Overall plan for new drillings and surveys in Söderfjärden

– Anton Grindgärds, Åbo Akademi University, 2013 –

This plan has been prepared within the Sundom village associations LEADER-funded development project Urkrater.

Table of content

Introduction

When geologists from Pargas Kalk Ab (current Nordkalk Ab) and University of Oulu independently studied satellite images (Landsat 1) in the early 1970's the unusual shape of Söderfjärden arouse interest. During the years 1975-76 Pargas Kalk Ab performed a gravimetric survey, a seismic refraction survey and drilled four holes into the formation in the hope of finding economically valuable sedimentary limestone. In 1979 Jyrki Lehtovaara (University of Turku) drilled an additional hole and in 1983 two more shallow holes was drilled by Heikki Hirvas (Geological Survey of Finland (GTK)). A total of seven holes have been drilled in Söderfjärden. Several different proposals on how this structure has been formed were presented during these years. In 1984 Jyrki Lehtovaara concluded that the most likely cause for the formation of Söderfjärden was a meteorite impact. Lehtovaara also tried to carry out an age determination of the impact by radiometric dating but the attempt failed. The dating as of today for the crater (530-520 Ma, middle-lower cambrian) is based solely on micro-fossils in the Cambrian sediments (Tynni 1979, 1982 and Hagenfeldt 1988, 1989a, b). After mid-1980s research on Söderfjärden stagnated until Andreas Abels in 2003 in his doctoral thesis further confirms that Söderfjärden is a meteorite crater. In 2013 Öhman and Preeden further consolidates that Söderfjärden is a meteorite crater in an article on chock metamorphic features in quarts from Söderfjärden. The Quaternary deposits in the crater have not been studied to any significant extent. For a much more detailed explanation of previously done research work on Söderfjärden the reader is referred to Abels´ (2003) doctoral thesis in which the author gives a detailed description of available data and gaps in current knowledge about Söderfjärden.

The initiative to engage in further research on Söderfjärden was raised by the Meteoria section within Sundom village association that runs the Meteoria Söderfjärden Visitors Centre with Matts Andersén as head man. The Visitors Centre has in recent years at-

tracted many visitors, which of course raises a need for further development. To implement a credible and meaningful development more documentation in the form of scientific publications is needed and which can be popularized to the public at the Visitors Centre. A first step in this direction is the implementation of the LEADER funded project Urkrater resulting in, among other things, the establishment of Söderfjärden Research Program Consortium.

Söderfjärden Research Program Consortium (SRPC)

The purpose of this consortium and project is to realize new drillings and surveys in Söderfjärden meteorite crater. The new data acquired shall be divided among the participants in a multidisciplinary research network. These operations are performed on the basis of this plan developed within the LEADER funded project Urkrater, which is owned by Sundom village association during the project period 1.4 - 31.12.2013.

The ultimate aim of the project can be divided into two main groups 1) Producing new knowledge about Söderfjärden to be presented in the scientific literature. 2) To popularize research results and create new information to present to the public at the Meteoria Söderfjärden Visitors Centre and also in the region's museums, schools and via different media, even with international distribution.

Journey to the popularization:
Drilling => new primary data => new scientific information => Popularization => Information about the events in Söderfjärden

In order to produce new material, new drillings and investigations (geophysics, etc.) is required. By drilling into the unique sediment archives that Söderfjärden contains new knowledge of the following could be acquired; early life on Earth during the Cambrian

period, various Phanerozoic glacial deposits, deposits that describes the development of the Baltic Sea, how anthropogenic interference affected soils and waters in Söderfjärden during historic times and high resolution cultural signals (pollen) from early settlement around Söderfjärden. It could also be possible to create a reconstruction of the landscape and climate on a local scale. Besides this, new valuable knowledge on the meteorite impact could be acquired. For example, how much heat energy that emerged from the collision, an absolute radiometric dating of the impact event and the real depth of the crater. The crater pit in Söderfjärden contains very thick deposits of sediment formed after the last ice age. A sampling of the entire sediment sequence can provide very valuable information to the research on soils already undertaken at Söderfjärden (CATERMASS / BEFCASS). The drilling would reveal the depth of the sulphur-rich sediments and potential chemical variations in stratigraphy within them. Such knowledge is valuable in the evaluation of the environmental risks that might arise from the use of land in areas with acid sulphate soils in Ostrobothnia.

