Use of SPOT and Landsat TM satellite data in geological reconnaisance

Tapani Tukiainen and Leif Thorning

As a part of the SUPRASYD project in southern Greenland (Garde & Schønwandt, this report) a pilot project was initiated in order to assess the use of satellite based remote sensing in mineral ressource reconnaissance work (the GIRS project: **G**eological **I**nformation from **R**emote **S**ensing). The objectives were to evaluate the usefulness of modern satellite data imagery during the various stages of a GGU field programme. A detailed account of the project is given in Tukiainen *et al.* (1993), this note briefly summarises some of the main results.

Choice of satellite imagery

Landsat TM and SPOT satellite systems, which have a spatial resolution of 30 and 20 metres respectively, are frequently used for geological remote sensing. The older Landsat MSS images have an inferior spatial resolution of 79 m, and were not considered adequate for the present study; they have previously been used in other studies of South Greenland (e.g. Condradsen *et al.*, 1984). At the beginning of the pilot study, only SPOT scenes were available for most of the SUPRASYD field area. Landsat TM scenes could not be obtained in time because it would have required a special agreement on programming of the satellite. Thus, although spectral considerations advocated the use of Landsat TM, the fact that the data had to be ready for use during the 1992 SUPRASYD field work excluded the use of Landsat TM data at the outset of the project. The pilot study was therefore primarily based on SPOT multispectral imagery. Subsequent to the conclusion of the 1992 field season new Landsat TM scenes of moderate quality were acquired. Satelittbild (the Swedish Space Corporation, SSC) was contracted to supply and process the SPOT satellite images to be delivered by early June before the start of the 1992 field work. SSC subsequently also delivered the Landsat TM data, although processing was carried out entirely by GGU.

Processing assessment

The Swedish Space Corporation delivered two sets of orthoscopic satellite image maps in UTM projection at a scale of 1:100 000; one set consisted of seven 'standard' false colour composite maps and the other set comprised seven colour composite maps with 'extracted geological information' (Westin & Zeidlitz, 1992). The coverage of the delivered maps and the corresponding digital data is shown in Fig. 1.

The standard maps are adequate base maps, on which mainly structural elements can be observed. The processing behind the maps with 'extracted geological information' is essentially a spatial enhancement of the SW–NE trending structures which was applied to the intensity component of the IHS-transformed data. These maps were received immediately before the 1992 field season and no additional processing could be carried out before going into the field. During the 1992 SUPRASYD field season one team checked the quality of the maps produced by SSC, and

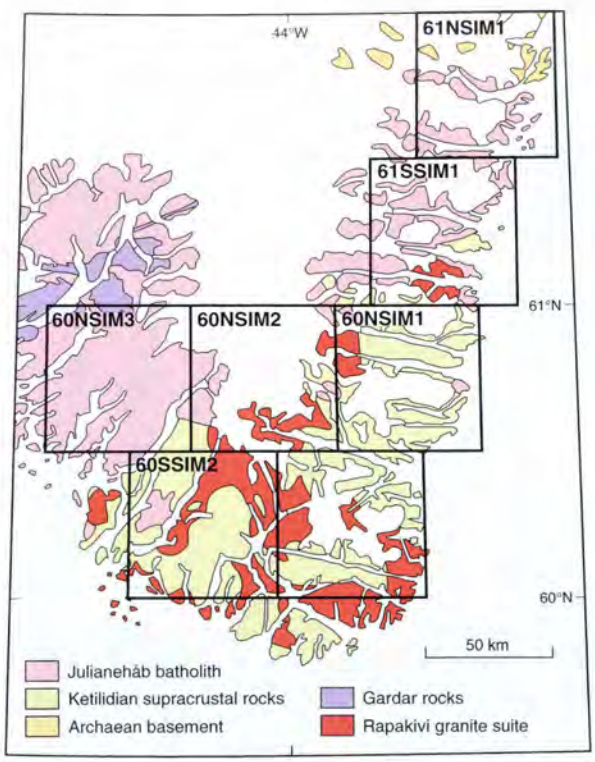

Fig. 1. Index map of 1:100 000 scale orthoscopic satellite image maps based on the SPOT imagery

