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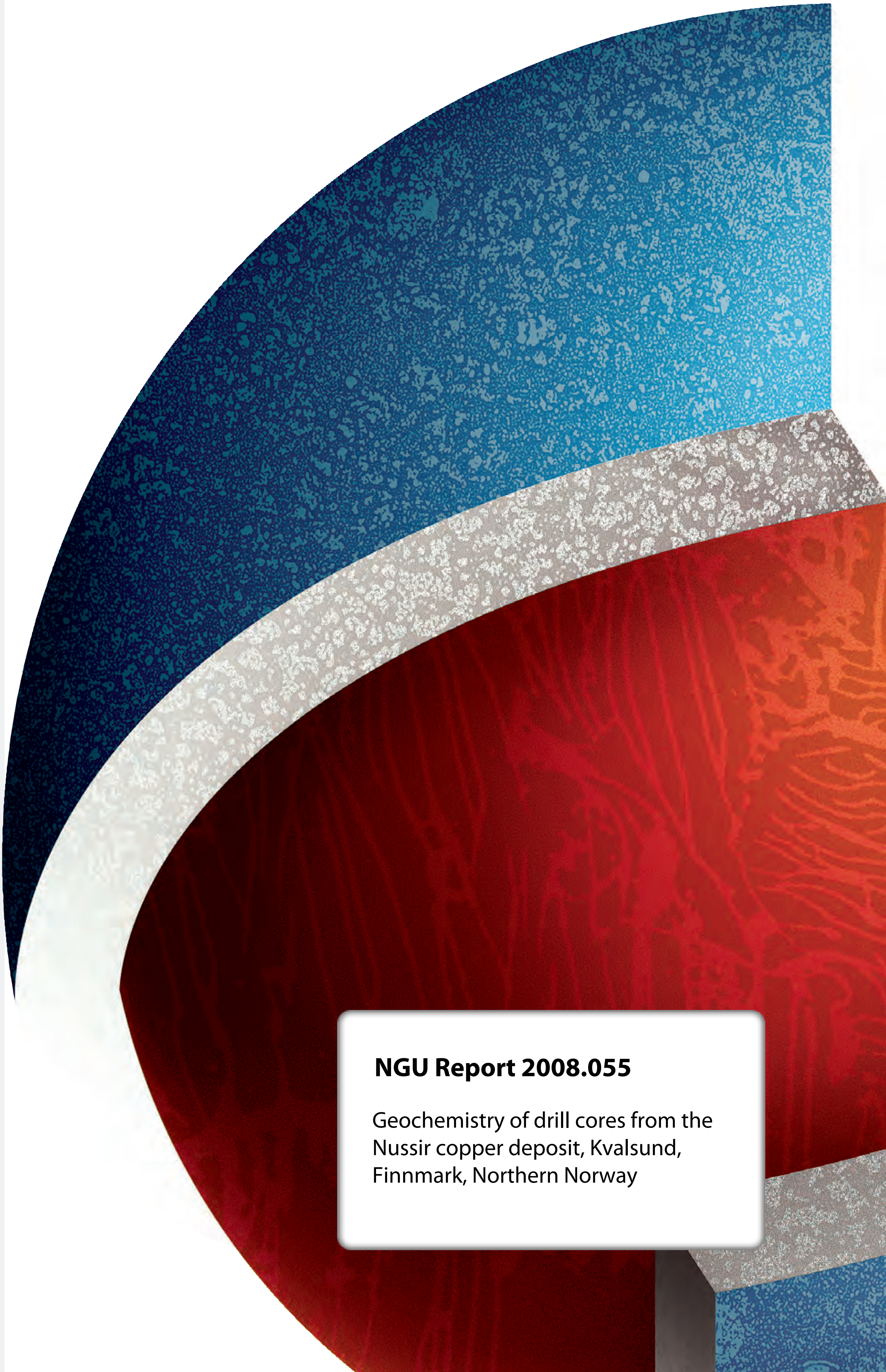

NGU Report 2008.055

Geochemistry of drill cores from the Nussir copper deposit, Kvalsund, Finnmark, Northern Norway

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REPORT

Report no.: 2008.055	ISSN 0800-3416	Grading: Confidential until 30.05.2011	
Title: Geochemistry of drill cores from the Nussir copper deposit, Kvalsund, Finnmark, Northern Norway			
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County: Finnmark		Commune: Kvalsund	
Map-sheet name (M=1:250.000): Honningsvåg		Map-sheet no. and -name (M=1:50.000): 1935 I Repparfjorden	
Deposit name and grid-reference: Nussir, 35W 390500 7818100		Number of pages: 49 Price (NOK): 185,- Map enclosures: 1	
Fieldwork carried out: -	Date of report: 30.05.2008	Project no.: 320600	Person responsible: R. Boyd

Summary:

The study is based on over 1000 analysed drill core samples, drilled before 2007, from the Nussir copper-deposit in Kvalsund in Finnmark, Northern Norway. The scope of the study was to find any correlations among the metals and eventually any metal zonations.

Several conclusions can be drawn from the study of chemical composition of the drill cores. However, some of them are indicative and should be confirmed by further analyses, re-logging of the drill cores and mineralogical studies.

Analyses of acid-soluble digestions show the metal distributions as well as give indications of lithologies present. There is, to a varying degree a positive correlation between Cu and Ag, S, As, Co, Au and Fe. The enrichments of other transitions metals than Cu are limited.

High Cu-values are found both within and in the footwall of the assumed ‘ore dolomite’ zone. Actually, the highest Cu-values commonly occur in the footwall of the dolomite. The ore dolomite is best defined in the western part of the deposit, and the Cu-mineralisations occur in less dolomitic rocks in the eastern part. The core length of the Cu-mineralised zone is, in several sections, several meters, up to 8-9 m when the cut-off is taken as 0.25 % Cu.

The relationship between Cu, Fe and S can be used to give indications on both lateral and vertical zonation of different copper minerals. The highest proportions of the Cu-rich sulphides; bornite and chalcocite/ digenite occur in the westernmost and in the eastern parts of the deposit. The highest Ag values are found in chalcopyrite-rich samples in the folded part of the deposit. Further studies are needed to verify whether this zonation and Ag distribution are a primary feature or due to later remobilisation.

The host rocks of the two Cu-mineralised zones in the westernmost part of the area have different chemical composition. The chemical characteristics of the lower Cu-zone, which includes enrichment of Pt, are only found in drill hole Bh 60.

Keywords: ore geology	geochemistry	core samples
copper		

CONTENT

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1. INTRODUCTION

These studies are based on over 1000 analysed drill core samples from the Nussir copper-deposit in Kvalsund in Finnmark, Northern Norway. All the analysed samples are from cores drilled before 2007. In the period 1985-1996 a total of 50 holes were drilled over a length of 9 km. Based on the results of reconnaissance logging of drill cores at Løkken in Januray 2008 it was decided to perform further analyses on some of these drill cores. These analyses and previous analyses where then studied to find correlations among the metals and eventually metal zonations. The distribution of the precious metals was also to be investigated.

The analyses have been performed over several years in different batches. They were in this study compiled into three separate tables, and usually plotted in separate diagrams if not otherwise is stated:

- Analyses have been received of nearly 600 samples from 43 drill holes from the first period of the investigations, 1985-1996. All of the samples had been analysed for copper (Cu), and many of them also for silver (Ag) and gold (Au) by different laboratories. The analytical methods are not known. These analyses are referred to as 'pre-2000 analyses' in the text. The analysed core lengths are usually 1m or shorter.

- In 2002, 63 samples from 9 holes were analysed for 47 elements by Aqua Regia digestion and ICP by OMAC Laboratories, Ireland. Only Ag among the precious metals was analysed. The samples are from drill holes Bh 21, 25, 26, 27, 28, 29, 35, 38 and 40, but only a few meters of each of the drill cores were analysed. The analysed core lengths are usually 1m.

- 407 samples from 9 holes were analysed in 2008 for 46 elements by Aqua Regia digestion and ICP-OES by OMAC Laboratories, Ireland. The digestion is partial for some elements especially Al, Ba, Cr, K, Na, Sn, Sr, Ta, Ti, V and W. In addition Au, Pt and Pd were analysed by Fire Assay/AA on 30 gm samples. The whole cores from drill holes Bh 39 (117.6 m), 40 (43.2 m) and 60 (120 m) were analysed, whereas parts of Bh 19, 20, 54, 55, 57 and 90 were analysed. The analysed core lengths are 1-2m. These analyses are referred to as '2008-analyses' in the text.

No whole rock analyses have been performed, but the analyses of acid soluble solutions give some indication as to which type of rock it is that has been analysed. The carbonate minerals are supposed to be completely dissolved, and high content of magnesium (Mg) are mainly assumed to represent the 'ore dolomite'. Carbonates are generally characterised by low values of the transition metals like Cu, Ni, and Cr, while mafic metavolcanites have elevated values of these. The relationship between weigth% Mg:Ca is nearly 2:3 in a stochiometric dolomite, ($CaMg(CO_3)_2$ - 13.18 % Mg and 21.73 % Ca)¸ i.e. if an analysis has 6 % Mg the corresponding content of Ca should be around 9 %, if both Mg and Ca only occur in dolomite in the sample.

In this report the correlations between various metals are first addressed in scatter-diagrams, with a few comments on some of the variations along the strike. Then the chemical variations along the individual drill holes from west to east are shown. The profiles in that section refer to the drill section used in the 'Nussir Prospectus' made by Terra Control in November 2003.

The locations of the drill holes are shown in Appendix 1. It was also planned to show the results in 3D, but with the relatively few analyses available combined with large geochemical variations along dip compared to changes along strike, it has been more appropriate to study the relations between the elements along the individual drill holes with comments on variations along the strike.

2. SCATTER DIAGRAMS

The correlations between copper (Cu) and the other elements have been investigated. In the diagrams the values for Cu are given in ppm (i.e. 10000 ppm Cu equals 1 % Cu). The correlations between Cu and the precious metals is of major importance in an economical evaluation of the deposit, and the correlation with other elements could give indications on the ore control of the deposit and hence the potential for extending the mineralisations.

2.1 Cu-precious metals (Au/Pt/Ag)

There is no clear positive correlation between Cu and gold (Au) (Figure 1). The results show that samples with high Cu values also are found without significant enrichment of gold, and the other way around. The diagram also shows that the 'pre-2002 analyses' have a higher detection limit and lower precision than 2008-analyses. Plots of Cu-Au and Cu-Pt (platinum) do not show any correlation between these elements in the 2008-analyses, but the data are limited, especially for Pt (Figure 2). Analyses of Au, Pt and Pd were not made in 2002. All the five Pt values above 200 ppb are from the westernmost part of the area, drill holes Bh 20 (Figure 20) and 60 (Figure 17). The one sample with enrichments of both Cu and Pt is from Bh 40. Palladium (Pd) has very similar distribution as Pt (not shown).

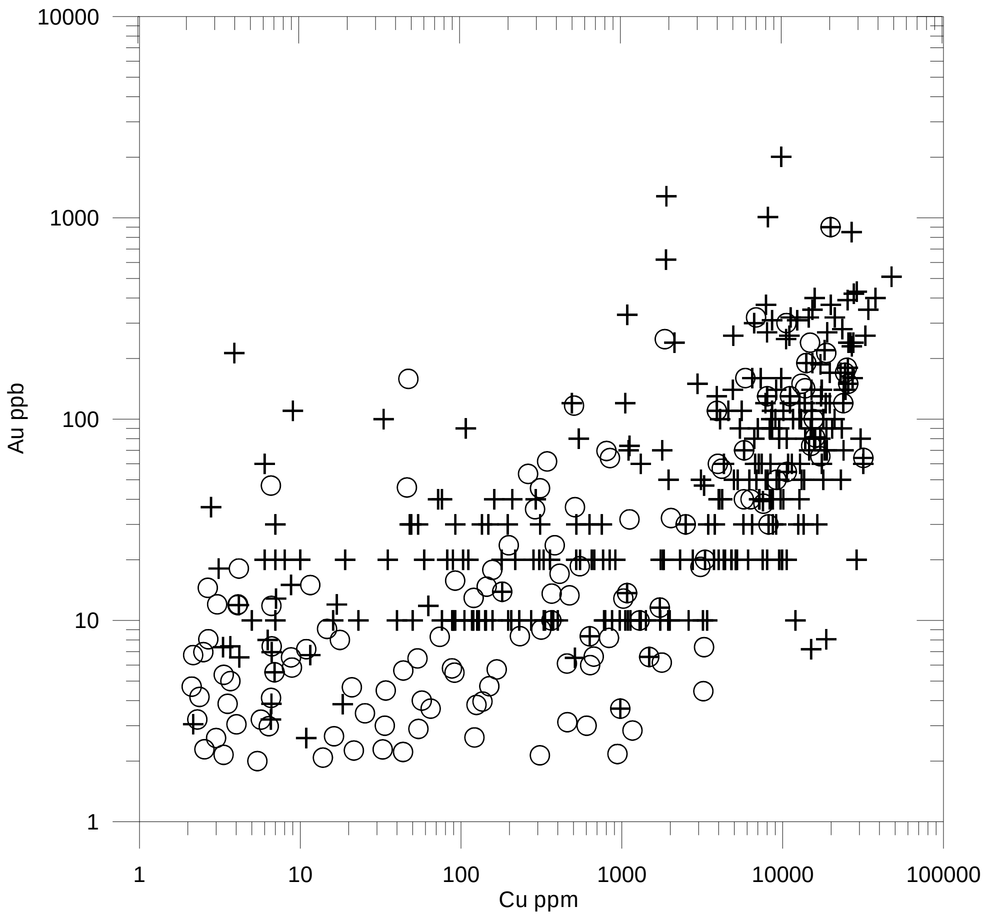


Figure 1: Scatter diagram of Cu in ppm and Au in ppb in drill core samples. Samples analysed in 2008 are marked with O *and pre-2000 with +.*

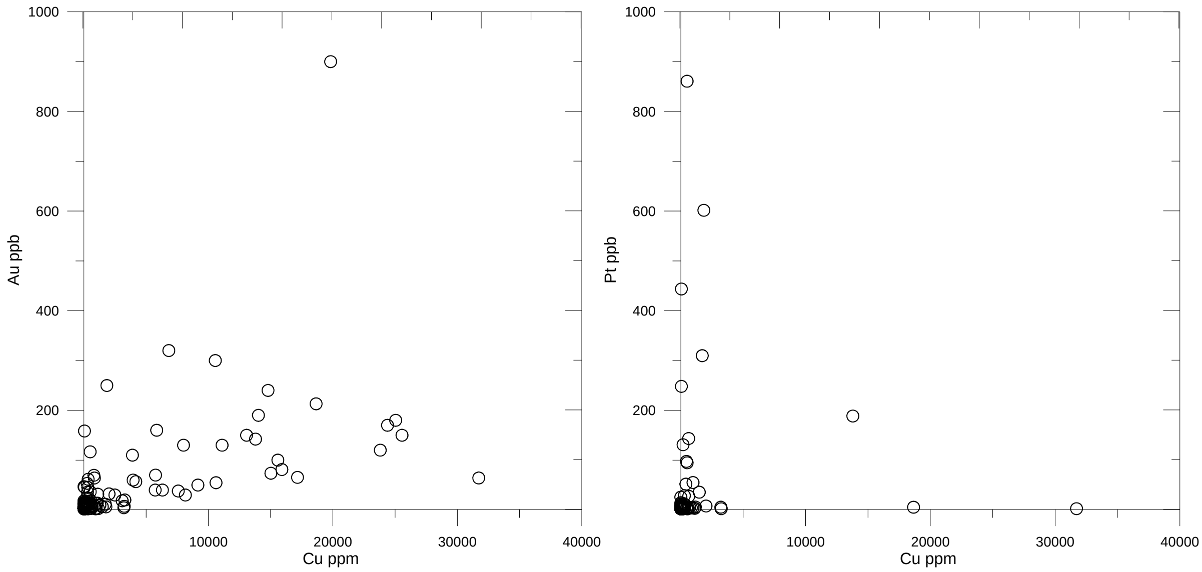


Figure 2: Scatter diagrams of Cu-Au and Cu-Pt in drill core samples analysed in 2008.

In Figure 3 there is a broad positive correlation between copper (Cu) and silver (Ag) for samples analysed in 2002 (+) and 2008 (O). The existence of two possible trends in the data is further discussed in Section 2.4. Plots of the pre-2000 analyses are not shown, but they give a similar pattern. However, the sample with the highest copper value in that batch, 4.75% Cu (47500 ppm Cu), contains only 12.1 ppm Ag and the highest silver value, 146.5 ppm Ag occurs in a sample with 3.77 % Cu (37700 ppm Cu).

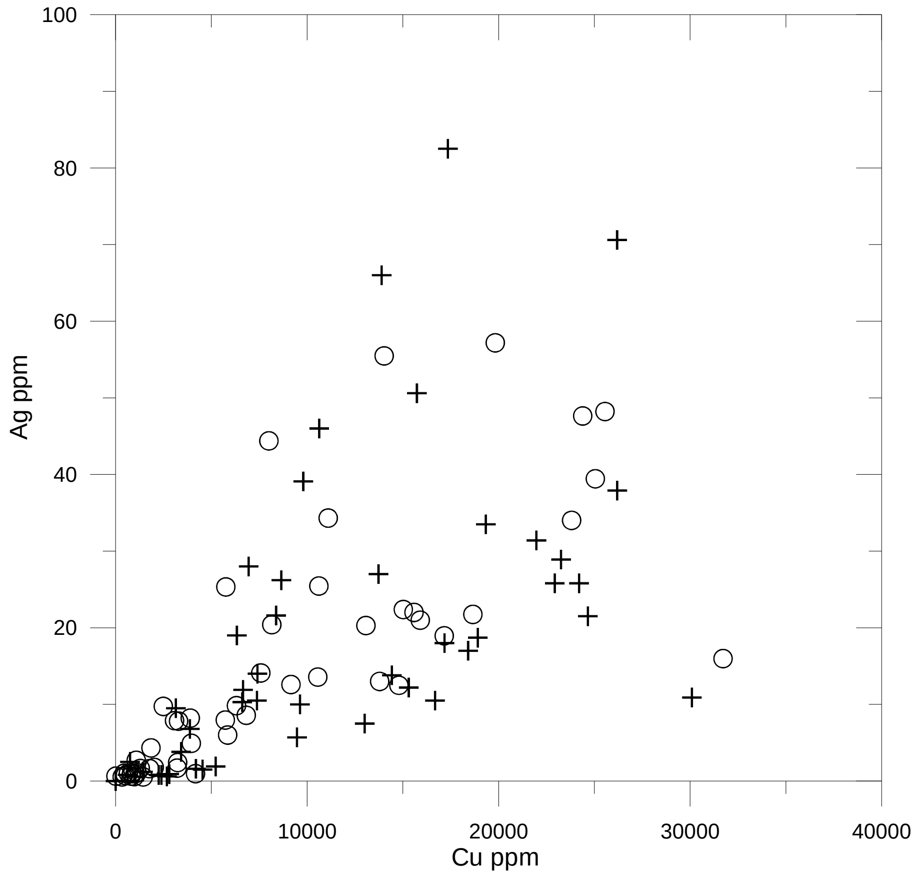


Figure 3: Scatter diagram of Cu and Ag in drill core samples. Samples analysed in 2008 are marked with O *and samples analysed in 2002 with* +.

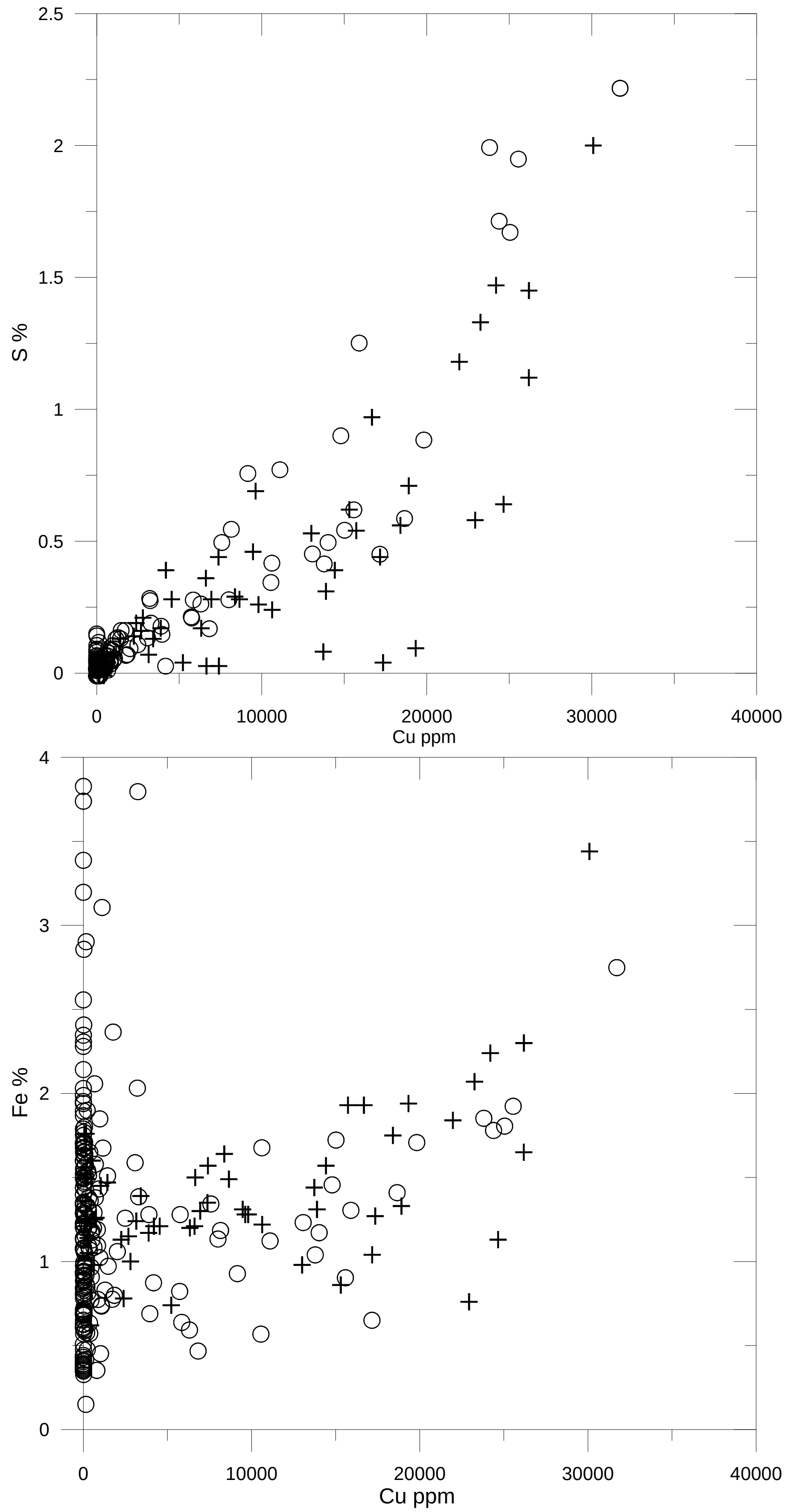


Figure 4: Scatter diagrams of Cu-S and Cu-Fe in drill core samples. The legend is as in Figure 3.

