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NEWNHAM EXPLORATION & MINING SERVICES

MINERAL RESOURCES
EL14/94
25 OCT 1996
See folio 42

MICROFILMED
FICHE No. 014410-14

E.L. 14/94

ZEEHAN AREA

ANNUAL REPORT FOR YEAR ENDING OCTOBER 96

Prepared for:

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October 11, 1996

AMG REFERENCE POINTS ADDED

CONTENTS

1. **SUMMARY**
2. **LOCATION and LAND TENURE**
3. **WORK COMPLETED**
4. **PROPOSED WORK**

Appendices:

1. **Technical Reports of the Geoelectrochemical Survey Method**
2. **Report on First Sampling Program**
3. **Initial Report on Second Sampling Program**
4. **Final Report on second Sampling Program**

338003

1. SUMMARY

Geoelectrochemical surveys completed in 1995 and 1996 indicate a lack of anomalism in the two southern areas but significant anomalism in the eastern areas.

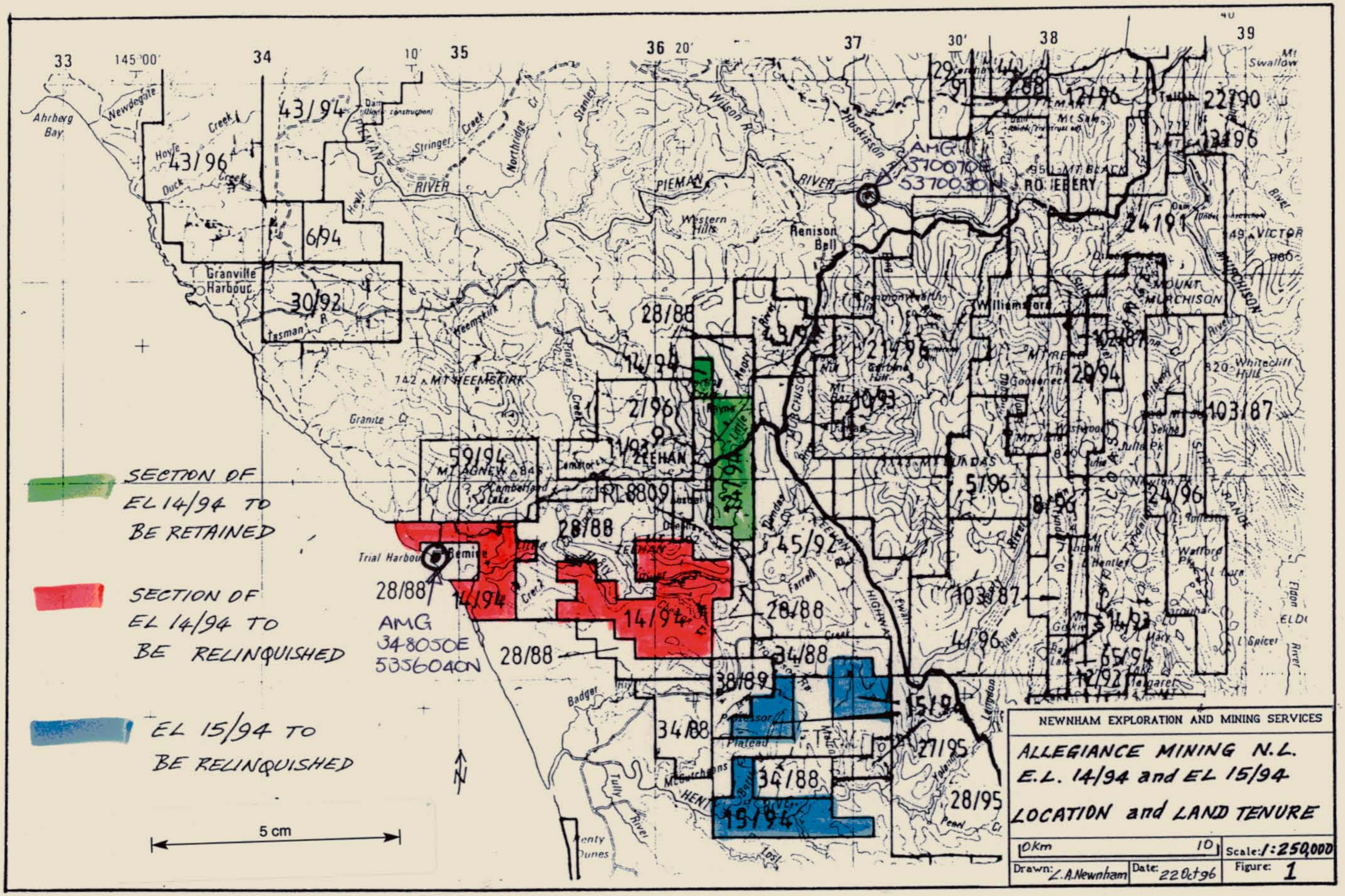
It is recommended that the southern areas be relinquished and detailed data collation and ground checking be undertaken on the remaining areas.

Expenditure to date is $33,837.

2. LOCATION and LAND TENURE (Fig 1)

E.L. 14/94 of 66 square kilometres was granted to Allegiance Mining N.L. on 25 November 1994.

The Licence consists of four separate areas lying to the East and South of Zeehan.



🟩 SECTION OF EL 14/94 TO BE RETAINED

🟥 SECTION OF EL 14/94 TO BE RELINQUISHED

🟦 EL 15/94 TO BE RELINQUISHED

NEWNHAM EXPLORATION AND MINING SERVICES

ALLEGIANCE MINING N.L.
E.L. 14/94 and EL 15/94
LOCATION and LAND TENURE

0Km 10	Scale: 1:250,000
Drawn: L.A.Newnham | Date: 22Oct96	Figure: 1

338005

AMG REFERENCE POINTS ADDED

3. WORK COMPLETED

Allegiance acquired E.L. 14/94 primarily to explore for deeply concealed base metal deposits by the application of geoelectrochemical exploration methods.

Geoelectrochemical exploration has been widely used in Russia and China for many years as a technique for exploring for deposits concealed by deep soils, glacials or other cover rocks. The technique is relatively new to Australia but several variations are currently under investigation.

A selection of papers on the geoelectrochemical technique and results of a number of successful test projects are attached as Appendix 1.

In January 1995, 140? widely spaced soil and rock samples were taken across E.L. 14/94 and sent to Russia for analysis. Only 70 samples were analysed.

The results of this work are presented in the report attached as Appendix 2, titled:

> *A Preliminary Report on Geoelectrochemical Investigations in the Area Zeehan (Tasmania). Prognostic Evaluation of the Territory Stage II,* by Dr. I. Goldberg, 1995

This survey indicated:

- the two eastern sections of E.L. 14/94 were anomalous for a wide range of base metals
- results from the other two sections of the Licence to the South of Zeehan were disappointing.

To follow up the anomalous eastern section, a further more detailed geoelectrochemical soil sampling program was completed in April 1996. This survey involved taking 79 samples, approximately 500 m. apart across the area. They were forwarded to Russia for analysis.

A preliminary report on this work is attached as Appendix 3:

> *Preliminary MPF Electrogeochemical Survey Carried Out by Ionex at E.L. 14/94, Zeehan, Tasmania,* by Manuel Zapata, May 1996

A more detailed report on this survey was prepared once all assays were received and interpreted, and this is attached as Appendix 4:

> *Report on Geoelectrochemical Investigations in the Area E.L. 14/94 Zeehan, Tasmania,* by Ionex, August 1996

Total expenditure to date is $33,837.

333009

APPENDIX 1

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4. PROPOSED WORK

In response to the geoelectrochemical results, it is recommended that the two southern blocks of E.L. 14/94 be relinquished and ground follow up work be undertaken on the anomalous eastern blocks.

