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Reconnaissance structural geological mapping and field XRF-analyses of the Ulveryggen copper deposit, Finnmark, Norway

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REPORT

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Title:
Reconnaissance structural geological mapping and field XRF-analyses of the Ulveryggen copper deposit, Finnmark, Norway

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Summary:
Reconnaissance structural geological mapping and field XRF-analyses with a portable XRF-analyzer were carried out at the now closed Ulveryggen copper mine, Repparfjord Window, Finnmark. The goals of the study were to better understand the structural setting of the mineralisations at Ulveryggen and to test a handheld XRF-analyzer on this type of copper deposit. Preliminary conclusions suggest a structural control of at least part of the mineralisations. Suggestions for further studies include a helicopter-borne geophysical survey, meso-scale structural geological mapping and detailed studies of mineralisations and micro-structures.

Keywords: ore geology	structural geology	copper
XRF-analyses		

CONTENT

1. INTRODUCTION

Reconnaissance structural geological mapping and field XRF-analyses with a portable XRF-analyzer were carried out at the now closed Ulveryggen Cu mine, Repparfjord Window, Finnmark. Field work in the Repparfjord-Alta areas was carried out in the period 1.-14. August 2007. The field geologists were Giulio Viola, Lars Petter Nilsson and Jan Sverre Sandstad from the Geological Survey of Norway (NGU).

The goals of the study were:

- to better understand the structural setting of the mineralisations at Ulveryggen and to compare structures in the abandoned pits with the structural setting of a number of other abandoned Cu operations within the Repparfjord tectonic window.
- to test thoroughly a portable XRF-analyzer on this type of mineralisations and to get a better view of the distribution of Cu-mineralisations within the deposit.

Interesting geological features were observed at Ulveryggen and some preliminary conclusions are already possible. Suggestions for further studies will also be made in this short report.

The geology and Cu-mineralisations of the Ulveryggen deposit have been described and discussed in several reports, theses and publications. The Cu-mineralisations at Ulveryggen were discovered around 1900. In 1903 the Swedish company 'Nordiska Grufaktiebolaget' started to explore the area by trenching and digging minor adits, but the ore was defined as uneconomic. The Canadian company 'Invex' drilled 2358 m in 1955-57 (Archibald 1957), before a Norwegian company acquired the rights in 1963. NGU carried out extensive investigations for 'A/S National Industri' in the 1960's and the results of the geological mapping and core drilling are summarized in several reports (e.g. Hovland 1965, 1967a,b, 1968 and Hovland & Paulsen 1966,1967). These investigations identified 10 Mt of ore with an average grade of 0,72 % Cu. Folldal Verk A/S acquired the rights to the deposit in 1970, and mined the deposit from May 1972 to June 1979. About 3 Mt of ore with an average copper content of 0,663 % were mined from four different open pits (Figure 2). Fabricius (1978, 1979) and Stribrny (1980, 1985) continued the research activity in the area, and their results are exposed in several reports and publications.

The copper mineralisations occur in a heterogeneous metasedimentary package comprising metasandstones, metaconglomeratic sandstones and metasiltstones of the Ulveryggen Formation, part of the Saltvatn Group. The main ore minerals are chalcopyrite and bornite that occur mainly as disseminations and, to a lesser extent, along veinlets and cracks. The genesis of the mineralisations has been intensively discussed, with both syngenetic (during sedimentary or diagenetic processes) and epigenetic processes proposed. Several authors (e.g. Hovland & Paulsen 1966, Stribrny 1985) have, however, also suggested a link between the mineralisation and deformation within the Ulveryggen formation, although a modern structural study of the area has yet to be made.

Figure 1: The 'Vestfelt' pit at Ulveryggen, looking towards northeast. (The area of Figure 10 is shown in the white frame).

2. STRUCTURAL ANALYSIS

The reconnaissance structural analysis was carried out in 'Hovedfelt' and 'Vestfelt', together with only a very a brief visit to Erik. Localities N 07/71 to 74 are from Hovedfelt, 75 from Erik and the remaining 76 to 78 are located in 'Vestfelt' (Figure 2).