Popularization of research results is not included in the schedule of this project. The drillings are the basis for research why they must be performed before the popularization of the results. But the drillings them self should be promoted and popularized. The drillings are assumed to draw attention to Söderfjärden not only from the media but also from the public. The project can produce information materials (signage and information on Meteoria Söderfjärden Visitors Centre webpage) to inform visitors on Söderfjärden about the drillings and thereby increase the expectations of the results. Meteoria Söderfjärden Visitors Centre has become a real attraction that annually attracts many thousands of visitors of all ages from around the world. This shows that the concept is based on a solid foundation and that it can be developed on the basis of new scientific evidence.

The Urkrater project arranged a work shop meeting in Solf Gästgivargård 20.09.2013 with following participants:

Emeritus Prof. Lauri Pesonen, University of Helsinki (Geophysics)
Prof. Leho Ainsaar, University of Tartu (Phanerozoic sedimentology)
PhD Fredrik Olsson, Umeå University (Environmental Archaeology)
Prof. Olav Eklund, Åbo Akademi University (Geology and Mineralogy)
M.Sc. Anton Grindgärds, Åbo Akademi University (Geology and Mineralogy)
Prof. Matti Räsänen, University of Turku (Department of Geography and Geology)
PhD Antti Ojala, (GTK, Espoo)
PhD Joonas Virtanen Salo (GTK, Espoo)
Research assistant Satu Hietala (GTK, Kuopio)
Dr. Peter Eden, (GTK, Kokkola)
M.Sc. Matts Andersén, Meteoria Söderfjärden Visitors Centre
Kaj Höglund, Ostrobothnian Museum (Senior Researcher for Provincial Matters)

In addition also Prof. Mats Åström (Environmental Geology) from Linnaeus University in Kalmar, Prof. Erik Sturkell (Geophysics) from the University of Gothenburg and associate professor at Åbo Akademi University and Research Professor Aarno Kotilainen from the Geological Survey of Finland (Espoo) are interested to participate in the research project. Participants in the work shop meeting presented several different scientific questions to which drillings in Söderfjärden could provide answers. All agreed that Söderfjärden is unique and new drillings should be realized - there is an abundance of data hidden in the sediments.

Participants in the SRPC gathered to the work shop meeting in Solf Gästgivargård 20.09.2013. (Photo: Matts Andersén)

In the regional program of Ostrobothnia for the years 2011 – 2014 (in Swedish) under priority area 5 (page 52) the following is mentioned (freely translated from Swedish): "By developing the network of geological sights in the landscape it is possible to make the Kvarken Archipelago (UNESCO World Heritage site), nature tourism objects in the landscape and geological attractions better known. Efforts to promote a diverse use of nature, in addition to economic impacts also have positive social (strengthens the relationship with the environment) and cultural (increasing awareness of the area's natural environment and cultural history) effects." Otherwise the program also mentions the development of cooperation in environmental research with Umeå University and a refinement of the regional environmental knowledge into an understandable and informative form. This project can help to achieve these objectives.

Important scientific points for Söderfjärden Research Program Consortium

Lauri Pesonen (Emeritus Prof. University of Helsinki)

- Is there an impact melt, including paleomagnetism and age determination
- Thermal modelling of the impact event (Ilmo Kukkonen, Argo Joeleht)

Leho Ainsaar (University of Tartu)

- The age of the oldest Cambrian sediments, refine the stratigraphy (Ar-Ar + acritarch analyses, provenance studies).
- Sedimentary environment, marine or continental?
- Paleoeroded crust

Matti Räsänen (University of Turku)

- Sequence stratigrafical interpretation of the quaternary glacial deposits

Johan Linderholm/Fredrik Olsson (Umeå University)

- High resolution cultural signals (pollen)
- Anthropogenic impact

Mats Åström (Linnaeus University, Kalmar)

- Fluctuations in main- and trace element distribution in the unconsolidated sediments
- Investigate the possibilities for an age determination (C-14) of the unconsolidated sediments (Peter Österholm from Åbo Akademi is also interested in this)

Antti Ojala/Joonas Virtasalo (GTK)

- Characterisation of interstadial deposits
- Characterisation of saline “Litorina” influence
- Water mass stratification

- Process of postglacial redeposition
- Variability of river run off and sediment provenance

Olav Eklund/Erik Sturkell/(Peter Österholm) (Åbo Akademi University)

- Shallow seismic reflection model, no good model exists. Erasmus money?
- Gravimetry
- Anthropogenic and natural impacts on the acidification of streams out from Söderfjärden.

