Geol. Bull. Univ. Peshawar, 1991, Vol. 24, pp. 147-160

GEOCHEMICAL DISPERSION OF COPPER IN LAKE BOTTOM SEDIMENTS OF LOKKEN AREA, NORWAY

KHALIL A. MALLICK, S.M. HASNAIN, E.A. KHAN & M.A. FAROOQUI

Department of Geology, University of Karachi, Karachi

ABSTRACT

Bottom sediments and water were sampled from the desired sites of lakes to study the dispersion of copper in contaminated and virgin lakes of Lokken area, Central Norway. This study was an effort to use the information as a tool for the geochemical exploration of ore deposites in glaciated terrain with higher density of lakes and poor rock exposures. For the above objective frozen lake sediments and water were collected by designing and fabricating new samplers in the work shop of Geological Survey of Norway at Trondheim. The results of the present work are encouraging both in the field of instrumentation and the study of dispersion of copper to be used as a tool in the geochemical exploration of ore deposits.

INTRODUCTION

Most of the work done todate by exploration geochemists have been on rocks, stream sediments, waters and soils. Attention has also been paid to the geochemical study of vegetation, but not much work has been done on lake bottom sediments and waters. In general, the problems in sampling of lake sediments are increased when the area is dominated by disorganized drainage, glacial lakes and poor bedrock exposures. In addition, perhaps, the variable limnological environment also affects the enrichment and depletion of metals in the lakes to great extent.

The study of lake sediments as a tool for geochemical exploration of ore deposits in a glacial terrain is relatively a new branch of exploration geochemistry and still in experimental stage. The results of recent work have shown that the lake sediment geochemistry can be used as an indicator of mineralization in reconnaissance level exploration, especially in areas of glacial overburden having indefinite and disorganized drainage where conventional geochemical exploration techniques involving sampling and analysis of sediments have limited applications.

The present study deals with the geochemical dispersion of copper in lake sediments of Lokken area, Norway. For the above objective a new method of sampling was introduced, and new samplers were designed and fabricated in the workshop of the Geological Survey of Norway with the hope of greater scope and future of the method in geochemical exploration of ore deposits in glaciated terrains having abundant lakes and poor bedrock exposures (Mallick, 1989).

The earliest reference to the use of lake sediments in geochemical exploration is that of Schmidt (1956) who studied the adsorption of Cu, Pb and Zn on common rock forming minerals and its effects on lake sediments of New Brunswick and Quebec, Canada. Arnold (1970) studied the concentration of metals in lake water and sediments of the lakes associated with mineralization in the Flin Flon and Lac La-Range areas in Saskatchewan, Canada. Since the work of Schmidt and Arnold were based on insufficient number of samples and therefore, these initial investigations can be considered as good hypotheses in the field of geochemical exploration for ore deposits.

Allan (1971) surveyed and sampled copper mine River area of the Northwestern Territories of Canada for use of lake sediment geochemistry in mineral exploration. He concluded that lake sediments are promising tools for regional resource assesment of the Canadian Shield. He also observed that Cu from lake water in that area is complicated and involves precipitation due to sorption of Cu by suspended loads of uncontaminated sediments, organic complexing agent, and iron phosphate gels.

Lake sediments from greenstone belts within the Lake Superior Province, Canada were studied by Cooker and Nichol (1974) to investigate the nature of metal dispersion in lake sediments associated with mineralization.

Nichol et al. (1975) suggested that the relationship between the composition of lake sediments and mineralization is affected by organic matter, metal scavenging by iron and manganese oxides and the sediment sorting by wave action. Nichol et al. also suggested that the nature of samples, sample density, analytical and interpretational procedures should be decided according to the local conditions and exploration target, and recommended the recording of pH, conductivity and oxygen content of the lake water at the time of sampling.

GENERAL GEOLOGY

The area selected for the collection of lake sediment samples is known as Lokken (Fig. 1). It is 70 km southeast of Trondheim at an elevation of 300 meters. There are three main valleys in this area. These valleys trend north-south and have dense