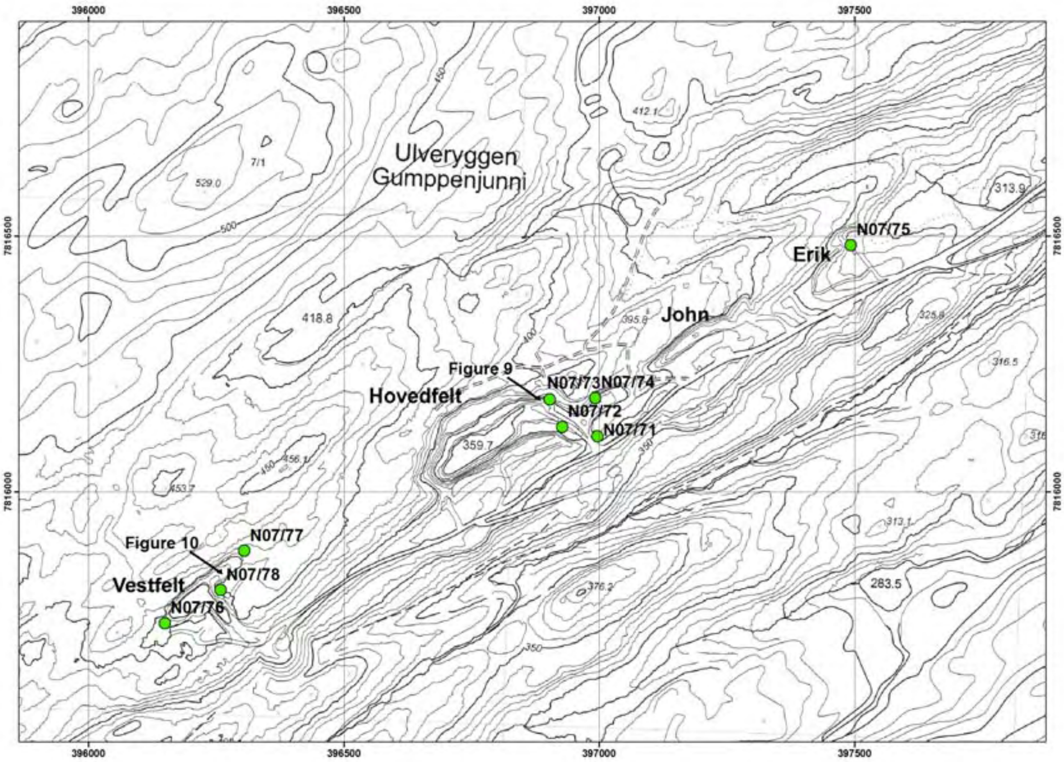

Figure 2: Observation localities in the Ulveryggen area. The four main pits; 'Vestfelt', 'Hovedfelt', John and Erik, and the location of XRF-profiles shown in Figure 9 and 10 are also marked.

Ulveryggen 'Hovedfelt':

Observations in 'Hovedfelt' suggest a relatively constant dip direction of the bedding to the NW and exclude significant mesoscopic open folding of the sequence at the outcrop scale (Figure 3). As shown in Figure 3, there are clear angular relationships between bedding (S_0) and cleavage (S_1), with the latter being systematically steeper than bedding in the outcrops studied during this project. This observation, together with a consistent younging direction towards the NW (established from primary structures in the metasediments) is consistent with the local large-scale geometry of the Repparfjord Window, which is characterized by a megascopic antiform to the south of the studied area, with Ulveryggen being located on its northwestern limb.

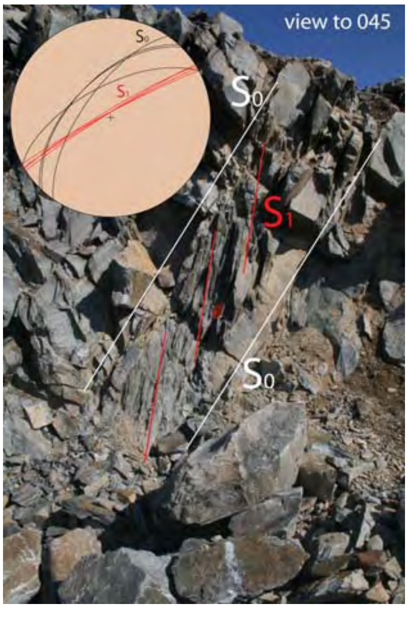

Figure 3: Bedding-cleavage relationships observed at locality N 07/71. The cleavage is developed in a more shaly bed of the metasedimentary sequence.