Satu Hietala (GTK)

- Assistance with interpretation of possible impact related rock sample findings

Geophysical surveys

In the mid-1970s, both gravity and seismic refraction surveys was performed in Söderfjärden. These studies were conducted by Pargas Kalk Ab (current Nordkalk Ab) under supervision of Lennart Laurén (Laurén et al, 1978). To complement and further enhance the incomplete geophysical models available, further investigations need to be carried out as in new gravity measurements and a seismic reflection survey. New studies are required because the raw data from previous seismic surveys are no longer available according to Abels´ (2003) personal communication with Lennart Laurén. According to Abels (2003), the existing gravity model very simple and could be further improved, Abels further believes that new seismic surveys also could clarify the distribution of basement blocks in the crater and possibly also reveal the maximum depth of the crater. The implementation of a seismic reflection survey includes blasting work. When placing the detonation points, it is important to take into account the subsurface drainage pipes that are common on the farming lands in Söderfjärden in order to avoid them being damaged. During the work shop meeting the opinion of the participants was, that no good geophysical models exist and that it is of great interest to improve these. Results from a seismic reflection survey are also very helpful in position-

ing the new boreholes. Reliable geophysical models can also contribute significantly to future popularization and visualization of the results at Meteoria Söderfjärden Visitors Centre.

Gravimetric surveys are preferably carried out during the winter months when the ground is frozen. Seismic surveys should be conducted when the ground is not frozen and the most suitable time for this would be in the fall immediately after harvest has ended. In this way, the agriculture is minimally disturbed by the geophysical surveys. The geophysical surveys should be carried out before any drilling to thereby provide a basis for the planning of the borehole locations.

Sampling of the Quaternary sediments

A large part of the researchers involved in SRPC is interested in analysing the Quaternary (soft) sediments deposited in the crater. These sediments form the upper part of the internal stratigraphy in the crater and consist mostly of Holocene clay- and silt sediments and till, which may possibly have been formed during several ice ages. In the drilling carried out previously the maximum thickness of the Quaternary sediments is 74.4 meters, this can be held to be the minimum depth of new drilling/sampling. A careful sampling methodology is very important for analyses and results to be both reliable and representative. Sampling should seek to obtain as mechanically undisturbed samples as possible, as the samples should represent the sampled material *in situ.* Chemical contamination of the sampled material should also be avoided because the chemical composition in the sediments is also of interest to researchers. During drilling and sampling it is very important to continuously keep as detailed record of the sampling as possible. For the drilling and sampling of the Quaternary sediments in Söderfjärden there are two different methods that are suitable for this purpose. Overall it can be concluded that this type of drilling and sampling of deep soft sediment is practically very difficult to implement, especially when a continuous sampling is needed.

To date, the deepest drilling with continuous sampling of soil in Finland was conducted in Liminka where the borehole was 140.5 meters. Olli Breilin and Niko Putkinen from Geological Survey of Finland (GTK) were responsible for this drilling. The drilling lasted six weeks and was done with a GM 200 drilling rig equipped with both a cone shaped drill bit which is pressed into the sediments and a drill bit to drill through the till. This sampling and drilling was successful and a continuous series of samples could be obtained. (Breilin and Putkinen, 2012)

Niko Putkinen says that, at the drilling project in Limanka they drilled three separate holes that could complement each other for sediment core losses etc. that are common in this type of drilling. Niko estimates that the time required for a drilling and sampling of the soft sediments in Söderfjärden is about four weeks per sampling point (3 holes / point). Niko also think it's very difficult to predict the best location of the sampling points in advance on the basis of geophysical surveys etc. Niko therefore suggests that the best way to plan the drilling and sampling is based on the results from the existing boreholes and to also perform "exploratory drilling" without sampling, which is much faster, approximately 2 days/hole. For a greater chance of success with the drillings, it is also very important to hire a drilling contractor with experienced staff who have an understanding of scientific drilling and the need for accuracy, Niko recommend Juhani Hiltunen from Destia Oy for this purpose. Niko is also very willing to contribute with his knowledge and experience in this project, at the latest in the drilling phase. (Personal email correspondence with Niko Putkinen, 2013)

Another drilling method that would be very suitable to use in the sampling of the soft sediments is a method called sonic drilling. This is a modern method which, according to the contractors' marketing, is considered to be the fastest method for continuous sampling of sediment with minimal core losses. Since the drilling can be performed

relatively fast this method also becomes very cost effective. The sonic drilling method also produces relatively undisturbed sediment samples. None of the participants in the SRPC has any practical experience of this method. The initiative to investigate whether it is possible to use this method on Söderfjärden comes from Prof. Matti Räsänen at the University of Turku.