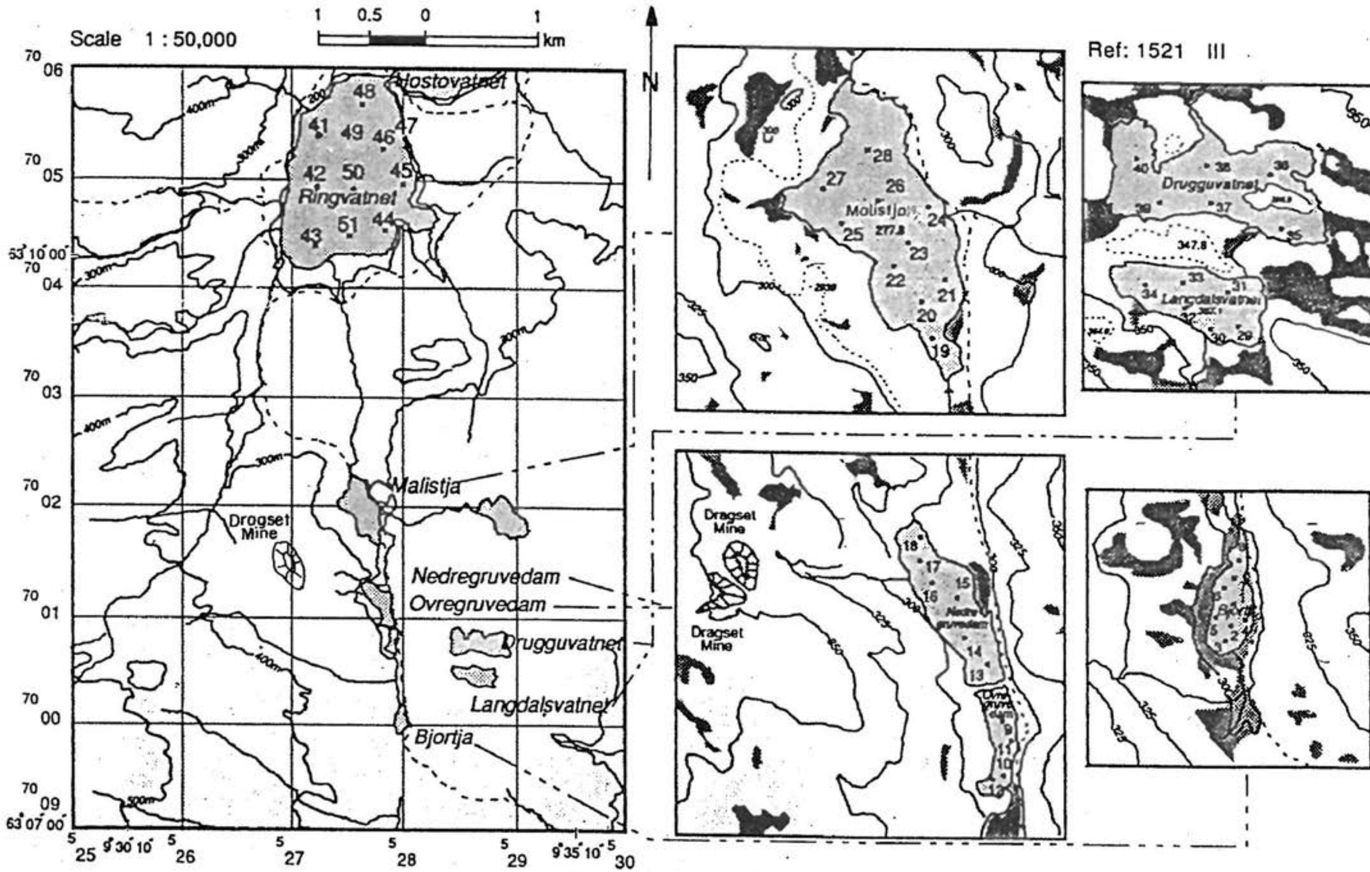

Fig. 1. Map showing location of sample sites, Lokken Area, Norway.

vegetation of pine trees. The rocks exposed in this area are of Roros Group, Storen Group and Hoven Group. The Roros Group mainly consists of mica schist amphibolites and gneisses. The age of this group is not yet definitely known, but is older than upper Cambrian. The rocks of Storen Group are mainly basic lavas, pyroclasts and acidic rocks of upper Cambrian age. The copper rich pyritic ores containing 0.9 to 2% copper are found in the basic lava. The copper ore was under active mining and production from 1646 to 1946, but after the World War II the mining activities were dropped. The cupriferous pyrite also contains lead and zinc mineralization. Commonly the rocks of this group are known as Greenstone and all lakes of glacial origin are situated on the rocks of this group. The rocks of Hoven Group of middle Ordovician age are mainly conglomerates, shales, sandstones and the limestones. Since the entire area is below treeline it is covered by dense vegetation of pine trees in which marshy land and the lakes of varying sizes and depths are common.