The fold pattern of the metasediment package is confirmed by the observation that several bedding planes are striated, with oblique dextral to reverse slickensides. The reconstructed kinematics for these slip surfaces in 'Hovedfelt' is consistently dextral at the outcrop, indicating a NW-side upward movement component (Figure 4).

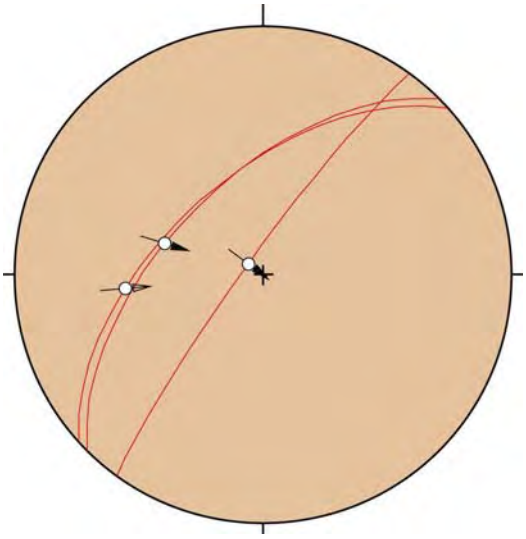

Figure 4: Kinematics of bed-bed interface planes containing oblique reverse to dipslip reverse striations. A NW-side up component is indicated.

This in turn suggests a flexural-slip folding mechanism, whereby the progressive shortening of the multilayered metasedimentary sequence about shallowly NE-plunging fold axes (orthogonal to the striations) was accommodated in part by slip along bed-bed interfaces.
Although the metasedimentary sequence at Ulveryggen has been described as intensively folded and the mineralization has been suggested to be strongly controlled by the fold geometry and the folding mechanism (e.g. Stribny 1985), no obvious mesoscale folds were observed along the sections inspected, which are instead characterized by a constant dip direction in the bedding and by the same bedding-cleavage relationships throughout the open pit.

The most interesting structural observation in 'Hovedfelt' (and in the nearby 'Vestfelt') is, however, the presence of a significant brittle/ductile shear zone, seemingly associated with high copper values within the metasandstones (see Ch. 3). Structural observations revealed that fracture density in 'Hovedfelt' increases remarkably from the sides of the open pit towards its central part, which indeed follows the strike of this shear zone. The zone is clearly visible in the upper photograph of Figure 5, a view to NE of the northeasternmost wall of 'Hovedfelt'. Intense fracturing with narrowly spaced systematic sets of steep fractures characterizes the core of the shear zone. A diffuse green-grey colour is typical of the fault core and reflects the presence of abundant malachite along several fracture planes and in their immediate surroundings.

