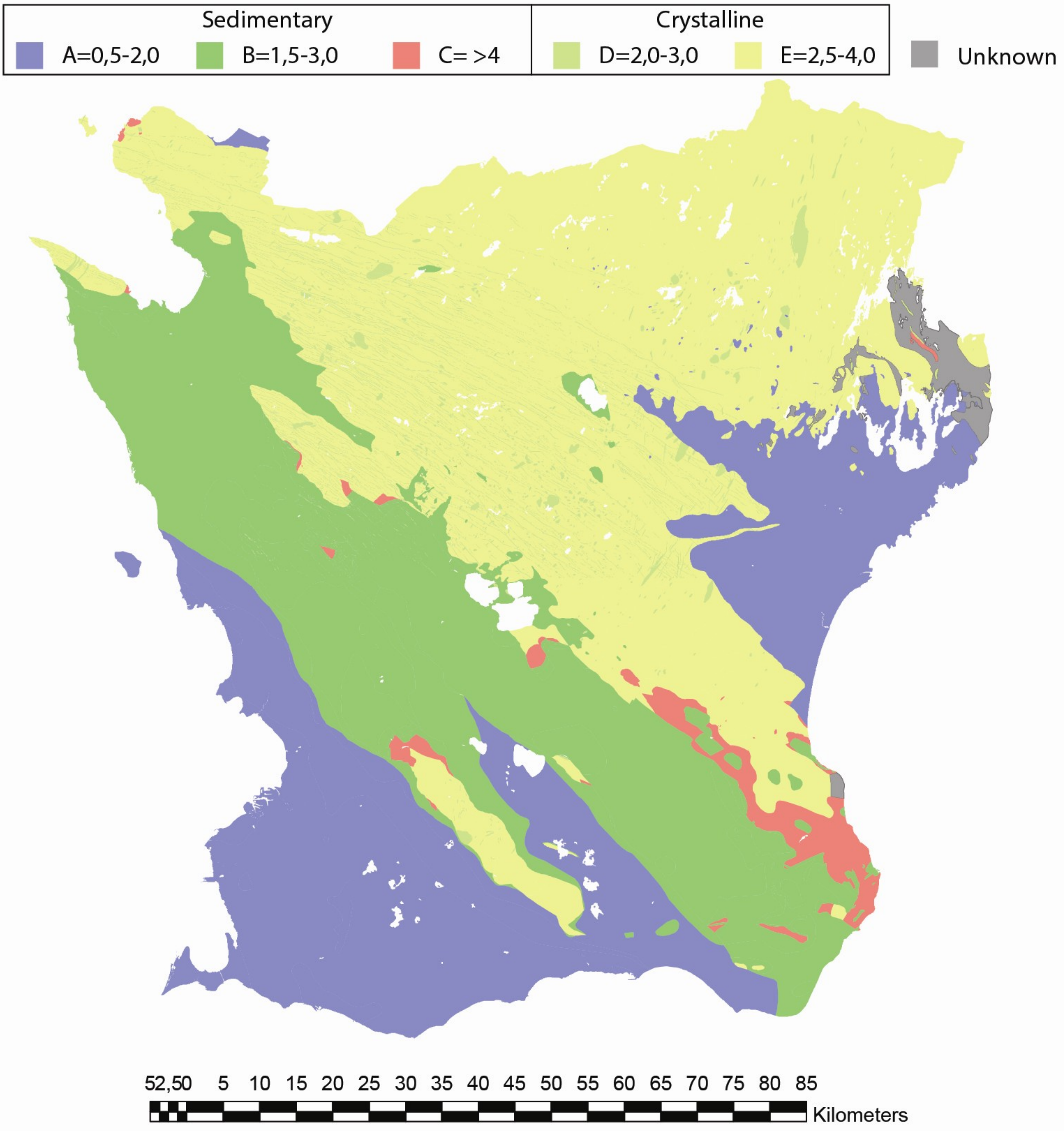
Case Processing Summary

	GROUP	Cases					
		Valid		Missing		Total	
		N	Percent	N	Percent	N	Percent
TDS	1.00	1	100.0%	0	0.0%	1	100.0%
	2.00	3	100.0%	0	0.0%	3	100.0%
	3.00	4	100.0%	0	0.0%	4	100.0%
	4.00	6	100.0%	0	0.0%	6	100.0%
	5.00	15	93.8%	1	6.2%	16	100.0%
	6.00	1	100.0%	0	0.0%	1	100.0%
	7.00	8	88.9%	1	11.1%	9	100.0%
	8.00	9	90.0%	1	10.0%	10	100.0%
	9.00	3	100.0%	0	0.0%	3	100.0%
	10.00	1	100.0%	0	0.0%	1	100.0%
	11.00	7	41.2%	10	58.8%	17	100.0%
	12.00	4	17.4%	19	82.6%	23	100.0%
	13.00	1	100.0%	0	0.0%	1	100.0%
	14.00	5	4.5%	106	95.5%	111	100.0%
	15.00	13	11.2%	103	88.8%	116	100.0%
	16.00	5	7.9%	58	92.1%	63	100.0%
	17.00	3	9.4%	29	90.6%	32	100.0%
	18.00	12	13.6%	76	86.4%	88	100.0%
	19.00	1	10.0%	9	90.0%	10	100.0%
	20.00	14	11.7%	106	88.3%	120	100.0%
	21.00	5	41.7%	7	58.3%	12	100.0%
	22.00	34	16.1%	177	83.9%	211	100.0%
	23.00	1	1.8%	54	98.2%	55	100.0%


● Mineral distribution data
● Complementary
● Analyzed
0 4 8 16 24 32 40
Kilometers
N

Thermal Conductivity of the Scanian bedrock



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