© GGU, Copenhagen, 1995

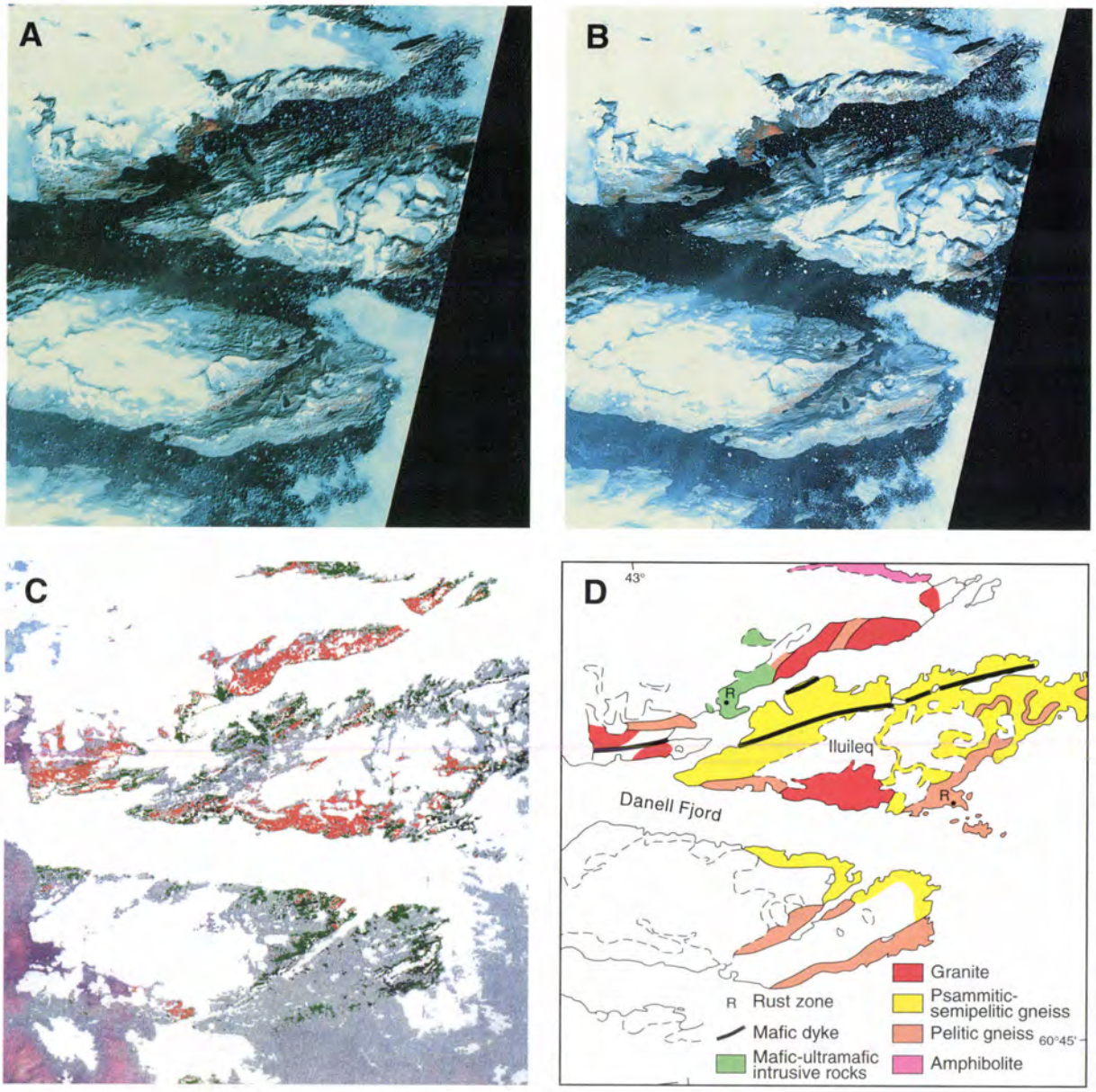

Fig 2. SPOT and Landsat TM sub-scenes of the Iluileq area: (A) Satellite image map with 'extracted geological information' (SSC/SPOT); (B) Standard satellite image map (SSC/SPOT); (C) Colour composite of the histogram stretched 2nd (red), 3rd (green) and 4th (blue) principal component image of the Landsat TM bands 1, 2, 3, 4, 5, and 7. The pixels with ice, snow, vegetation and water are masked; (D) Observed geology.

carried out experiments on processing the digital data.

The standard false colour composite maps are the most accurate maps for this part of Greenland because they were rectified with the most up-to-date ground control points supplied by Kort- og Matrikelstyrelsen (National Survey and Cadastre - formerly Geodetic Institute). The colour composites are of good quality for most of the project area, although there are some localities along the east coast of southern Greenland where it is almost impossible to distinguish between land and sea as both appear very dark.