METHOD AND MATERIAL

Since the present work is first of its kind in Norway, the area Lokken known for its mineralization of Cu, Pb and Zn was selected to determine the suitability of sediment geochemistry as a tool for geochemical exploration of ore deposits in glaciated terrains of the country. In Lokken area Ovregruvedam and Nedregruvedam are thought to be affected by the abandoned mining activities for Copper, Lead and Zinc from the massive sulphides of the Caledonides. Other lakes of the same area apparently have no drainage from the known mineralized areas (Fig. 1). Such lakes namely Drugguvatnet and Langdalsvatnet were taken as virgin or noncontaminated lakes. The virgin lakes were sampled to obtain background data and for a comparative account of the degree of contamination and the depth of lake sediments contaminated. The geochemical data is also expected to help in determining the rate of sedimentation in the lakes and evalution of possible mineralized localities.

Lakes chosen for present study were sampled during winter when the surface water of the lakes is frozen and it is possible to walk on and drill holes in the ice to collect water and bottom sediment samples from the desired sites in the lakes (Fig. 2).

Winter season was considered the most suitable time for sampling because of minimum upwelling effects in the lake water and less disturbance in the chemical startification of the water. The inlet streams were also not having any pronounced contamination effects on the lake water and sediments due to frozen condition. In order to obtain the true thickness of the sediments from bottom of the lake and to record data from the sediment-water interface, a new sampler was devised in the workshop of the Geological Survey of Norway which proved very useful for the present work (Mallick, 1989).

Fig. 2. Snow bore hole on frozen lake water for the collection of sediment and water samples from the lake bottom.

COLLECTION OF WATER SAMPLE AND OTHER FIELD DATA

Water sample from sediment water interface of each site were collected in polythene bottles just after making a bore hole through the frozen surface water of the lake. Salinity, pH, dissolved oxygen and temprature at the sediment-water interface and one meter above it were also determined at each site of the lake. To evaluate the suitability of the method adopted the geochemical dispersion of copper has been used to describe the degree and depth of contamination it can impart to the sediments of the lakes under study. The lakes selected for the present study are Bjortja, Ovre Gruvedam, Nedre Gruvedam, Malistja and Ringvatnet extending from South and North and are inter-connected. The lakes Drugguvatnet and Langdalsvatnet are at higher elevation and expected to be uncontaminated.

Apparently Ovre Gruvedam is contaminated by Dragset Copper Mine workings and also by the incoming streams from the mine area. The water of Ovre Gruvedam overflows into Nedre Gruvadam which further flows northward into Malistja and the water of Malistja pours in Ringvatnet, the largest lake in the studied area. Lang dalsvatnet and Drugguvatnet located further east at higher elevation are not connected to the lakes chain.

DISPERSION OF COPPER

The plot of copper concentration is expected to reveal the depth of contamination and the dispersion pattern in the lake sediments of Nedre Gruvedam and other interconnected lakes like Bjortja, Ovre Gruvedam, Malistja and Ringvatnet. Any deviation from the background value of copper in the lake sediments would further facilitate the determination of sources of contamination and thus would help in locating unknown mineralization in the surroundings.

The above hypothesis is based on the assumption that the lake-bottom sediments represent the average chemical composition of the surrounding rocks and any deviation from the average chemical composition is a reflection of contaminating sources like mining activities or an indication of some unknown mineralization in the area. Although the complex situation in nature and the type of mineral deposits will not make the assumption rigorously true for all cases, the overall effect as judged from many samples may give a good indication of the composition of the element under study. For this purpose, the sediment samples from the top 0 to 3 cm depth level were not taken into consideration to avoid complexities due to redox potential and other related factors. The lake sediments showing average concentration of copper equal to standard average of soils (av. 15ppm) below 3 cm sediment depth or an increase with depth has been considered as non-contaminated lake.

Lakes showing higher and variable concentration of copper at and below 3 cm sediment depth or to a certain depth but turn again to nearly uniform concentration of copper in the deeper parts of the sediment column have been considered as contaminated lakes. The lakes getting stream water directly from the mine area or flow of water from the contaminated lake into the adjacent lakes are also considered as contaminated lakes of varying degrees.

COPPER CONCENTRATION IN THE SEDIMENT COLUMN

It appears from the study of profile plot for the lakes under study that the copper mining activities which were operating in Dragset area abgout 42 years ago could not affect the sediments of some of the lake like Bjortja and Ringvatnet which form the true ends of the chain in contaminated lakes (Fig. 3). Same non-contaminated conditions with respect to copper concentration in the sediments of Langdalsvatnet and Drugguvatnet were observed. Perhaps the wind direction and its intensities were not competent to blow the particles from the mining wastes to these lakes at higher altitudes.

