AUTOMATIC SEARCH FOR NEW IMPACT STRUCTURES IN FENNOSCANDIA A.F. Chicarro[1] and H. Dypvik[2], L.J. Pesonen[3], A.P. Rossi[1], S.O. Krøgli[2], H. Zumspregel[3], [1]ESA/ESTEC, Scientific Programme, Postbus 299, 2200 AG Noordwijk, The Netherlands (agustin.chicarro@esa.int). [2]Department of Geosciences, University of Oslo, P.O.Box 1047, N-0316 Oslo, Norway. [3]Division of Geophysics, University of Helsinki, P.O. Box 64, FI-00014 Helsinki, Finland.

Summary: This abstract summarizes a new co-operation program on impact crater discovery between the European Space Agency (ESA) and the Universities of Oslo and Helsinki, together with the Geological Surveys of several countries. The main aim is to implement an intelligent search program to identify unrecognized meteorite impact structures in Fennoscandia. The search would be based on applying the mathematical Hough-transform (a tool to recognize circular features) and related pattern recognition algorithms to digital elevation models and geophysical data such as topography, bathymetry, airborne magnetic data, etc. in order to identify new meteorite impact structures which are expected to be of circular shape. This tool has been previously used at ESA/ESTEC in planetary applications [1] and a simplified version is being successfully tested on Norwegian data sets.

Introduction: Impact craters caused by asteroid and comets are an ubiquitous feature in our Solar System [2]. Craters play a key role in understanding the geological and biological evolution of the Earth. Detecting impact craters on Earth is difficult [3], mostly because terrestrial processes (weathering, sedimentation, plate tectonics, etc.) either cover or erase the surface expression of impact structures. Many such structures are in addition covered by younger post-impact sediments, while other impacts have been destroyed by erosion. Currently, about 175 impact structures are recognised on Earth, of which about 20 are localized in Fennoscandia [4]. Of these 11 are found in Finland, 6 in Sweden and 2 in Norway. In Finland, seven out of the eleven impact structures were discovered in the last ten years. The success in finding new impact craters in Fennoscandia in general, and in the Precamrian shield in particular, is mainly due to (i) high-resolution geophysical methods, coupled with drilling of the circular structures, and (ii) detailed petrographic studies of the potential impact-related rocks.

Rationale: The Fennoscandian land surface has been leveled out several times throughout geological history and got its final shape during the last glaciation, ending about 10.000 years ago. Due to this old exposed land surface and to the extended geological and geophysical knowledge of the area, a relatively large number of asteroid and cometary impact craters have been found in the region. Presently about 20 known craters have been recognized as having an impact origin, and in addition some 60 possible impact structures have been suggested. The diameters of the Finnish structures vary from 0.1 to 55 km and the ages from recent to ca. 2.3 Ga [4]. The recognition of impact craters is, however, not equally distributed in the region. A large number of craters have been found in Sweden and Finland, while in Norway only two impact structures have been discovered so far.

Crater Recognition: On Earth, basically all small craters are relatively young, because erosional processes obliterate small (0.5–10 km in diameter) craters after a few million years, causing a severe deficit of such small craters. In terms of cratering rates, there are many craters left to be detected (e.g., [5, 6]). In this context, we address the issue of recognition and detection of impact craters on the Earth by applying processing techniques to Earth observation products, complemented by Digital Elevation Models (DEM), to auto-matically highlight potential targets for future explora-tion.

Objectives: The main objective of this project is first to develop methods helping to identify circular impact structures time- and cost-effectively, and to identify circular structures which will pass some of the pre-established criteria demonstrating that a circular shape has an impact origin. In this project, we will use digital techniques within a Geographical Information System (GIS) framework, in addition to geological and geophysical mapping.

Workflow: The first phase (Figure 1) of the project is to compile existing geoscientific data sets which may disclose unknown impact structures. These data sets are:

- remote sensing imagery
- topographic (digital elevation) data
- lake and sea bathymetric data
- geological data
- ground geophysical data
- airborne geophysical data

The data will be compiled and transformed into digital form enabling their manipulation using various search programs. As outlined above, impact structures have a circular shape due to their formation mechanism, which will be the main diagnostic search item. The second phase of the project deals with organizing the various datasets into digital forms. Most of the Nordic data (topographic and geophysical) already can be obtained in digital form; the rest requires digitizing them with selected interpolation and gridding techniques.