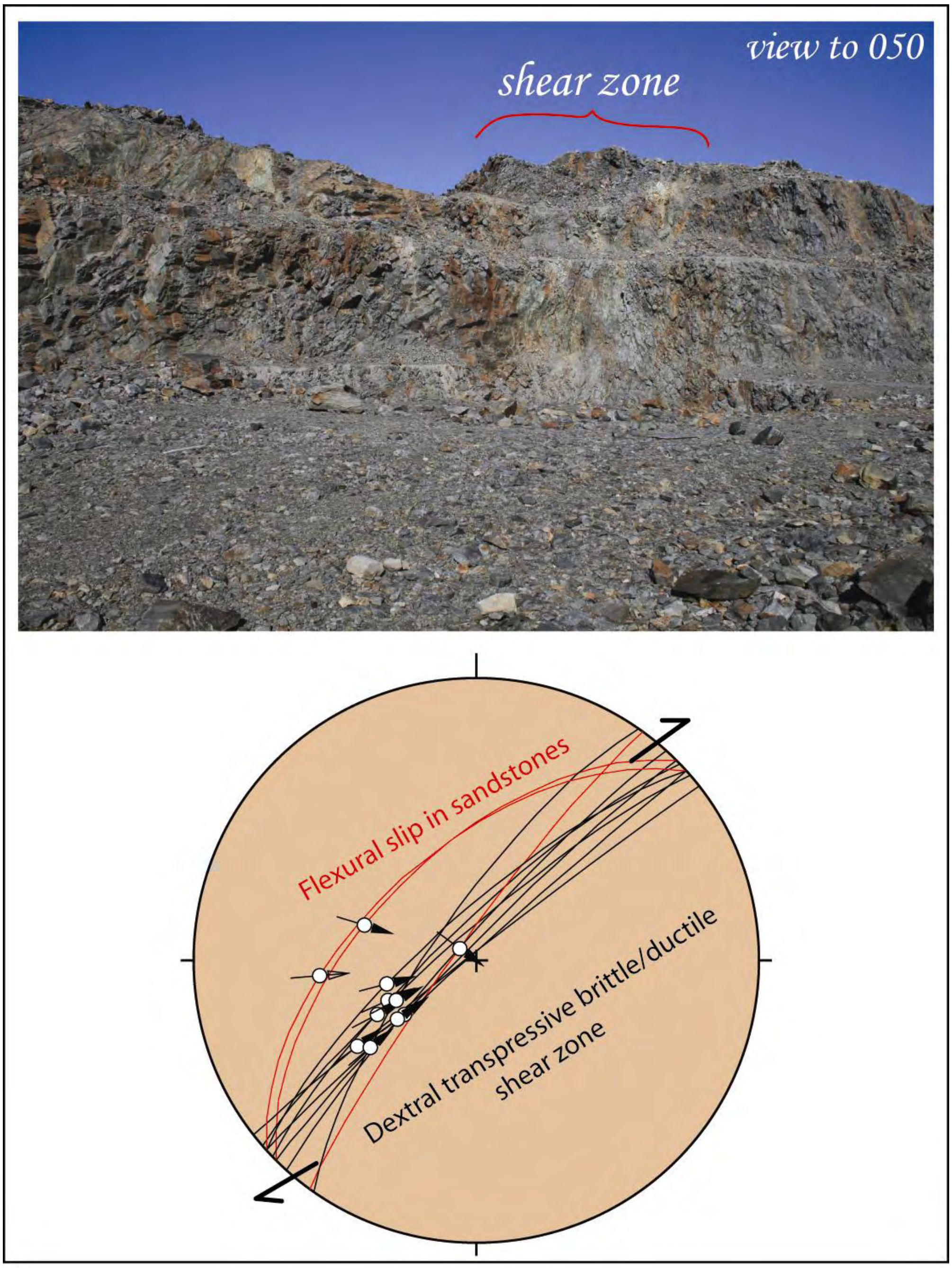

Figure 5: View to NE of the 'Hovedfelt' northeastern face. Note the c. 35 m wide shear zone that characterizes the central part of the cliff. The stereonet shows the dextral reverse kinematics of a number of subvertical NE-SW striking striated fractures from the shear zone.

Structural analysis of a number of striated planes found not only in the core of the zone but also within its lateral transition/damage zones has shown that the shear zone strikes subvertically NE-SW (subparallel to the bedding strike) and that it has an overall dextral kinematics. Striations plunge moderately to steeply W/WSW and thus define a dextral transpressional character of the deformation zone (Figure 5).

Ulveryggen Erik:

Due to the unstable conditions of most of the pit walls, we did not enter the pit and limited ourselves to analysis of the marginal parts of the rock faces (locality N 07/75, Figure 2).

The only structural feature observed is shown in the stereonet of Figure 6. A striated fracture plane has the same orientation as the shear zone in 'Hovedfelt', but unfortunately no kinematics could be assigned to the fracture plane, although dextral reverse is very likely. A thorough study of the brittle deformation along this newly identified deformation zone is needed to better define its geometry, kinematics and its role in the regional framework.

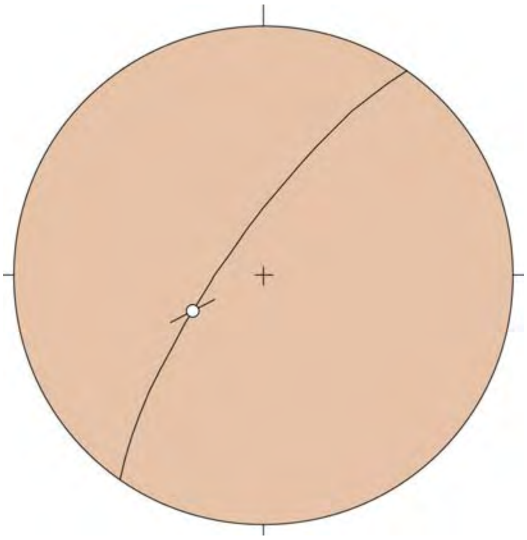

Figure 6: NE-SW striking fracture plane and SW-plunging striation observed in Erik. No kinematics was established.