The copper concentration in the sediments of lake Bjortja does not show any significant variation with depth but the concentration is higher than the average standard value (40-90 ppm). The sediments from different parts of this lake do not show

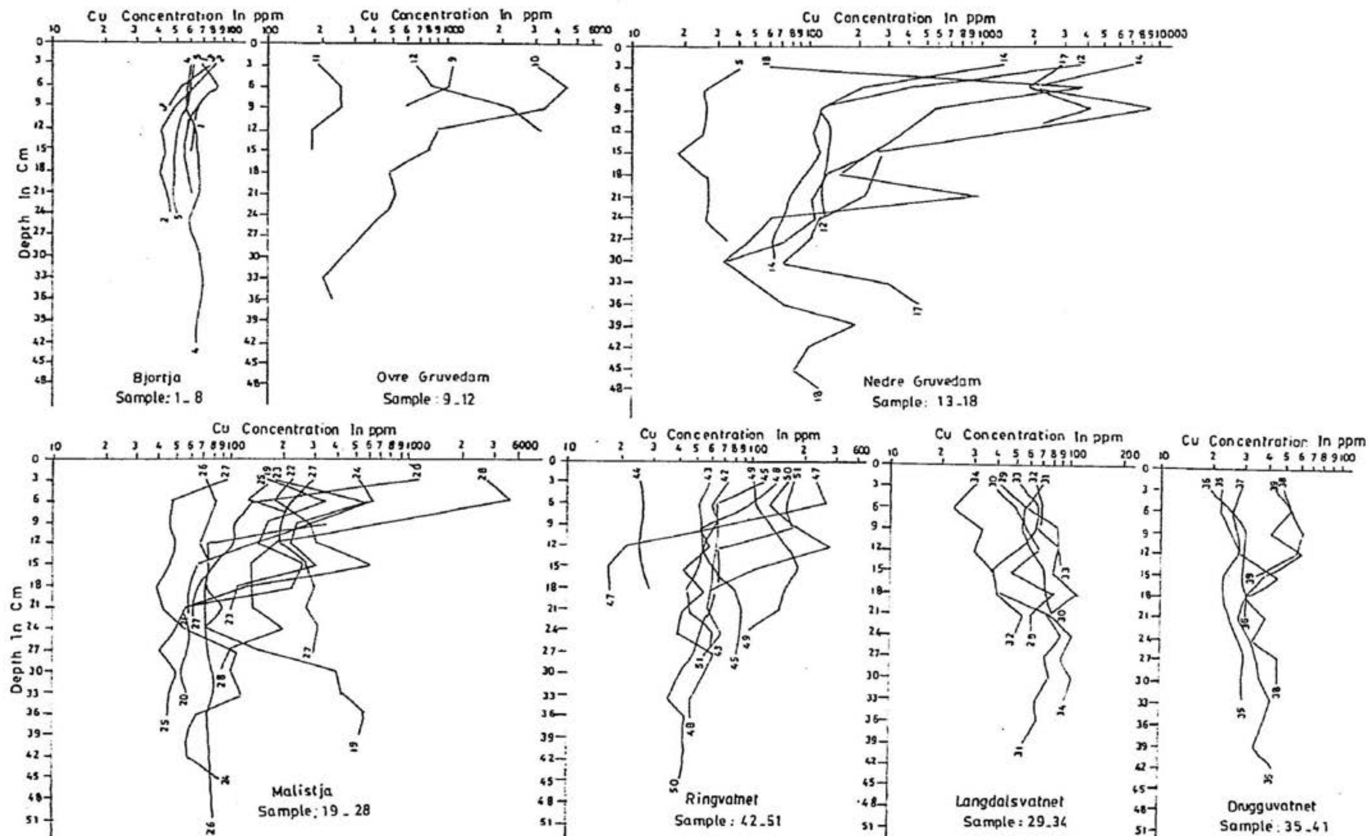

Fig. 3. Profile of copper concentration in contaminated and non-contaminated sediments of Lokken Area, Norway.

any sign of appreciable concentration change in copper. On the contrary, the sediments of lake Langdalsvatnet, which is further east of the abandoned copper mine, show more variation in concentration of copper as compared to Bjortja (Ca 25-100 ppm). The concentration of copper in the sediments of lake Drugguvatnet (20-60 ppm) is less than Langdalsvatnet (30-100 ppm) which is a neighbouring and connected lkake.