In the first instance, it is recommended that this follow up work include:

- collation of the geoelectrochemical data on a set of more detailed geological base maps
- literature search of previous exploration programs in that area
- ground checking of the anomalous sample points to investigate geology and take some more detailed soil samples if appropriate

338010

Appendix

1. Report on Canadian Survey - Siegal & Ryss

   Results of Geoelectrochemical surveys conducted by Rudgeofizika and Scintrex Canada.

2. Journal of Geochemical Exploration - Antropova & Goldberg

   Article in Journal of Geochemical Exploration. co authored by Dr. Goldberg that details Geoelectrochemical methods.

3. Preliminary Studies of CHIM - Smith, Hoover & Sanzolone

   Analysis of CHIM by U.S. Geological Survey.Note reference to Dr. Goldberg as developer on Page 258 1st Paragraph.

X

4. Curriculum Vitae; Anthony Howland-Rose

   Note geophysical contribution to discoveries of ore bodies on Page 2 4th Paragraph.

5. Integrated Methods in Exploration and Discovery - US. Geological Survey

   Conference paper on Geoelectochemistry.

Title: SOME RESULTS OF APPLYING RUSSIAN GEOELECTROCHEMICAL METHODS IN CANADA

Authors: Yu S. Ryss* and H. O. Seigel**

Abstract:

Three geoelectrochemical methods, designated as CHIM, MPF and TMGM, developed by Rudgeofizika, Russia, were tested over five mineral occurrence in Canada in 1990.

The results of these tests show that these methods are capable of indicating the presence of certain base metal occurrences, which lie under as much as 55m of glacial overburden. The tests over two gold occurrences were hampered by limitations of the sensitivity of the analytical method employed. Nevertheless, one of the gold deposits appears to have been detected.

Some operational limitations of the methods were noted during these tests, including the occasional difficulty of obtaining good sampling material for one or more methods, and interferences from surface pollution.

Despite these limitations it is apparent that the GEC methods can play a useful role in future mineral exploration programs in Canada.

* Rudgeofizika, St. Petersburg, Russia
** Scintrex Limited, Concord, Ontario, Canada

SOME RESULTS OF APPLYING RUSSIAN GEOELECTROCHEMICAL METHODS IN CANADA

INTRODUCTION

In the field of resource exploration, the former Soviet Union appears to have developed in somewhat technical isolation from the rest of the world. It has had a massive effort in this field, probably equal to that of the rest of the world combined, at least in terms of manpower. For example, its Ministry of Geology employed over one million people, of whom a total of one hundred thousand worked for their geophysical department alone. They had fifteen research institutes of the Ministry, working on new exploration methods. Much of this enormous structure is still in place, now reporting to the Committee for Geology of Russia.

There are certain areas of the U.S.S.R. exploration technology which are relatively little known in the West, in terms of theory, practice and field results. One such area is in the field of what they call "Geoelectrochemical" (GEC) methods. These, consisting in five variants, have been developed over the past twenty years by Rudgeofizika, a large research institute in St. Petersburg, one of the fifteen such mentioned above.

Scintrex first became aware of the GEC methods in 1983 and entered into a lengthy process of discussion with the Ministry of Geology, which eventually opened the way to the introduction of these methods outside of the U.S.S.R. A formal partnership, named Geoelectrochemical Surveys Partnership (GECP) was formed between Scintrex and Rudgeofizika, for this purpose, in 1991.

THE 1990 CANADIAN FIELD PROGRAM

Whereas there appeared to be ample Soviet case histories on specific Soviet mineral deposits, attesting to the efficiency of these methods, it was Scintrex' opinion that it would be imperative to carry out a test program in Canada, over a range of typical ore deposits of economic interest, in various geologic circumstances. Only in this manner could the application of the methods to the detection of buried mineral deposits, under Canadian conditions, be proven.

With considerable effort, sufficient support was mustered from the Canadian mining industry, the Ministry of External Affairs and International Trade of Canada, and the Ontario Ministry of Northern Development and Mines, to launch an appropriate test program in the summary of 1990. Twelve major mining companies entered into individual agreements for a three-month test program entailing these three geoelectrochemical methods. These sponsors included, in alphabetical order, BHP Mines Ltd., BP Canada Limited, Cominco Ltd., Corona Corporation, Falconbridge Limited, Granges Exploration Limited, Hudson Bay Exploration and Development Co. Ltd., Inco Exploration and Technical Services, Inc. Lac Minerals Ltd., Noranda Exploration Limited, Rio Algom Limited, and Teck Explorations Limited.

A team of 10 senior scientists of Rudgeofizika under the direction of Prof. Yuri S. Ryss, the Chief of the Rudgeofizika Geoelectrochemistry and Geochemistry Division, arrived in Canada in June 1990, together with all their field equipment and one large Russian truck and trailer-mounted MG set. They were joined by a Scintrex party chief and chemist.

The 1990 field test program lasted three months, during which three GEC methods were applied on five mineral occurrences in northeastern Ontario. Fig. 1. These included two gold deposits, one copper-zinc occurrence, one lead-zinc occurrence and one nickel-copper deposit, affording a great range of geological and geomorphological conditions. Figure 1 shows the location of the deposits tested.

A condition of this test program was that the results thereof were to remain confidential until November 1992. Since this restriction has now expired, it would be useful to present some details of this test program and its results.

It may be noted, in passing, that a further GEC program, entailing the same methods, was carried out in Canada in the summer of 1991, over five additional sites in locations ranging from Quebec to Manitoba on behalf of individual clients who participated in the 1990 program.

A test GEC program, of similar scale, was conducted in Australia in 1992, on behalf of five major Australian exploration companies.

AN OVERVIEW OF THE GEOELECTROCHEMICAL METHODS

Scintrex became interested in the geoelectrochemical methods because they appeared to successfully detect ore deposits in some situations where traditional geochemistry would have difficulty in so doing. Examples of some such problem situations are: 1) transported cover, 2) blind deposits and, 3) deposits which are difficult to detect directly because they do not have marked chemical or physical signatures which are detectable at surface. Such problems are often encountered in Canada, particularly in areas covered with glacially transported soils. The three geoelectrochemical (GEC) methods, employed on these programs, are as follows:

- MPF: Method of Prospecting According to the Forms of Elements
- TMGM: Thermomagnetic Method, and
- CHIM: Method of Partial Extraction of Metals

These methods are all based on the hypothesis of the movement of mobile metallic ions, upward from mineral deposits in the earth. These ions may move either passively in the earth due to diffusion forces and natural electricfields, or by virtue of induced electrical fields created for the purpose. Slides 2, 3 & 4.

The MPF technique takes advantage of the fact that soil organics naturally trap mobile ions. Samples of the appropriate organic-rich soil horizon are taken. Extraction of the metal-organics of interest is done, their metal content is analyzed and the result is normalized for the carbon content. Whereas a lithogeochemistry anomaly may be laterally displaced by groundwater movement and topography, etc., MPF anomalies often lie directly over ore deposits. MPF has also been found to work in semi-arid areas where there is very little evident organic material.

The TMGM method is based on the scavenging of mobile ions by iron and manganese oxides in mineral soils. As a rule ,these oxides are found at a depth of 15 to 50 cm. When such samples are heated, the oxides became magnetic, permitting them to be concentrated. Chemical extraction and analysis of the trace metals, associated with the oxides, follows.

While methods based on similar partial extraction procedures have been attempted in North America and elsewhere, the key to Rudgeofizika's success with MPF and TMGM lies in their skill in sampling the appropriate horizons, and in their unique extraction technology.