Ulveryggen 'Vestfelt':

Structural observations at 'Vestfelt' confirmed the findings of the 'Hovedfelt', showing that the mining operations followed the strike of the transpressive dextral brittle/ductile shear zone so clearly identified in 'Hovedfelt'.

Moreover, two other important observations were made in 'Vestfelt':

a) At locality N 07/77 part of the shear zone is exposed in a flat, subhorizontal outcrop. The outcrop confirms that the metasandstones are locally strongly affected by a dextral shear zone, which, seen on a map view, is characterized by phyllonitic fault strands and associated dextral riedel shears (Figure 7).

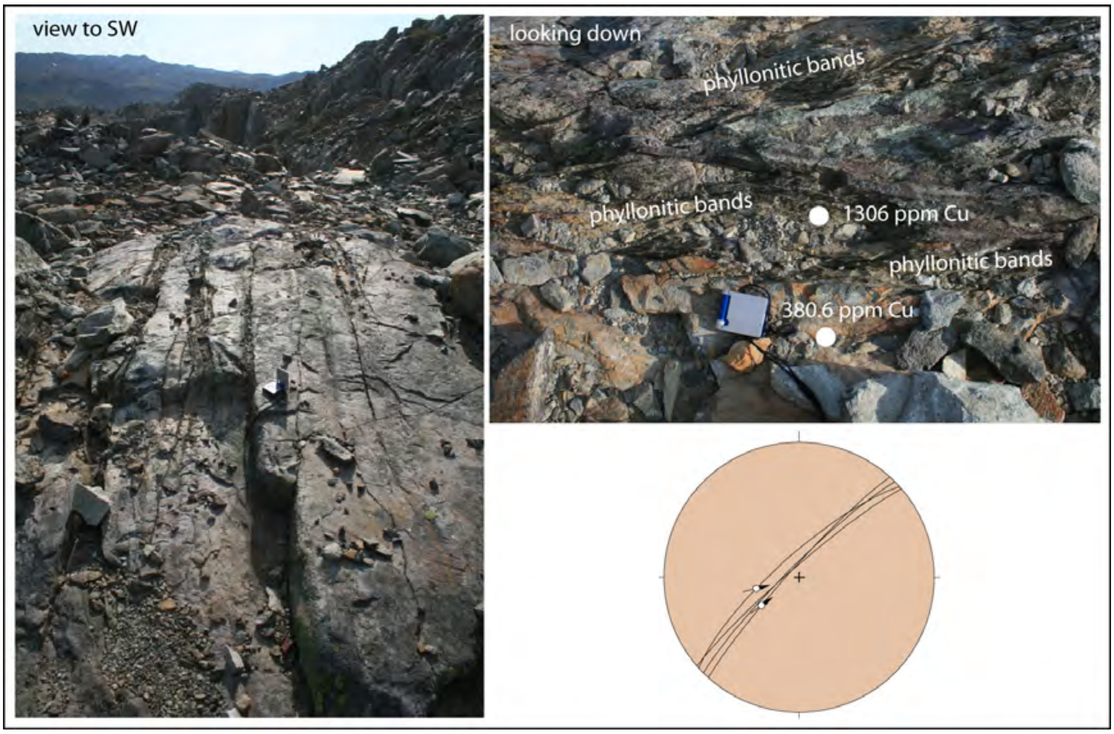

Figure 7: Shear zone strand in 'Vestfelt' (Locality N 07/77 in Figure 2; compass for scale). The shear zone is here exposed in a flat, subhorizontal pavement. Sheared domains are phyllonitic and contain higher Cu concentrations than the surrounding, undeformed metasandstones. The stereonet plots the orientation of individual fractures in 'Vestfelt' and confirms the dextral transpressive nature of the shear zone established in 'Hovedfelt'.

