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Interpretation of SkyTEM data from Skorovas, Nord-Trøndelag, Norway

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Summary

Helicopterborne geophysical data collected by SkyTEM Surveys Aps covering an area around the closed mine at Skorovas, Nord-Trøndelag, Norway, have been studied and interpreted. A large number of geophysical anomalies were identified that are interpreted to be caused by electrically conductive bodies in the sub-surface. The anomalies have been compared with information about known mineralizations. Except for the ore bodies at the closed Skorovas mine, chemical assays on samples from the known mineralizations have not indicated any interesting grades of e.g. Cu, Zn or Au. A major part of the anomalies could be explained by those mineralizations. Other anomalies are caused by the remaining part of the Skorovas ore bodies.

However, a number of geophysical anomalies were identified that, with the available background information, could not be tied to any known mineral occurrence. Some of the anomalies are interpreted to be caused by rather poorly conducting bodies. Other anomalies do however indicate good conductors, some of which appear to be blind (not outcropping) bodies.

It is recommended that the geophysical anomalies are followed up. Data and information from previous exploration work should be checked in more detail. Field checks should also be made in order to see if the causes to the geophysical anomalies can be identified. After that, ground geophysics can be used to better locate and delineate conductive bodies that are judged as interesting exploration targets.

Contents

1 Background

1.1 Scope of study

The purpose of the presented work was to review helicopterborne geophysical data from the Skorovas area in Nord-Trøndelag, Norway. The survey was carried out around the Skorovas mine that was closed in 1984. A number of other sulphide mineralizations are known in the area. The data have already been interpreted and compared to older information by NGU. The presented study has been limited to the helicopterborne data and a few selected older references. An attempt has been made to check for anomalies in the helicopterborne data that can be worth a follow-up, both in the field and against a broader selection of previous investigations.

1.2 Disclaimer

Any evaluation that is presented in this report is strictly an interpretation. There are always ambiguities in geophysical interpretation. Also, the interpreted geophysical character of rock volumes have no direct relation to the possible economic value of a mineralization. Thus, any decision made, based on the outcome of this work, is solely on the client’s responsibility.

It is incumbent upon the client to check and approve the data and delivered results and as soon as possible notify GeoVista AB of any complaints or remarks.

2 Input data

The helicopterborne survey was carried out by SkyTEM Surveys Aps, Denmark (SkyTEM 2015). The measurements included time-domain electromagnetic measurements and magnetometry. Survey lines were directed east-west with a nominal separation of 200 m. North-south tie-lines were flown with a spacing of 2000 m.

2.1 Helicopterborne TEM

The used time-domain system had a peak moment of 10^6 NIA (effective transmitter area times current). Measurements were carried out with the SkyTEM high-moment (HM) option, i.e. no low-moment data were collected.

Time-domain electromagnetic measurements (TEM) record the decaying secondary transient from currents in the ground induced by a pulse-shaped primary magnetic field. Confined conductors (like sulphide mineralized bodies) in the ground can be characterised based on the decay rate of the secondary field. Well conducting bodies will give rise to slowly decaying secondary fields and vice versa. The magnitude of the secondary field also depends on the depth to the conductor and the size. The measurements are carried out by sub-dividing the transient into time gates.

Chargeable bodies (typically disseminated mineralization or clay) may under some circumstances give rise to transients of reversed polarity.

False anomalies in TEM measurements may be caused by powerlines, telephone lines, fences, railways and other metallic infrastructure.

An example of TEM data from Skorovas can be seen in Figure 2-1. The map shows the magnitude of the secondary field in an early time gate. Both good and poor conductors may therefore be indicated.

2.2 Helicopterborne magnetometry

Magnetic data were also recorded during the SkyTEM survey. The mineralized bodies are not associated with magnetic anomalies. The data have therefore not been used in this study. The magnetic data may however be used to interpret the structural setting of mineralizations. Such work was however beyond the scope of the project.