In the CHIM method, an electric field is established, which attracts near-surface mobile ions to collector electrodes, which are normally cathodes. The solutions in these electrodes are then analyzed for the metals of interest. An advantage of the CHIM method is that a well-defined surface anomaly usually occurs directly over the mineralization. It is this method which has the closest affinity to a geophysical method, as it functions on the basis of electrochemistry as does the IP method.

The MPF, TMGM and CHIM methods have each demonstrated their ability to detect polymetallic, tin, gold, lead-zinc, copper-nickel, copper, molybdenum, rare earth and kimberlite deposits, to depths of hundreds of meters, under a wide range of conditions in the U.S.S.R.

The above three methods rely on similar principals for their function. These principals are: 1) **selectivity, 2) preconcentration, 3) aureole detection.**

In standard geochemistry, one analyzes the total specific metal content of a sample, or of a portion of that sample which has been selected, or example, on the basis of its particle size. The GEC mobile ion content, however, may constitute less than 1% of the total metal content of a sample. In terms of the complete, original sample, therefore, the GEC component of interest will commonly lie in the sub-p.p.m. range, and, in the case of Au in CHIM, in the sub-p.p.b. level. **Preconcentration** is therefore necessary in order to raise the content of mobile ions in the soil up to a sufficient level for analytical measurement. In MPF and TMGM, this is done naturally, in-situ, over long periods of time, by organics, or by iron and manganese oxides, respectively. In CHIM, this is done by transporting mobile metallic ions to an electrode under the influence of an induced electric field. This process effectively samples a much larger volume than the usual soil sample.

Based on Soviet experiences with these methods, ore deposits sometimes can be detected at depths of up to a few hundred of meters. A logical explanation appears to be that a deposit has an aureole of mobile metallic ions, some of which may move at unexpectedly high rates, and which may be detected at a large distance from the deposit, while the total metal content in the soil at the surface may not be high enough to provide a standard geochemical indication.

FIELD PROCEDURES

Samples were obtained for all three methods at stations which are 20m apart, on (generally) three lines across each target area, with some intermediate stations and lines in areas of particular interest. Each profile would be about 1.5km long and their separation would be 100m to 200m, depending on the size of targets of interest.

The CHIM equipment, slides 5, 6, 7 & 8, employed includes a 40 channel transmitter, capable of feeding an equal number of cathodes ("element receivers") simultaneously. It was powered by a 10 KW motor-generator set. Current was commonly passed for up to 20 hours, and the electrolyte containing the collected metals was then retrieved for analysis. In the 1990 program, the CHIM samples were analyzed, in the field, using a Scintrex AAZ-2 atomic absorption spectrometer for base metals, and a Russian polarograph for gold.

The MPF and TMGM samples, gathered from their appropriate horizons, were bagged, dried, and sent out for selective extraction and analysis. These analyses were generally performed using atomic emission spectroscopy. The elements to be analyzed would depend on the metals expected to occur in mineral deposits in the prevailing geological environment.

In addition, as an independent check on how standard geochemistry works in the area and as a check on the possibility of surface contamination, standard soil samples were sometimes taken from the same stations and analyzed for total metal content.

GEC results, like all geochemical results, tend to be "spikey" i.e. there may be considerable variations between adjacent samples, due to the statistical variations of mobile metal content in-situ. For this reason, GEC data are best plotted in profile form. In the case of the CHIM method, results for the 1990 program have been plotted in units of micrograms of metal in the electrode receiver. In terms of concentration values, the equivalence is approximately 1 microgram = 10 parts per billion in solution.

For the TMGM method, the units are percent of the iron and manganese fraction. For the MPF method the units are the ratio of metal to carbon, again in percent.

Profiles may also be presented of the cross-product of the above mentioned results, for several metals which are characteristic of specific types of deposits, e.g. CuxZnxPbxAg in the case of a polymetallic deposit. These cross-product profiles tend to accentuate geoelectrochemical indications from such deposits.

CASE HISTORIES

1. *Montcalm Test Site* Fig. 9

The Montcalm nickel-copper deposits are situated in north-central Montcalm Township, about 70 km northwest of Timmins. They contain 4.2 million tons grading 1.4% nickel, 0.7% copper and 0.1-0.2% cobalt in two main and several smaller lenses. They occur in a gabbro intrusive into volcanics. The deposit is covered by glacial overburden 10-40 cm thick (mainly varved clays, some gravel and sandy till and capped by up to 5 m of peat). Figure 2 shows the results of one of the two profiles over the deposit. The deposit is indicated by nickel and copper responses on the CHIM profiles and the MPF profiles. The TMGM results are not corroborative, largely, it is believed, because good sampling material for TMGM could not be obtained over the area of interest because of thick swamp. The crew was, unfortunately, not equipped with augers long enough to reach into the proper horizon for TMGM samples.

A second GEC line, 70 m away, yielded a somewhat similar response pattern over the deposit.

This case history illustrates two aspects of these methods. Firstly, proper sampling material is necessary if the results are to be meaningful. Secondly, the CHIM and MPF have indicated the presence of this nickel-copper body, through 40 m of glacial overburden.

2. Chance Test Site Fig. 10

This site lies about 2 km northwest of the Kidd Creek polymetallic, VMS deposit, about 30 km north of Timmins. The deposit itself is small (about 200,000 tons) but high grade (3% lead, 13% zinc and approximately 200 g/t of silver), in a VMS body which sub-outcrops under about 55 m of glacial overburden. It is hosted by a sequence of vertically dipping volcanics.

Figure 3 shows the GEC results over the main section of this small lens. The line shown runs parallel to, and within about 100 m of a mine waste road operated by the Kidd Creek mine. The roadbed has been created by dumping minewaste, including suphide-rich boulders. It lies up-drainage from the survey line. Thus, the possibility of surface contamination from this road was a concern during the course of the survey.

The CHIM results amply confirm the surface contamination, showing very high values for copper, lead and zinc, essentially all along the profile.

The TMGM and MPF results, however, show quite a different picture. They indicate lead, zinc and silver responses which are localized in two areas, the larger one being almost directly over the deposit and a smaller one, in a similar geologic environment, about 400 m to the north. The latter location correlates with a known, narrow but persistent, zone of lowgrade zinc. It should be noted that the CHIM results in the latter area are relatively low. The TMGM cross-product (copper x lead x zinc x silver) profile gives a very clear indication of the deposit.

One conclusion here is that the Chance deposit is shown up on both the MPF and TMGM results, despite being hidden under more than 50 m of glacial overburden. A second conclusion is that the CHIM results are very much affected by surfacial contamination from the mine-waste road. The belief that this contamination does not extend deeply enough to affect the MPF and TMGM results is also supported by carefully executed vertical soil profiles, carried out later by Prof. Ian Nichol of Queens University.

3. Harker-Holloway Test Site Fig. 11

This is a gold deposit, lying on the west boundary of Holloway Township, about 45 km NNE of Kirkland Lake. Gold occurs with fine dusty pyrite and some arsenopyrite, in basalts near an ultramafic contact. The deposit is stratabound and dips at 60 degrees to the south. Overburden is less than 20 m thick and includes clay, sand and boulders. Some outcrop occurs on the grid area, including some earlier exploratory workings.

At the time of the GEC survey the property was being actively drilled. Surface contamination was anticipated to be a potential problem as a result.

Figure 4 shows one GEC profile with results of all three methods. CHIM samples were analyzed for gold only, by polarograph, in the field. About 85% of CHIM gold analyses were below the lower limit of detectibility of the analytical method (.01 microgram, or 100 ppt).