The orientation and the kinematics of two striated planes are identical to that established in 'Hovedfelt' (Figure 7). Direct XRF measurements on the flat pavement shown in Figure 7 show a significant enrichment in Cu within the strongly sheared phyllonitic band compared to the undeformed metasandstone (1306 vs. 380.6 ppm Cu; Figure 7).

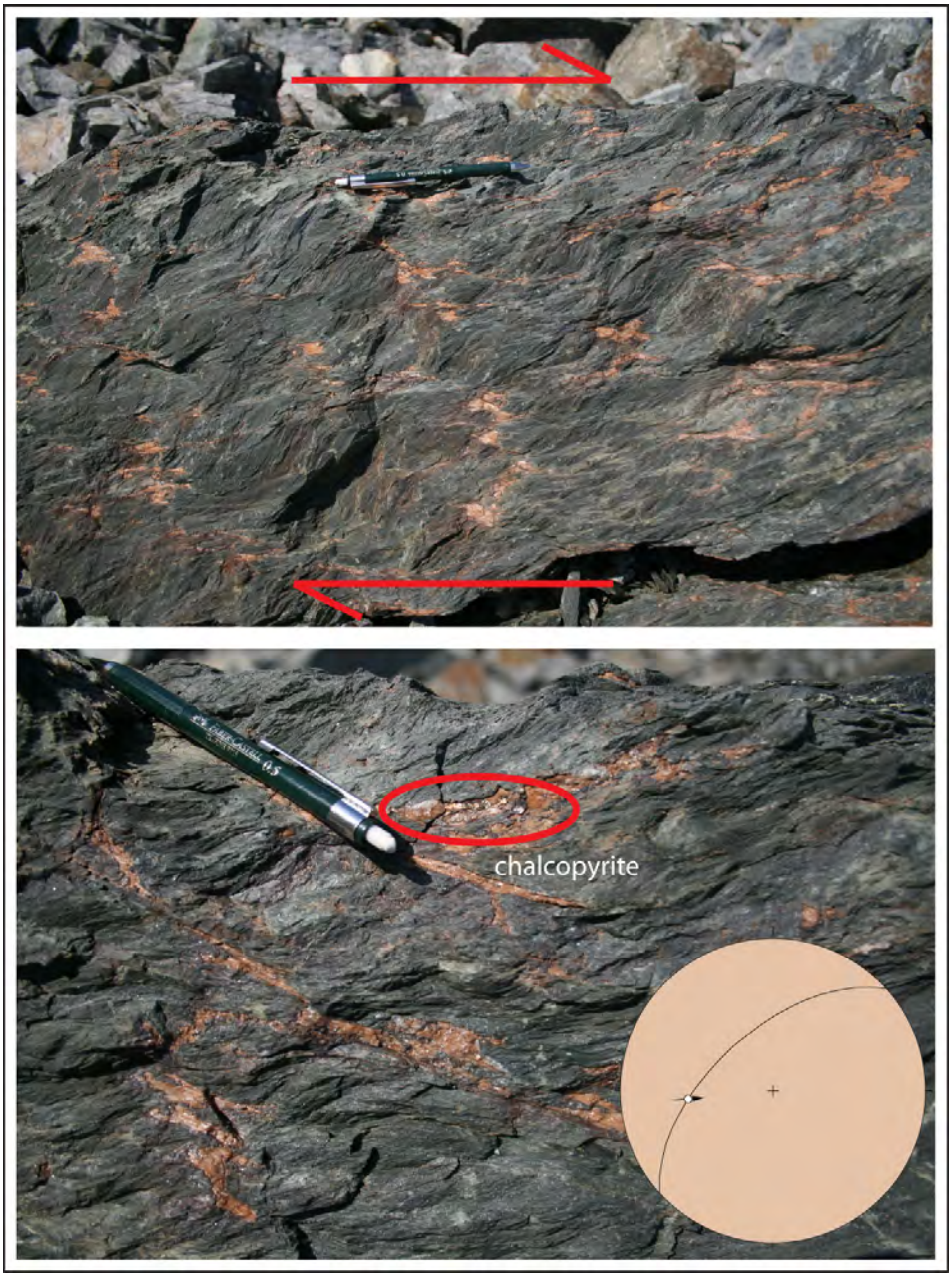

Figure 8: Dextral extensional crenulation cleavage developed in a mafic sill mapped in 'Vestfelt'. The orientation of the mylonitic foliation and of a stria in the sill is identical to the shear zone defined in 'Hovedfelt'. The dilational spaces within the extensional shear bands are filled in by quartz and sulphides (chalcopyrite in the bottom photograph).