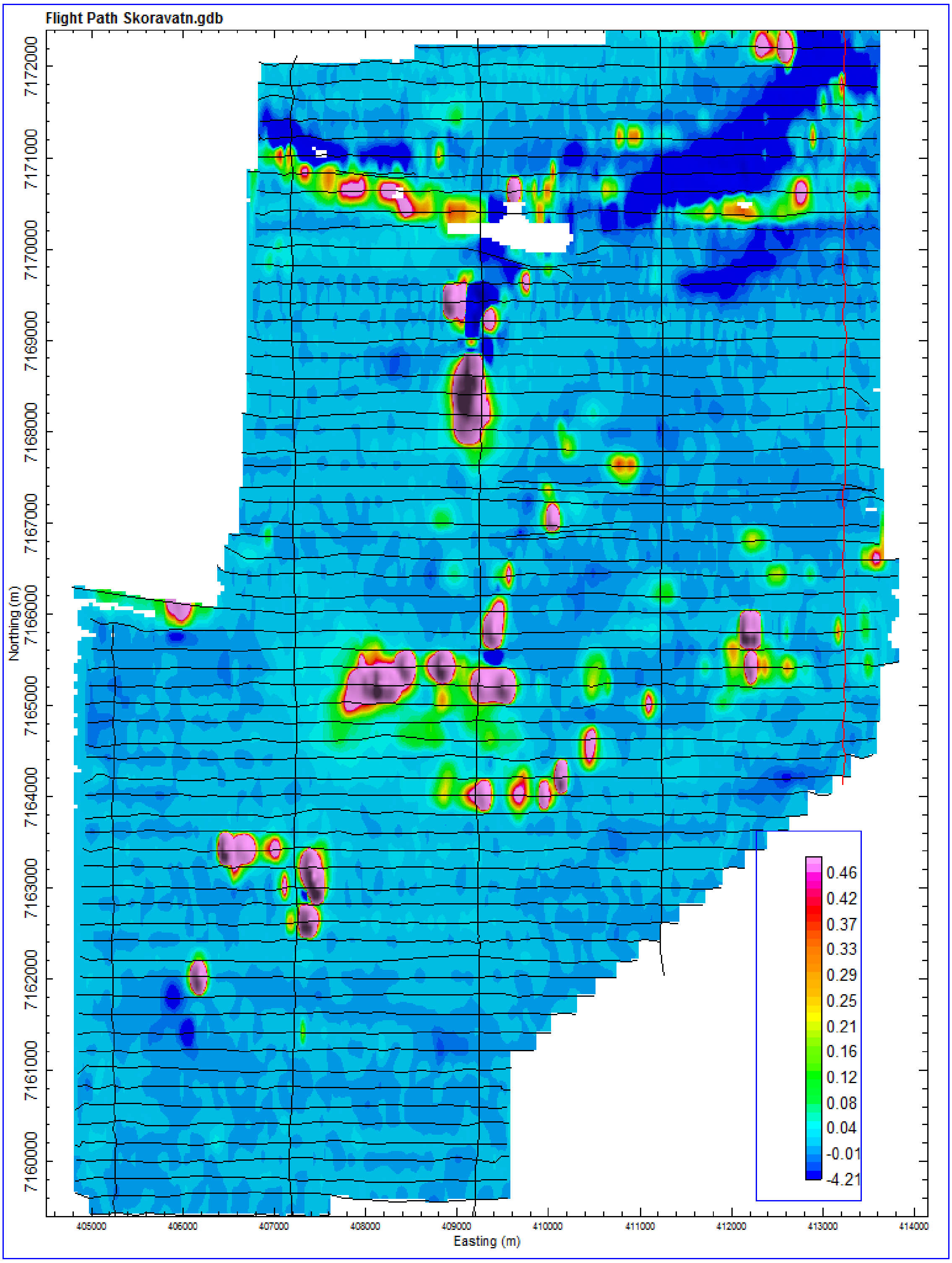

Figure 2-1. *Map showing SkyTEM data (time gate HM19, pV/(m^4·A)). Warm colours indicate conducting bodies. Dark blue colour indicate recorded transients of reversed polarity. Black lines shows the flight lines. The data are disturbed around the Skorovatn village and along the road in the north.*

2.3 Geology and mineral occurences

Information about bedrock geology and mineral occurrences can be found at the website of the Geological Survey of Norway (www.ngu.no). The information includes sampling points for chemical assays. Information about the Skorovas ore body and the surrounding geology can be found in Sletten (2015).

2.4 Non-conformities

The work was carried out in accordance with plan.

3 Interpretation

3.1 Software

Geophysical and geological data have been visualized and interpreted with the help of the programs Discover PA and MapInfo Professional (Pitney Bowes). No numerical modelling or inversion has been carried out.