Those gold values above this threshold show the following: a) a grouping directly above the sub-outcrop of the gold bearing zone on this section, which essentially apexes about 200 m below surface b) one large and two small values near the Mining Corporation showing to the north and c) two other dual or triple adjacent value anomalies to the south. One of the latter may reflect contamination from a nearby drill hole, but the other is of unknown origin.

The iron and manganese oxides, on which the TMGM method relies, apparently have a low affinity for gold, so that TMGM samples are not analyzed for gold. The TMGM base metal data are not expected to be informative, in this case, as there is no known association with base metals for this gold deposit.

The MPF data also shows a much higher percentage of gold analyses above the analytical threshold. They provide a somewhat similar set of indications as the CHIM, including a series of values over the sub-outcrop of the gold-bearing zone, responses over the Mining Corporation showing on its up-dip extension, and the two indications farther to the south.

This case history illustrates a number of points, via:

a) the CHIM and MPF results appear to be reflecting the presence of the gold bearing zone on this property,
b) surface contamination is a problem, particularly near outcrops which are somewhat mineralized.
and c) an analytical method of higher sensitivity (at least 10 fold - i.e. to 10 ppt) for gold is required, to provide more meaningful CHIM data.

4. Currie-Bowman Test Site Fig. 12

This site is situated about 70 km east of Timmins, on the Currie-Bowman township line. It is essentially a polymetallic prospect where patchy, ill-defined, sulphide lenses containing copper, lead and zinc, have been intersected by drilling, in graphitic argillites near a contact with feldspathic volcanoclastics.

Overburden ranges from nil to 35 m, being thickest over the best part of the prospect. It consists of lacustrine clays and silts, overlying a thin layer of sands and gravels.

Figure 5 shows the GEC profile over the main mineralized zone on the site.

Well defined CHIM responses are to be seen directly over the zone, in lead, zinc, copper and silver. Strangely enough, this is not corroborated by the TMGM or MPF in the same location. These methods do show significant relief on all metals (particularly zinc) but these occur on the flanks of the mineralized zone, one of which coincides with an outcrop location.

This case history shows that a) the CHIM method can give positive indications directly over a polymetallic mineralized zone, which is buried beneath 35 m of glacial cover, largely lacustrine clays. The MPF and TMGM responses, whereas strong, do not spacially correlate with the zone, but flank it. Some of these responses may be associated with an outcrop in their vicinity.

5. Windjammer Test Site Fig. 13

This site lies astride the Dester-Porcupine fault zone, about midway between Matheson and the Quebec border. It contains two small, low-sulphide, quartz-carbonate stockworks carrying gold values. The host rocks are conglomerates and greywackes.

The site is overlain by the east flank of the Munro esker, with 38 to 88 m thickness of sand and silt.

Figure 6 shows a GEC traverse over one of these gold-bearing zones; where the esker is 40-50 m thick.

The CHIM samples were analyzed for gold, zinc and silver. Over 60% of the samples returned gold values of less than the analytical threshold. These samples which were above the threshold in gold are largely in the section of the profile containing the auriferous zone. However, these samples are by no means continuous.

As in the case of the Harker-Holloway site, it is clear that an analytical technique of higher sensitivity is required for gold analyses on CHIM samples.

The TMGM results were not analyzed for gold for reasons already stated. So far as the MPF results are concerned, the levels of gold in the organic fraction were too low to be detectible.

Curiously enough, there appears to be an indication of the auriferous zone on the TMGM cross-product profile (copper x lead x zinc x silver).

This case history is more indicative of problem areas than of a fruitful application of the GEC methods. Firstly, an esker provides poor sampling material for the MPF and TMGM methods. Secondly, for CHIM gold analyses, a higher analytical sensitivity (or lower threshold of detection) is required.

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CONCLUSIONS

The results of the limited geoelectrochemical test work over known mineral occurrences in Canada in 1990 have confirmed that the methods are capable of indicating the presence of certain base metal and gold occurrences, which are overlain by as much as 55m of glacial overburden. Such overburden cover generally precludes the effective use of standard soil geochemistry. The deposits are usually best indicated by anomalies in the ore metals, but often associated, non-ore elements, are useful for detection as well.

There are some limitations to the GEC methods, that have appeared in the work to date.

Firstly, not all methods, necessarily, give a significant indication of the mineral occurrence in each case. Insufficient work has, as yet, been done to be able to predict which of the methods will work best in any particular set of circumstances. The Russians appear to have come to the same conclusion, in that they recommend the use of both MPF and TMGM simultaneously, for reconnaissance exploration.

Secondly, certain types of overburden conditions (e.g. esker) may make it difficult to obtain good sample material for the MPF or TMGM methods (lately using ICP-MS in Australia, for this purpose).

Thirdly, care should be taken to avoid areas of surfacial contamination, as this may obscure some of the GEC results. The CHIM method is particularly sensitive to such contamination.

Lastly, a method of analysis for gold, of higher sensitivity, than that employed to date, is required for the CHIM samples.

Despite these limitations, it is apparent that GEC methods can play a useful role in the future in mineral exploration programs in Canada. Moreover, it is expected that some of these limitations can be reduced or even overcome by careful planning, sampling, and development of analytical techniques, in due course.

Typical Canadian exploration problems to which these methods may be applied may include, for example;

1) testing of conductors located by airborne or ground electromagnetic surveys, to ascertain which sections of them may be of potential economic interest, and therefore warrant drilling.

2) exploration for blind and deeply buried deposits in areas of favourable geology; and

3) direct exploration for gold deposits which do not have a high sulphide association.

December 21, 1992

Yuri S. Ryss
Harold O. Seigel

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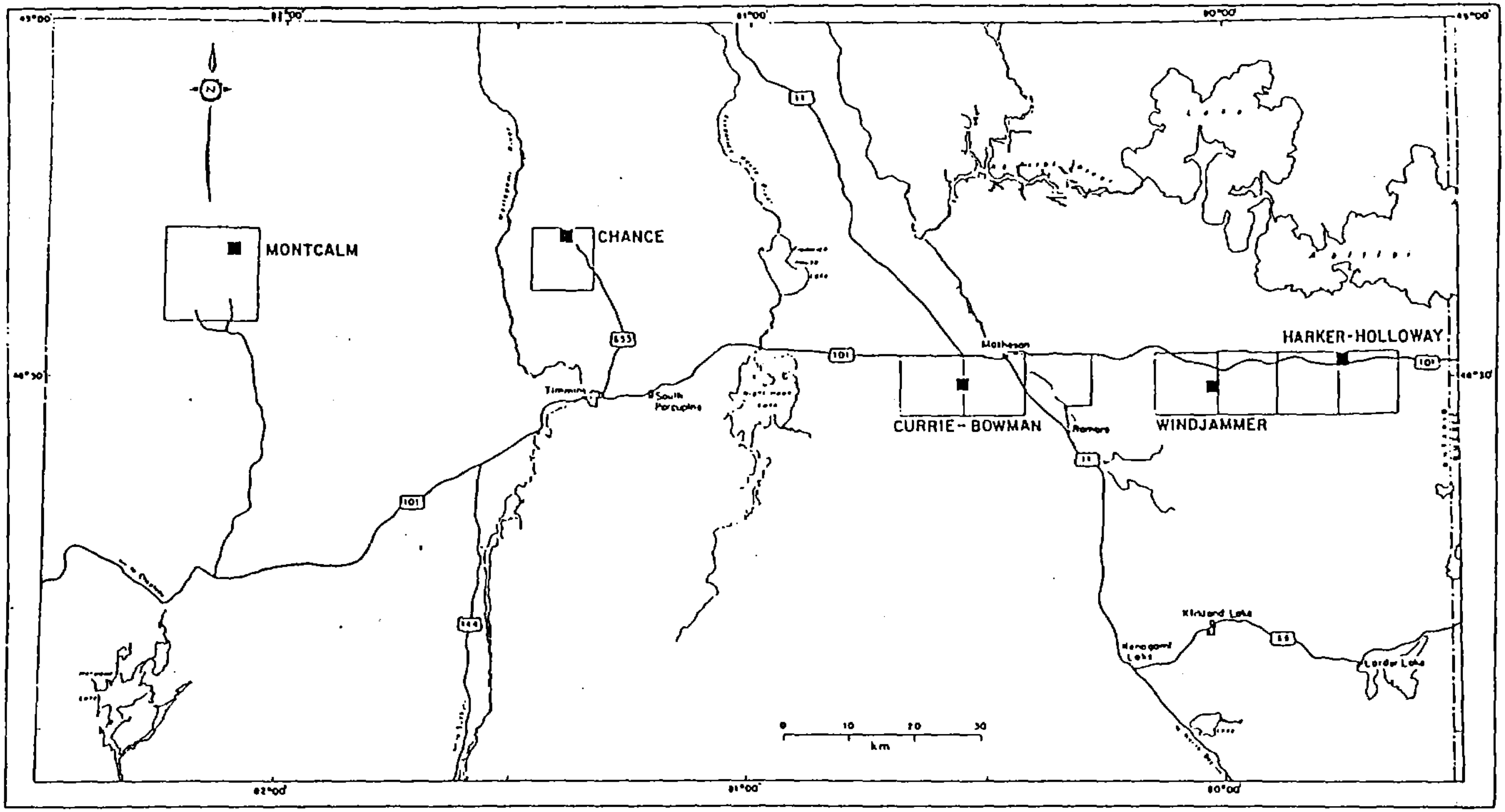