According to Internet searches there seems to be no contractor in Finland that offer sonic drilling services. The company SonicSampDrill in Holland can offer their services also in Finland. Huug Eijkelkamp at SonicSampDrill estimated that a drilling of two holes á 70 meters with 76.2 mm sample diameter would take about two days per hole, giving a total of four days. This drilling would also provide a sample diameter of about 30 mm greater than the method used in Liminka (Breilin and Putkinen, 2012). During the work shop meeting it was noted that a drilling which gives as great sample diameter as practically possible is preferable. Sonic drilling method can provide a sample diameter up to 200 mm, but according to Huug Eijkelkamp it will be difficult for even the largest sonic drilling rigs available on the market to drill 70 meters with such a large sample diameter or it must be very soft sediments. Therefore, it is perhaps preferable to drill with a smaller diameter in order to avoid unnecessary problems and extra costs.

In Sweden there are also contractors offering sonic drilling services, for example Borrcenter. However, it is unclear whether their drilling rigs have the capacity to drill as deep as needed in Söderfjärden.

According to the marketing, the sonic drilling method can also be used for drilling sedimentary and crystalline rocks. Thus, it can pay off when asking for a job estimate to also find out if the same company can drill these rock types in Söderfjärden. The depth of the borehole would then be a total of 400 - 500 meters, which can be above the capacity for this type of drilling rig.

When drilling the soft sediments in Söderfjärden, it would be most advantageous to use the sonic drilling method because it is fast, cost effective and above all it should provide good quality sediment samples. During the drilling and sampling that Geological Survey of Finland conducted in 1983 (H. Hirvas, unpubl.) gas was encountered in the sediment which to some extent interrupted drilling, this problem should therefore also be considered when new drillings eventually are realized.

Diamond drilling of sedimentary and crystalline rocks

Based on the geological information available today, the placing of new boreholes according to Abels (2003) proposal (Figure 1) is probably the one that gives the best chance to answer some of the scientific questions that are still unanswered. One borehole (~ 300 m deep) at Abels proposal A1 (Figure 1) could possibly strike impact melt, which is crucial for radiometric dating. The proposal is based on a magnetic anomaly in the central up lift of the crater. A more detailed study of this anomaly with a magnetometer could perhaps further define borehole location. A borehole at the proposed A2 (~ 500 m deep) could possibly expose a deeper part of the crater than drilled so far. The location of the boreholes can be further clarified or modified if new geophysical models give reasons for this. It is extremely important to make sure the contractor hired for the diamond drilling is able to drill with a technique that deliver oriented drill cores, a drill core which in retrospect can be oriented exactly as it lay *in situ,* this is especially important for the stratigraphic research.

The total length of the two boreholes should add up to somewhere between 800 - 1000 meters, based on the most recent interpretations of the available data. Diamond drilling can be carried out throughout the year, but could favourably be carried out in the autumn after the harvest has ended. If the drilling must be carried out before it should

only cause an affordable damage to crop plants as a diamond drilling rig do not need a very large space to operate. If the drilling is carried out during the winter months it is possible that the drilling contractor like to drill around the clock to prevent a freezing of the drilling fluid etc. Drilling during the winter months can therefore lead to higher costs.

In Finland there are several drilling contractors offering diamond drilling services. An E-mail with a few basic questions about such drilling has been sent to one of the major contractors in Finland, Oy Kati Ab, but no response has been received. Therefore, a large part of this description is based on own experiences and discussions with acquaintances in the mining industry. Availability of drilling contractors' services is highly dependent on the demand for drilling services in the mining industry. Some extreme years the queuing time for a drilling rig may reach one year, therefore the call for tenders and procurement of these diamond drillings should be fulfilled at such an early stage of the project as possible. This therefore means that the geophysical surveys that could facilitate the planning of the drilling should also be carried out as early as possible before the planning and procurement of drilling services.

When the drilling is carried out, it is very important that one or more representatives from the drilling project/consortium serves as a drilling supervisor and constantly follows the drilling process close by, in order to determine when the bore holes can be ended and to keep close contact with the drilling contractor on site.