2.2 Cu-transition metals, arsenic and sulphur (Co/Fe/As/S)

There is a strong positive correlation between Cu and sulphur (S) (Figure 4), which shows that most of the S occurs in the copper-sulphides. In a few of the samples high Cu contents are registered without any enrichment of S, which means that most of the Cu in these samples probably comprises malachite. They occur in drill holes Bh 28 and 29. A weak positive correlation between Cu and iron (Fe) in the copper-enriched samples is shown in Figure 4, and it is also obvious that Fe also occurs in other minerals than the Cu-minerals. Several samples with > 4 % Fe, and insignificant Cu values have been omitted from the diagram. The relationships between Cu, Fe and S are further discussed below (Section 2.4).

The Nussir Cu-deposit has been correlated with other sediment-hosted Cu-deposit like those in the Central African Copperbelt in Zambia and Congo and the Kupferschiefer in Poland and Germany. These deposits also contain elevated values of other transition metals (e.g. Kampunzu et al., 2005), compared to e.g. average post-Archaean shales that contain < 60 ppm Cu, < 30 ppm Co and < 100 ppm Ni (Taylor & McLennan, 1985). Enrichment of transition metals other than Cu and Fe is not common in the Nussir copper-mineralisation, but some enrichments of cobalt (Co) and arsenic (As) occur (Figure 5). One sample with the highest As value, 617 ppm As, contains 3.17 % Cu, and is not shown in the diagram.

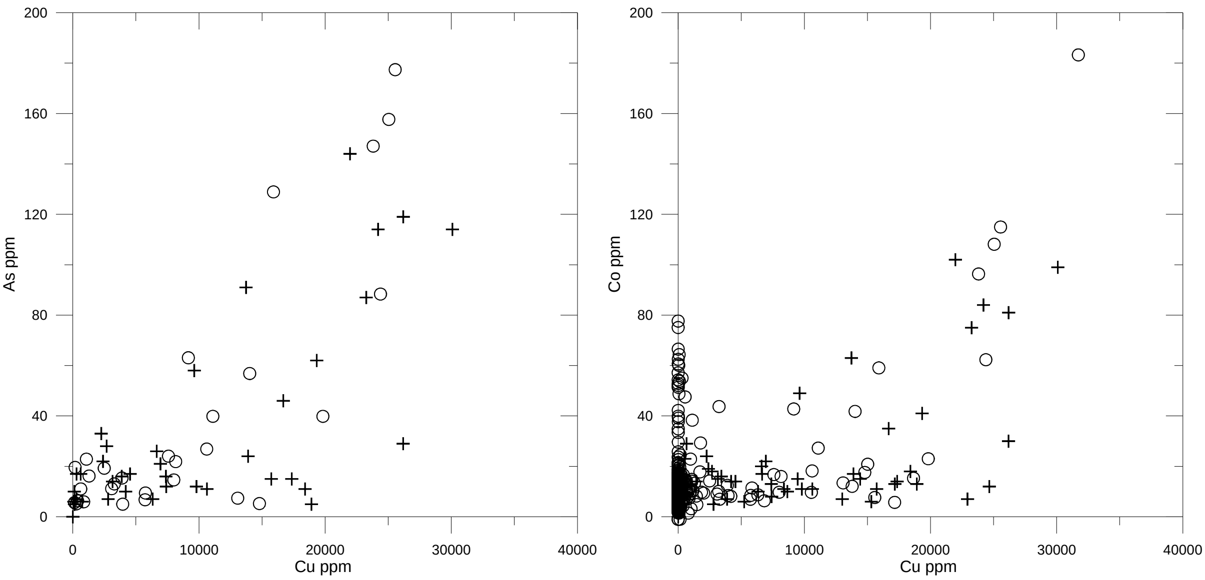


Figure 5: Scatter diagrams of Cu-As and Cu-Co in drill core samples. The legend is as in Figure 3.

The content of nickel in association with the copper mineralisations is low, although a slight increase in Ni values is found for the highest Cu-values (Figure 6). High contents of Ni in the core samples are mostly found in greenstones of the Nussir Group (see Figure 9).

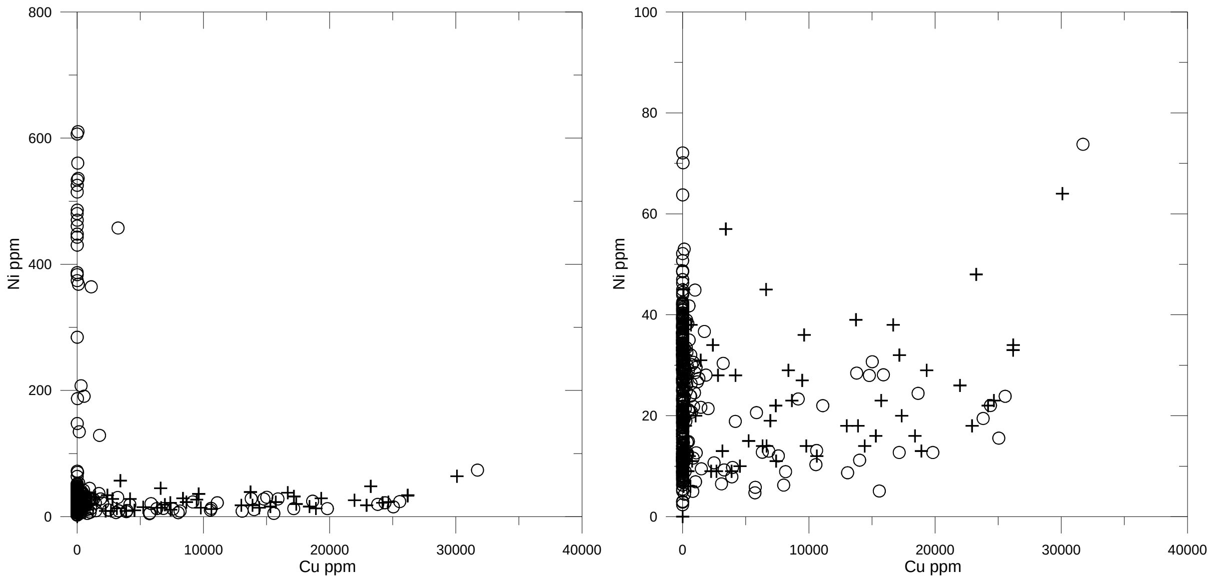


Figure 6: Scatter diagrams of Cu-Ni in drill core samples. Note the different scale for Ni in the two plots. The legend is as in Figure 3.

2.3 Cu-alkali and alkaline metals (K/Ba/Mg/Ca)

Potassium (K) shows only slight variations in content in Cu-mineralised samples (Figure 7). However, the analytical method used does not give the total K content. That also applies for barium (Ba) that does not show any correlation to Cu in the Nussir-deposit, although a few samples are enriched in both Cu and Ba (Figure 7). Ba is described to be enriched just above and below the ore zones in the Zambian copper-deposits (Sutton & Maynard, 2005). An enrichment of Ba is found just above the ore mineralisation in drill holes Bh 39 and 60.

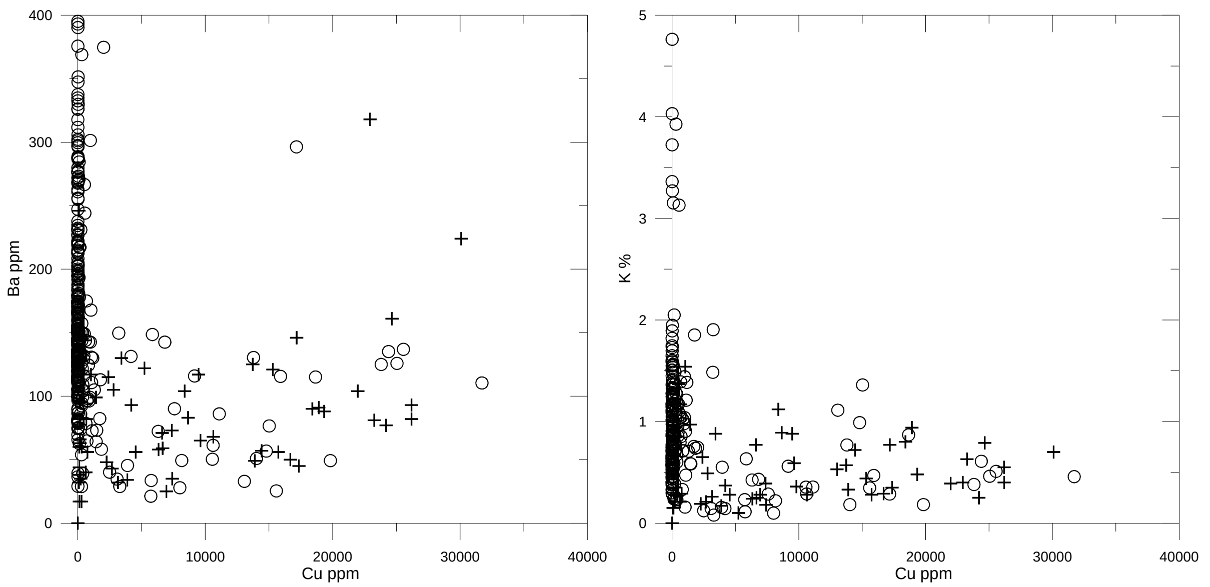


Figure 7: Scatter diagrams of Cu-Ba and Cu-K in drill core samples. The legend is as in Figure 3.

The plot of Cu and magnesium (Mg) shows that the copper-mineralisations in Nussir are hosted by rocks of varying Mg content that shows a bimodal distribution (Figure 8). Values >

4 % Mg probably represent samples of the 'ore dolomite' and values < 2.5 % Mg of less carbonated, sedimentary or altered rocks. Very few samples contain Mg values in the interval between, i.e. 2.5-4 % Mg. In plots of the chemical variation along the drill holes in Section 3, the 'ore dolomite' is marked for zones with > 4% Mg if there is no other chemical characteristics that indicate otherwise. For example, the greenstone of the Nussir Group has similar a Mg content, but is strongly enriched in nickel and chromium compared to the dolomite (Figure 34).

A similar bimodal distribution of calcium (Ca) is distinct in the '2002-analyses', due to samples of either dolomite or sediments, but is not obvious in the '2008-analyses' due to several samples of greenstones and assumed alteration of rocks in the analysed batch (Figure 8).

All the samples with Ni content > 150 ppm (Figure 9) are from drill holes Bh 39, 40 and 54, i.e. the eastern part of the deposit (Appendix 1). Most of them represent the Nussir greenstone. The samples with lower Ni values, but still > 3 % Mg are all from the western part of the deposit, from drill hole 35 and westwards. This implies that all the Cu-mineralised samples within the 'ore dolomite' are from the western part of the deposit, and that the samples of the Cu-mineralisations in the eastern part occur in less dolomitic rocks. That can be tested by re-logging the drill cores properly.

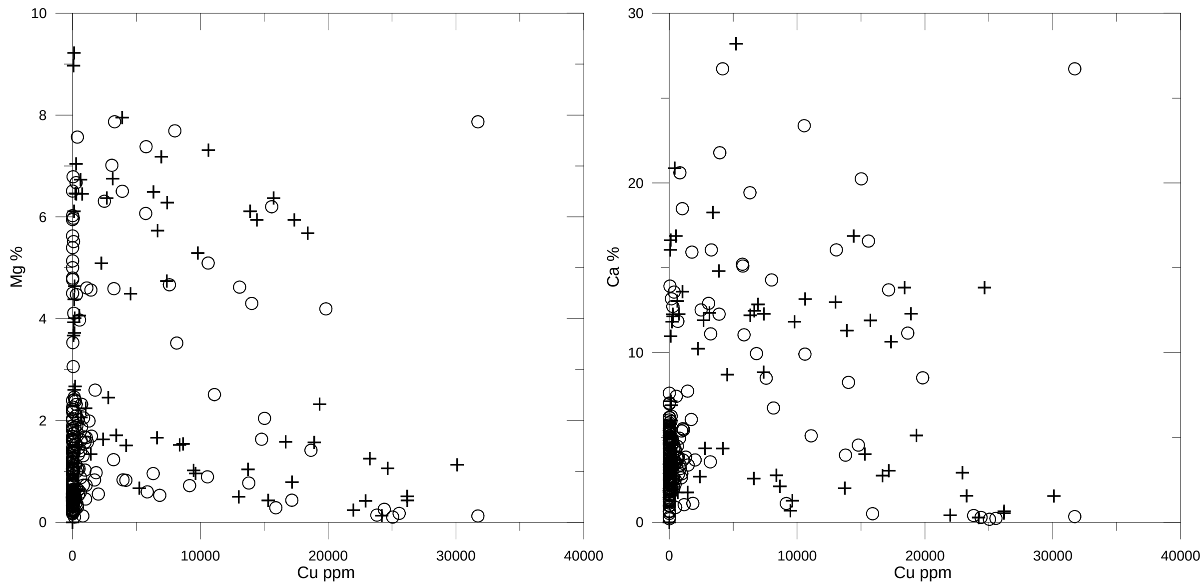


Figure 8: Scatter diagrams of Cu-Mg and Cu-Ca in drill core samples. The legend is as in Figure 3.

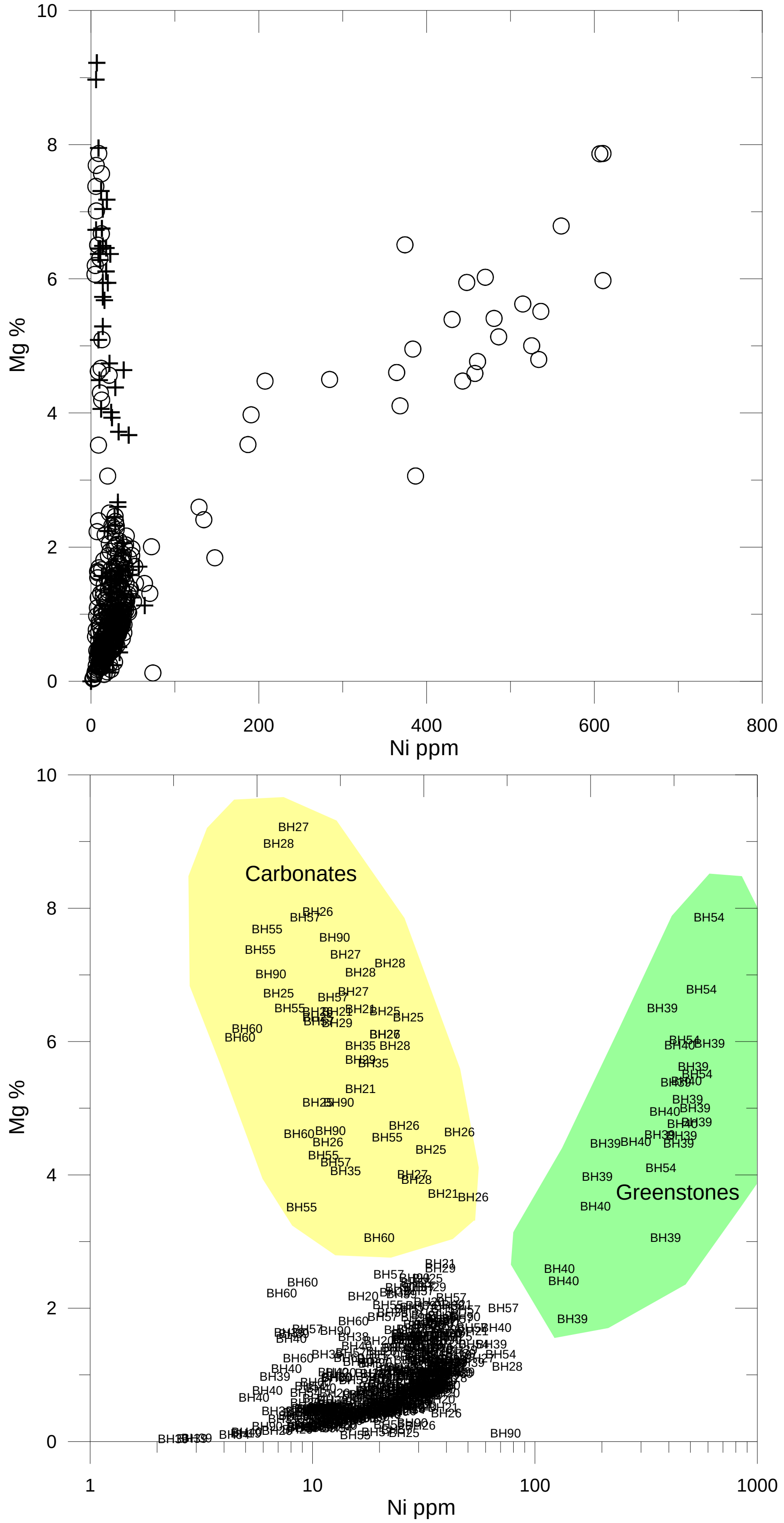


Figure 9: Scatter diagrams of Ni-Mg in drill core samples. The legend is as in Figure 3 and drill hole numbers. Areas for carbonates and greenstones marked, and log scale for Ni at the bottom.

2.4 Cu-Fe-S

Most Central African Copperbelt deposits display a vertical and lateral zoning of the disseminated copper sulphides (i.e. Sweeney et al., 1991, Cailteux et al., 2005). For example, in the Zambian-type, the vertical zoning starts with the Cu-rich chalcocite-digenite-bornite at the bottom, followed by bornite-chalcopyrite and chalcopyrite dominant zones, but variable zonations are also detected.

The major copper sulphides in the Nussir deposit are chalcopyrite ($CuFeS_2$) and bornite (Cu_5FeS_4). In addition occur more copper-rich minerals as digenite (Cu_9S_5), chalcocite (Cu_2S), and malachite ($Cu_2CO_3(OH)_2$). In order to investigate any zoning in the Nussir deposit the relationships between copper, iron and sulphur have been used, as the composition of these elements vary considerably in these minerals (Table 1). Although, the analytical methods used put some constrains on the interpretation, some deductions can be made. These have to be verified by mineralogical studies.

Table 1: Composition of Cu, Fe and S in weight% and relationships between them in some copper sulphides and malachite.

Mineral	Cu weight%	Fe weight%	S weight%	Cu/Fe	Cu/S	Cu/Cu+Fe
Chalcopyrite	34.63	30.43	34.94	1.14	0.99	0.53
Bornite	63.31	11.13	25.56	5.69	2.48	0.50
Digenite	78.10		21.90		3.57	
Chalcocite	79.85		20.15		3.96	
Malachite	57.48					

There is a large spread in the Cu/Fe ratio with a maximum value of 3.02 (Figure 10). The ratio seems to increase proportionally with Cu content up towards 1 %. With increasing Cu values the spread in the data increases. When the Cu/Fe > 1.14, more Cu-rich minerals than chalcopyrite have to be present (Table 1). Additionally, it is unlikely that Fe occurs only in copper sulphides, and the amount of Cu-minerals other than chalcopyrite is higher than the diagram indicates. The highest proportion of Cu-rich minerals seems to be found in Bh 21, 35, 40, 54 and 60; i.e. in the westernmost and along the eastern part of the deposit. Lower ratios occur in drill holes Bh 25, 26, 27, 28, 29, 55, 57 and 90; in the folded part of the deposit. The relationship between Cu and S is shown in Figure 12. The Cu/Cu+Fe ratio is chosen to get an appropriate scale. A good correlation is seen between this ratio and S for most of the samples, except for the samples showing increase in S content without any significant increase in the Cu contents, implying that these samples contain higher proportions of chalcopyrite and/or pyrite. They are all from drill holes in the central, folded part of the ore zone; i.e. drill holes 25, 26, 28, 55, 57 and 90. The Cu-Fe-S relationship is further discussed in plots along the drill holes (Section 3).

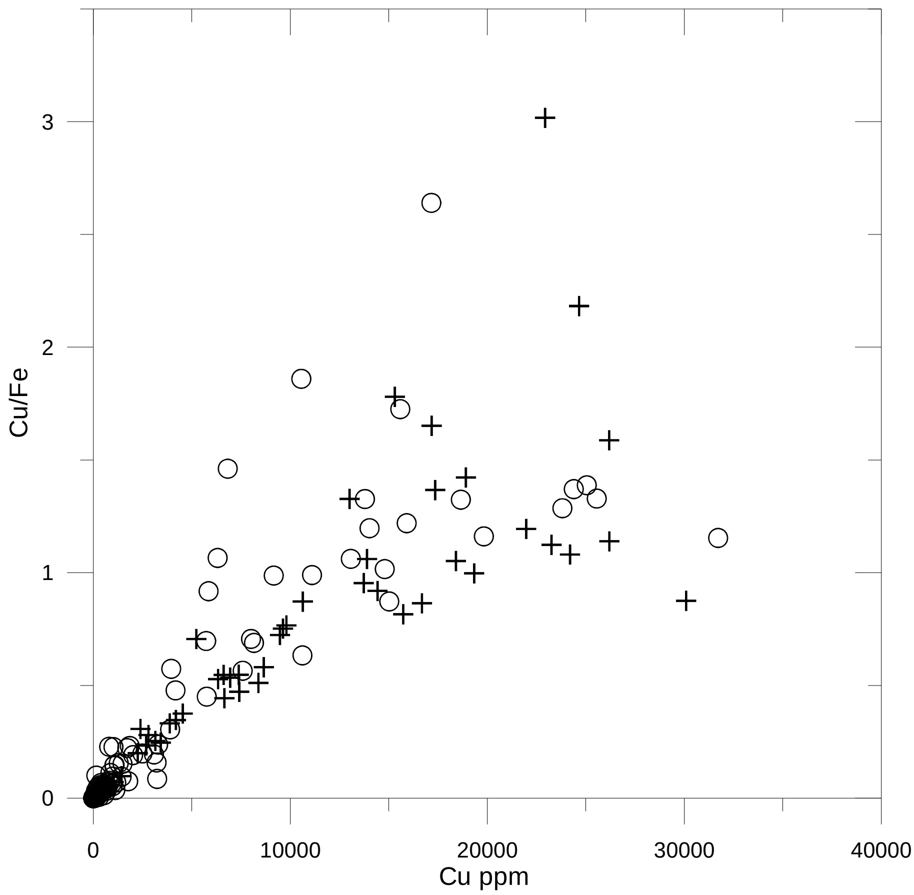


Figure 10: Scatter diagram of Cu-Cu/Fe ratio. The legend is as in Figure 3.