SITE LOCATION PLAN

5 cm

FIG 1

MONTCALM TEST SITE

580 N PROFILE

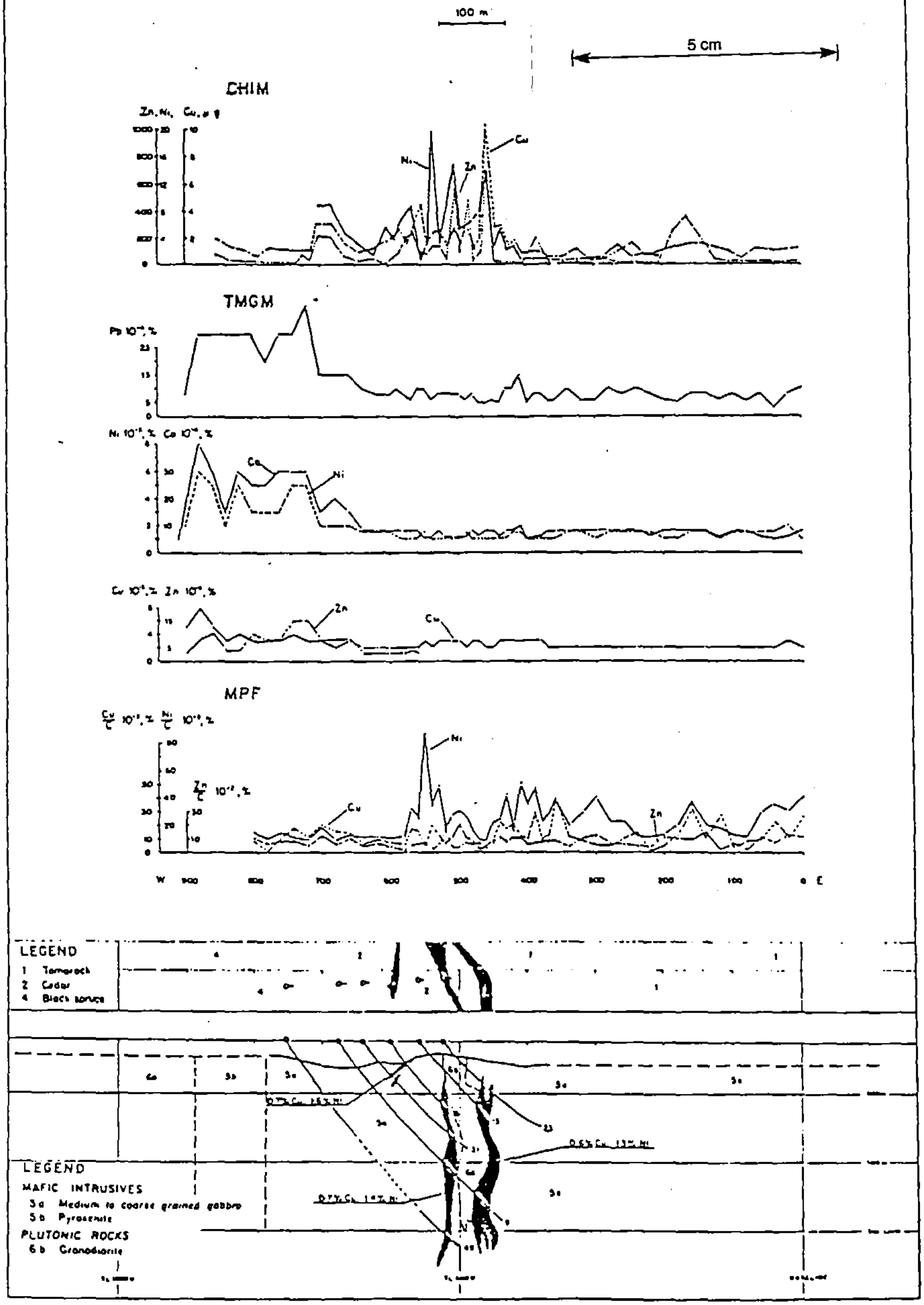

FIG. 2

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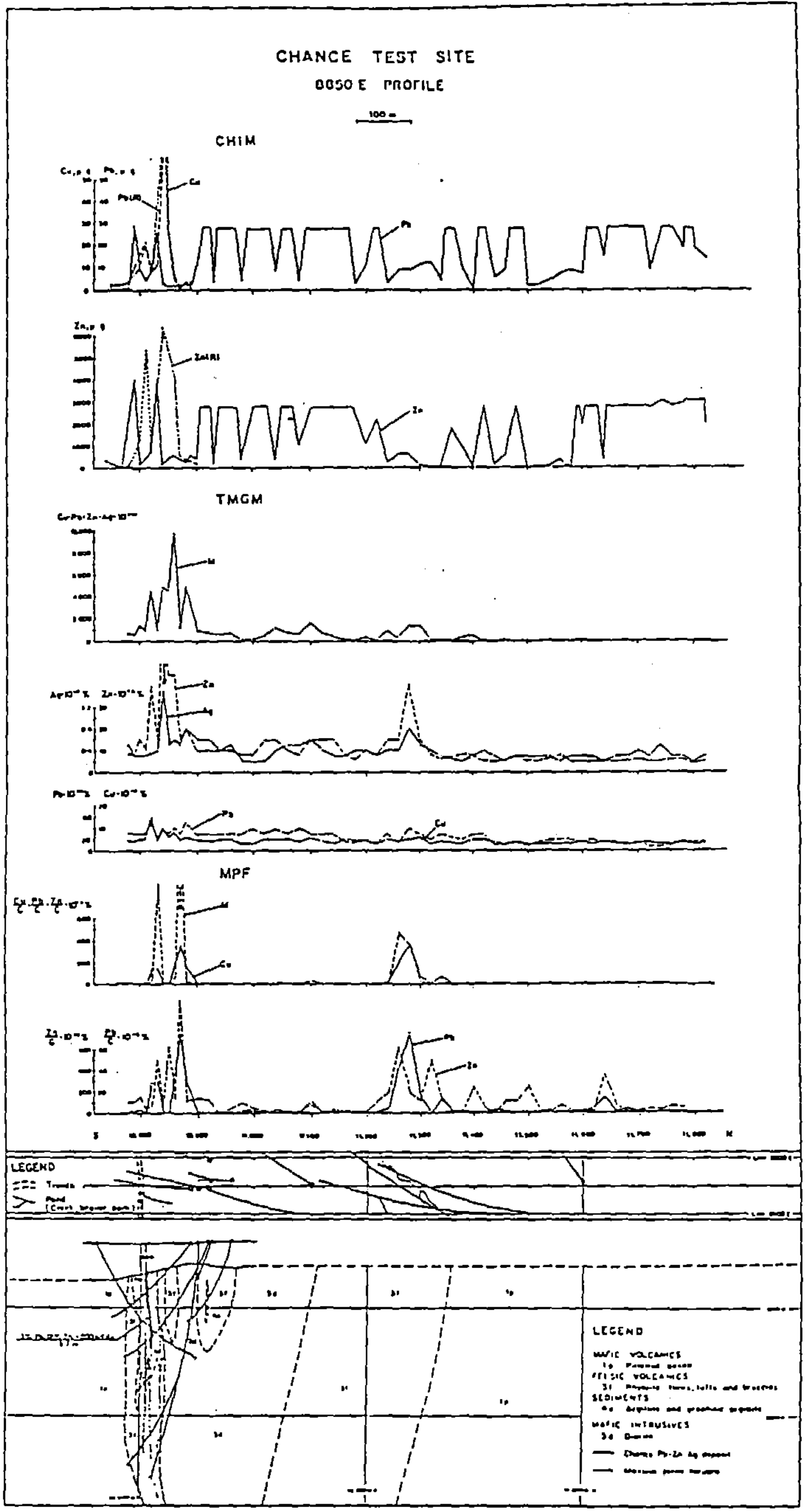