Apparently, lake Ovre Gruvedam is not having any feeding stream from the mine area and only the water of Lake Bjortja pours into it. This lake shows radical and diverse change in copper concentration with depth at different sample sites. The copper content in sediment sample of site 11 is nearly equal to the average standard concentration. The variation in copper concentration at different sample sites are probably due to varying degree of contamination in different parts of this lake. This condition of copper enrichment and depletion at different sites may probably be due to incipient drainage. The higher value of copper concentration in deeper parts of sediments column (Ca 200-5000 ppm) at site 10 may be attributed to the possibility of higher degree of contamination around the sample site. However, it requires further investigation and field observations to conclude the possible causes.

Nedre Gruvedam has incoming streams directly from the abandoned Dargset Mine area. The copper concentration in the sediments of different sites of this lake show a general decrease in its concentration with increase in depth of sediments. Sample site 13 of lake Nedre Gruvedam is not far from the adjacent lake Ovre Gruvedam which feeds the bulk of its water to this lake, but very high concentration of copper as compared to site 14 and 15 of the same lake can be observed. The effect of contamination is more pronounced in the upper 15 cm thickness of the sediments except in the samples of site 15 which shows copper concentration nearly equal to standard average concentration. The samples from 6 cm depth of this lake from different sites show wide variation in copper content but with increase in depth, a general decrease in copper concentration can be observed. At depth of about 15 cm in lake-bottom sediment column of this lake appears as a turning point in the concentration level of copper. No effects of copper concentration was found in the sediment column below this depth even in other knwon contaminated lakes.

Site 17 in Lake Nedre Gruvedam is not far from the incoming stream from the mine locality but the sediments do not show any higher concentration of copper as compared to sites 13 and 14 probably due to movement of water towards the deeper part, away from the inlet stream.

Lake Malistja receives the bulk of its water from the contaminated lake Nedre Gruvedam. In addition to the streams from the eastern side, no sign of any stream coming from the mine area into this lake is observable. The higher concentration of copper in the uppper 12 cm of the sediment column of sample site 28 is quite prominent and can be considered as the depth of contamination. The higher concentration decreases with depth and reaches to about 100 ppm below 21 cm depth level from each site except site 19 which needs further investigation to conclude possible mineralization. Wide dispersion of copper is prominent in the sediments of this lake, but the degree of dispersion is less erratic than Nedre Gruvedam. The decrease in depth of contamination and more erratic dispersion of copper is probably because of dilution of copper by the bulk of water and lesser quantity of fine sediments and copper ions transported from lake Nedre Gruvedam to Malistja. Organic matter present in the lake water and sediments are probably the important factors in irregular distribution of copper in lake bottom sediments.

Lake Ringvatnet has its main water supply from lake Malistja but there are also two incoming streams from the western side not far from the sample sites 41 and two streams from the eastern side which fall in the lake near sites 45 and 47. The thickness of sediments at sites 41 and 46 are very small and have not been plotted in the graph. The copper concentration in the sediments samples 42 and 44 are exceptionally low and show invariable distribution. Other sample sites show variation in concentration with depth in the upper 12 cm thickness of the sediment column. This variation in the concentration of copper in the upper 12 cm thickness of sediments is probably due to variable dilution of the contamination coming in the largest lake water of the area from lake Malistja.

Lake Langsdalsvatnet and Drugguvatnet do not show any significant change in copper enrichment and depletion with respect to sediment depth and can be considered as noncontaminated lakes of the area. It is remarkable to note that the background values of copper concentration are higher in this locality. These higher background values are most probably due to the development of the lakes on the rocks of Storen Group known as Greenstone that contains cupriferous pyrite with Pb and Zn.

CONCENTRATION CONTOURING

The plot of horizontal dispersion of copper at 6 cm & 21 cm sediment depths are expected to reflect the effects of possible contaminations through various sources at shallower depth and uncontaminated dispersion of copper at deeper depth levels in the lakes.

The concentration contours at 6 cm sediment depth in Lake Nedre Gruvedam which receives stream sediment and water from the abandoned Dragset copper mine during summer shows a minimum concentration of 100 ppm in nearly the middle part and gradual increases on either ends of the lake (Fig. 4). Lake Nedre Gruvedam shows much higher Cu content (7500 ppm) in sediments near its out-let end. The same pattern of copper dispersion in Malistja is probably due to higher mobility and transpsort of Cu in solution from the contaminated lake Nedre Gruvedam. The higher