During the work shop meeting with SRPC on 20.09.2013, it was decided that the best place to store the drill cores after drilling is GTK's drill core archive in Loppi, Finland. In this drill core archive the various researchers have access to the cores independently of each other and there are also nice areas for core logging. Transport of the cores from Söderfjärden to Loppi (including costs) also needs to be taken into account in the planning of the drilling project.

Pseudotachylites and shatter cones

Occurrence of pseudotachylites (Figure 1), in Söderfjärden was first scientifically described by Abels (2003), even though he was probably not the one who first found them (pers. comm. Teemu Öhman, 2013). These pseudotachylites have probably been formed by frictional melting at the meteorite impact. The use of the term *pseudotachylite* requires clear evidence that a melt existed. Öhman and Raitala (2005) find no clear evidence for this and they choose to call these *dark veinlets* instead. If a melt formed in these dark veinlets, it could be possible to make a radiometric dating of these and thus also get an age on the actual impact. The dark veinlets found, so far, are unfortunately too narrow for an accurate sampling of these. Therefore, new discoveries of these dark veinlets are of special interest.

Participants in the work shop meeting 20.09.2013 examine dark veinlets/pseudotachylites in an outcrop situated in Solf center. From left: Research assistant Satu Hietala (GTK), Prof. Olav Eklund (Åbo Akademi University) and Emeritus Prof. Lauri Pesonen (University of Helsinki).

Shatter cone is a structure that forms naturally in the bedrock at meteorite impact and artificially by blasting of bedrock. No shatter cones have yet been found in the terrain around Söderfjärden although these clearly should be there.

Information on how these two important structures related to the meteorite impact looks like have distributed to the public within the Urkrater project in the hope of finding more interesting outcrops.

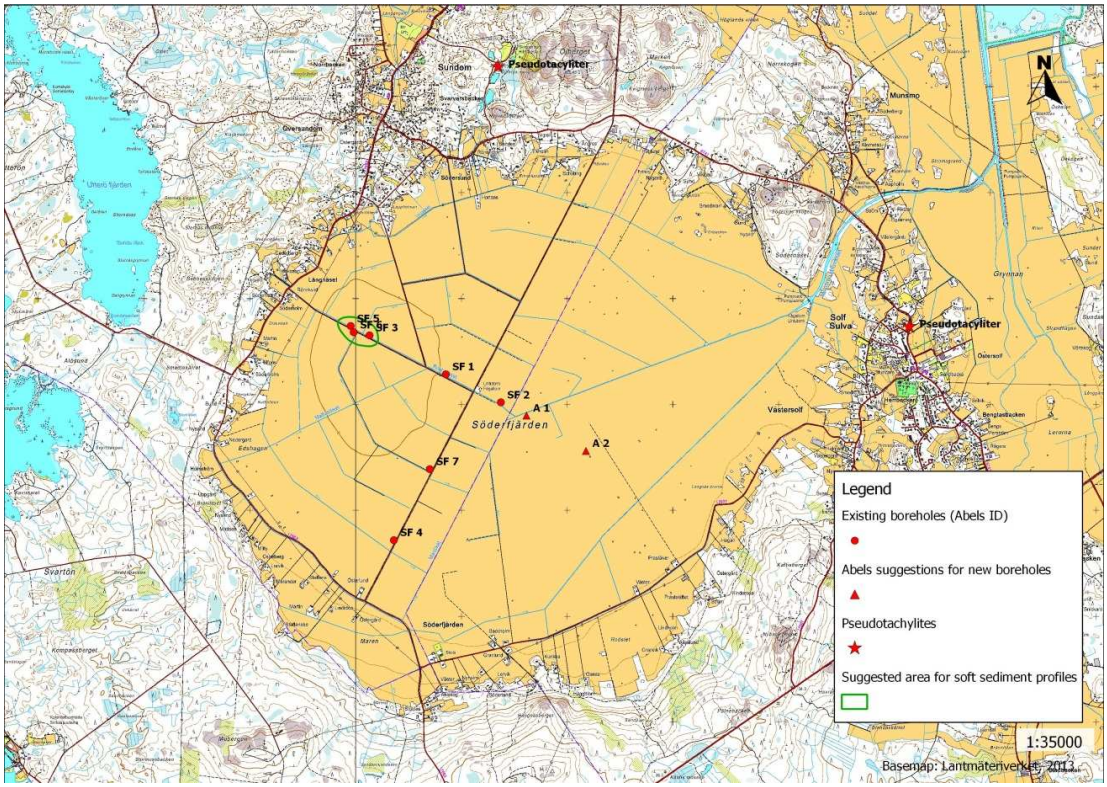

Figure 1. Presentation of the existing boreholes and proposed placements for new ones. The proposed area for sampling of soft sediments is the area where the sediment depth is likely to be the greatest, based on the old borehole descriptions and topography. Dark veinlets/pseudotachylites are marked based on Abels (2003).