FIG 3

5 cm

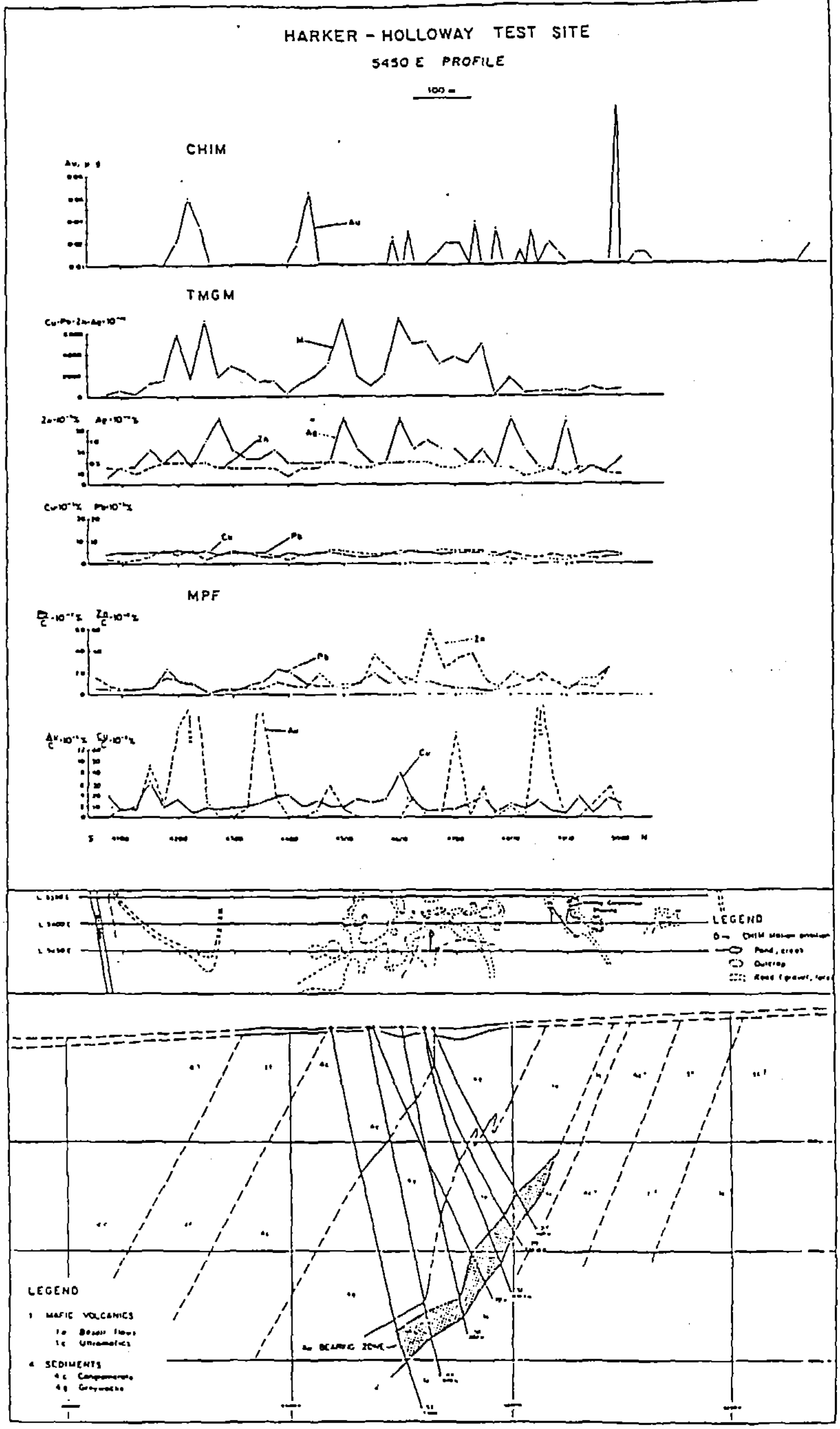
HARKER - HOLLOWAY TEST SITE
5450 E PROFILE
100 m
CHIM
Au
TMGM
M
Zn
Ag
Cu
Pb
MPF
Pb
Zn
Au
Cu
S
N
LEGEND
CHIM
Pond, creek
Outcrop
Road (gravel, ...
Au BEARING ZONE
LEGEND
1 MAFIC VOLCANICS
1a Basalt flows
1c Ultramafics
4 SEDIMENTS
4c Conglomerate
4g Greywacke