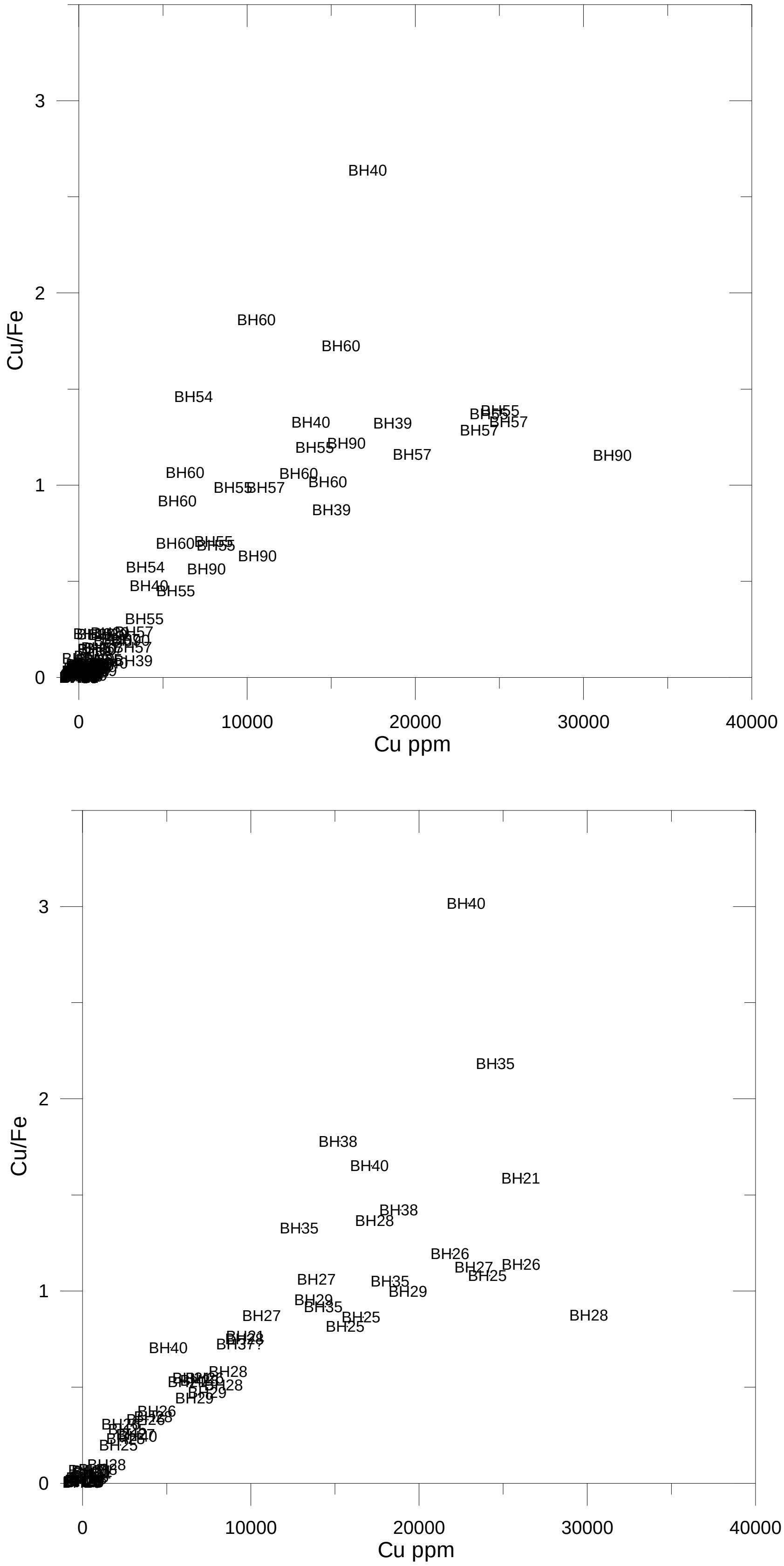


Figure 11: Scatter diagrams of Cu-Cu/Fe ratio as in Figure 10, with drill hole numbers.

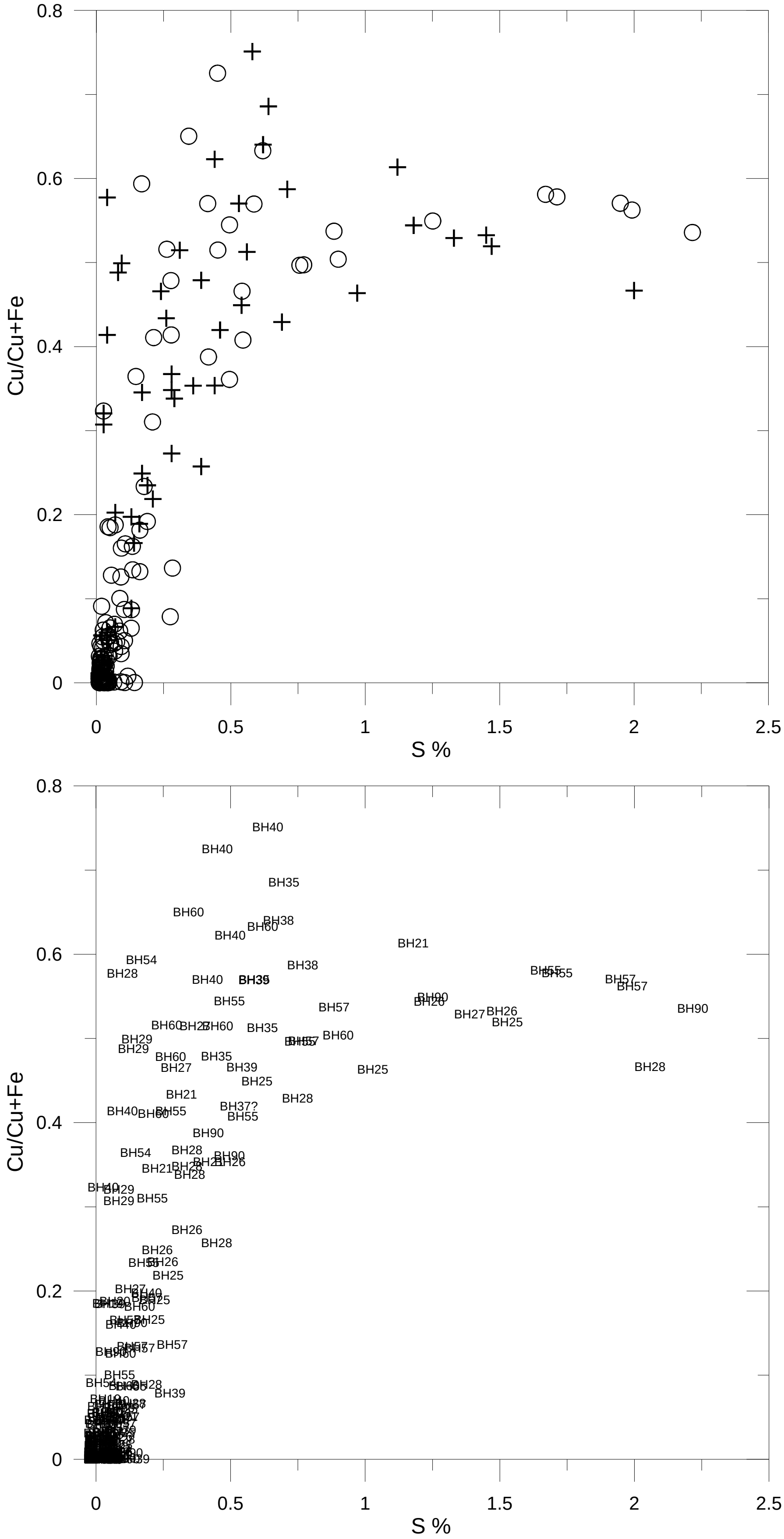


Figure 12: Scatter diagrams of S-Cu/Cu+Fe ratio. The legend is as in Figure 3 and drill hole numbers.

The Cu-S diagram can also be used to illustrate the distribution of the various Cu-sulphides (Figure 1). The Cu/S ratio 3:1 is the set as an average ratio for the Cu-rich minerals, whereas chalcopyrite has the Cu/S ratio 1:1 (Table 1). According to this diagram the most chalcopyrite rich samples occur in drill holes Bh 25, 26, 27, 28, 55, 57 and 90, i.e. in the folded part of the deposit.

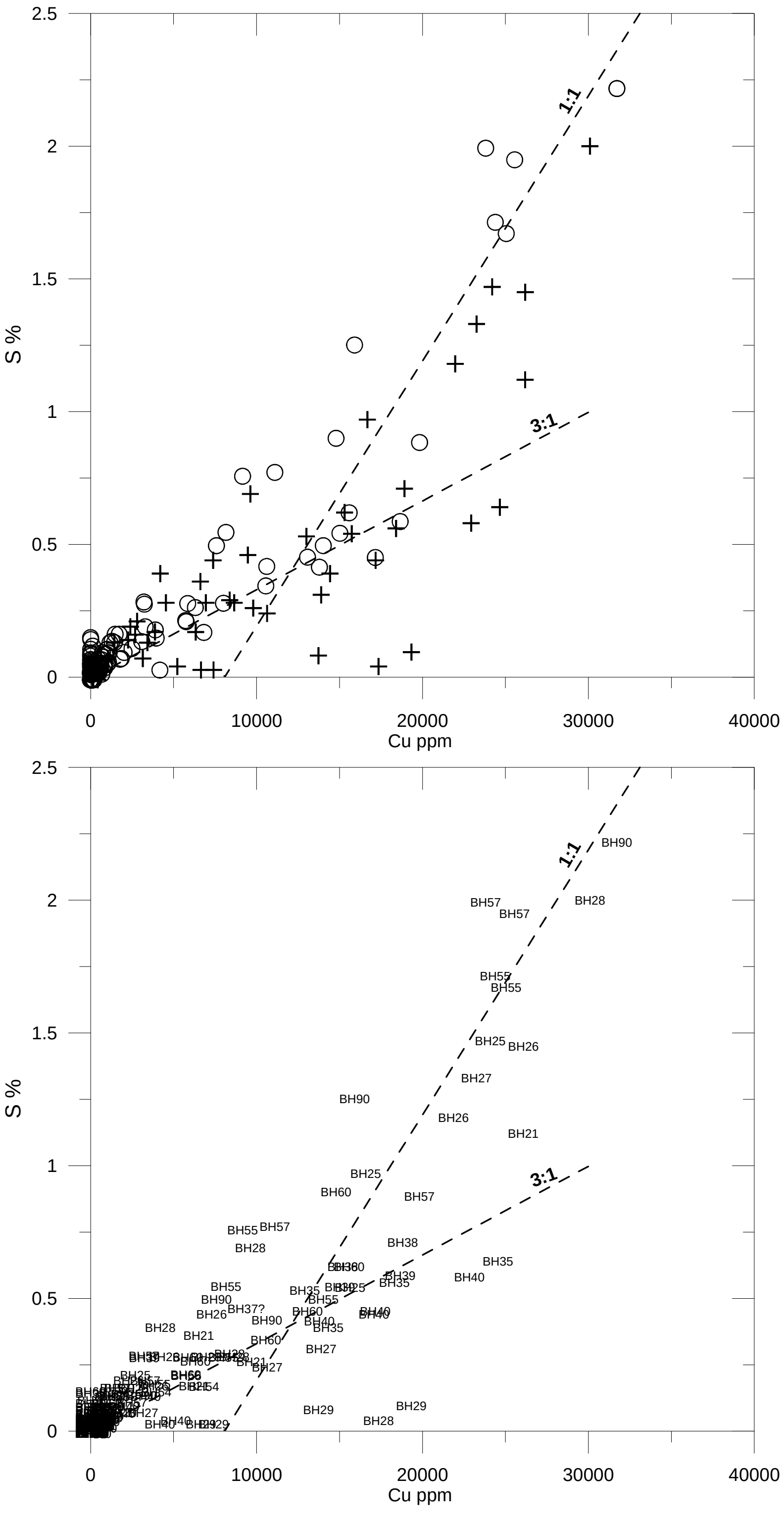


Figure 13: Scatter diagrams of Cu-S in drill core samples. The legend is as in Figure 3 and drill hole numbers. The Cu/S ratios 3:1 and 1:1 are marked (see text).

The Cu/Fe ratio is also used to investigate the relationship between Ag and the copper mineralogy. Two trends are clearly visible in Figure 14. The highest Ag values occur in samples with low to moderate Cu/Fe ratios, i.e. samples that contain higher proportions of chalcopyrite. They are from the central, folded part of the deposit, drill holes Bh 21, 26, 27, 28, 55 and 57 (Figure 14). Lower Ag contents are found in samples with high Cu/Fe ratios, i.e. samples with high proportions of Cu-rich minerals.

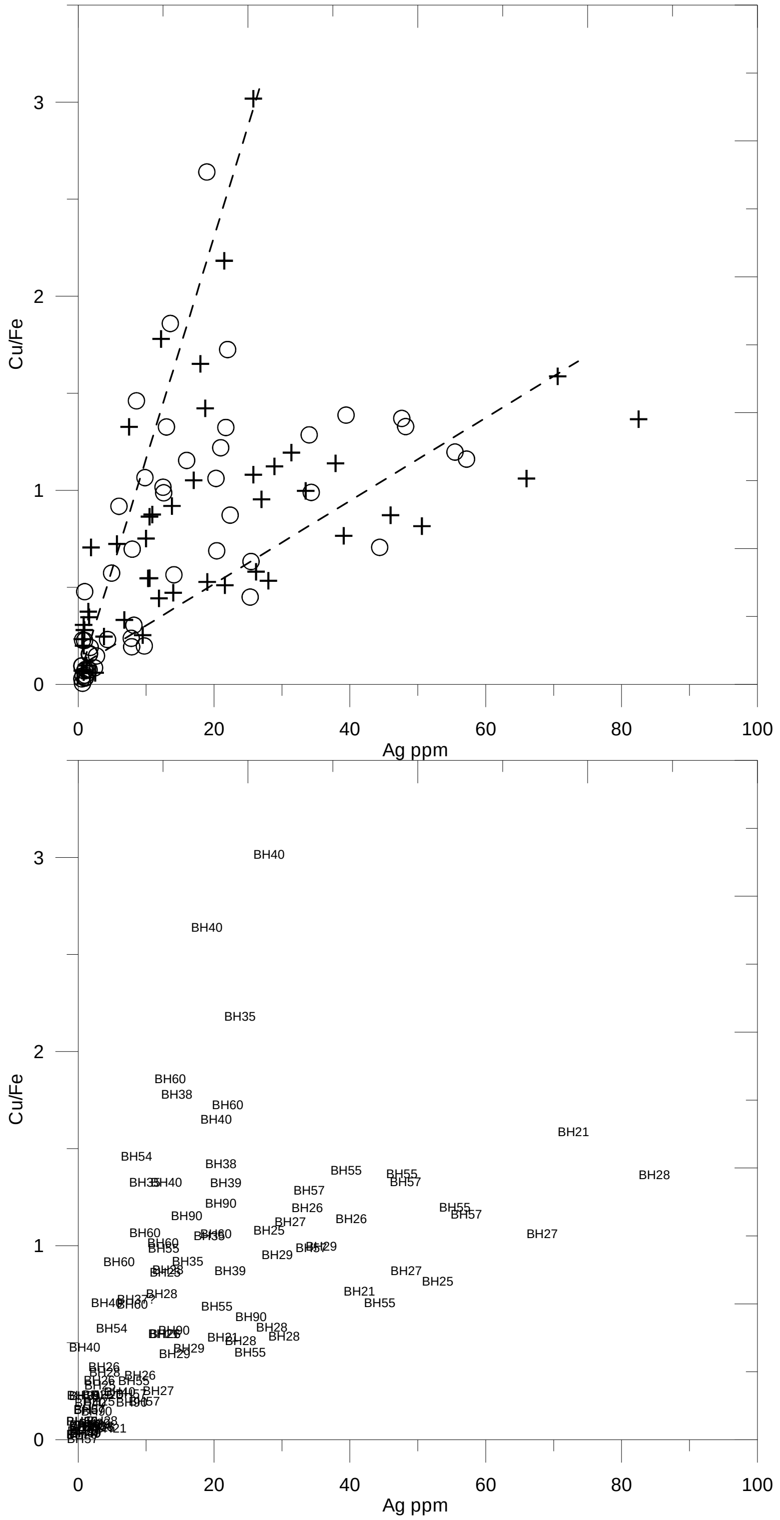


Figure 14: Scatter diagrams of Ag-Cu/Fe ratio. The legend is as in Figure 3 and drill hole numbers.

2.5 Au-Ag/S/As

The relationships between Au and other metals than copper have been studied. There is no correlation between Au and Ag in samples analysed in 2002 (+) and 2008 (O) (Figure 15). All the precious metals, i.e. Au, Pt and Pd were analysed only in 2008. No correlation is encountered between Au and S and Au and As in these samples (Figure 16), and there is not found any relationship between Au and copper mineralogy. The few analyses with elevated values of Pt and Pd do not show any correlations with other elements.

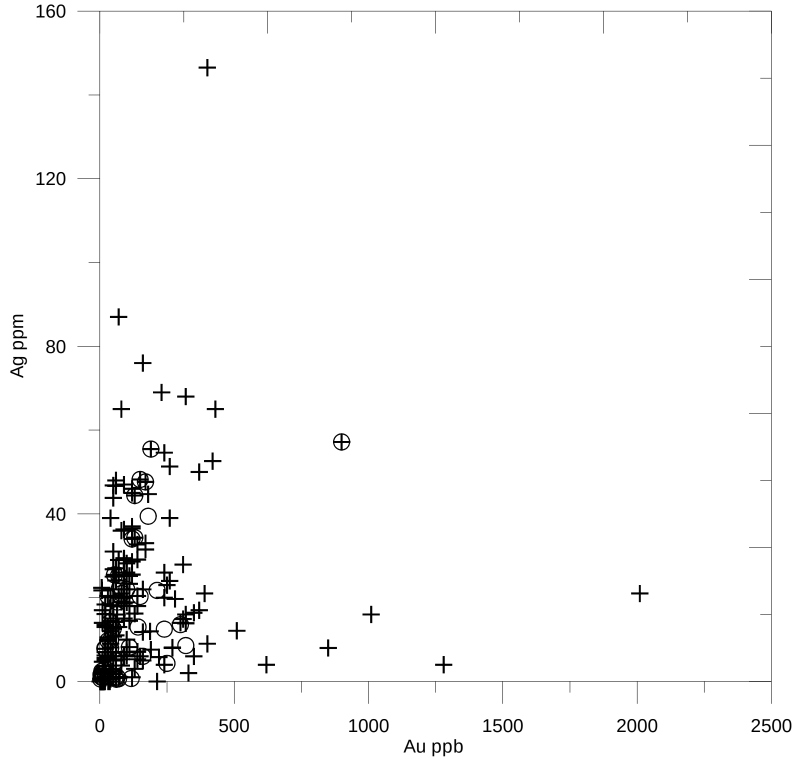


Figure 15: Scatter diagram of Au-Ag in drill core samples. Samples analysed in 2008 are marked with O *and pre-2000 with* +.

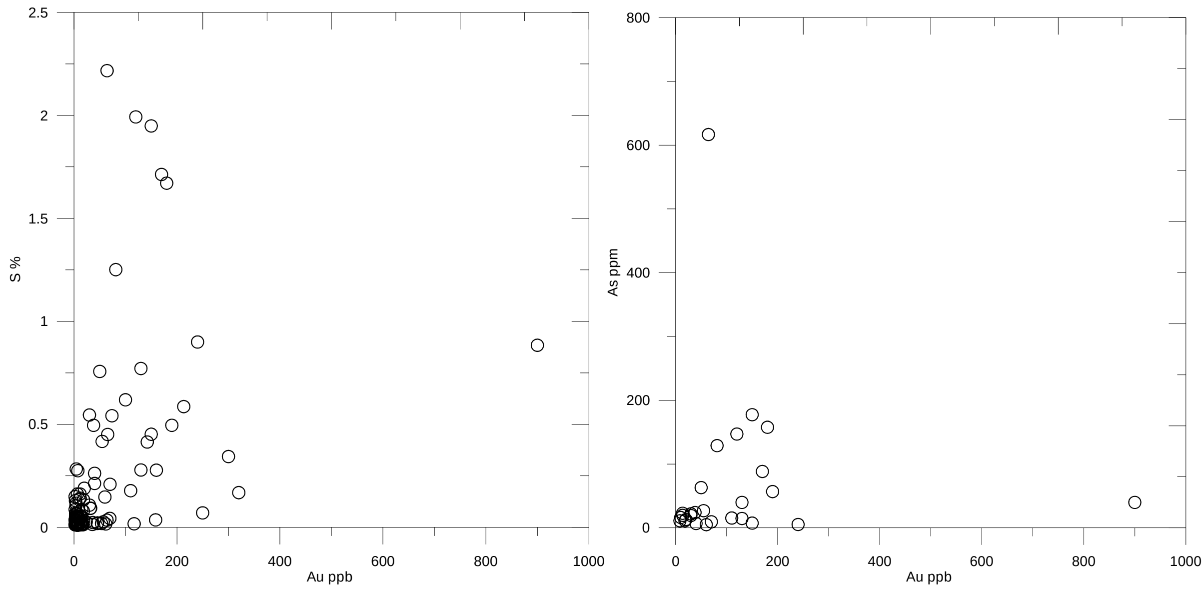


Figure 16: Scatter diagrams of Au-S and Au-As in drill core samples analysed in 2008.

3. CHEMISTRY ALONG DRILL HOLES

In this section the variation in chemical composition of the core samples in the individual drill holes from west to east is shown. The profiles mentioned in the text refer to the drill sections used in the 'Nussir Prospectus' made by Terra Control in November 2003. In these plots, the 'ore dolomite' is marked for zones with ≥ 4% Mg, if there are no other chemical characteristics that indicate otherwise.

Bh 60 is the westernmost drill hole (Appendix 1, Figure 17). It is 120 m long, and the whole core, 68 samples in total, has been analysed for 49 elements including Au, Pt and Pd. Most of the samples represent two meters of core. Two zones of Cu-mineralisation are registered, and both are enriched in precious metals; Au, Ag and Pt. The chemical compositions of the two zones differ in other ways. The upper zone is partly associated with elevated values of both magnesium (Mg) and calcium (Ca), while in the lower zone, only high contents of Ca are found. These zones are enriched in manganese (Mn) and depleted in nickel (Ni) suggesting that both represent carbonate-rich zones. The upper zone probably represents dolomite (the 'ore dolomite') with some excess calcite (Figure 18). It is hard to decide whether the lower zone is a calcite marble or strongly carbonate-altered rock that contains abundant thin calcite veinlets as observed in drill cores. The latter interpretation is preferred. It also has to be noted that the Cu-mineralisations extend, in the footwall, beneath both of the carbonate-rich zones. Additionally, in Bh 60 two thin zones that are slightly enriched in Mg and Ca, indicating a dolomitic rock, and with low Cu values, are found towards the bottom of the hole (at depth 92-96 and 116-118m). It should be noted that Pt analyses are missing from the upper Cu-zone.

The data do not support any theory of folding of the dolomite or the Cu-mineralisation, if the latter is supposed to be of stratabound origin. The closest ore sections further east, from drill holes Bh 12, and Bh 19/20 have not been analyzed sufficiently to shed further light on this question (Figure 19), although two Cu-zones are registered in Bh 19. Note the high Au values in the upper zone (max. 2010 ppm Au).

It is of interest to note in Bh 20 that high Cu contents are also encountered when the Mg and Ca contents are low (Figure 20). In this drill hole there are significantly higher contents of Pt (max. 570 ppb Pt), and to a minor extent also Au, in a lower zone showing no significant enrichment of Cu. This zone might represent the extension of the lower mineralised zone encountered in Bh 60 (Figure 17). However, the data is too limited to draw any firm conclusion. The highly variable content of Ca in the lower part of Bh 20 is most likely attributed to calcite-veining and hydrothermal alteration. Highly variable amounts of calcite veinlets have been observed during the reconnaissance examination of the drill cores at Løkken in January 2008. Additional analyses should be extended upwards in Bh 20 to investigate the content of e.g. Pt.