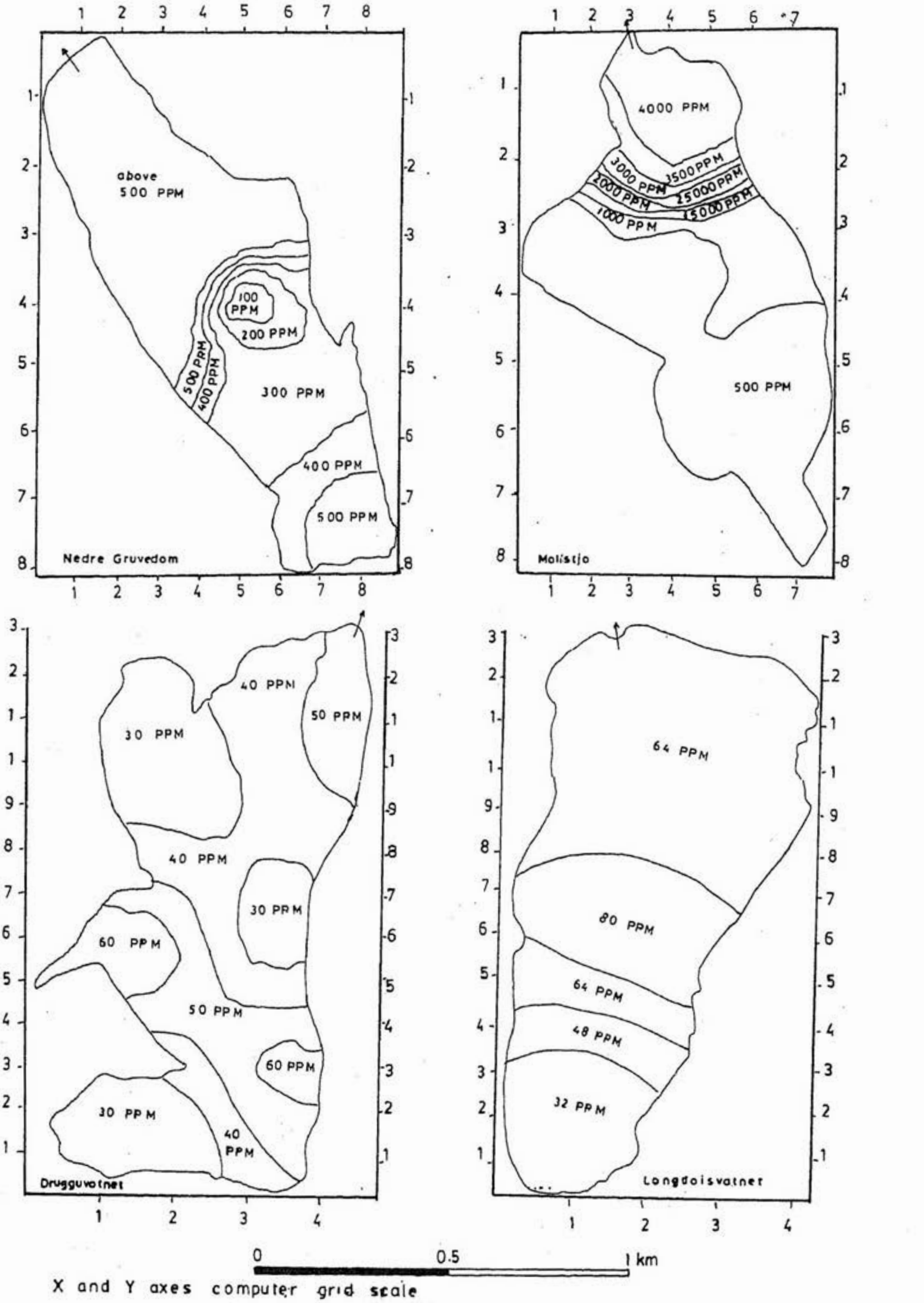

Fig.. 4. Copper concentration contours for selected lakes of Lokken Area, Norway at 6 cm sediment depth.

concentration of copper in sediment is most probably a result of sorption by clays, sediments, scavenging by Fe and Mn in an environment of relatively deeper calm water suitable for precepitation of copper.

Lake Langdalsvatnet shows its copper dispersion pattern similar to lake Malistja but the concentration is comparatively very low. It appears from the dispersion pattern that the mechanism of transport and concentration is the same as described for lake Malistja but with no contaminating sources. It is also important to note that the background value of copper in this lake also is higher than the standard average value for sediments. Same is true for lake Drugguvatnet. The possible causes for higher background value of copper may be attributed to cupriferous shield rocks over which the lakes are developed.

At 21 cm sediment depth levels in the lakes under study the dispersion pattern of copper is different from 6 cm depth levels. Nedre Gruvedam reveals a new site of higher Cu concentration (1000 ppm) near to the western margin and water outlet of the lake (Fig. 5). The concentration contours show decreasing values for copper on either ends. This shift in copper dispersion pattern at 21 cm sediment depth may be an indication of unknown mineralization zone. However, it requires more work for reaching to final conclusion.