b) At locality N 07/78 there is a c. 1.8 m thick mafic sill, oriented parallel to the bedding of the metasandstones. The dyke is deformed ductilely and contains a pervasive dextral extensional crenulation cleavage (ECC; Figure 8). The orientation of the ductile fabric is identical to that of the brittle shear zone, indicating that at least part of the shear zone-related strain zone was accommodated under ductile conditions. The dilatant spaces associated with the ECC fabric are filled in by quartz and sulphides. The handheld XRF-analyzer showed that the mafic sill is enriched in copper, 0,1-0,4 % Cu. Whether this indicates that the sill represents one possible source rock or that the Cu enrichment is due to later remobilisation is not clear.

3. XRF ANALYSES

Field XRF analyses were carried out by using a Thermo Scientific NITON XLp Analyzer. This handheld x-ray fluorescence (XRF) analyzer offers the user a choice of radioisotope sources to carry out nondestructive analyses of a wide group of elements in rocks and other materials (appendix 1). The element group calibrated to be used during this study included Sn, Ag, As, Pb, Zn, Cu, Ni, Co, Fe, Mn, Cr, Sb, Cd, Sr, U, Th, Se and Hg. The time used for each measurement was 30 s, and it seemed to be adequate for this purpose. A total of 179 analyses were made, including 133 analyses along seven profiles in three of the open pits at Ulveryggen, 32 analysis from the Roar prospect, which is located 2 km SW of the mining area, and some test anaylises of various mineralised boulders. So far the accuracy of the analyses has not been verified by laboratory analyses of rock samples, but the precision of the analyses was confirmed by several repetitions on reference samples.

The analyses were mostly carried out along across-strike profiles in NE facing walls within the open pits, three profiles in the 'Hovedfelt' and 'Vestfelt', and a final profile in the NE-wall of the northeasternmost Erik pit. The analyses commonly show strong variation along these profiles, but an example of rather homogeneous values was also found in the section in the lowermost NE-wall in the 'Hovedfelt', i.e. within the wide shear zone described above (Figure 9 and Figure 5).

Figure 9: Cu-analyses (in %) by handheld XRF-analyzer along a profile in the lowermost NE-wall in 'Hovedfelt' (for location see Figure 2).