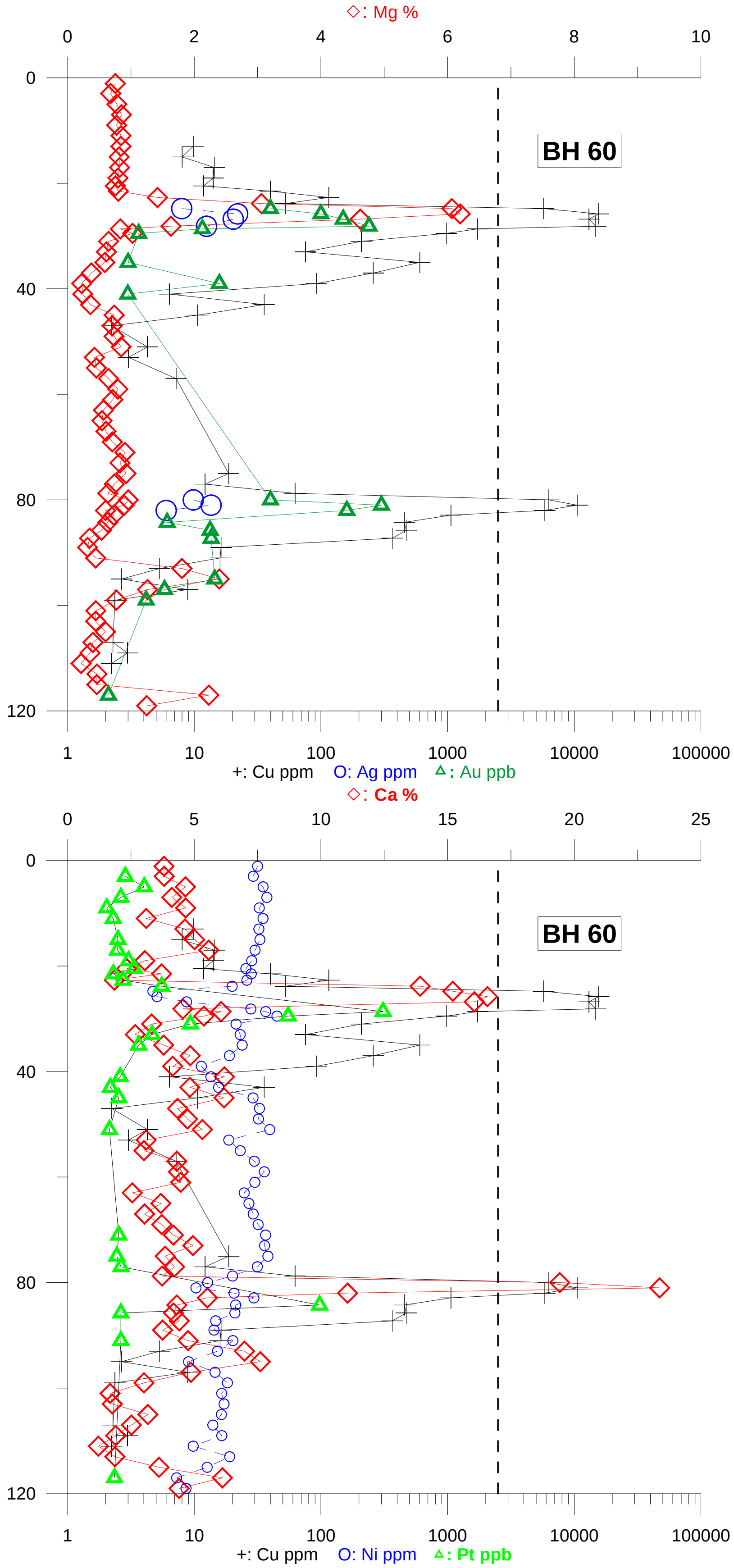


Figure 17: Concentrations of Cu, Mg, Ag and Au, and Cu, Ca, Ni and Pt (horizontal scale) plotted against depth (vertical scale) in drill hole Bh 60. Stippled line for 2500 ppm (0.25 %) Cu.

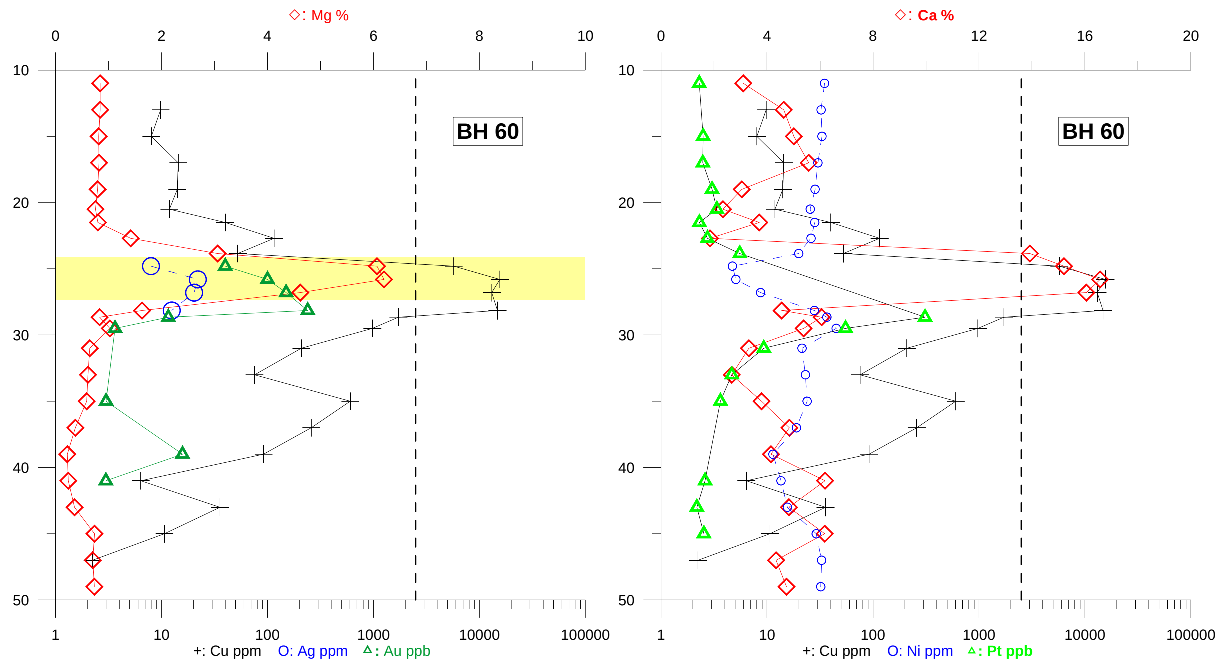


Figure 18: Concentrations of Cu, Mg, Ag and Au, and Cu, Ca, Ni and Pt (horizontal scale) plotted against depth (vertical scale), upper part in drill hole Bh 60. Stippled line for 2500 ppm (0.25 %) Cu and the 'ore dolomite' is marked with a yellow box.

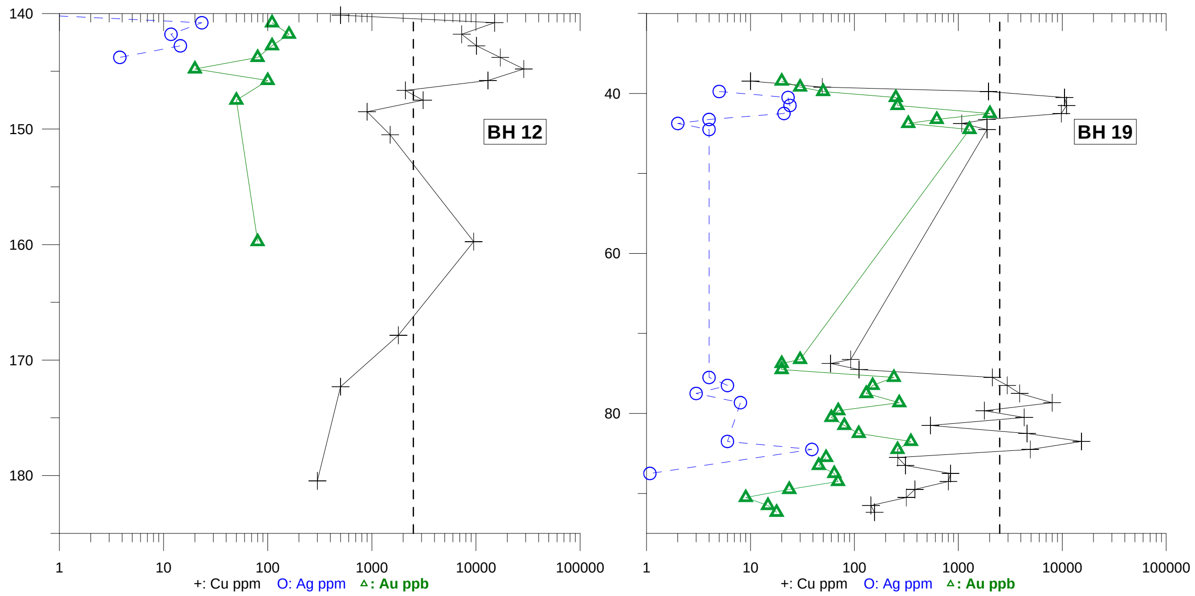


Figure 19: Concentrations of Cu, Ag and Au (horizontal scale) plotted against depth (vertical scale) in drill holes Bh 12 and 19. Stippled line for 2500 ppm (0.25 %) Cu.

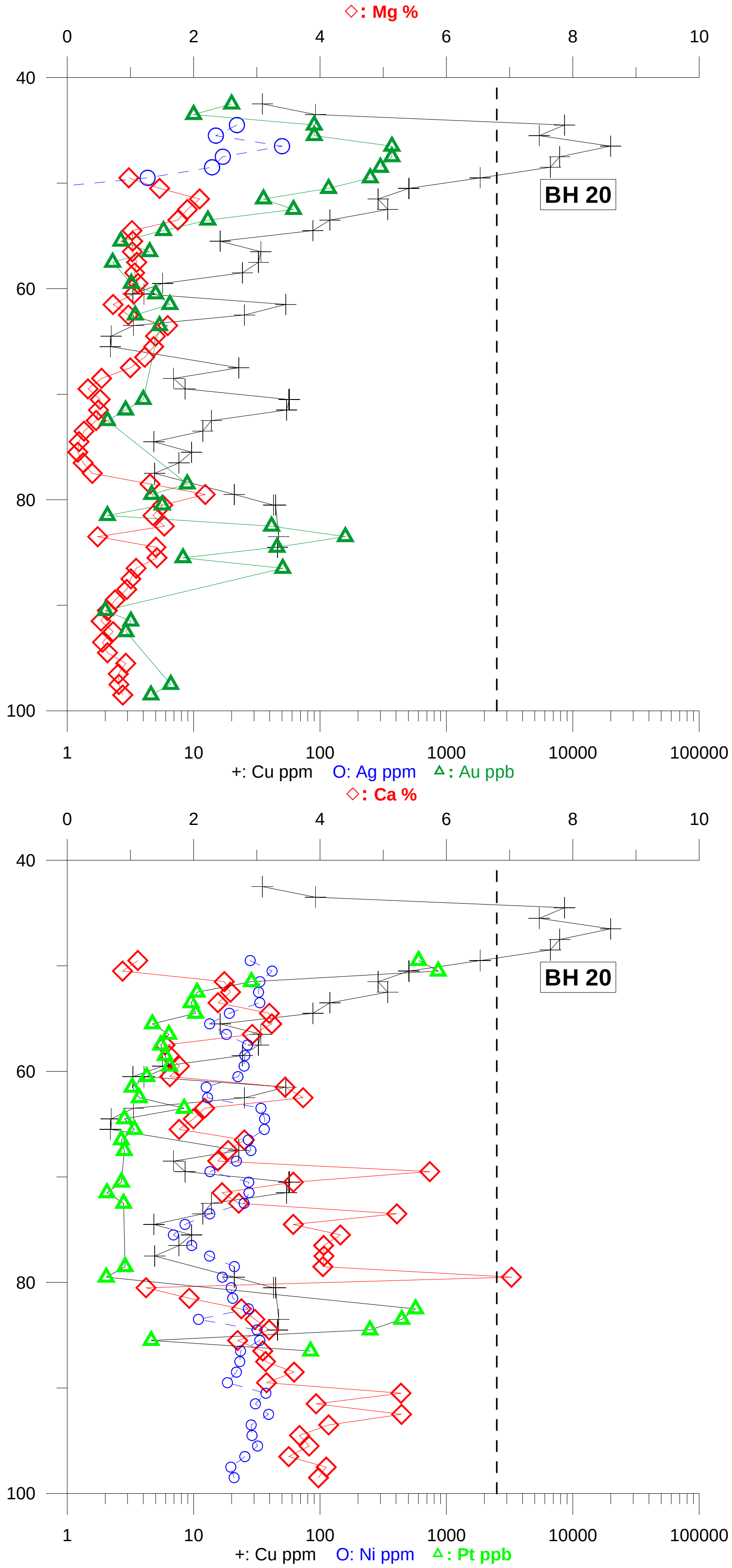


Figure 20: Concentrations of Cu, Mg, Ag and Au, and Cu, Ca, Ni and Pt (horizontal scale) plotted against depth (vertical scale) in drill hole Bh 20. Stippled line for 2500 ppm (0.25 %) Cu.

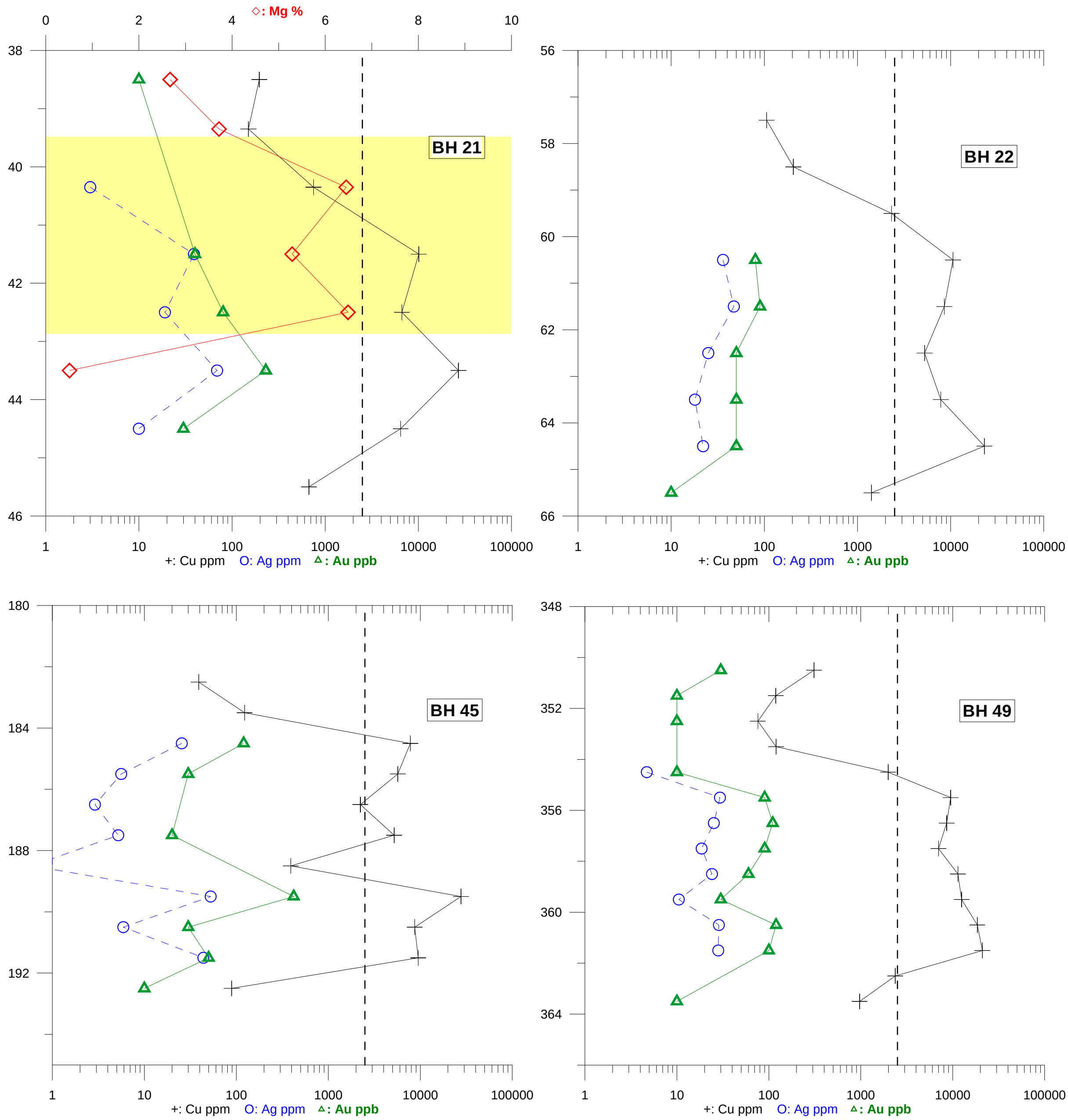


Figure 21: Concentrations of Cu, Mg, Ag and Au (horizontal scale) plotted against depth (vertical scale) in drill holes Bh 21, 22, 45 and 49. Stippled line for 2500 ppm (0.25 %) Cu and the 'ore dolomite' is marked with a yellow box in Bh 21.

Plots of the chemical composition around the Cu-mineralised zones in drill section 11 (Bh 21/22) and drill section 11 (-70m) (Bh 45/49) are shown in Figure 21. They demonstrate that the width of the ore zone could be up to 8-9 m (not considering the true width) if the cut-off is set to 0.25 % Cu. Only part of Bh 21 has been analysed for all the elements (except Pt and Pd). The copper mineralisation clearly also extends beneath the dolomite in this hole and shows the highest grades in the footwall of the dolomite.

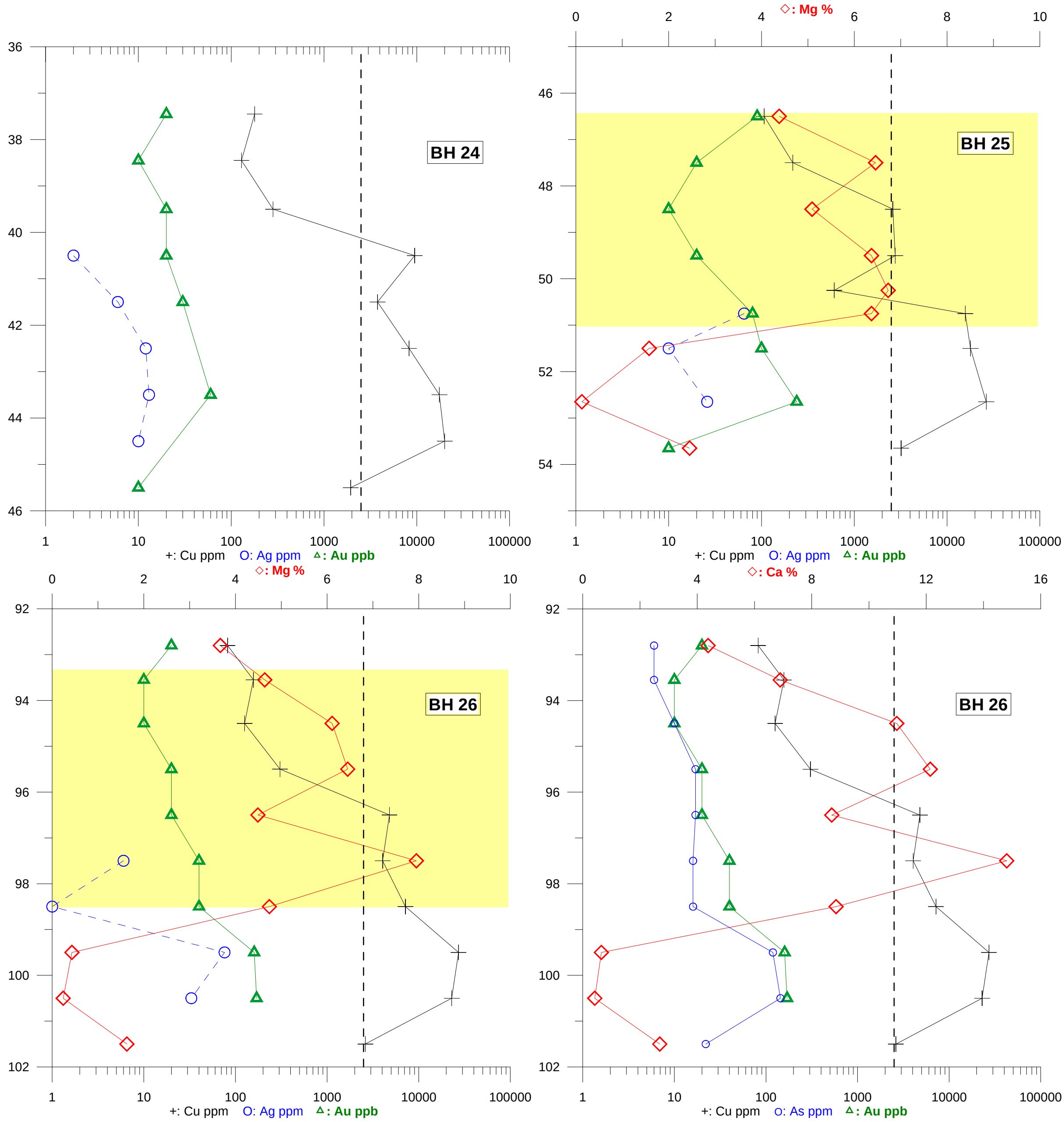


Figure 22: Concentrations of Cu, Ag and Au (horizontal scale) in drill hole Bh 21 and Cu, Mg, Ag and Au in drill holes 25 and 26, and Cu, Ca, As and Au (horizontal scale) in drill hole 26 plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu and the 'ore dolomite' is marked with a yellow box in Bh 25 and 26.

The drill holes, Bh 24, 25 and 26 in (Figure 22) all transect the copper-mineralisation along a east- west profile, along drill section 10. The copper mineralisation in this section is also found to extend in the footwall of the 'ore dolomite'. The lower part of the ore zone is depleted in Mg, Ca and Mn. No other significant variation is found in the other elements analysed, except a slight increase in the content of arsenic (As) in the lower part of the Cu-mineralisation. It is thus likely that this zone comprises a quartz-rich rock that can be tested by logging. Silicified and cherty-looking rock were observed in Bh 20 during the reconnaissance examination of the drill cores at Løkken in January 2008, and mineralogical investigations have to be carried out to verify the exact nature. The content of Mg and Ca correlate very well and indicate a ≥ 4 m wide dolomite. No analyses have been received from Bh 58, which has also been drilled along the same section.