3.2 Method

The work was carried out in the following steps:

1. **Compilation of data and background information**. Geological maps and sampling data were found at the NGU website. Information about the helicopterborne survey was found in SkyTEM (2015). Information about previous interpretations of the SkyTEM data was found in NGU (2016) and about the Skorovas mine in Sletten (2015). An extensive list of historic references can be found in Høgaas (2014). It was not within the scope of the study to go through all that historic material. However, old geophysical results in the form of Turam (electromagnetic) interpretation maps were found in Singsaas et al. (1974), Carstens (1981) and Eidsvig (1983).
2. **Interpretation of geophysical data.** The inverted sections produced by SkyTEM are based on an assumed horizontally stratified earth. Such a model is not really valid for the conductors at Skorovas and the sections have therefore not been used in this work. Instead, the SkyTEM (secondary field) data were studied on a line by line basis. Anomalies that were interpreted to be caused by confined conductive bodies in the sub-surface were identified and classified based on the decay rate of the secondary field. The classification was carried out by visual inspection of the data and may therefore to some extent be subjective. Note that anomalies from deep sources may be of low magnitude and therefore not show up very well in e.g. maps like Figure 2-1. Such deep sources may still cause slowly decaying transients indicative of a good conductor.
3. **Comparisons with older information**. The identified anomalies were compared with positions of known mineralizations and with sample sites (www.ngu.no). The anomalies were also compared with historic Turam results and with positions of borehole collars. A significant part of the identified anomalies could therefore be classified as “known” (caused by already investigated mineralizations). Note that there has not been time within the project to go through all historic material or to contact any geologist that knows the area well. It is therefore quite likely that some of the anomalies that not have been classified as known actually might be so.
4. **Description of interesting geophysical anomalies**. Remaining anomalies (not classified as caused by known mineral occurrences) were grouped and are presented in the following section.

3.3 Results of interpretation

Anomalies that were interpreted to be caused by confined conductors are shown in the map in Figure 3-1. The anomalies have been classified by visually estimating the decay rate of the associated secondary magnetic field. The following classes have been used:

- **Magenta symbols**. Very good conductors that produce secondary fields that are of significant magnitude even in the last recorded time gates. The anomalies may be caused by massive to semi-massive sulphide mineralization.
- **Red symbols**. Good conductors that produce secondary fields that can be seen at late time gates. In some cases the secondary field has switched polarity at late time gates, possibly due to strong chargeability.
- **Yellow symbols**. Conductors of moderate conductivity that produce significant anomalies at early time gates, but where the secondary field has decayed to below the noise threshold of the survey system at late time gates.
- **Green symbols**. Conductors that only produce weak anomalies at early time gates. Such conductors might correspond to low-grade sulphide mineralization, but it is also possible that water-bearing and/or altered deformation zones in the rock can be the cause to the anomalies.
- **Blue symbols**. Bodies that produce transients of reversed polarity. Such bodies have poor conductivity but significant chargeability. The cause to such anomalies can be disseminated mineralization or clay minerals.

The position of geophysical anomalies shown in Figure 3-1 were compared to positions of borehole collars (Sletten 2015) and surface assay sample points (www.ngu.no). A significant part of the anomalies could then be explained by known ore bodies or pyrite dominated mineralizations, most having insignificant grades of e.g. copper and zinc (Figure 3-2), at least according to assay results published at www.ngu.no. Examples of mineralizations are (locations shown in Figure 3-3):

A. Skorovas ore bodies
B. Øverste Nesåvatnet and Nesåflyin
C. Langtjønna and Blindtarmen
D. Finnkrudomma
E. Lillefjellklumpen and Bjørknesbekken

Other geophysical anomalies can also be tied to these mineral occurrences based on interpreted connections to neighbouring flight lines. The geophysical anomalies that by such reasoning are considered to be explained by known mineral occurrences are shown with diamond symbols in Figures 3-2 and 3-3. Anomalies that are not explained are shown with circles. Please note that some of those anomalies also might be possible to explain with present geological knowledge, but such information has not been at hand during this work. Figure 3-3 shows geophysical anomaly groups and how they have been connected to known mineral occurrences.