Permission

To carry out the drilling permission and consent from landowners is required (Ilkka Keskitalo, Tukes, 2013 pers. comm.). Based on the impressions I got during summer (2013) meetings with the public at Meteoria Söderfjärden Visitors Centre I find it hard to imagine that the landowners' permission would be difficult to obtain. Residents around Söderfjärden seem very interested in contributing to further research on the meteorite crater.

When performing seismic reflection surveys it is required that an artificial shock wave is generated. This shock wave is created mostly through the detonation of explosives on the ground. When preparing and setting of the explosives it is required that the work is carried out under the Directives set out in *Statsrådets förordning om säkerheten vid sprängnings- och brytningsarbeten (16.6.2011/644.) (*The *Government Decree on the safety of blasting and mining work (16.6.2011/644)).* For blasting work it is required that someone in the team holds expertise letter for charger or blasters, depending on where blasting is performed. To obtain these expertise letters both an examination and work experience with blasting work is required. If no one in the team who will carry out the seismic surveys already possesses those expertise letters it is probably easiest to hire a contractor within the excavation industry for carrying out the blasting required for the seismic surveys. In addition to this, a notification of blasting work to the Police is also required. This notification must be made at least seven days before the blasting starts and can be done using a form available for printing on the police website.

Costs

No exact costs of realizing new drillings and geophysical surveys have been investigated in the framework of this project. Since no call for tenders have been sent out to various contractors, the estimate of the costs becomes very rough. During the work shop meeting with those involved in the SRPC it was decided that a total cost of EUR 300 000 for the project is a realistic amount to work from. The following cost estimate is based on this amount, but the estimate should only be considered as indicative since no real costs and prices for drilling services, etc. have been requested. The calculation of staff costs is based on a full-time position for one year for a project coordinator/leader and a shorter employment of a field assistant, when recruited via the Åbo Akademi University.

COST-ESTIMATE

1. Staff costs	**71916**
12 x € 3,660/month x 1.3	57096
6 x 1900 €/month x 1.3	14820
2. Purchases of services	**200000**
Diamond drilling 150 €/m x 800m	120000
Soft sediments 375 €/m x 160m	60000
Geophysics	15000
Unforeseen	5000
3. Travel expenses	**12000**
4. Acquisition of machinery and equipment	**3000**
5. Rental costs	**1200**
6. Office expenses	**2000**
7. Other expenses	**10000**
Potential compensation to landowners, etc.	
TOTAL COSTS (EUR)	**300116**

Existing drill cores and other material

Anneli Uutela, who has done some work on the fossils found in the Cambrian sediments in Söderfjärden, has announced that all her material (including preparations, notes and publications) is available in GTK's drill core archive in Loppi.
Drill cores from all previous drilling are also available at Nordkalk Ab in Pargas, in GTK´s drill core archive in Loppi and in Meteoria Söderfjärden Visitors Centre. A table of drill cores and its storage location is given in Appendix 1.

Involvement of the public

In 2013 two occasions, addressed to the public, for searching traces of the crater in the surroundings around Söderfjärden was organized in the framework of the project Urkrater. The attendance was good, with a total of thirty interested participants. Several interesting findings were made in the form of Cambrian sandstones and smaller pieces of rock that may possibly be related to the actual meteorite impact. These findings have been forwarded to a research assistant Satu Hietala at the Geological Survey of Finland in Kuopio for further analysis. Satu also participated with her expertise in one of the occasions in Söderfjärden.
A brief guide to the various structures and rock types that may be of interest for research on Söderfjärden was compiled by the project leader and can be studied in full in Appendix 2 (in Swedish only). This guide was handed out to the participants in the latter crater tracking event in order that they also on their own can hopefully make interesting findings as they move in the terrain around Söderfjärden. By informing the public about what types of findings that are of interest to research the chances of finding, for example, more dark veinlets/pseudotachylites and shatter cones increases. Since most outcrops in the area are covered with lichen and moss etc. it is very hard to catch sight of these structures, so it is important to take advantage of opportunities to study freshly exposed outcrops at e.g. excavation work sites.