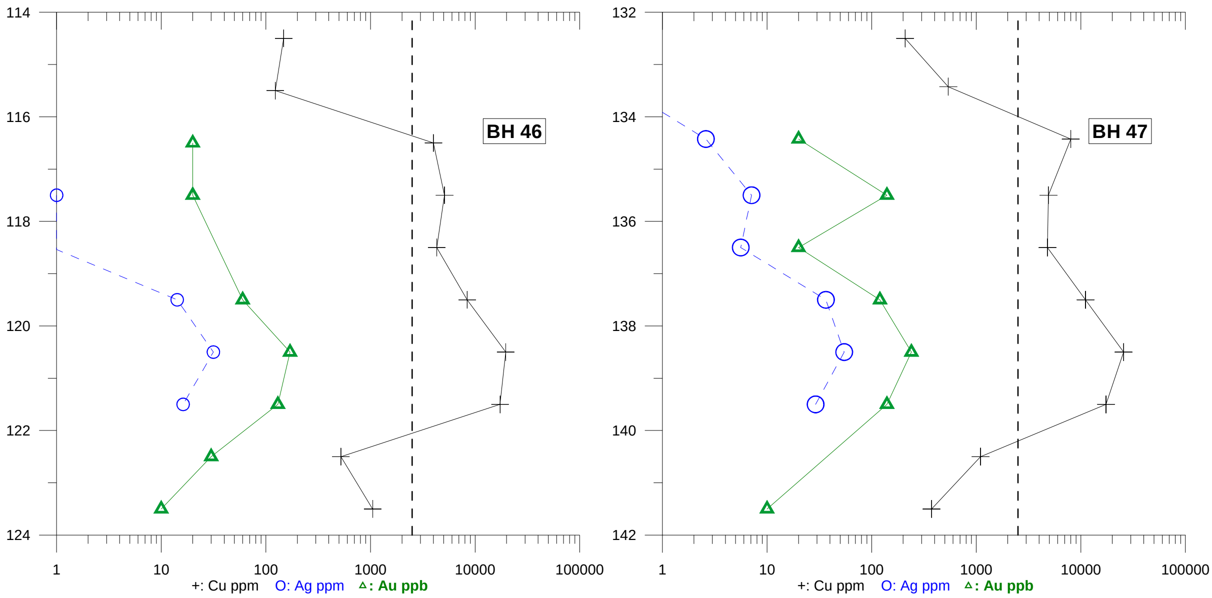


Figure 23: Concentrations of Cu, Ag and Au (horizontal scale) plotted against depth (vertical scale), drill holes Bh 46 and 47. Stippled line for 2500 ppm (0.25 %) Cu.

The drill holes, Bh 46 and 47 in Figure 23 are located in drill section 9 (+350m), along a NW-SE orientated profile. They transect the ore zone approximately 100m apart along the dip, and show that the width of the ore mineralisation is relatively constant.

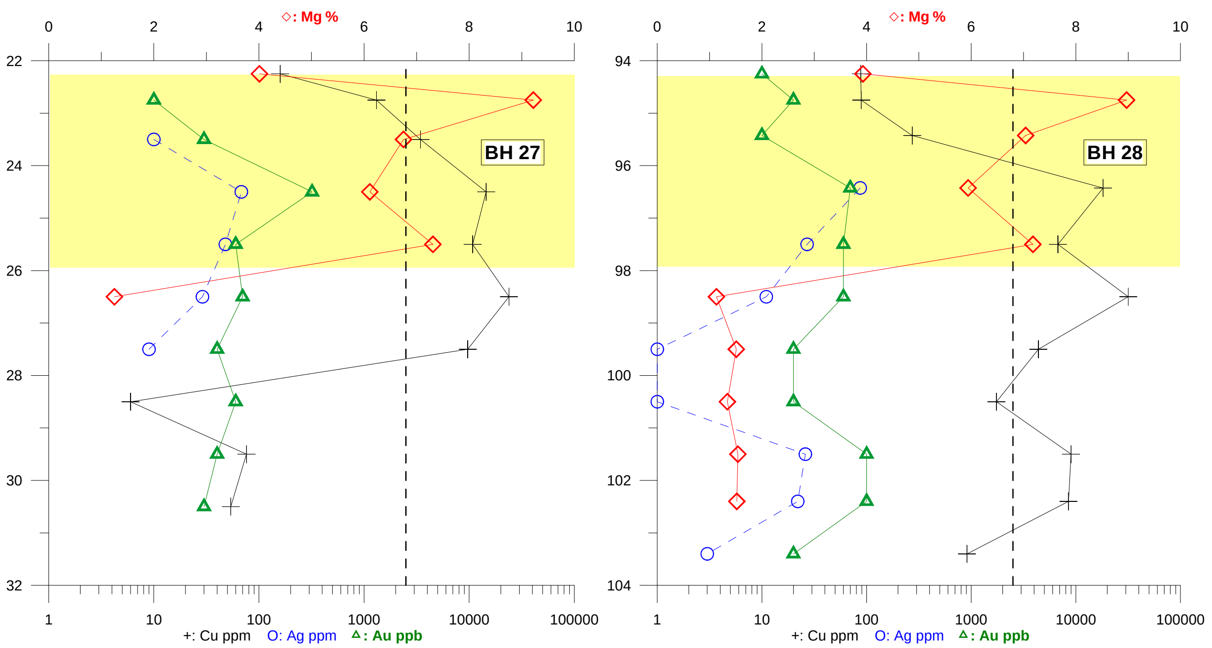
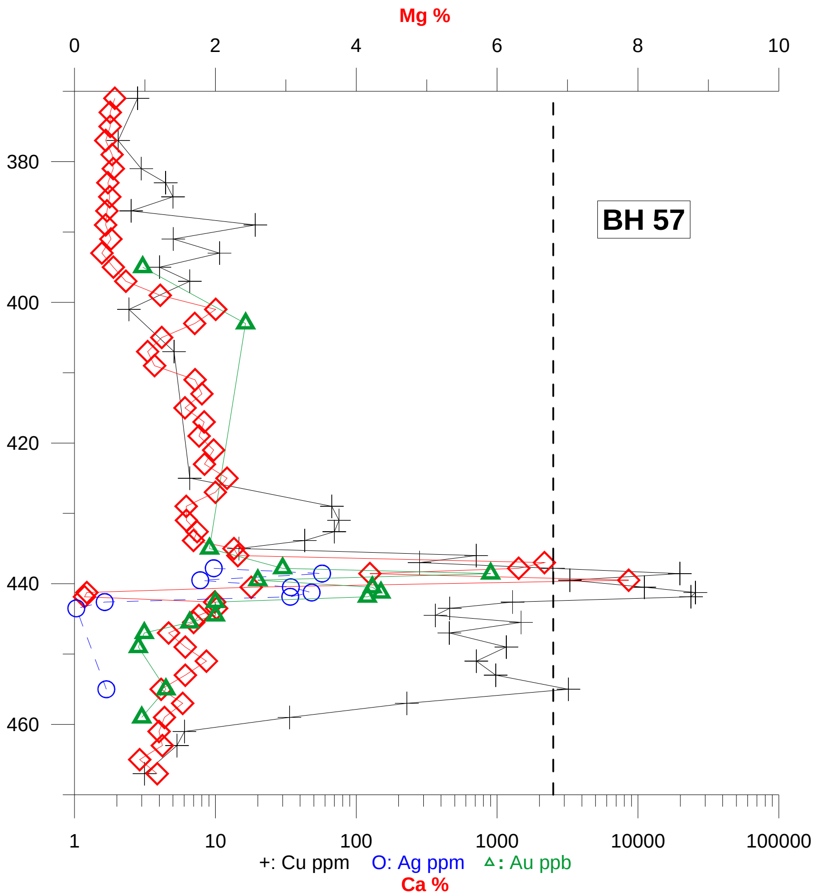


Figure 24: Concentrations of Cu, Mg, Ag and Au (horizontal scale) in drill hole Bh 27 and 28 plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu and the 'ore dolomite' is marked with a yellow box.



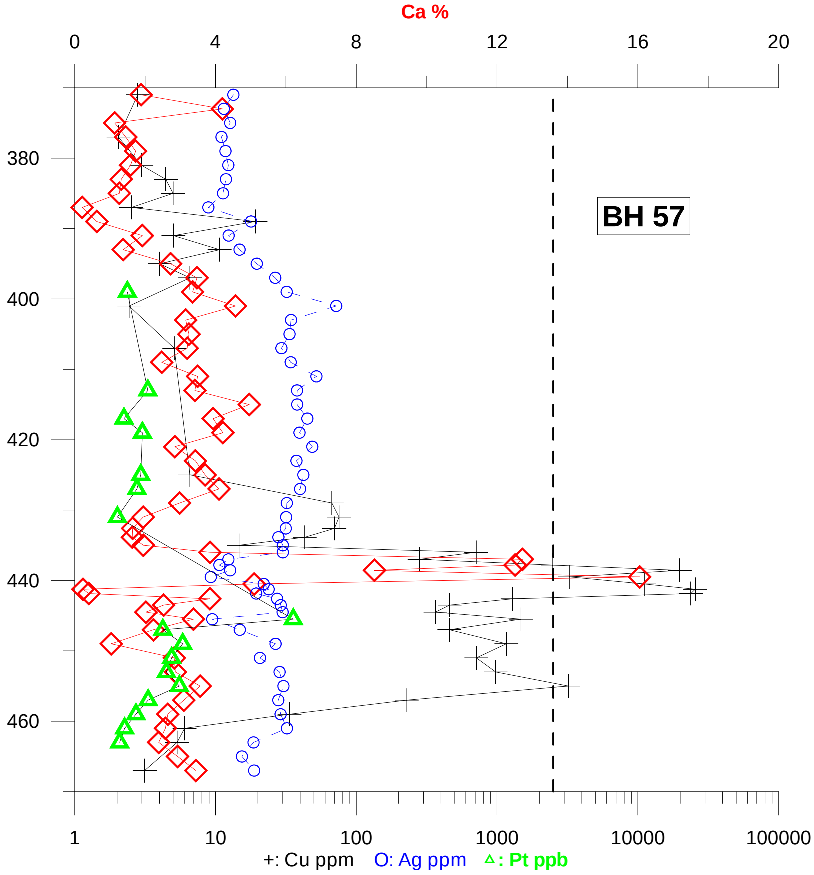


Figure 25: Concentrations of Cu, Mg, Ag and Au and Cu, Ca, Ag and Pt (horizontal scale) in drill hole Bh 57 plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu.

Cu-mineralisations are found both within and in the footwall of the dolomite also in Bh 27, 28 (Figure 24) and Bh 57 (Figure 25), which are located along drill section 9 (Appendix 1). Actually, the highest Cu values occur where both the Mg and Ca contents are lower, as clearly seen in Bh 57 (Figure 25). A distinct enrichment of cobalt (Co) and As (max 177 ppm As) is seen where the lowermost contents of Mg and Ca are found (441-442.2m), whereas Ni, Ti and V are depleted. The highest Au values correlate well with the highest Cu values. A rather thick Cu-enriched zone, ~25m with > 200 ppm Cu, occurs in Bh 57, whereas the 'ore dolomite' is rather thin, 3-4 m (Figure 26).

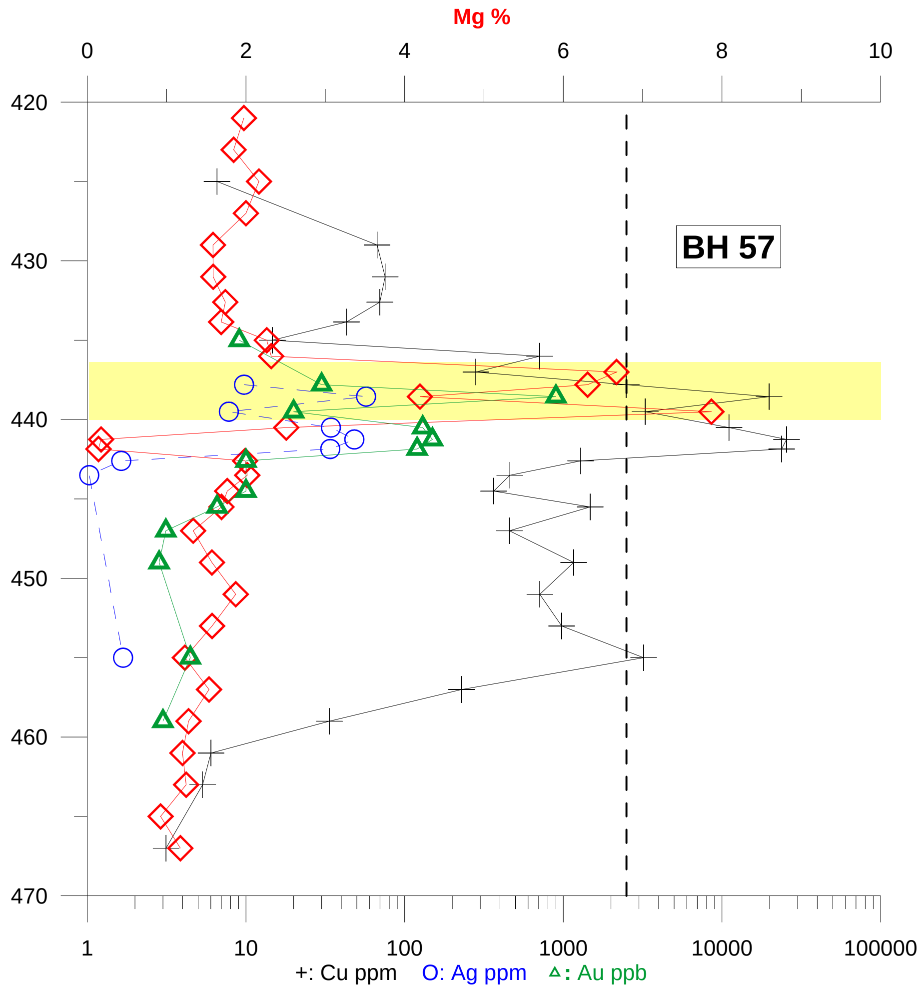


Figure 26: Concentrations of Cu, Mg, Ag and Au and Cu, Ca, Ag and Pt (horizontal scale) in the lower part of drill hole Bh 57 plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu and the 'ore dolomite' is marked with a yellow box.

Bh 55 is drilled from the same collar as Bh 57, but in a more southeasternly direction. Figure 27 shows the analysed section, with Cu-mineralisation both within and beneath the dolomite. The zone with Cu > 0.25 % has a of nearly 8 m, and the length of this zone could be similar in Bh 50, along drill section 8 (+80m). Bh 29 and 30 were drilled from the same collar along drill section 8, and the analyses (Figure 28) show chemical variations similar to Bh 55 and 57. A clear depletion of Ti is found when Mg is most enriched as in e.g. Bh 57 (not shown) indicating the presence of carbonate rocks.

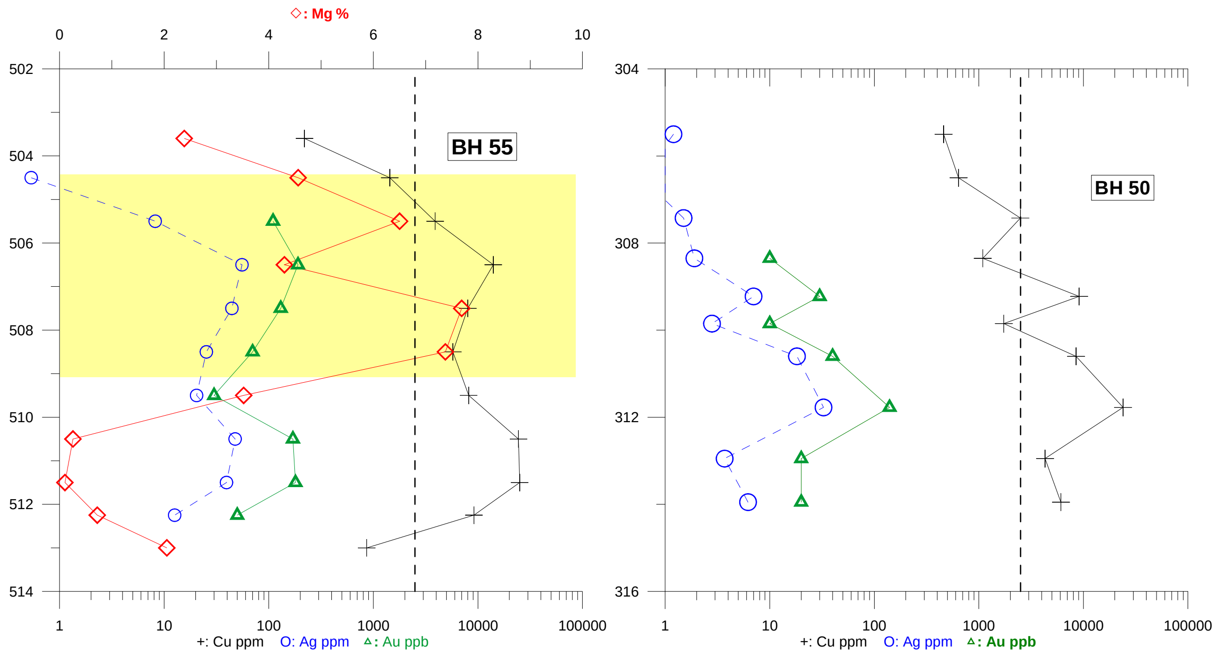


Figure 27: Concentrations of Cu, Mg, Ag and Au in Bh 55 and Cu, Ag and Au in Bh 50 (horizontal scale) plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu and the 'ore dolomite' in Bh 55 is marked with a yellow box.

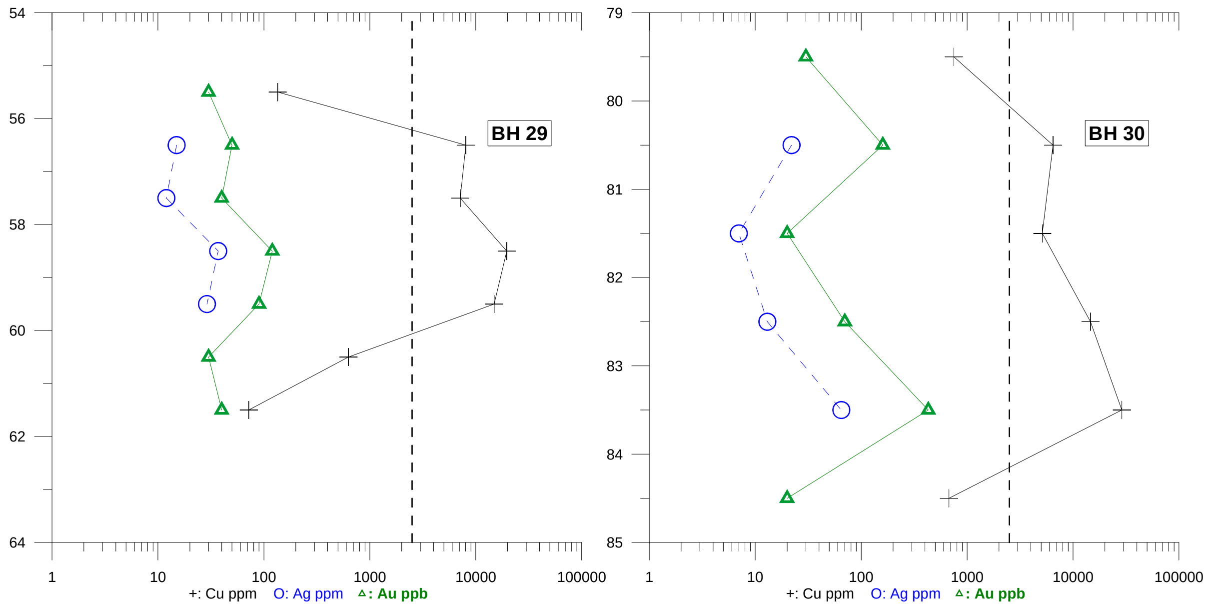


Figure 28: Concentrations of Cu, Ag and Au (horizontal scale) in drill holes Bh 29 and 30 plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu.

A wide Cu-enriched zone (nearly 15m) is found both above and beneath a relatively thin dolomite layer in Bh 90 (Figure 29, Figure 30). The highest Cu contents occur along the footwall of the dolomite, where also the highest As-value in the data-sets (max. 617 ppm As) is found, in a probably silica-rich rock with very low Mg and Ca. Co is also enriched in this rock. Au correlates well with the high Cu-values, whereas Pt is enriched in the lower part of the Cu-mineralised zone. The highly variable content of Ca is most likely attributable to variable contents of calcite veinlets.

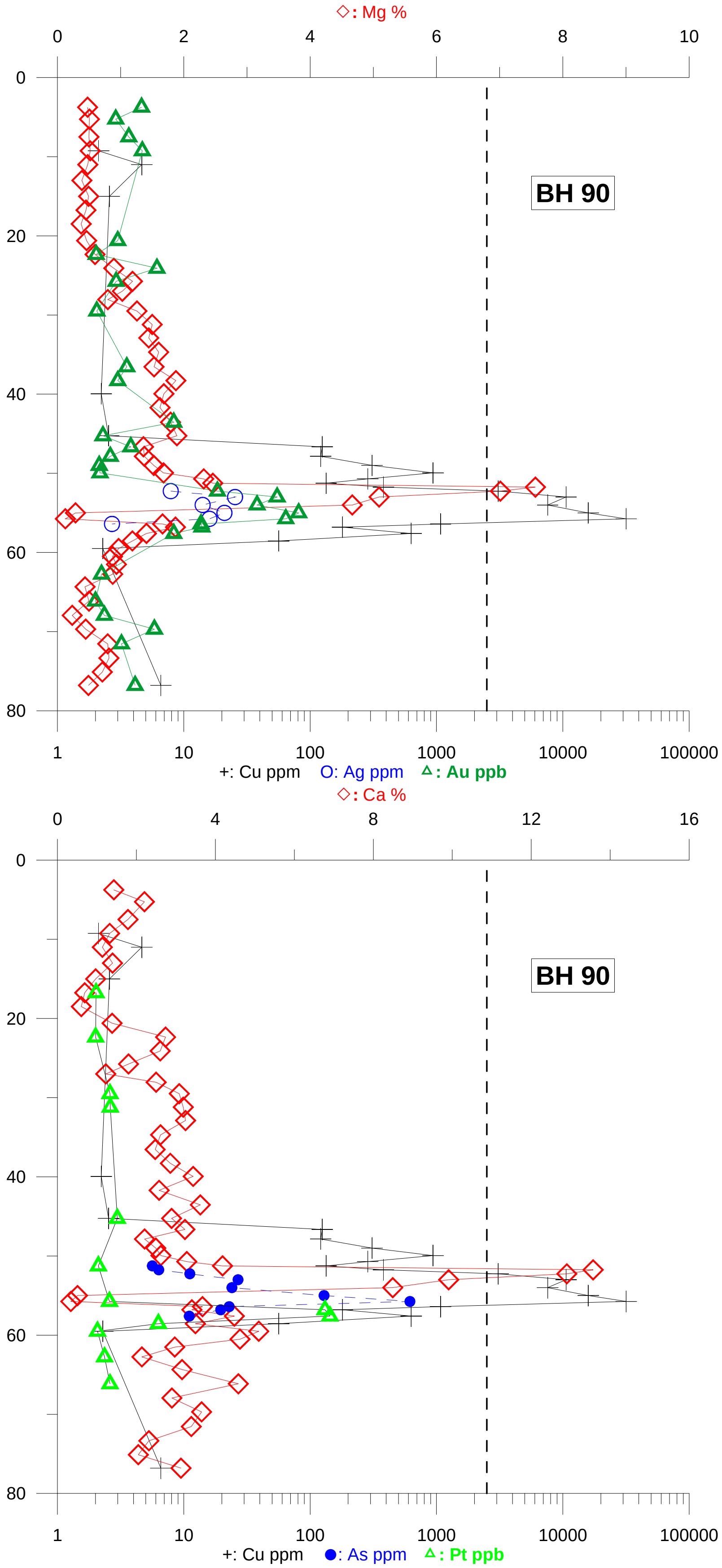


Figure 29: Concentrations of Cu, Mg, Ag and Au and Cu, Ca, As and Pt (horizontal scale) in drill hole Bh 90 plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %)Cu.