Most of the geophysical anomalies that can be considered to be caused by good or very good conductors can be tied to known mineral occurrences. However, there are a few such anomalies that should be considered for more follow-up. It should also be realized that in some cases it is not the best electrically conductive bodies that are of economic interest. Non-economic pyrite and pyrrhotite is often the dominating mineral in good conductors, whereas sphalerite and disseminated chalcopyrite mineralizations (±pyrite, pyrrhotite) can correspond to poor or moderate conductors.

The geophysical anomalies that should be considered for additional follow-up have been grouped together in Figure 3-4 and they are briefly commented below:

1. A good conductor is identified in data from two neighbouring flight lines. The anomalies are located around 750 metres towards east from boreholes directed towards the eastern Skorovas ore-body, south of the small lake Gruvetjønna. The causative conductors are probably shallow, possibly outcropping. The anomalies are just outside the area covered by historic Turam-measurements.
2. The geophysical anomalies of group 2 are located north-east of the known mineral occurrence Nesåflyin and west of the occurrences Blindtarmen and Langtjønna. However, it is not obvious from the available data that the anomalies can be tied to any of these mineralizations. The anomalies with the slowest signal decay (best conductors) are of long spatial wave-length and the anomalies are therefore probably caused by blind (not outcropping) bodies.
3. The anomalies of group 3 are located at the easternmost part of the survey flight lines. Some of the anomalies are quite weak and at the very end of the flight lines. However, a good conductor is indicated at one flight line. The area is located east of the mineral occurrence Langtjønna and it is of course possible that the anomalies are caused by mineralization of the same type.
4. The anomalies of group 4 are located in the westernmost part of the survey area. The flight lines in the southern part of the survey area start further west compared to the northern part (Figure 3-4). The strongest anomalies of group 4 are seen on the northernmost flight line of the southern part of the area. That means that there is no neighbour line towards north to compare with. The strongest anomalies are located around 2 km from any of the known mineral occurrences (Figure 3-3) in an area with different surface geology.
5. The anomalies of group 5 are primarily seen on northernmost part of one of the north-south directed tie lines. The anomalies are located around 600 metres from the Ni-Cu-PGE mineralization Lillefjellklumpen. The anomaly with slowest signal decay probably correspond to a blind body. It is not possible to say whether the geophysical anomalies are caused by similar type of mineralization but it is interesting to note that Lillefjellklumpen holds good grades of Ni, Cu and PGE.
6. A number of anomalies caused by rather poorly conducting bodies are indicated on the southern slope of Skorovasklumpen, north of Skorovatn. These anomalies correlate well with anomalies in historic Turam data. No information has been available about whether those anomalies have been followed up after the turam measurements.
7. Anomaly group 7 is located east of group 6 in a similar geographic and geologic setting. However, group 7 is not covered by the historic turam measurements.
8. Group 8 is actually part of the known mineral occurrence Finnkrudomma in the south. A number of anomalies can be seen in the data that only give transients of reversed polarity. The character of the anomalies are thus different from the rest of the Finnkrudomma mineralization, indicating significant chargeability but poor conductivity. It is of course possible that the anomalies correspond to the same type of mineralization as the rest of Finnkrudomma, but with significantly less content of sulphide minerals, but it is also possible that the mineralogy is different.