Lake Malistja with the highest value of copper concentration (4000 ppm) at 6 cm sediment depth indicates lower content of copper (160 ppm) and the pattern of concentration is also changed at 21 cm depth level. However, higher background value for copper in lake sediments is obvious and the reasons are the same as described for Langdalsvatnet.

No appreciable change in copper concentration and distribution patterns was observable in sediments of Langdalsvatnet and Drugguvatnet at 6 & 21 cm depth levels expect a slight change in values of contents. Most probably this character indicates no effectsd of contamination.

CONCLUSIONS

1. It is more convenient to work on frozen lakes to get sediment column exactly from the desired site of the lake without any disturbance of physical characteristics of sediments.

2. The depth of contamination in the studied sediments is observed to be less than sixteen centimeters.

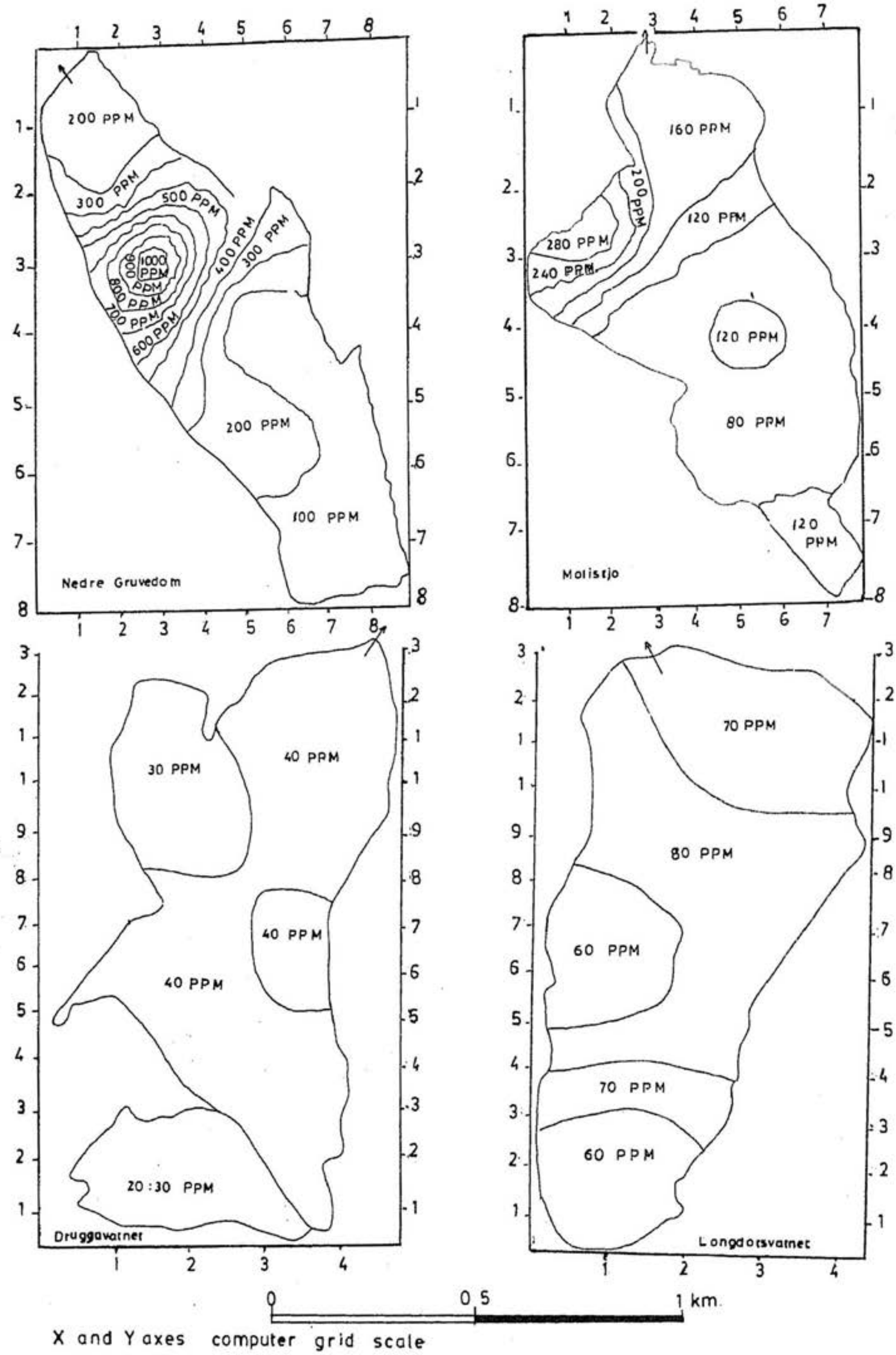

Fig. 5. Copper concentration contours for selected lakes of Lokken Area, Norway at 21 cm sediment depth.