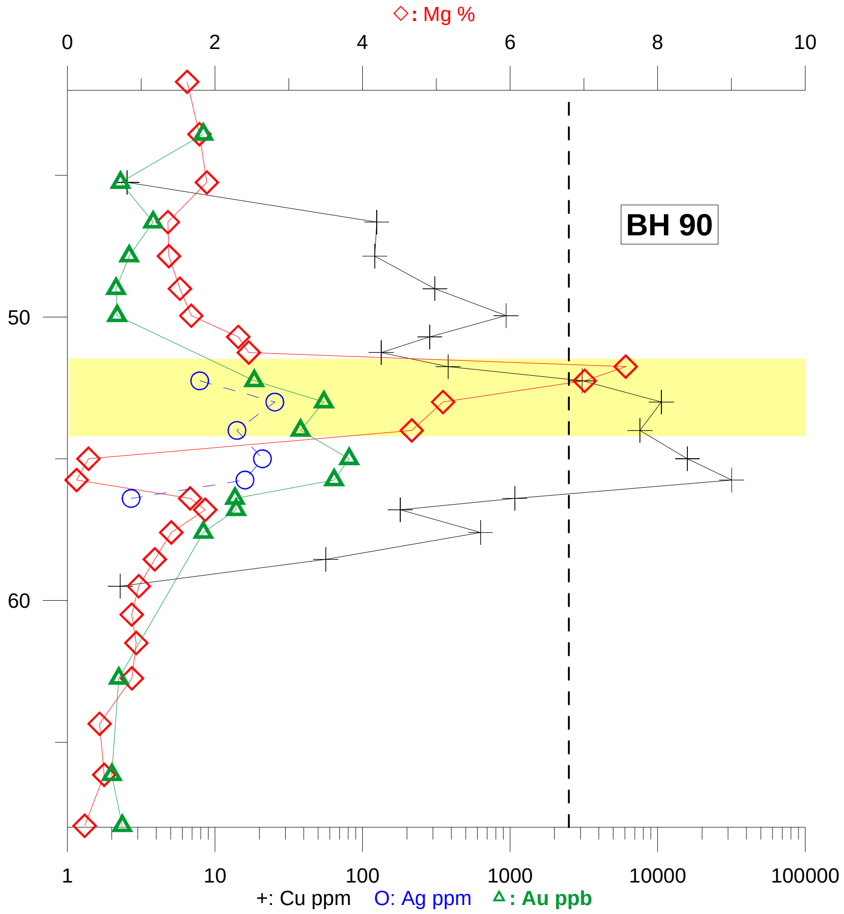


Figure 30: Concentrations of Cu, Mg, Ag and Au (horizontal scale) in drill hole Bh 90 plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu and the 'ore dolomite' is marked with a yellow box.

Analyses of the drill cores in drill section 7 show relatively weak mineralisations in the upper parts of Bh 31 and 32, whereas the intersection at depth in drill hole Bh 51 yields > 1 % Cu over a length of around 4 m (Figure 31). Cu correlates very well with Au and Ag in this section. Weak mineralisations are also encountered in drill section 6; Bh 33. Zones with highly deformed rocks have been reported in cores from these sections.

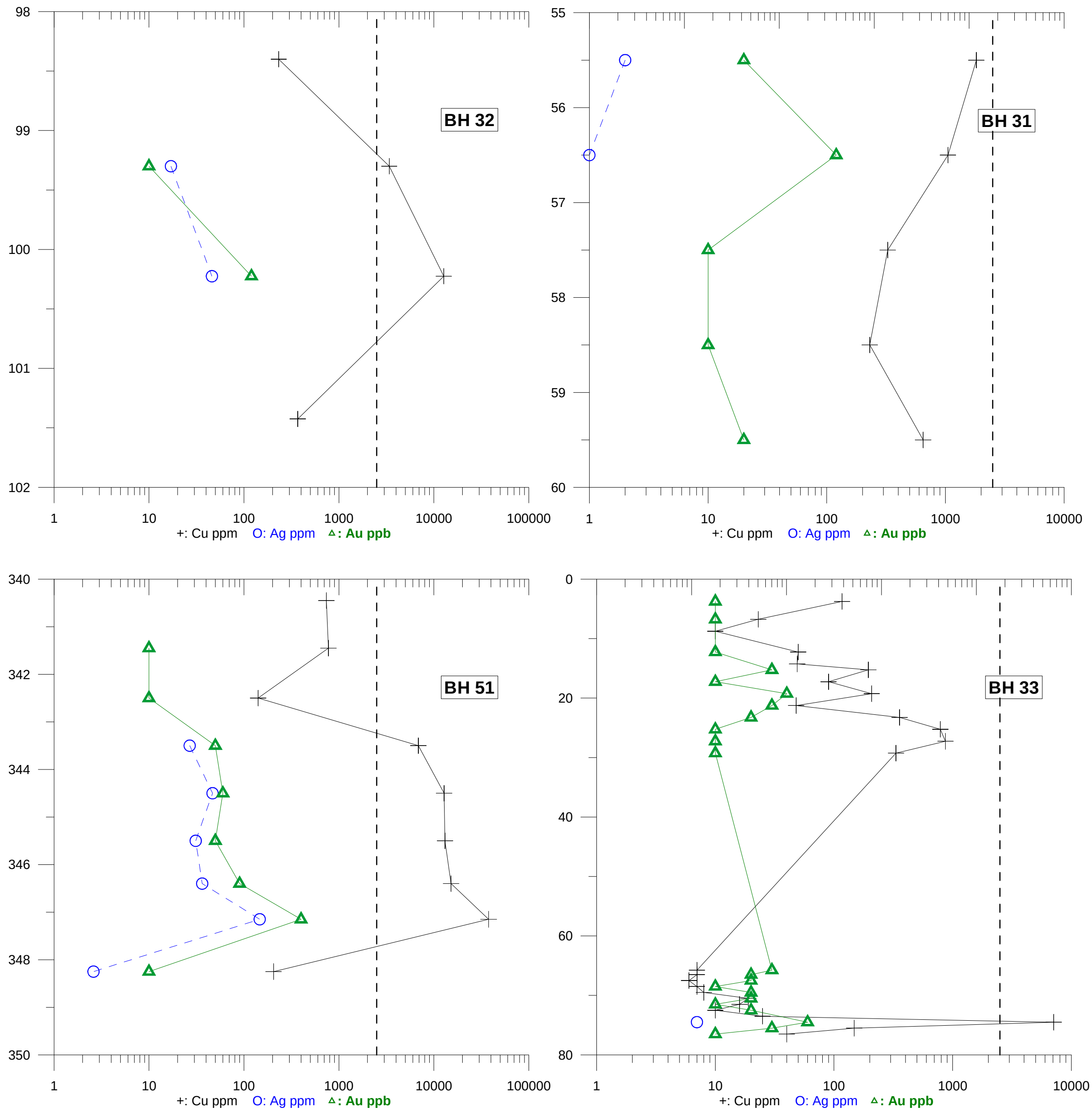


Figure 31: Concentrations of Cu, Ag and Au (horizontal scale) in drill holes Bh 31, 32, 51 and 33 plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu.

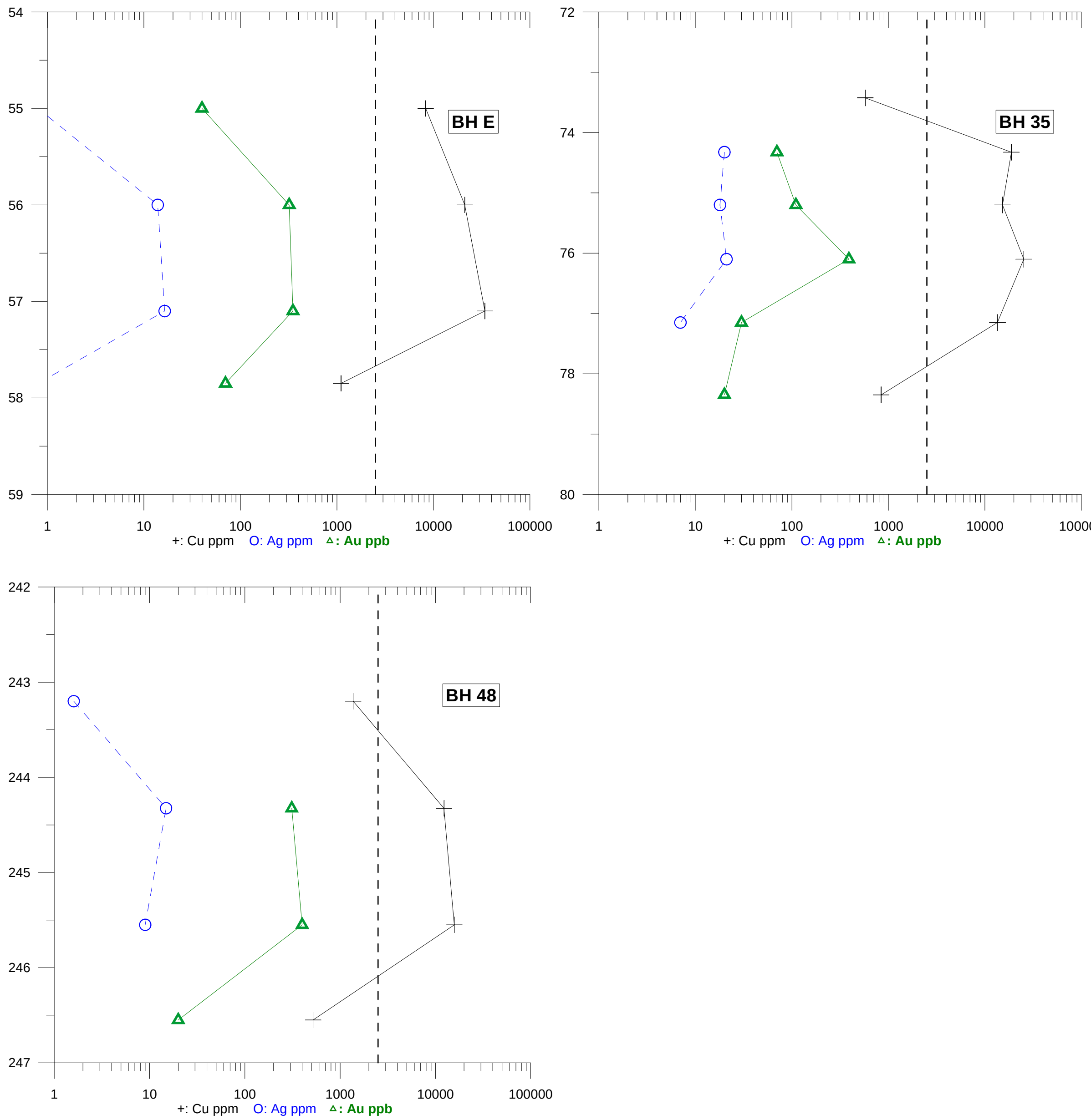


Figure 32: Concentrations of Cu, Ag and Au (horizontal scale) in drill holes Bh E, 35 and 48 along drill section 5 plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu.

The drill holes, Bh E, 35 and 48 in Figure 32 transect the mineralisations at different depths along a north-south profile, drill section 5. Data has not been received from Bh 56, which is also drilled along the same section. The best intersection is found in Bh 35, while further analyses should be carried out, especially of cores from Bh E.

The Cu-mineralisations were also intersected at different depths along a north-south profile, drill section 4 by the drill holes Bh 36, 37 and 38 (Figure 33). Bh 36 was aborted, but there is indication that the Cu-mineralised zone continues, although it is only ~2 m in Bh 38.

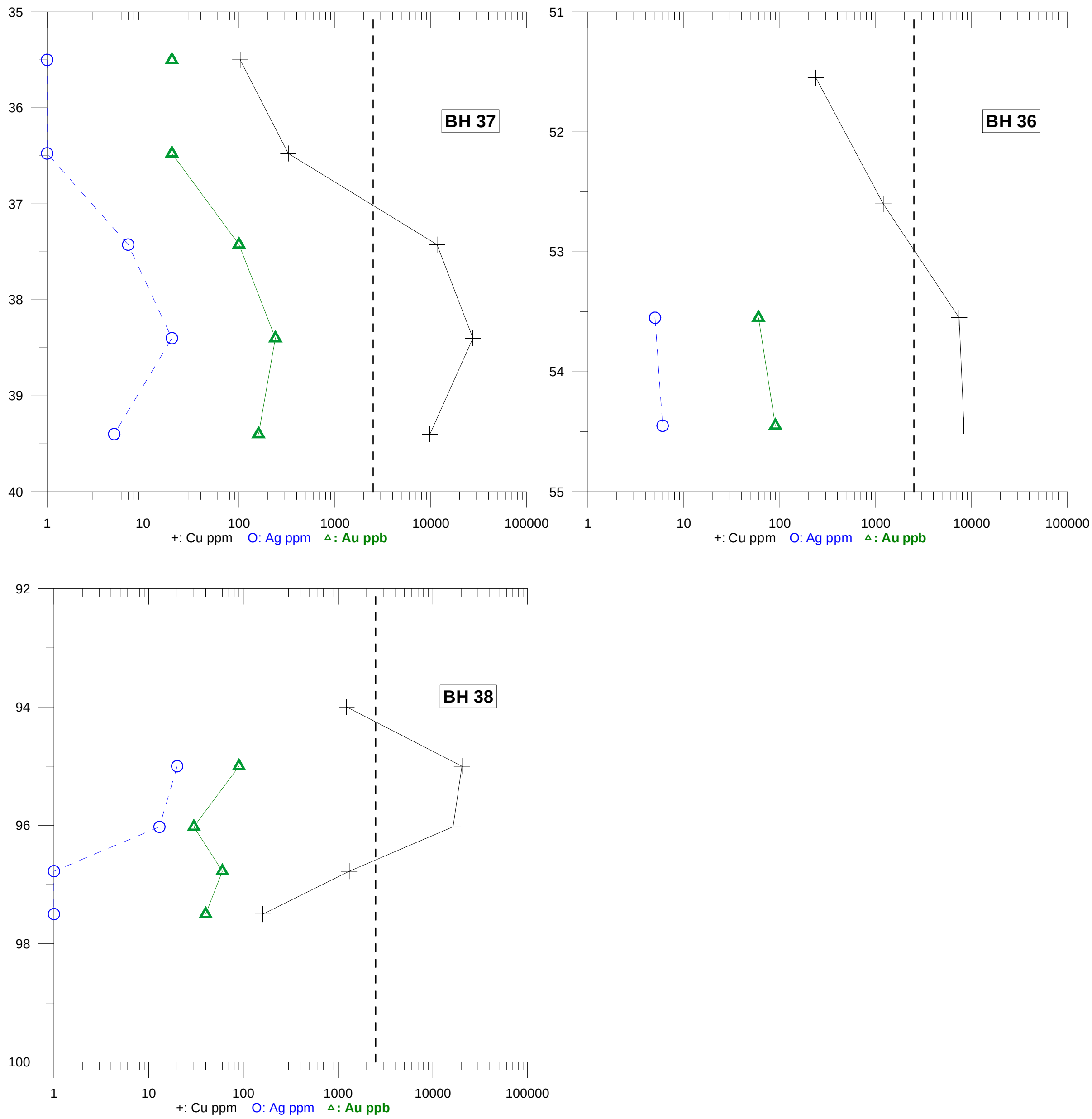


Figure 33: Concentrations of Cu, Ag and Au (horizontal scale) in drill holes Bh 37, 36 and 38 along drill section 4 plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu.

The complete cores of drill holes 39 and 40, along drill section 3, have been analysed for all the 49 elements. The highest Cu-values in Bh 39 (in the section 98-100m, Figure 34) are not found within dolomite, but occur most probably in calcite-veined schist. The most Au-enriched samples are from the same zone. Elevated contents of Mg, Ni and Cr (not shown) and moderate to low contents of Ca above this zone, indicate the existence of a mafic rock, probably a meta-dolerite. Similar contents of these elements are found in the rocks from the uppermost part of the core, and these represent the overlying greenstones of the Nussir Group. Some Cu-enrichment also occurs in carbonate-altered rock/schist? above the meta-dolerite. The overlying schist consists clearly of at least two different units as indicated by a change in the level of Ni-content observed around 32-33m, where Ni is strongly depleted. The same chemical patterns are seen in cores from Bh 40 (Figure 35), which intersect the mineralised zone at a higher level. The chemical analyses give no indication of a Cu-mineralised dolomite.

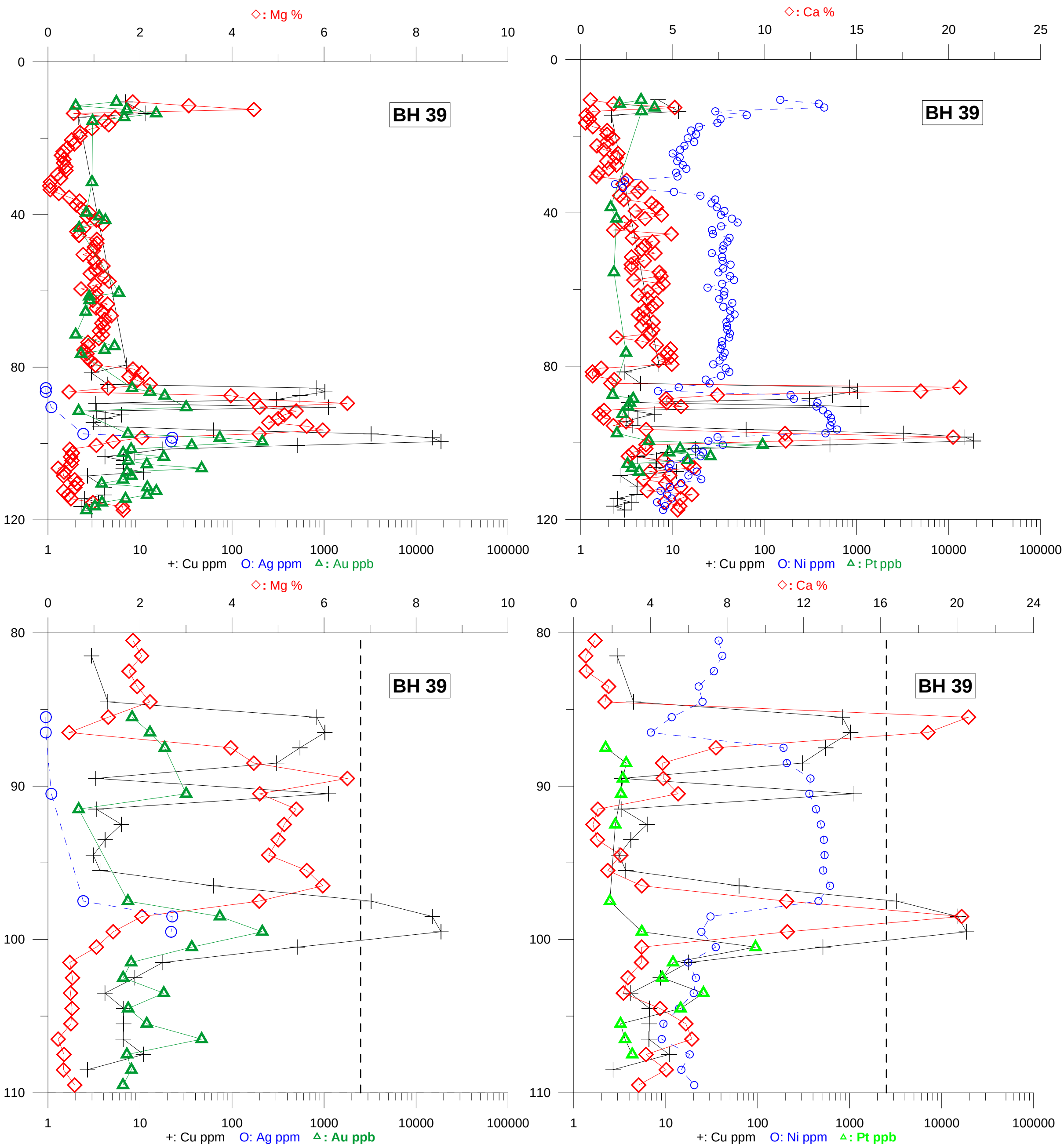


Figure 34: Concentrations of Cu, Mg, Ag and Au and Cu, Ca, Ni and Pt (horizontal scale) in drill hole Bh 39 plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu.

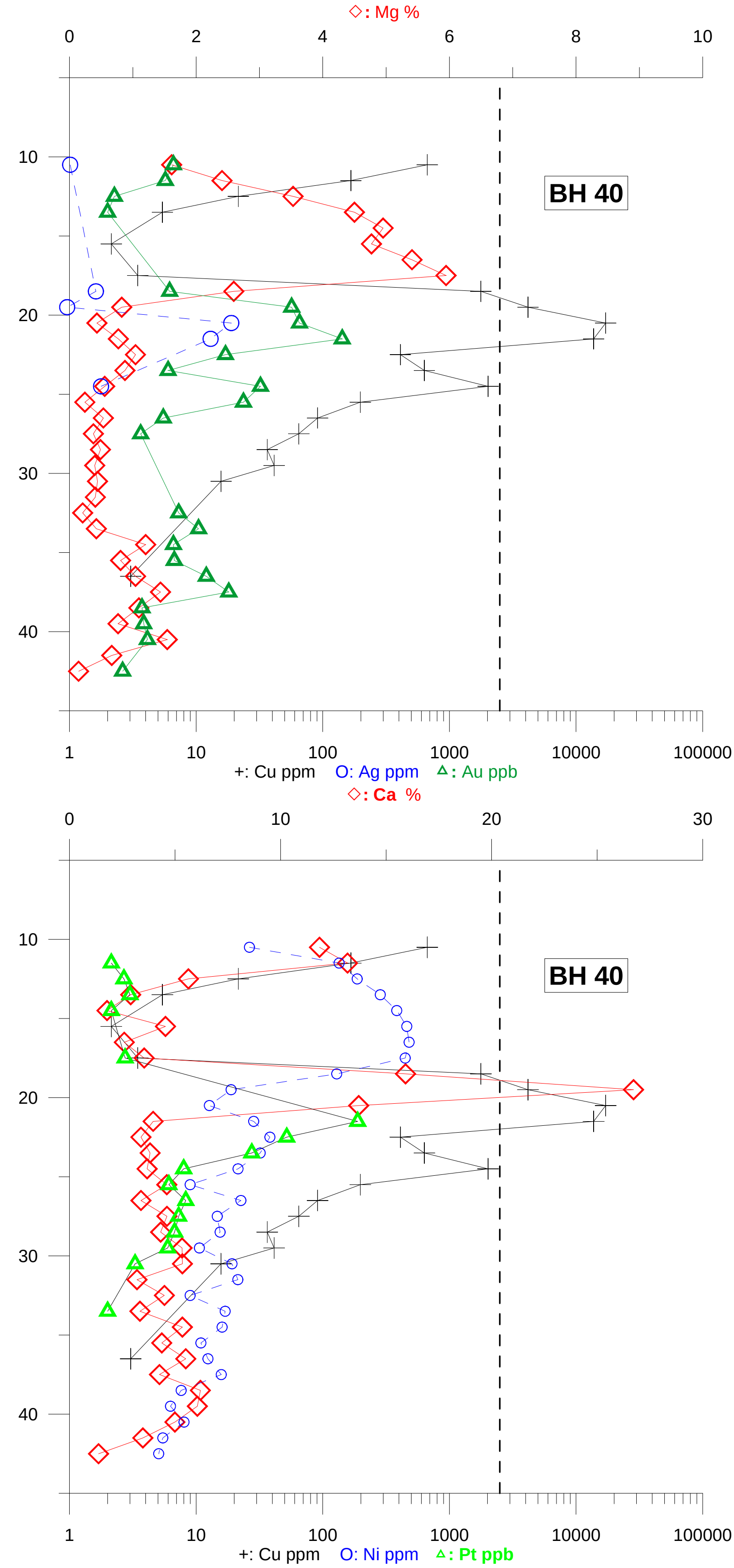


Figure 35: Concentrations of Cu, Mg, Ag and Au and Cu, Ca, Ni and Pt (horizontal scale) in drill hole Bh 40 plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu.