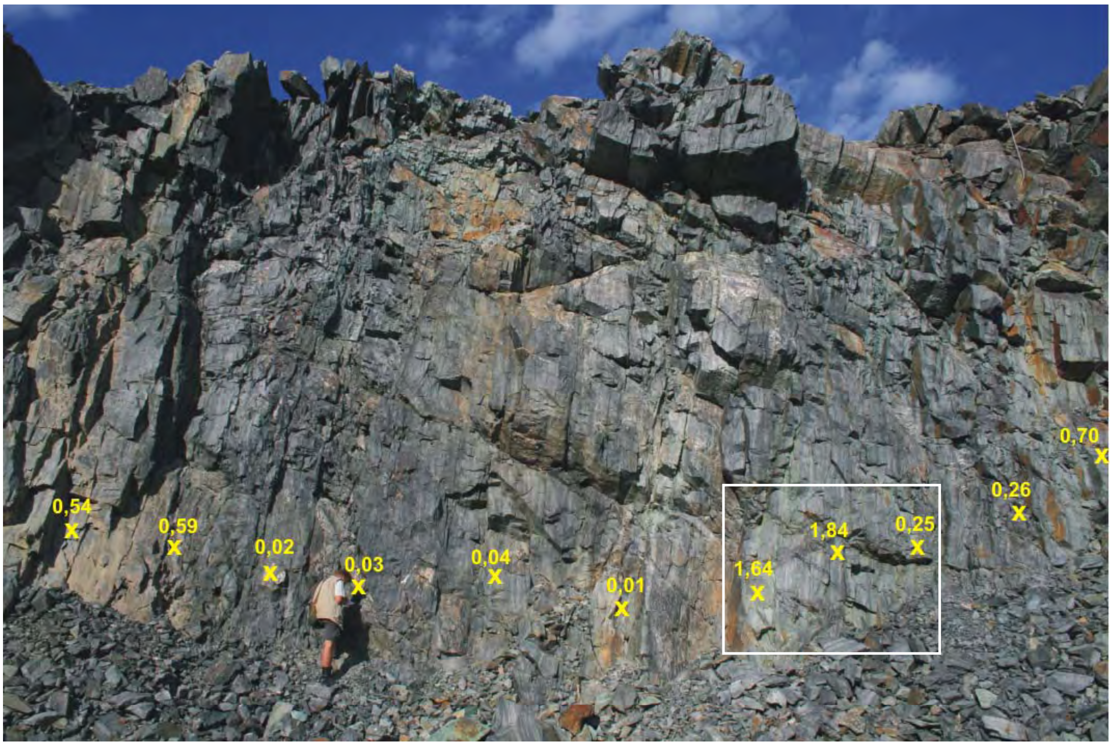

Figure 10: Cu-analyses (in %) by handheld XRF-analyzer along a profile in the NE-wall in 'Vestfelt'. The area of Figure 11 is shown in the white frame (for location see Figure 2).

Strong variations in the Cu % values were, however, observed along a section in the upper NE wall in 'Vestfelt' (Figure 10). The highest Cu-values were recorded in the right central part of the section, with some high Cu-contents found also in the NW (left) and SE (right) terminations of the profile.This profile is located within the southwesternmost exposure of the shear zone described above in the structural analysis section. The highest copper values occur in a 2 m wide, partly strongly sheared part of the sandstone to the left of the geolgist in Figure 11. The intimate spatial association of the locally very high Cu values and sheared volumes of the Ulveryggen Formation suggests a structural control on at least part of the mineralisation at Ulveryggen. Brittle/ductile shear zones are generally characterized by complex internal architectures, with irregular distribution of highly sheared and practically undeformed domains, separated by anastomosing and irregular fracture networks. Fractures, depending on their formation mechanism and on the composition of the rock type they deform, can act as impermeable buffers or as preferential conduits for fluid circulation, strongly enhancing the secondary permeability of the rock. Detailed microstructural work on selected fractured volumes of rock could lead to a better understanding of fluid/rock interaction at Ulveryggen and thereby shed light on the importance of shearing for the Cu mineralisation.

A few meter wide shear zone also occurs on top of the southwestern end of 'Vestfelt' pit. Some elevated copper values (up to 0,1 % Cu) were registered, while a 80 m long profile across strike in the continuation towards the NW from the pit revealed very low values.

No distinct correlations between copper and other metals was registered. This might also be due to the low content of other base metals in the mining area, e.g. no values above 100 ppm were detected for Zn, Pb or As. The accuracy of the the XRF-analyzer is not expected to be good at such low levels, and the errors measured were relatively high. Up to 900 ppm Co and 600 ppm Sb were registered but the associated errors were too high for the values to be considered meaningful.

Figure 11: C. 2 m wide strongly copper mineralised, sheared sandstone in the NE-wall in Vestfelt (above). Detail of the section in the white frame of the upper photograph (below).

The highest Cu content measured was detected on a boulder of sandstone with strong dissemination of bornite and chalcopyrite and extensive malachite staining giving 22,1 % Cu. A few boulders with 10-12 % Cu were also detected.

4. SUGGESTIONS FOR FUTURE WORK IN THE AREA

- Helicopter-borne geophysical survey to help interpret the structures on a regional scale and locate areas with favourable structures (activity already being carried out).
- Meso-scale structural geological mapping of the whole mining area to help delineating the ore bodies and to help develop a better understanding of the formation of the mineralisations. A more detailed knowledge of the shape of the ore bodies will improve the estimations of the ore reserves based on the results from the older core drilling programs and will be pivotal for future drilling phases.
- Microstructural analysis on selected volumes of sheared/fractured meta-sandstones, so as to characterize the fractures and to elucidate the role of fluid/rock interaction during shearing at Ulveryggen.
- More systematic and detailed analyses by handheld XRF-analyzer to register the distribution of Cu both regionally and locally; is the distribution controlled by sedimentary or tectonic structures (or both)?
- A detailed study of the ore mineralisations, by means of lab analysis of selected samples, including chemical analysis and studies of thin sections, also in conjunction with the proposed microstructural work. Studies of the weathering of the sulphides, which might effect extraction of copper should also be included.

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