The third phase consists of computer processing of these digital datasets with selected criteria of circularity. The criteria are to be selected in the earliest phase of the project. These analyses will be performed on available satellite imaging, morphological, topographical, geological and geophysical data. We consider this as a large step forward, in particular when planetary analyses could benefit from terrestrial results, in combination with the surface morphology.

Algorithm: Impact craters on the Earth exhibit a much greater degree of variation than impact craters on other planets. Concentrating too heavily on specific crater morphology can be misleading, since similarly sized impact craters on the Earth's surface often exhibit contrasting characteristics. In this context, we have begun characterizing impact craters in a very simple way by using their circularity as their main feature.

Previous ESA-sponsored and -funded studies [1, 7] examine the use of a modified Circular Hough Transform to provide this model. This type of algorithm works best on binary edge-detected (or gradient) images. Where the circular features are not clearly discernable in the original image, edge-detection is unlikely to result in identifiable circles that would fit the simple circle model.

The Radial Consistency algorithm developed by [1] and to be used also in this work models impact craters as having localised rotational symmetry – this replaces the Circular Hough Transform test, that each pixel (x,y) lies on the circle defined by the triple {a,b,r} with the test that the pixel lies within a region of rotational symmetry centred at (a,b). The peaks in the parameter space {a,b} then correspond to the most likely locations of these regions of rotation symmetry in the input image. This allows partially circular features to be picked up, and provides a natural way of fusing the results from multiple data sources [1].

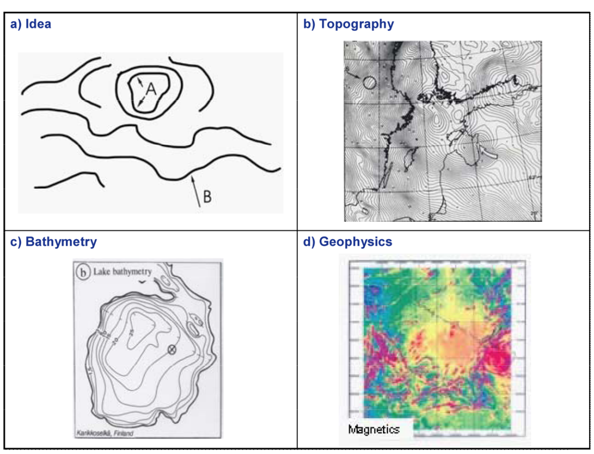

Fig. 1: Multiple datasets, from ground, aerial or satellite observations, which could be used for identifying new crater-like features of impact origin.

Discussion and Conclusions: Early results of this study are encouraging. The use of multiple datasets greatly increases the possibility of circular structure detections with multiple algorithms. Also, the use of data fusion techniques combining multispectral and DEM datasets can aid the detection process. Implementing such a novel computer-based approach to the search of yet to be discovered impact craters in Precambrian shield areas like Fennoscandia could prove quite a useful tool in augmenting the number of confirmed impact structures on Earth. If successful, the approach will be extended to the discovery of new impact structures planetwide.

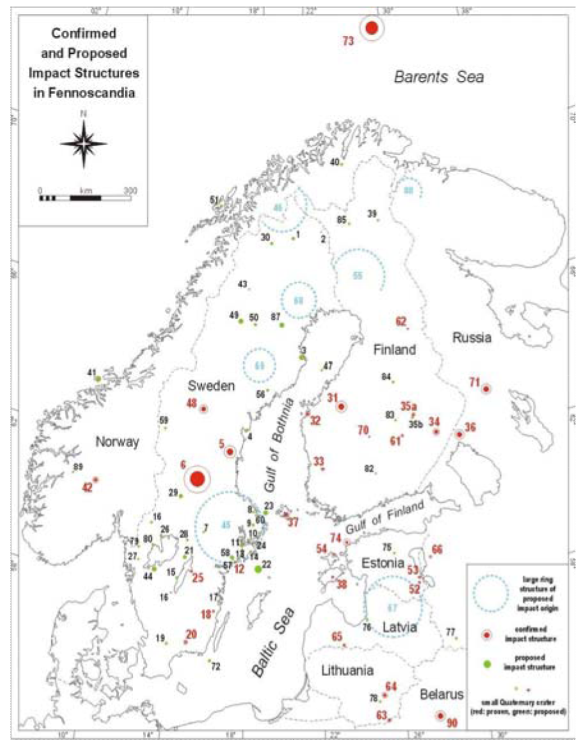

Fig. 2: Confirmed and proposed impact structures in Fennoscandia [4].

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