Source reference

Laurén L., Lehtovaara J., Boström R. and Tynni R. (1978). On the geology and the Cambrian sediments of the circular depression at Söderfjärden, Western Finland. Geological Survey of Finland, Bulletin 297:5–81.

Abels A. (2003). Investigation of impact structures in Finland (Söderfjärden, Lumparn, Lappajärvi) by digital integration of multidisciplinary geodata. Ph.D. thesis, Westfälische Wilhelms-Universität, Münster, Germany.

Breilin O. och Putkinen N. (2012). Limingan Vesikari – syvin maaperäkairaus Suomessa. Geologiska Sällskapet i Finland. Geologi 4/2012.

Statsrådets förordning om säkerheten vid sprängnings- och brytningsarbeten (16.6.2011/644) http://www.tyosuojelu.fi/se/20110644sv/3941 (read 3.12.2013)

Tynni R., 1978, Lower Cambrian fossils and acritarchs in the sedimentary rocks of Söderfjärden, western Finland. In: Laurén L., Lehtovaara J., Boström R., Tynni R., On the geology and the Cambrian sediments of the circular depression at Söderfjärden, western Finland. Geological Survey of Finland Bulletin 297: 39-81.

Tynni R., 1982, New results of studies on the fossils in the Lower Cambrian sediment deposit of the Söderfjärden basin. Bulletin of the Geological Society of Finland 54: 57-68.

Hagenfeldt S.E., 1988, Acritarch assemblages of Early and Middle Cambrian age in the Baltic depression and south-central Sweden. In: Winterhalter B. (ed.), The Baltic Sea. Geological Survey of Finland, Special Paper 6: 151-161.

Hagenfeldt S.E., 1989a, Lower Cambrian acritarchs from the Baltic depression and south-central Sweden, taxonomy and biostratigraphy. Stockholm Contributions in Geology 41(1): 1-176.

Hagenfeldt S.E., 1989b, Middle Cambrian acritarchs from the Baltic depression and south-central Sweden, taxonomy and biostratigraphy. Stockholm Contributions in Geology 41(2): 177-250.

Öhman T. och Preeden U. 2013. Shock metamorphic features in quartz grains from the Saarijärvi and Söderfjärden impact structures, Finland. Meteoritics & Planetary Science 1–21 (2013)

[1]Öhman T. och [2]Raitala J. 2005. Geochemistry of the dark veinlets in the granitoids from the Söderfjärden impact structure, Finland: preliminary results. [1]Department of Geosciences, Division of Geology, University of Oulu, Finland, [2]Department of Physical Sciences, Division of Astronomy, University of Oulu, Finland.

Drill cores from Söderfjärden

ID (Abels ID)	Drill year	Storage	Availability	Reference
DH 1 (SF 1)	1975	Nordkalk in Pargas	Available	Gerhard Hakkarainen (Nordkalk)
DH 2 (SF 2)	1975	Nordkalk in Pargas	Available	Gerhard Hakkarainen (Nordkalk)
DH 3 (SF 3)	1975	Nordkalk in Pargas	Available	Gerhard Hakkarainen (Nordkalk)
DH 4 (SF 4)	1976	Nordkalk in Pargas	Available	Gerhard Hakkarainen (Nordkalk)
SF 1 (SF 5)	1979	Nordkalk in Pargas	Available	Gerhard Hakkarainen (Nordkalk)
Nr. 5 (SF 6)	1983	Loppi (M52-1331-83-RP.1)	3 boxes (all) available	Marko Puonti (GTK, Loppi)
Nr. 6 (SF 7)	1983	Only soft sediments, unpublished. Drilling notes from Peter Edén (GTK).		

The following five boxes from bore hole SF 1(SF 5) are stored at Meteoria Söderfjärden Visitors Centre: L 1, L 22, L 29, L 36 and L 37

En sammanställning av de spår från meteoritkratern som kan hittas i terrängen kring Söderfjärden

Anton Grindgärds
Åbo Akademi

AKTION ÖSTERBOTTEN LEADER
Europeiska jordbruksfonden för landsbygdsutveckling:
Europa investerar i landsbygdsområden

Stenar (Bergarter)

- Stenar och lösa stenblock som bildats i kratern eller vid själva meteoritnedslaget kan idag hittas i moränavlagringar kring Söderfjärden
- Dessa har under senaste istid transporterats från kratern av inlandsisen
- Störst chans att hitta intressanta stenar finns i den södra och syd-östra delen av kraterringen, eftersom inlandsisen avancerade mot denna riktning