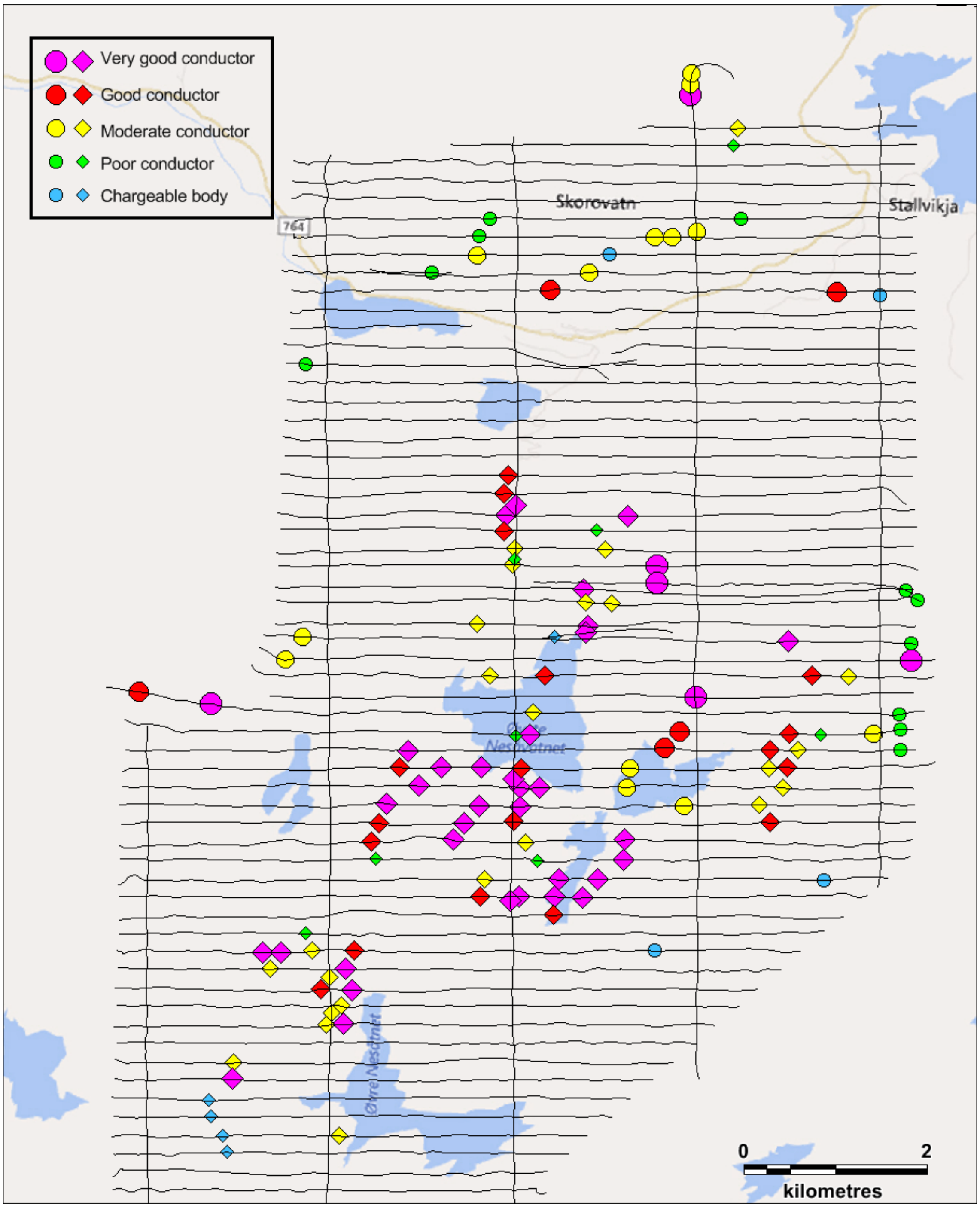

Figure 3-1. *Map showing identified anomalies that are interpreted to be caused by confined conductors in the sub-surface.*