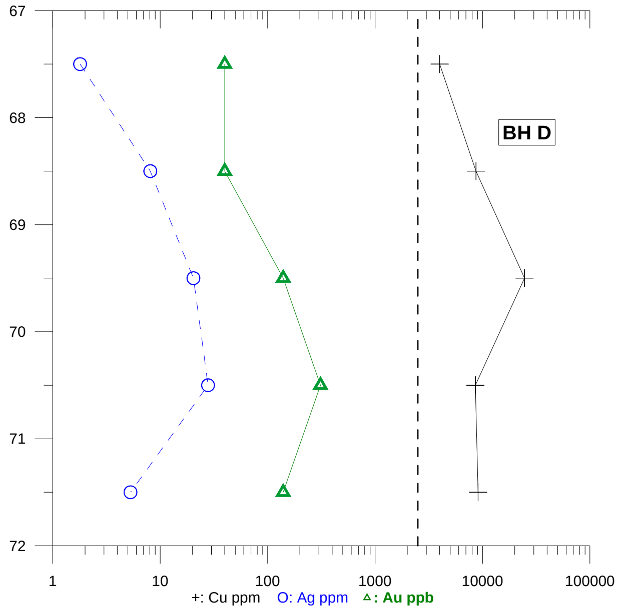


Figure 36: Concentrations of Cu, Ag and Au (horizontal scale) in drill hole Bh D plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu.

Bh D (Figure 36) is drilled from the same collar as Bh 39, along the same section as Bh 39 and 40 and intersects the mineralised section in between these. Further analyses should be carried out downwards in this hole.

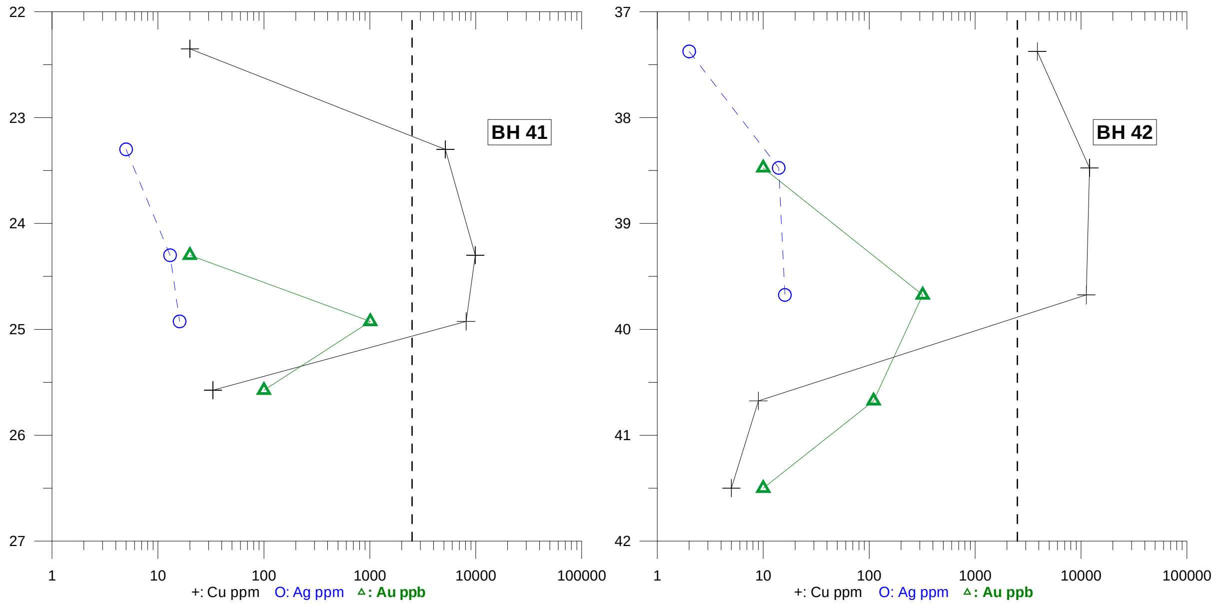


Figure 37: Concentrations of Cu, Ag and Au (horizontal scale) in drill holes Bh 41 and 42 plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu.

The Cu-mineralised zone seems to be well defined in Bh 41, but additional analyses should have been carried out further upwards in Bh 42 (Figure 37), which intersects the mineralisation at a lower level in drill section 2.

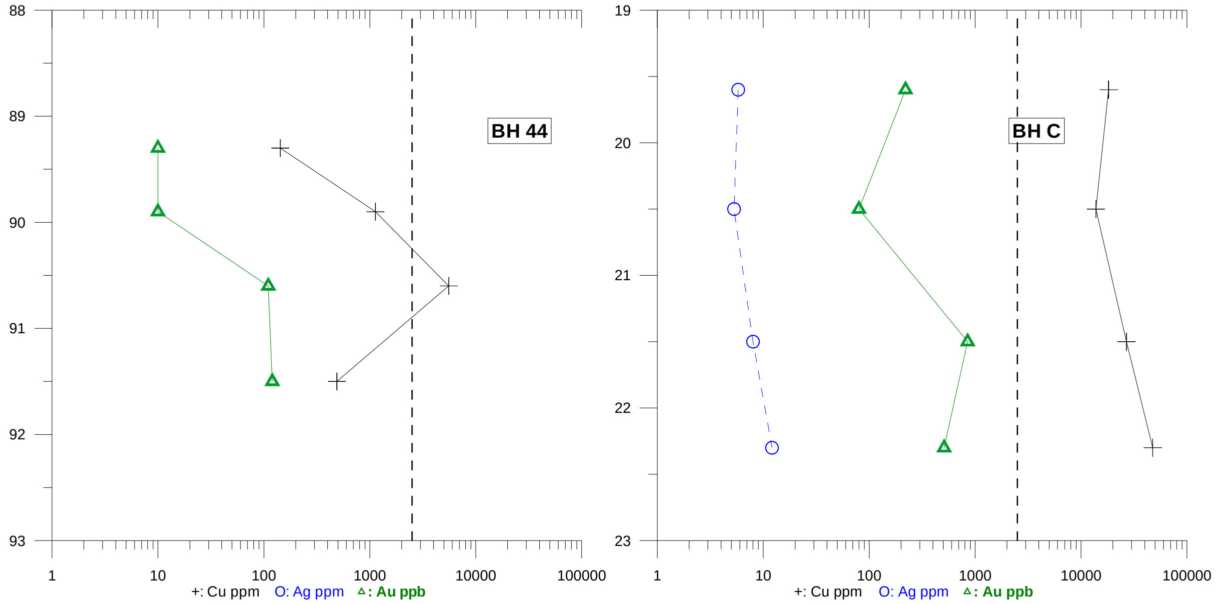


Figure 38: Concentrations of Cu, Ag and Au (horizontal scale) in drill holes Bh 44 and C plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu.

Figure 38 shows that only weak Cu-mineralisation is registered in cores from Bh 44 (drill section 1), while very rich mineralisation is found in Bh C (drill section -1), which is located 400 m further east.

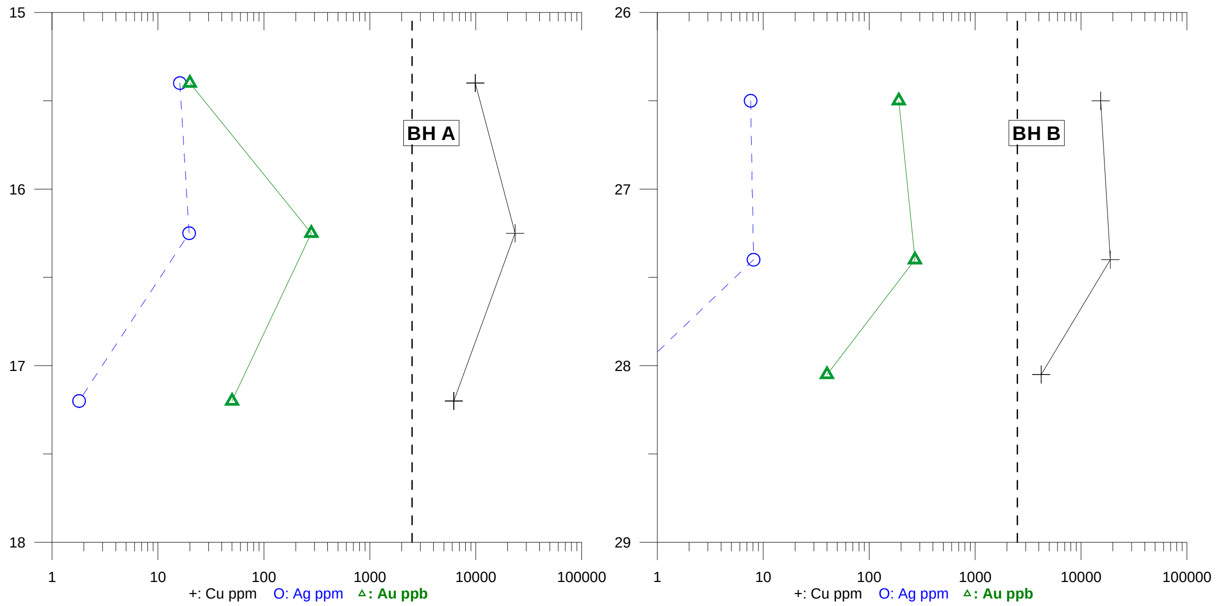


Figure 39: Concentrations of Cu, Ag and Au (horizontal scale) in drill holes Bh A and B plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu.

Only a few analyses exist from Bh A and B along drill section -2, but they give high average Cu-values (Figure 39).

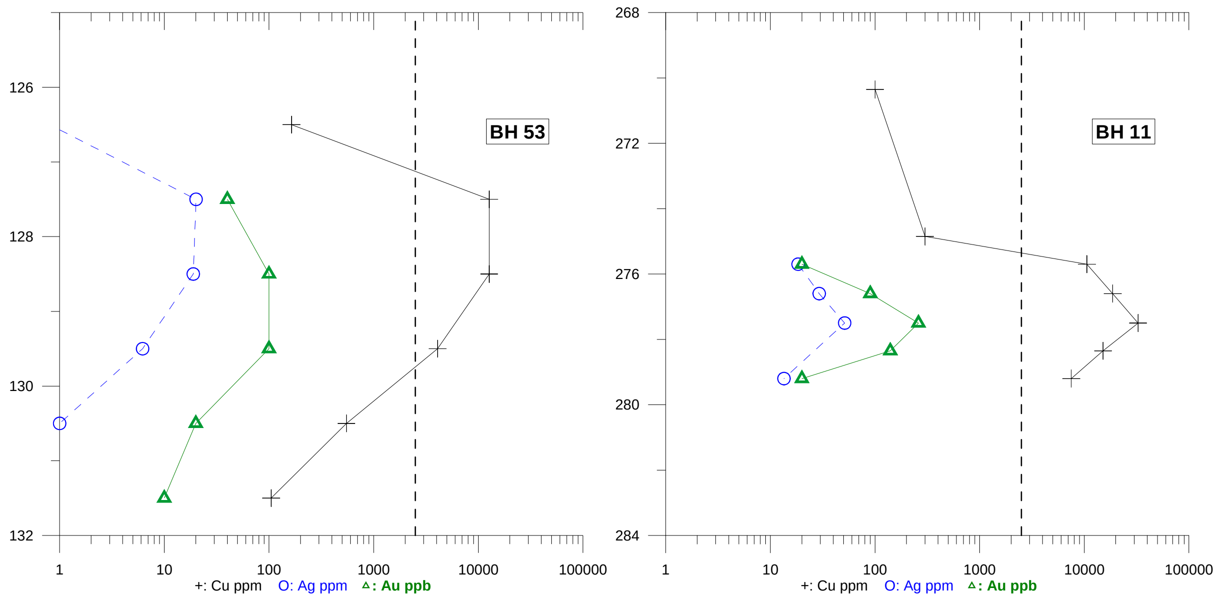


Figure 40: Concentrations of Cu, Ag and Au (horizontal scale) in drill holes Bh 53 and 11 plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu.

Bh 11 and 53 are drilled along drill section -3, and high values of copper are registered in both cores (Figure 40). Bh 13 is also located in the same section, but analyses are missing.

The easternmost drill hole with analyses received is Bh 54. No 'ore dolomite' could be registered in the analyses. The highest Cu-values are not found within dolomite, but occur most probably in carbonate-altered schist. The most Au-enriched samples are from the same zone. Elevated contents of Mg, Ni and Cr (not shown) above this zone indicate a mafic rock, most probably greenstone of the Nussir Group.

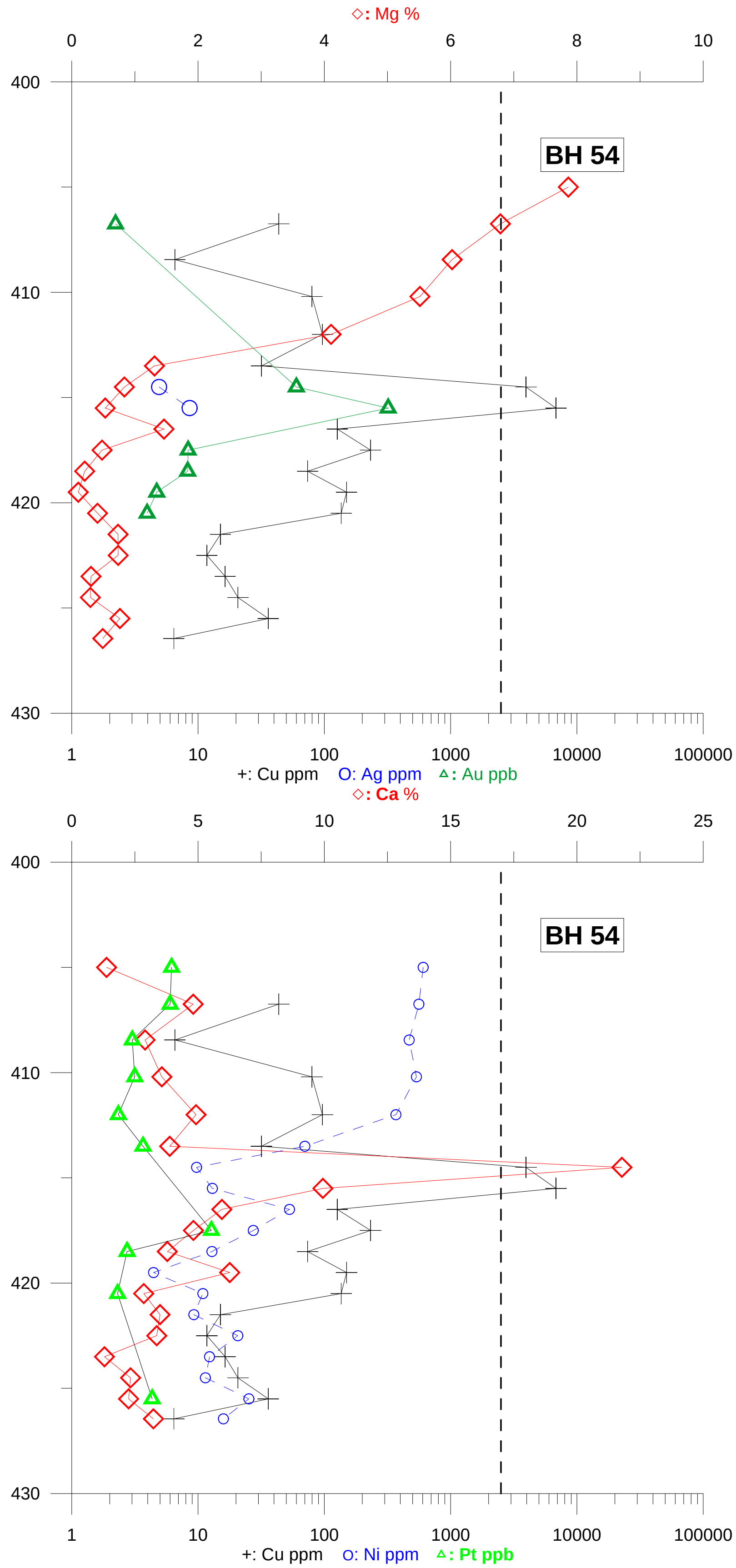


Figure 41: Concentrations of Cu, Mg, Ag and Au and Cu, Ca, Ni and Pt (horizontal scale) in drill hole Bh 40 plotted against depth (vertical scale). Stippled line for 2500 ppm (0.25 %) Cu.

3.1 Cu-Fe-S along drill holes

Lateral variations of Cu, Fe and S were discussed in Section 2, while the vertical variations along the drill holes are discussed here from west to east as in the previous section. The Cu/Fe ratio is used together with plots of the individual elements. Note that a linear scale, and not the logarithmic scale as in the previous section, is used for the Cu values.

In the westernmost drill hole Bh 60 there is a clear difference between the upper and lower Cu-zones (Figure 42). Relatively high proportions of Cu-rich minerals (bornite, chalcocite and digenite) occur in both zones. In the lower zone the proportion is highest, as indicated by high Cu/Fe and lower total Cu content. In the upper zone an increase in the proportion of Cu-rich minerals upwards is clearly indicated by the Cu/Fe ratios. The Fe content is variable in the whole core and is not especially enriched in the ore zones.

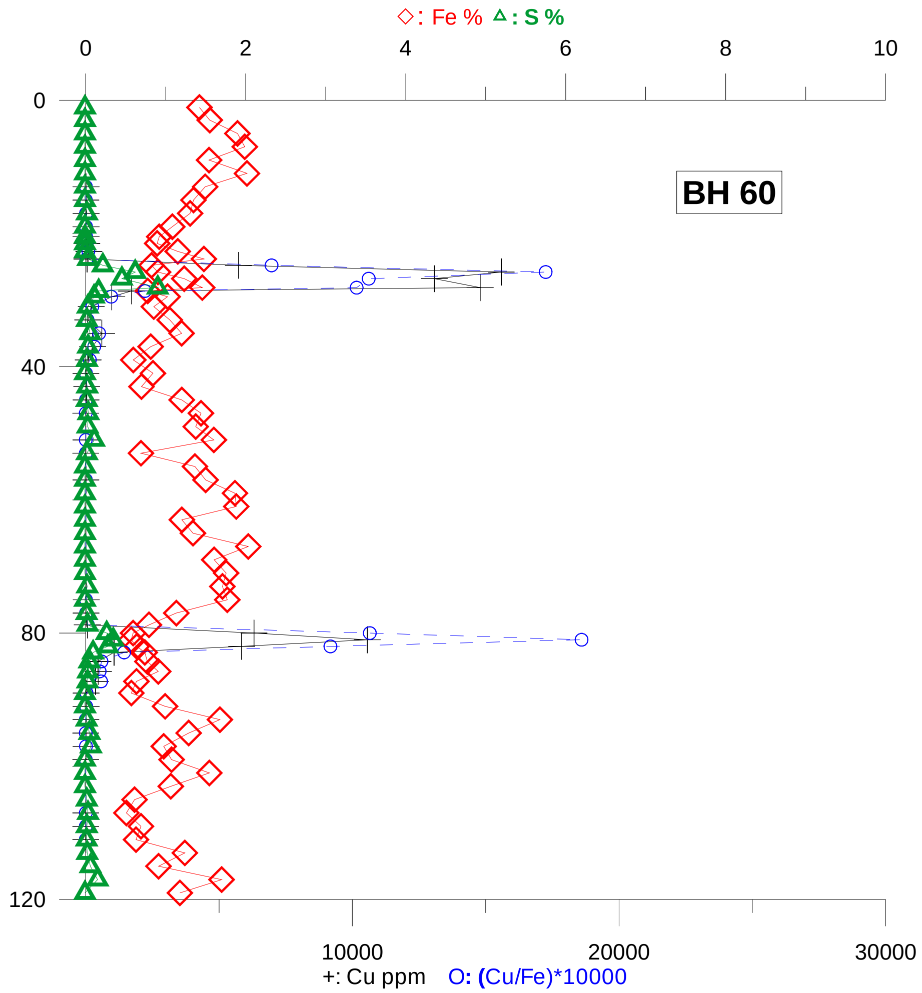


Figure 42: Cu/Fe-ratio and concentrations of Cu, Fe and S (horizontal scale) in drill hole Bh 60 plotted against depth (vertical scale).

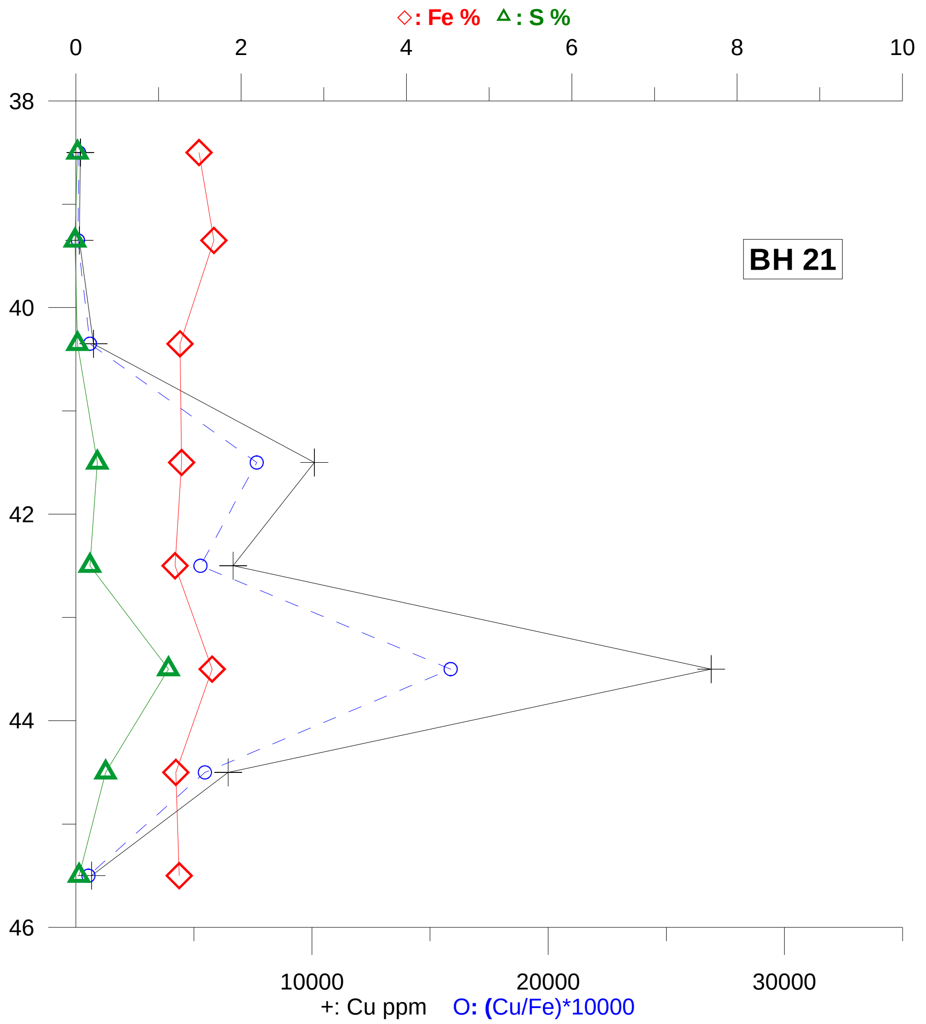


Figure 43: Cu/Fe-ratio and concentrations of Cu, Fe and S (horizontal scale) in drill hole Bh 21 plotted against depth (vertical scale).