Stenar (Bergarter)

- Kambrisk sandsten
  - Bergart som bildats genom att sand- och siltavlagringar pressats ihop. Bergarten är jämt gråaktig eller uppvisar omväxlande ljusare och mörkare lager
  - Bergarten har bildats i kratergropen efter nedslaget och transporterats därifrån med inlandsisen
  - Denna bergart kan innehålla fossiler
  - Exempel från sandgrop söder om Söderfjärden

Stenar (Bergarter)

- Breccia
  - Bergart med kantiga bergartsfragment inneslutna i finare material.
  - Olika typer av impaktit breccior bildas under flera olika faser i samband med nedslaget.
  - Exempelbilder på intressanta breccior som hittats kring Söderfjärden:

Samma stenblock

(http://www.impactstructures.com/impact-rocksimpactites/the-impact-brecciapage/lithic-impact-breccia)

(Abels A. 2003. Investigation of impact structures in Finland (Söderfjärden, Lumparn, Lappajärvi) by digital integration of multidisciplinary geodata. Doktorsavhandling, Westfälische Wilhelms-Universität, Münster, Tyskland.)

Stenar (Bergarter)

- Impaktit smälta
  - Helt eller delvis smält, mörk glasartad bergart som kan innehålla fragment av ljusare material. Här ses kärnäit från Lappajärvi kratern.

Kärnäit fotograferad vid Oravais stenpark. (http://pentinluonto.1g.fi/kuvat/Rock%20and%20minerals%2C%20Kivi%20ja%20mineraalit./K%E4rn%E4iitti.jpg?img=img1440)

Kärnäit polerad yta. (http://www.impact-structures.com/wp-content/uploads/2011/12/4-lappa.jpg)

Spår i berghällar

- Spår efter själva meteoritnedslaget kan också hittas i fasta berghällar kring hela Söderfjärden
- Hittills har inte många spår från nedslaget hittats i berghällar kring Söderfjärden, därför är nedanstående strukturer och formationer speciellt intressanta att hitta

Spår i berghällar

- Slagkäglor (shatter cones)
  - Slagkäglor är en tydligt räfflad konisk struktur i en bergart som drabbats av en chockvåg i samband med ett meteoritnedslag. Den räfflade och konformade strukturen kan variera i storlek från enstaka millimeter till flera meter. Liknar hästsvansar och går genom hela stenen – ej enbart på ytan.
  - Slagkäglor har ännu inte påträffats i Söderfjärden

Slagkäglor från Steinhem meteoritkrater i Tyskland. (http://upload.wikimedia.org/wikipedia/commons/0/02/Shatter_Cone.jpg)

Slagkäglor i en bergshäll från Charlevoix meteoritkrater i Quebec, Kanada. (http://epod.typepad.com/.a/6a0105371bb32c970b0115719ab839970b-pi)

Spår i berghällar

- Pseudotachyliter
  - Pseudotachyliter är mörka glasliknande gångar eller ådror i berghällar som bildats genom friktionssmältning av intilliggande bergarter.
  - Kan också innehålla små fragment av intilliggande bergart

Pseudotachyliter i en berghäll i Solf by. Notera att den bredare ljusa gången har förflyttats. (Abels A. 2003)

Nätverket av mörka ådror är pseudotacyliter i Vredefortkratern i Syd-Afrika. (http://www.meteorite-craters.impact-structures.com/gloss/impactpseudotachylite.jpg)

Spår i berghällar

- Eftersom de flesta berghällar är bevuxna med lav och annan växtlighet så kan det vara väldigt svårt att få syn på dessa spår
- Därför är rena hällar som nyligen grävts fram väldigt intressanta eftersom det blir betydligt smidigare att undersöka hällen

Om ni hittar något intressant:

- Markera gärna fyndplatsen på en karta eller notera GPS-koordinaterna om ni har möjlighet
- Ta gärna bilder av fyndet
- Meddela om dina fynd så att dessa eventuellt kan komma till nytta för vidare forskning om Söderfjärden meteoritkrater
  - Meteoria-sektionen: Ordf. Matts Andersén, tfn 045-6324024 eller via e-post: matts.andersen@sundom.fi
  - eller till URKRATER-projektets ledare Anton Grindgärds: agrindga@abo.fi