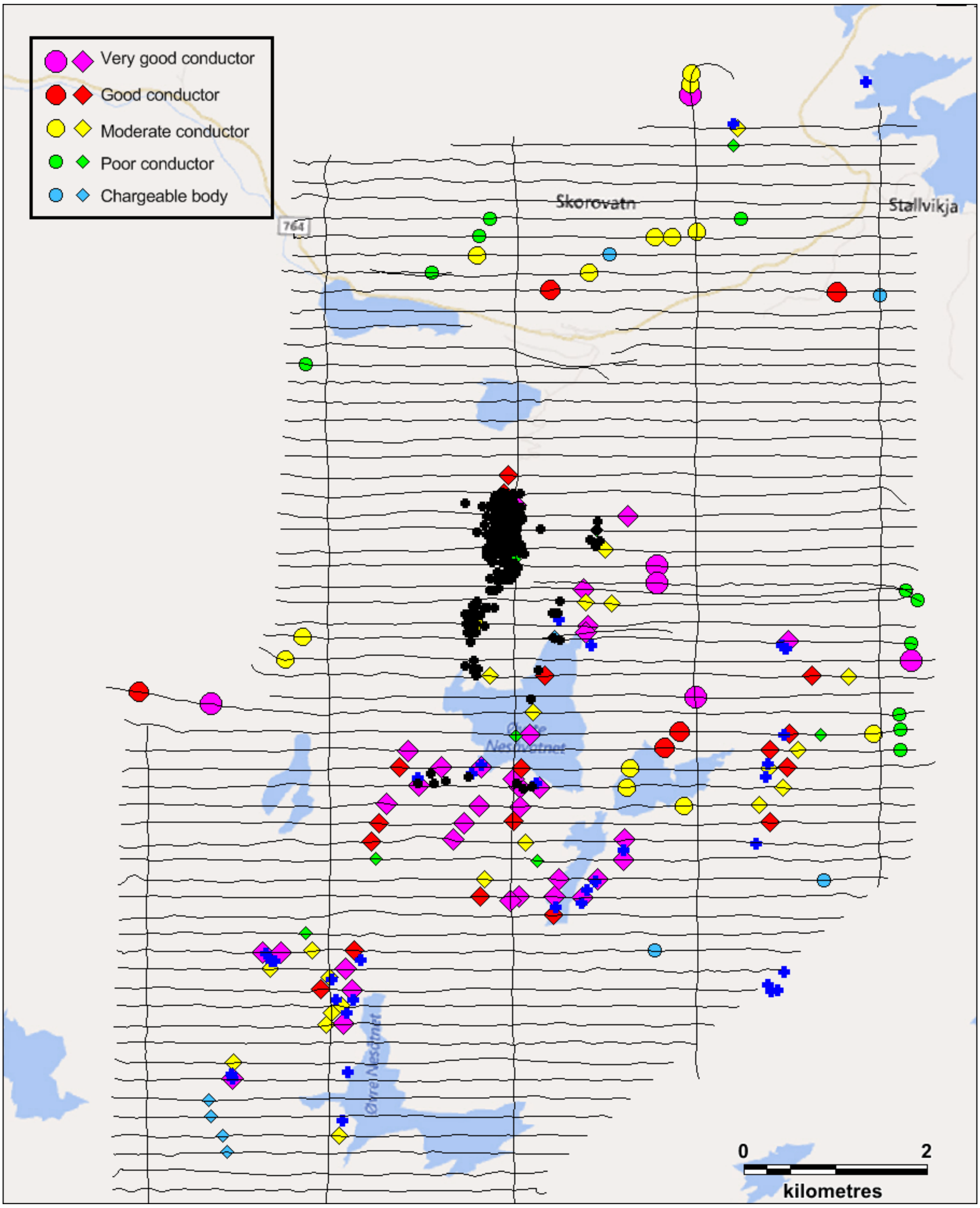

Figure 3-2. *Map showing identified anomalies that are interpreted to be caused by confined conductors in the sub-surface. Borehole collars (Sletten 2015) are shown with black dots and assay sample positions (www.ngu.no) with blue crosses.*