3. Background value for copper in the area understudy is higher than the recommended standard value range, most probably due to development of lakes on cupriferous greenstone of Storon Group.

4. Lake sediment grochemistry can be used as an indicator of mineralization in reconnaissance level of exploration in areas of glacial over-burden where conventional geochemical techniqaues have limited applications.

5. Copper concentration from the contaminated and non-contaminated lakes under study show encouraging results to use this technique for geochemical exploration of ore deposits in glaciated terrains. However, some more work should be done to reach the final conclusions.

Acknowledgements: The senior author is very much indebted to Norwegian Agency for International Development for offering a post-doctoral fellowship and financial assistance which made the work possible. He has also deep sense of gratitude to late Professor Dr. Chr. Oftedhal, Director, Institute of Geology, Technical University of Norway and Dr. B. Bolviken, Director, Chemical Division, Geological Survey of Norway, Trondheim for their interest, incouragment and providing necessary facilities during the work. Thanks are also due to Engr. Rolf Nelsen and his colleagues who cooperated and assisted KAM in the field during collection of samples and field data in severe winter season of Central Norway. The chemical analysis work done for major and minor elements in the Geochemical Laboratories of Geological Survey of Norway is acknowledged with thanks and gratitude.

REFERENCES

Allan, R.J., 1971. Lake sediment: A medium for regional geochemical exploration of the Canadian Shield. Can. Inst. Min. Metall. Bull. 64, 43-59.

Allan, R.J. Cameron, E.M. & Durhan, C.C., 1972. Lake Geochemistry a low sample density technique for reconnaissance geochemical exploration and mapping of the Canadian Shield. Geochemical Exploration Proceeding, 131-160.

Arnold, R.G., 1970. The Concentrations of metals in lake waters and sediments of some Precambrian lakes in the flin Flon and La Ronge areas. Circ. Geol. Div. Sask. Rc. Council. 4, 1-30.

Coker, W.B. & Nichol, I., 1974. Metal dispersion in lake sediments related to mineralization and its role in reconnaissance in the Southern Canadian Shield. Geochemical Exploration Sp. Pub. 2, 549-553.

Coker, W.B. & Nichol, I., 1975. The relation of lake sediment geochemistry to mineralization in the North-Western Ontario region of the Canadian Shield. Econ. Geol. 70, 79-71.

Dyck, W., 1971. Lake sampling VS stream sampling for regional geochemical surveys. Geol. Surv. Paper 71-1, 70-71.

Fedricksson, I. & Qvarfort, U., 1973. The mercury content of sediments from two lakes in Dalarna, Sweden. Geo. For. Stick. Forth.92, 237-242.

Gorham, E., 1955. On some factors affecting composition of Swedish fresh waters. Geochem. et Cosmochem Acta 7, 129-150.

Gorham, E. & Swaine, D.J., 1965. The influence of oxidizing and reducing conditions upon distribution of some elements in lake sediments. Limnol. Oceanogr.29, 53-90.

Hansen, K., 1959. Sediments from Danish lakes. Jour. Sed. Pet.29, 38-46.

Rose, A.W., Hawkes, H.E. & Webb, J.S., 1979. Geochemistry in Mineral Exploration (2nd ed.) Academic Press London.

Kennedy, E.J., Ruch, R.R. & Shimp, N.F., 1971. Distribution of mercury in unconsolidated sediments from southern lake Michigan. Illinoois Geol. Sur. Environ. Geol. Note 44, 1-18.

Mackereth, F.J.H., 1965. Chemical investigations of lake sediments and their interpretations. Proc. R. Soc. B. 161, 295-309.

Mallick, K.A., 1989. Sampling of lake bottom sediments and water from Central Norway. Jour. Sc. Japan (in press).

Motimer, C.H., 1941/42. The exchange of dissolved substances between mud and water in lakes. Jour. Ecol. 29, 30, 280-320 and 147-07 respectively.

Shimp, N.F., Leland, H.V. & White, W.A., 1970. Distribution of major, minor and trace constituents in unconsolidated sediments from Southern Lake Michigan. Illinois Geol. Environ. Geol. Note 32, 1-19.