A high proportion of bornite and possibly also chalcocite/digenite is also found in the most Cu-rich part of the ore zone in Bh 21 (Figure 43). High increase in the Cu contents is associated with moderate and just slight increase in S and Fe contents, respectively. In Bh 25 and 26 the amounts of chalcopyrite are higher, as is indicated by the low Cu/Fe ratios and more pronounced enrichments of both S and Fe. Similar patterns are also seen in Bh 27 and 28 (Figure 44). In addition, there is a clear enrichment of Cu-rich minerals in the upper part of the ore zone in Bh 28 where the Cu/Fe ratios are high without any rise in Fe contents.

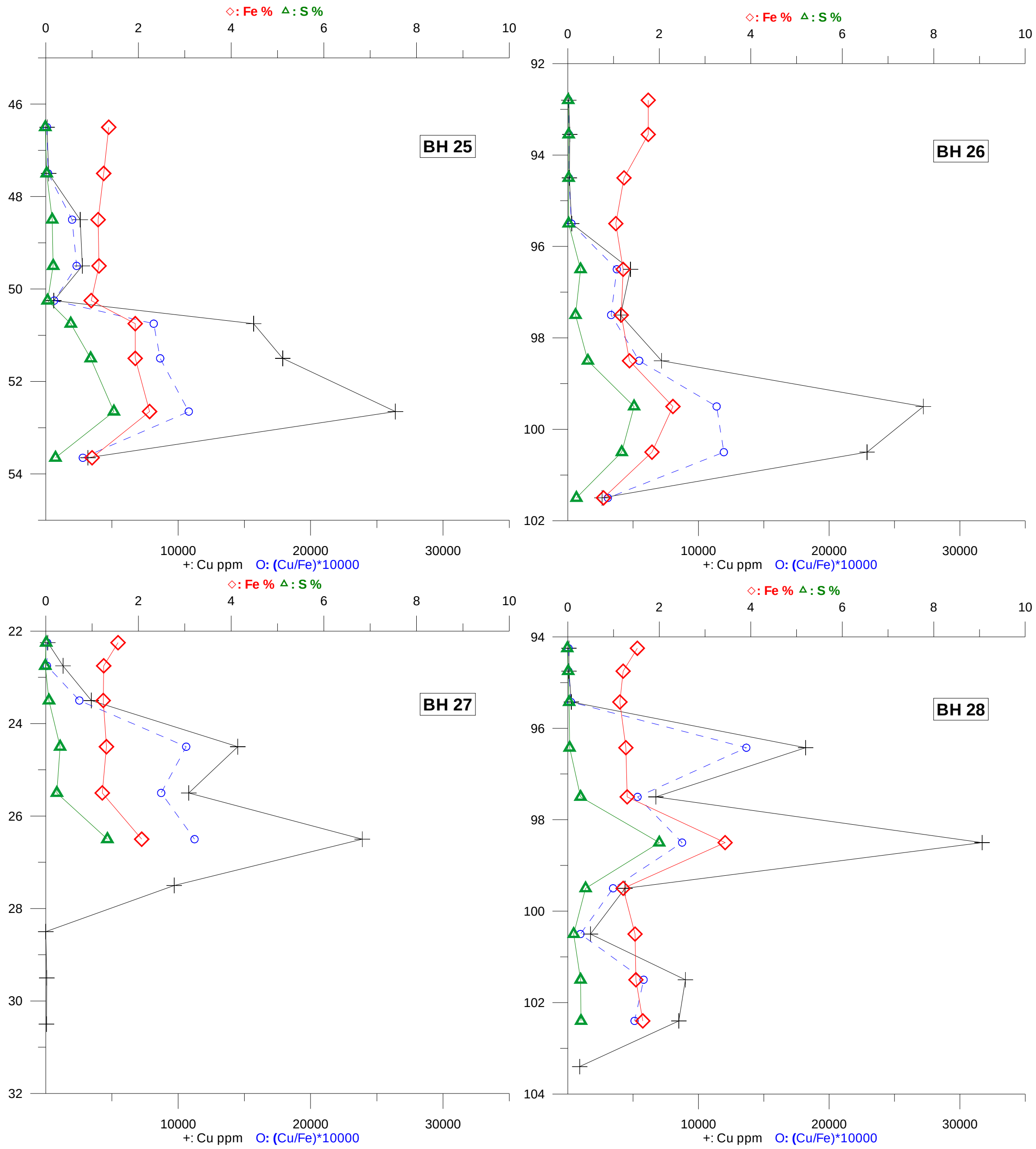


Figure 44: Cu/Fe-ratio and concentrations of Cu, Fe and S (horizontal scale) in drill holes Bh 25, 26, 27 and 28 plotted against depth (vertical scale).

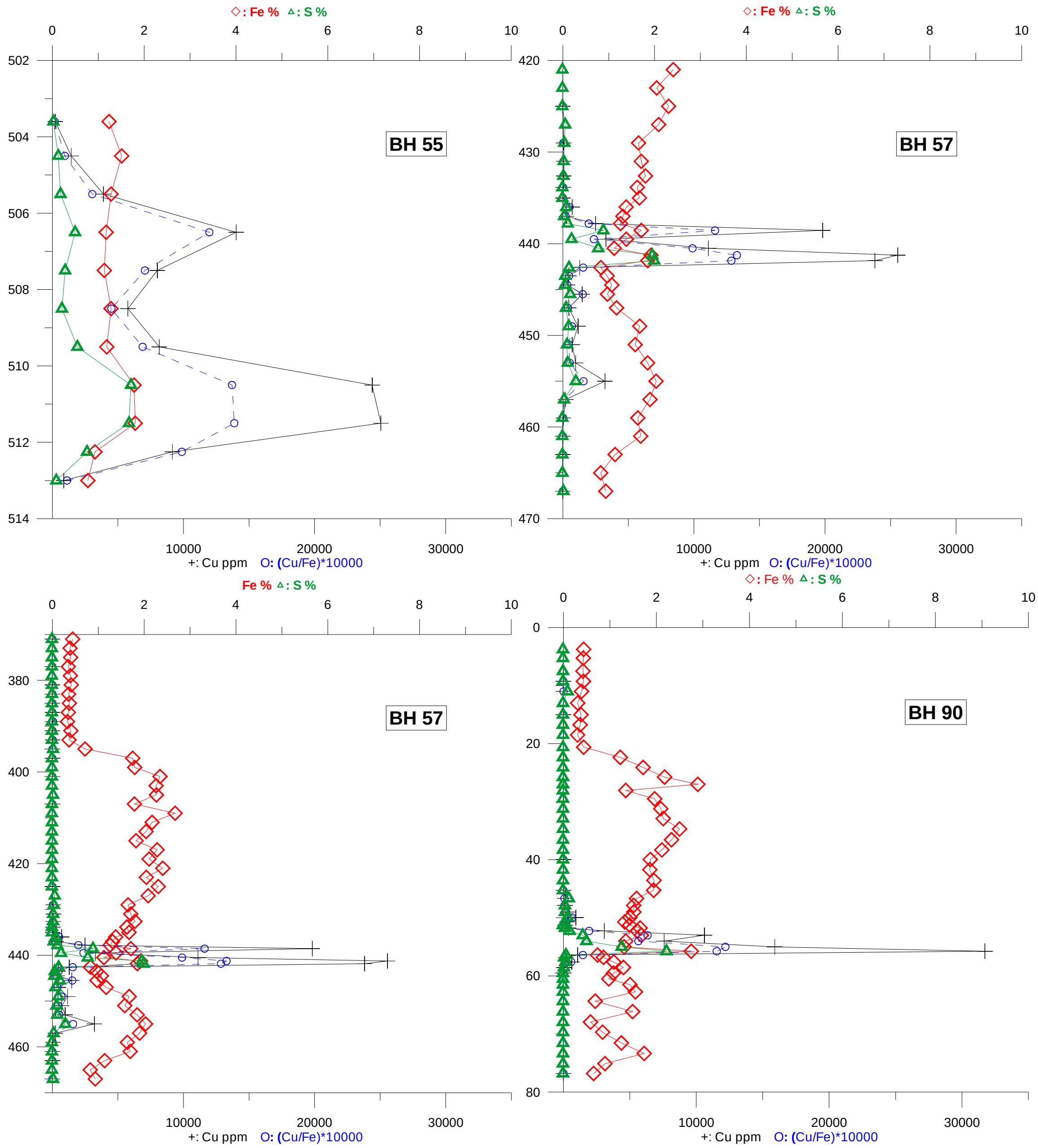


Figure 45: Cu/Fe-ratio and concentrations of Cu, Fe and S (horizontal scale) in drill holes Bh 55, 57 and 90 plotted against depth (vertical scale).

Higher proportions of Cu-rich minerals are also encountered in the upper part of the ore zone in Bh 55, although the enrichments of S and Fe indicate that chalcopyrite is among the dominant copper sulphides (Figure 45). A lithological change is indicated by the drop in Fe contents around 400 m in Bh 57 as also emphasized by Mg (Figure 25). This drop in Fe contents is also found in Bh 90 (≥ 20 m depth), while chalcopyrite predominate in the ore zone.

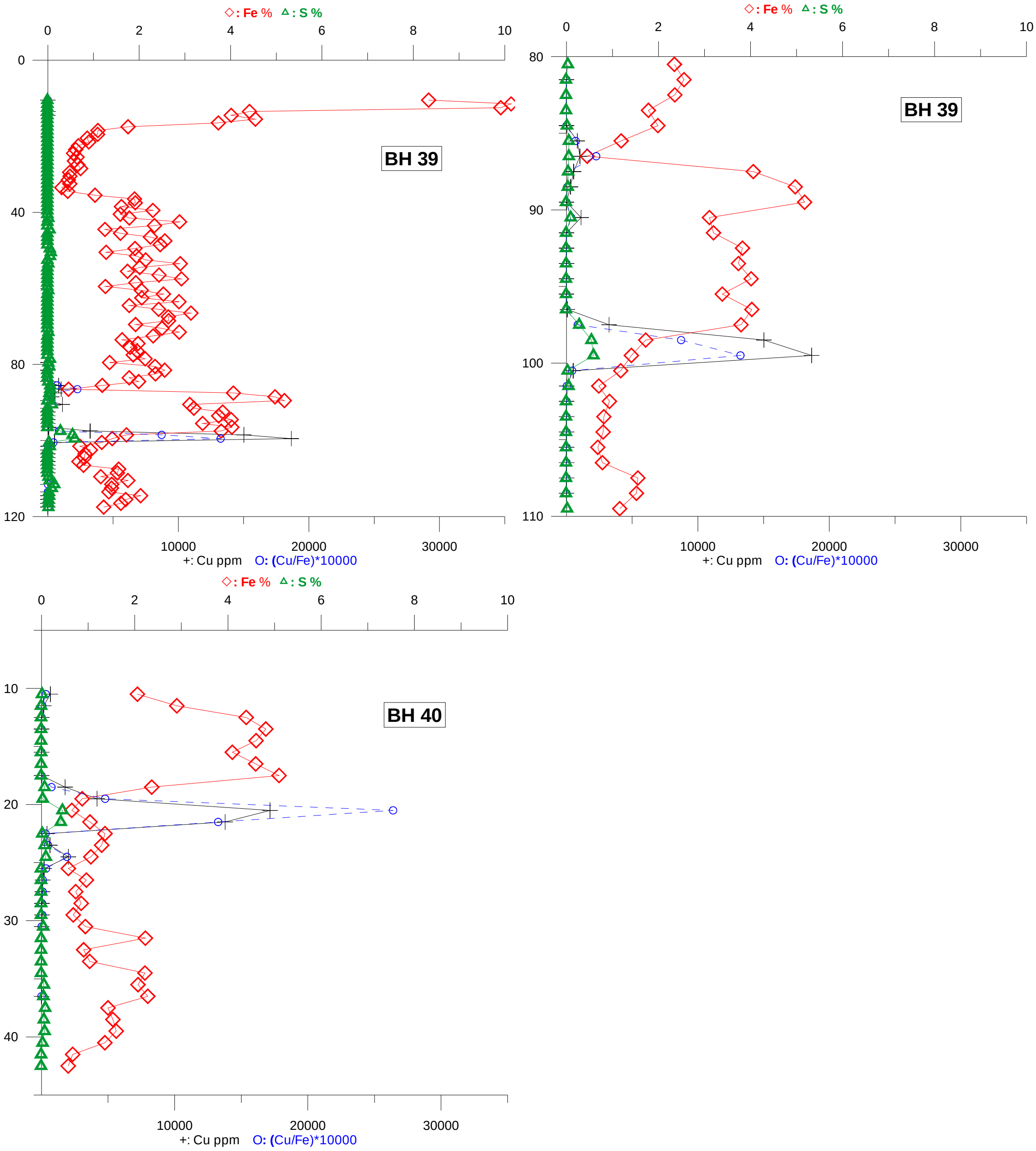


Figure 46: Cu/Fe-ratio and concentrations of Cu, Fe and S (horizontal scale) in drill holes Bh 39 and 40 plotted against depth (vertical scale).

Relatively higher proportions of Cu-rich minerals in the ore zone are found in Bh 39, although this feature is much more pronounced in the ore zone in Bh 40 that is drilled along the same drill section 3. This is also shown by the increase in S and decrease in Fe in the most Cu-rich part, i.e. a high proportion of digenite/chalcocite is expected. In Bh 39 lithological changes are clearly visible, with the Fe-rich (~4-5 % Fe) assumed meta-dolerite just above the ore zone and the Fe-rich (> 8 % Fe) greenstones of the Nussir Group, in the top of the hole. The low-Fe unit encountered in Bh 57 and 90 (Figure 45) probably occurs in the interval ~20-35 m in Bh 39.

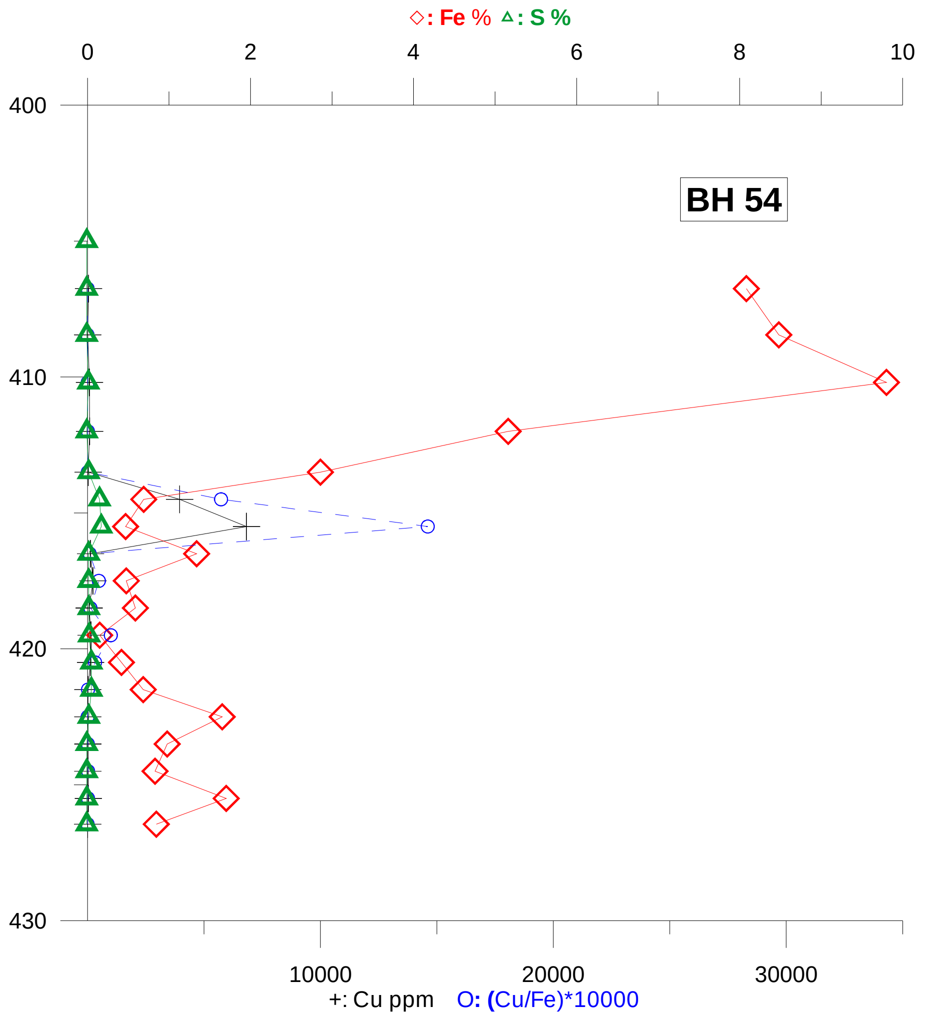


Figure 47: Cu/Fe-ratio and concentrations of Cu, Fe and S (horizontal scale) in drill hole Bh 54 plotted against depth (vertical scale).

The ore zone in Bh 54 is in close contact to the overlying greenstone of the Nussir Group with a high content of Fe. The ore zone is clearly dominated by Cu-rich mineral parageneses, digenite/chalcocite as indicated by its high Cu/Fe ratio (Figure 47).

4. CONCLUSIONS

Several conclusions can be drawn from the study of the chemical composition of the drill cores. However, some of them are tentative and should be confirmed by further analyses, logging of the drill cores and mineralogical studies. More analyses are recommended since the true width of the ore zone in many of the drill holes is not fully recognised.

- The analyses of acid-soluble digestions show the metal distributions as well as give indications of lithologies present
- There is a moderate positive correlation between Cu-Ag, Cu-S, Cu-As and Cu-Co
- There is a weak positive correlation between Cu-Au and Cu-Fe, with a strong positive correlation between the highest Cu and Au values
- Pt seems to have a more erratic distribution in relation to Cu, but the data are too limited for a firm conclusion
- Only minor enrichments of transitions metals other than Cu exist
- High Cu-values are found both within and in the footwall of the 'ore dolomite'.
- Actually, the highest Cu-values commonly occur in the footwall of the dolomite, most probably in a silica-rich rock
- The ore dolomite is best defined in the western part of the deposit. The Cu-mineralisations seem to occur in less dolomitic rocks in the eastern part of the deposit
- The width of the intersected Cu-mineralised zone is in several sections more than 3-4 m, and exploitable thicknesses will vary according to the cut-off grade for Cu
- The relationships between Cu, Fe and S can be used to give indications on the distribution of various copper minerals
- The highest proportions of the Cu-rich sulphides; bornite and chalcocite/digenite occur in the westernmost and in the eastern part of the deposit. Lower proportions occur in the folded part of the deposit.
- A vertical zonation of copper sulphides is found in a few drill holes
- The highest Ag values are found chalcopyrite-rich samples in the folded part of the deposit.
- Further studies are need to decide whether this mineral zonation and Ag distribution is a primary feature or due to later remobilisation
- The data are too limited to give any definite conclusion about the relationship between the two Cu-mineralised zones in the westernmost part of the area, but they are hosted by rocks of different chemical composition.
- The chemical characteristics of the lower western Cu-zone with enrichment of Pt, in Bh 60 is not found in other drill holes

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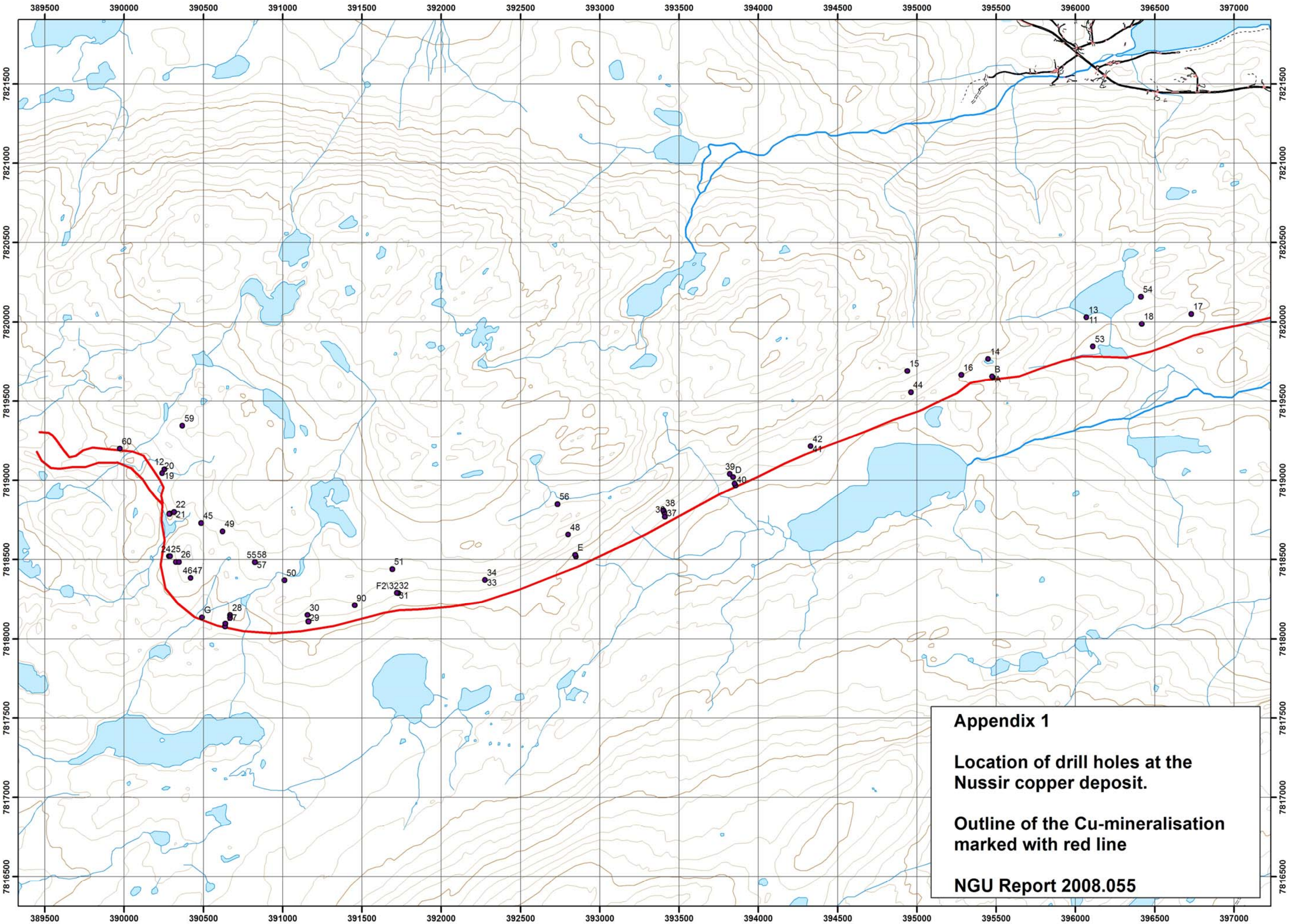

Appendix 1

Location of drill holes at the Nussir copper deposit.

Outline of the Cu-mineralisation marked with red line

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