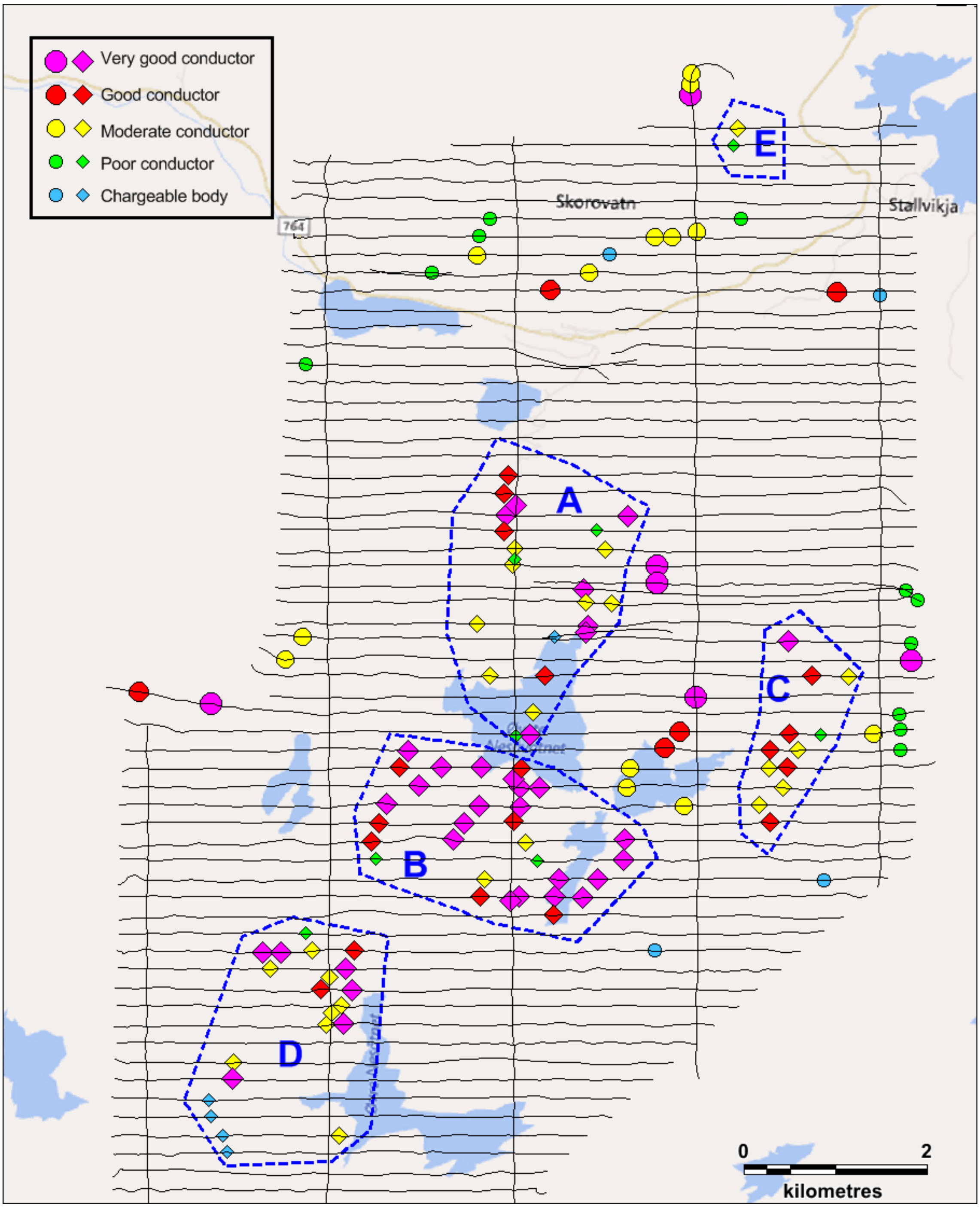

Figure 3-3. *Map showing identified anomalies that are interpreted to be caused by confined conductors in the sub-surface. Anomalies that are considered to be part of already known mineral occurrences are marked with polygons: A – Skorovas mine, including the main ore body, eastern ore, southern ore and south-eastern ore. B - Øverste Nesåvatnet and Nesåflyin, C – Langtjønna and Blindtarmen, D – Finnkrudomma, E – Lillefjellklumpen and Bjørknesbekken.*