FIG 4

5 cm

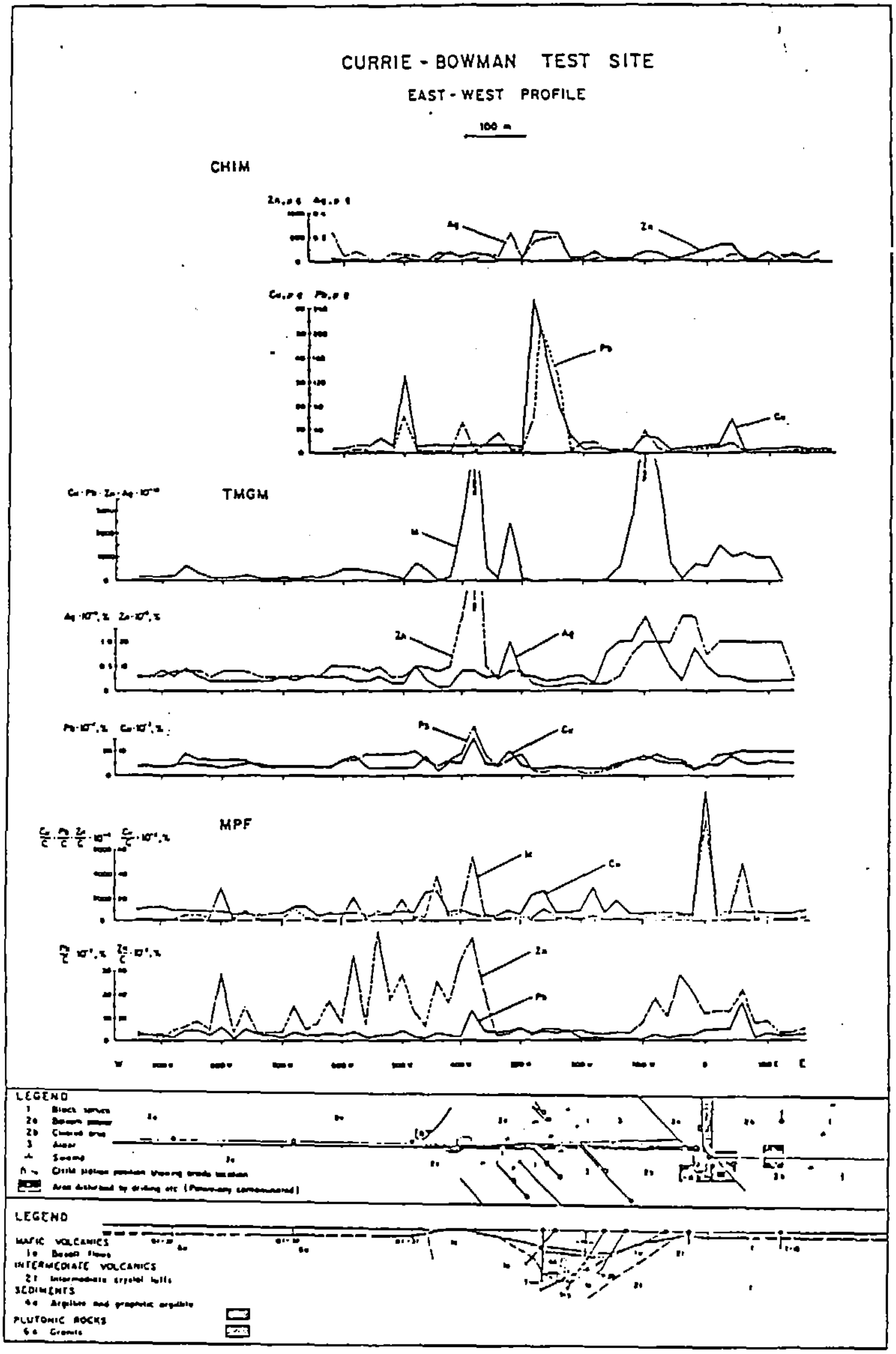
CURRIE - BOWMAN TEST SITE
EAST - WEST PROFILE
100 m
CHIM
Ag
Zn
Pb
Cu
TMGM
Zn
Ag
Pb
Cu
MPF
Zn
Pb
W
E
LEGEND
1 Black spruce
2b Cleared area
3 Alder
4 Swamp
LEGEND
MAFIC VOLCANICS
1a Basalt flows
INTERMEDIATE VOLCANICS
2i Intermediate crystal tuffs
SEDIMENTS
4a Argillite and graphitic argillite
PLUTONIC ROCKS
6a Granite

FIG 5

5 cm

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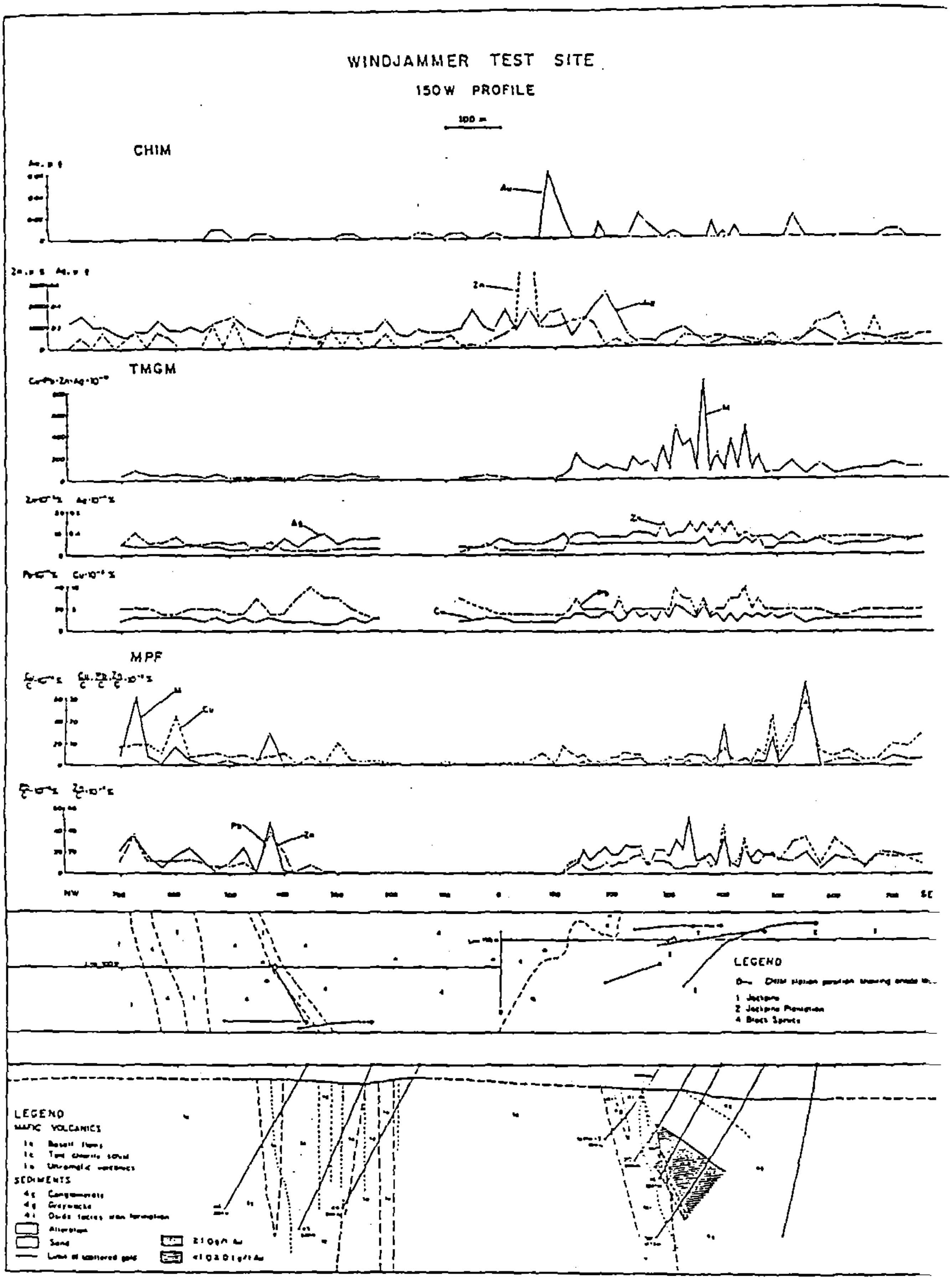

FIG

5 cm

338027

Journal of Geochemical Exploration, 43 (1992) 157–166
Elsevier Science Publishers B.V., Amsterdam

New methods of regional exploration for blind mineralization: application in the USSR

L.V. Antropova, I.S. Goldberg, N.A. Voroshilov and Ju.S. Ryss
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(Received 13 December 1990; accepted after revision 23 April 1991)

ABSTRACT

Antropova, L.V., Goldberg, I.S., Voroshilov, N.A. and Ryss, Ju.S., 1992. New methods of regional exploration for blind mineralization: application in the USSR. *J. Geochem. Explor.*, 43: 157–166.