During the field work it became clear that the colour composite maps with 'extracted geological information' based on SPOT imagery were not able to delineate to any degree of confidence the 'darker coloured' lithologies (pelite, amphibolite) in areas of intense mobilisation.

Several areas were examined in the field to obtain a

measure of ground control for the satellite image processing. The discussion here is limited to one area in the vicinity of the island Iluileq, near Danell Fjord (Fig. 1), where both SPOT and Landsat TM data of reasonable quality are now available. The processing of the Landsat TM data was carried out in GGU in early 1993 using a sub-scene of the Iluileq area for a more detailed analysis. The six Landsat TM bands were PC (principal component) transformed. In the case of the Iluileq sub-scene the PC images 1, 2, 3 and 4 accounted for 75.05, 23.10, 1.56 and 0.23 % of the total variance, respectively. The information in the first PC image is dominated by the topography showing shadows and highlights and is of no interest for enhancement of the lithological features. The PC images 2, 3 and 4 yield information which is most probably related to the lithology; the colour composite of these images is shown in Fig. 2C. The correlation with observed geology is excellent. The colour composite of the PC transformed Landsat TM data in Fig. 2C illustrates the power of the Landsat TM system to discriminate between major lithological units, e.g. granites and highly granitised rocks, psammites and pelites.

In contrast, the darker lithologies, typically pelite horizons in the study area, are only just discernible on the SPOT images (Fig. 2 A, B). The processing technique used by SSC for extracting geological information from the SPOT imagery cannot be considered particularly useful; in fact the standard false colour composite (Fig. 2A) yields more lithological information than that with 'extracted geological information' (Fig. 2B). Alternative processing techniques of the SPOT data were carried out in GGU with some improvement as a result. A combination of high pass filtering of the principal component transformed data and careful individual contrast stretching to some extent enhanced the lithological response at some localities (see Tukiainen *et al.*, 1993).

Conclusions

Two major aspects of satellite based remote sensing must be considered: spectral enhancement to create images providing an optimal display of the lithological variations within an area, and spatial enhancement for the mapping of geological structures. Since the former was a main objective of this project, the SPOT imagery available at the start of the project was not ideal. The good spatial resolution of the SPOT data makes it a good basis for the preparation of orthoscopic standard false colour composite maps and for structural analysis, but the extraction of geological information by spatial enhancement of the intensity component of IHS-transformed SPOT data did not prove useful in this project. Certain structural trends were enhanced, but at the cost of an overall degradation of other map information. Alternative processing techniques could to some extent enhance lithological differences at some localities, but on the whole SPOT data are inferior to Landsat TM data in this respect. The processing of the data, although by no means exhaustive, has demonstrated that the Landsat TM system is much better for the display of lithological variation, and that the spatial resolution of the data does not present serious problems in relation to the reconnaissance type of work in the SUPRASYD project. The Landsat TM system has been successfully used worldwide to map iron oxides and phyllosilicate minerals which are often characteristic by-products of ore-forming processes. The sulphide and graphite bearing localities within the area of the Iluileq sub-scene are too small to be detected by Landsat TM.

A processing technique based on principal component transformation is capable of discriminating between major lithological units with such a degree of confidence that the method must be considered a potential tool to be used before going into the field. The information thus obtained can be used to rationalise geological field campaigns. Experience with the present project demonstrates that processing and interpretation of satellite data should be commenced at least half a year before the start of a field season. Taking into account the constraints arising from limited availability of satellite data this means that for many parts of Greenland, snow covered throughout the year, it will often be necessary to request programmed recording of missing satellite scenes the summer before the field work starts.

Acknowledgements. This project was carried out with financial support from the Mineral Resources Administration for Greenland and in cooperation with Satellitbild, SSC, Kiruna, Sweden. Geodetic control points were supplied by Kort- og Matrikelstyrelsen (National Survey and Cadastre).

References

Conradsen, K., Nielsen, B. K., Nilsson, G. & Thyrsted, T. 1984: Application of remote sensing in uranium exploration in South Greenland. *Res. Rep. Inst. Math. Statistics Operations Research (IMSOR), Tech. Univ. Denm.* **22**, 164 pp.

Tukiainen, T., Erfurt, P. & Thorning, L. 1993: Project to assess the application of SPOT and Landsat TM imageries to geological reconnaissance, South-East Greenland. *Open File Ser. Grønlands geol. Unders.* **93/8**, 31 pp.

Westin, T. & Zeitlitz, P. 1993: Satellitbildskartor till GGU. Unpublished report (in Swedish) by the Swedish Space Corporation, 9 pp.

T. T. & L. T., Geological Survey of Denmark and Greenland, Copenhagen