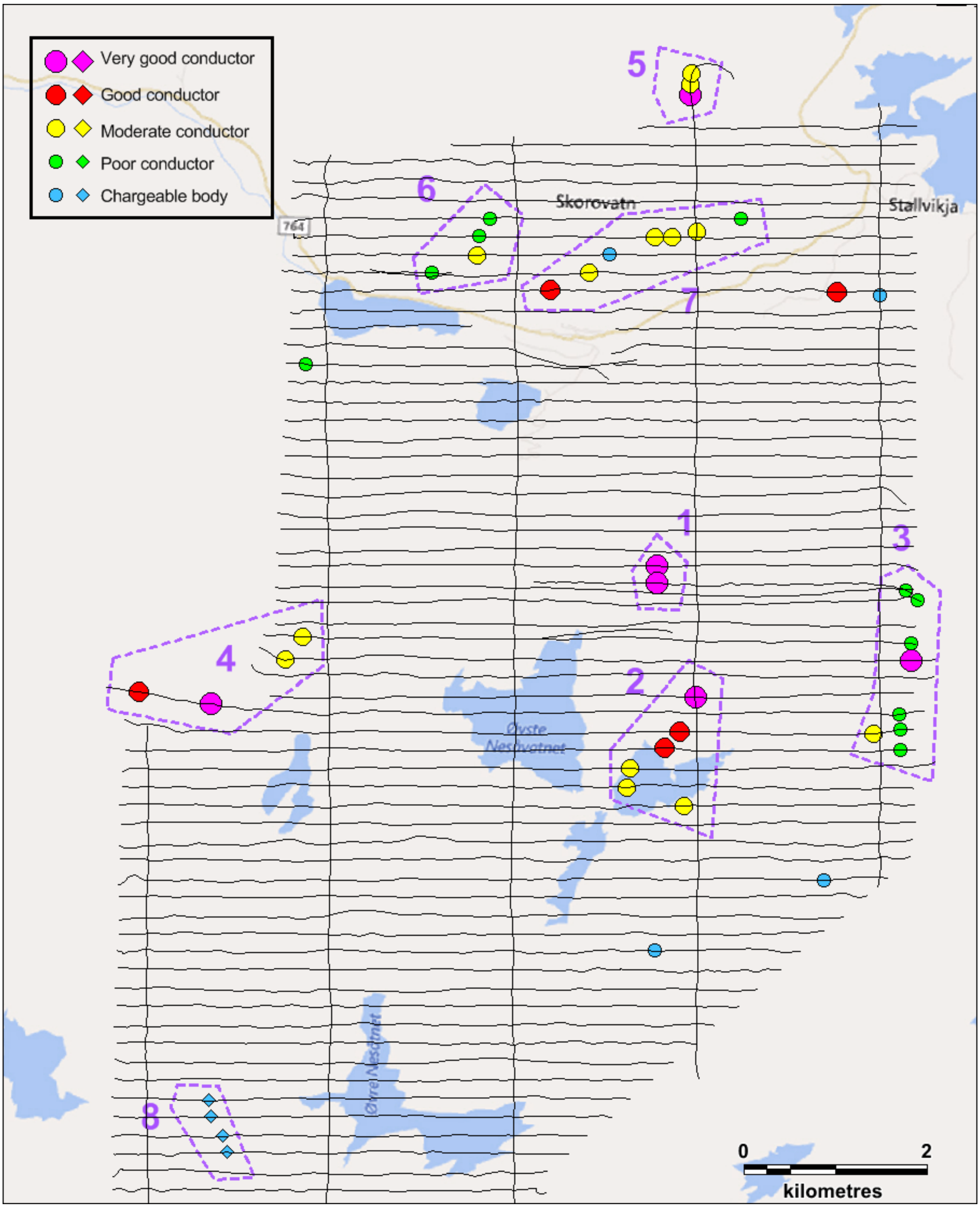

Figure 3-4. *Map showing identified anomalies that are interpreted to be caused by confined conductors in the sub-surface. The shown anomalies have not been tied to any known mineral occurrence within this work. See text for explanations.*

4 Conclusions and recommendations

A number of geophysical anomalies have been identified where the assumed sub-surface causative bodies have not been possible to tie to known mineralizations in this work. It is therefore recommended that some follow-up work is carried out. Possible actions are listed below. Exactly what to do is not possible to know without first making a more thorough check of previous exploration work carried out in the area. The following actions can be recommended:

- Data and observations from previous exploration work should be checked in order to see if the assumed anomalous bodies already have been identified and if they have been checked for possible economic value.
- Field visits should be made in order to see if causes to the geophysical anomalies can be identified. It is also important to check for man-made objects (fences or other metallic constructions) that mistakenly can be interpreted as sub-surface conductors.
- Samples should be collected for chemical assays if mineralization is found at locations of geophysical anomalies.
- Ground geophysics should be considered at locations where the SkyTEM anomalies cannot be explained by non-economic mineralization. TEM measurements is probably the best choice of method for this area. However, resistivity and IP measurements can also be considered. Ground geophysics should be carried out before any drilling since the detailed planning of any drillholes is difficult if it is based on just helicopterborne data. Ground TEM measurements are probably easiest to carry out during the winter by using snowmobiles.
- Drilling will be necessary to verify if any mineralization is of possible economic value.

The magnetometry data can be evaluated further in order to identify possible gold potential structures, traps and alterations patterns that can be worth investigating. Magnetometry data acquired by NGU can be used together with the SkyTEM dataset and an investigation can therefore cover a larger area than the SkyTEM survey. We have noted that there are gold occurrences like Sibirien and Storliseter immediately south of the Skorovas area. Gold mineralization is often structurally controlled. Thus, a structural interpretation with processing of magnetometry data, magnetic qualitative interpretation and targeting of general gold potential related settings and characteristics including structural, deformation, folding and granitoid patterns can be worthwhile. Such work is preferably also analysed together with other exploration data to prioritize the targeting.

5 Data delivery

The interpreted anomalies are delivered as a GIS layer in MapInfo format.

6 References

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