This paper briefly reviews and draws attention to more detailed reports in the USSR literature for new methods of exploration for blind mineralization. There are based on the selective extraction of trace elements in mobile form from bedrock and soil. These are: (1) regional exploration using organically bound forms of elements (MPF); (2) elements complexed by secondary iron and manganese oxides (TMGM); and (3) electrogeochemical (partial) extraction of elements (CHIM). Results are given for the application of the methods to several areas of the USSR. These results show that the methods can detect blind mineralization at a depth of 500 m or more in various landscape and climatic environments. The MPF and TMGM methods are applied at the regional level to identify prospective target areas, while the CHIM method is for detailed exploration.

INTRODUCTION

As well as improving existing techniques used to detect near-surface mineralization, new methods must be developed in order to successfully explore for blind deposits. An attempt has been made to apply the potential of electrogeochemical methods to the problem of exploration for blind mineralization by using selective extraction techniques to isolate and analyze the mobile form(s) of elements. As far back as 1936, N.I. Sarfronov (1936) identified a secondary (superimposed) component in dispersion haloes in addition to a mechanical (residual) component. The secondary component is the result of electrochemical and chemical processes. The latter causes changes in minerals, transformation of elements from primary forms of occurrence into mobile ones, and migration of elements in all directions, including vertically to the surface. Subsequent interaction between these elements and the enclosing medium results in transformation into various secondary forms of occur-

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338028

Fig. 1. Map of USSR showing the sites described in the text. The numbers on the map correspond to the figures listed below for each locality.

rence. Special methods for detecting and determining the secondary forms of elements are required, since only a relatively small portion of elements are found in secondary forms, compared to the total contents of those elements in bedrock. Investigations were initiated in the USSR to develop methods and equipment to provide selective extraction of individual forms of occurrence of trace elements derived from and in bedrock (Ryss and Golberg, 1973; Vostroknutov and Juskov, 1968; Albul et al., 1968; Mayorov, 1972; Sayet and Nesvizhskaya, 1974; Antropova, 1975; Bogoljubov et al., 1978; Voroshilova, 1982; Grigorjan, 1982).

Among others, the following new exploration techniques developed by Rudgeophysika have been proposed and are being introduced into geological organizations within the USSR:

1. regional exploration using the organically bound forms of occurrence of elements (MPF),
2. thermomagnetic (secondary iron and manganese complexed forms of occurrence of the elements) geochemical method of regional exploration (TMGM); and,
3. the electrogeochemical method of partial extraction of elements (CHIM).

The essence of each method is presented and examples of results obtained from different areas of the USSR (Fig. 1) by the application of the methods are given.

REGIONAL EXPLORATION USING THE ORGANICALLY BOUND FORMS OF OCCURRENCE OF ELEMENTS (MPF) (Antropova, 1975; Antropova et al., 1980)

The MPF method is based on the extraction of metal–organic acid compounds (fulvic–humic complexes: FHC) from soils. To extract FHC, a selective solvent, sodium pyrophosphate, was used. Sodium pyrophosphate also dissolves sorbates and water-soluble compounds, but these are present in insignificant quantities in comparison to the amount of trace elements in the organic complexes. For a quantitative assessment of the amount of organic matter, which is contained in the pyrophosphate extract, organic carbon is determined. The concentration of a trace element (Me) is described relative to the amount of organic carbon (%C) by Me/C. Such ratios satisfactorily show the concentrations of trace elements being collected in FHC, independent of the quantities of fulvates and humates. Normalizing to organic carbon compensates for errors arising from incomplete humate and fulvate extraction, and allows for partial extraction of FHC from soils (usually, samples are treated once using pyrophosphate). To determine trace amounts of elements in FHC, different types of analyses are carried out: photocolourimetry, polarography, chemico-spectral and others, which allow determination of elements in the ranges of $n\times10^{-1}$ to $n\times10^{8}$%. Elements determined include Pb, Zn, Cu, Ni, Co, Sn, W, Bi, Sb, As, Ga, Ge, Mo, Ag, Cr, V, Be, Y, Yb, Au and C.

Experience in the application of the MPF method for regional exploration has shown that deep-seated mineralization (up to 500 m) and those under thick unconsolidated overburden (in excess of 150 m) can be detected. As examples, results obtained in the search for both deep-seated polymetallic and gold mineralization are presented. Figure 2 shows the detection of polymetallic mineralization, in the humate–fulvate complexes of soils. This polymetal-

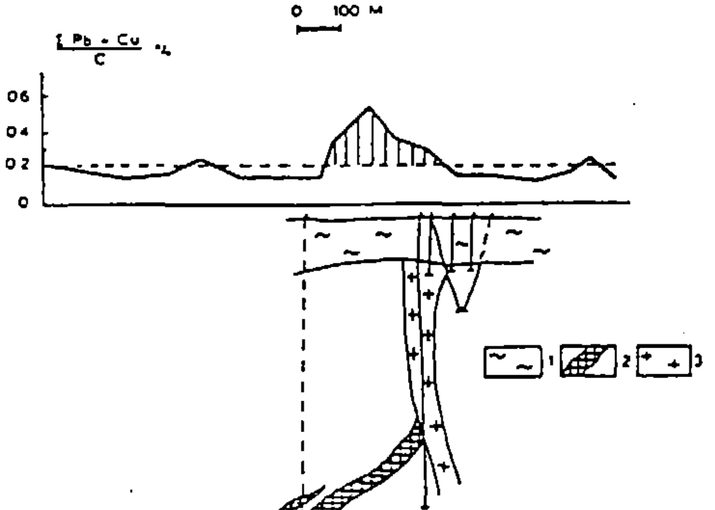

Fig. 2. Lead and copper in fulvate–humate complexes from soils over polymetallic mineralization at Rudny Altai. (1) Unconsolidated overburden. (2) Polymetallic mineralization. (3) Albite-porphyry dyke.

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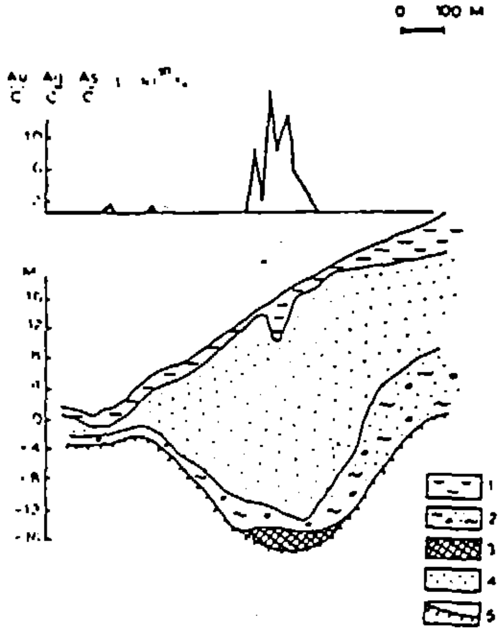

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Fig. 3. Gold, silver and arsenic in the fulvate–humate complexes from soils over an occurrence of placer gold. (1) Clay. (2) Gravels with sandy lenses. (3) Placer gold mineralization. (4) Bedrock.

lic mineralization, at Rudny Altai, occurs at a depth of 500 m and is cut by an albite-porphyry dyke. Transported overburden, represented by clays overlain by loam, ranges from 100–120 m in thickness. Figure 3 is an example illustrating the detection of placer gold mineralization in Zabarkalie buried beneath 40 m of unconsolidated sediments. Here, a multiplicative anomaly for Au, Ag, and As in fulvate-humate complexes is observed. The intensity of the anomaly is three orders of magnitude above background.

THERMOMAGNETIC GEOCHEMICAL METHOD OF REGIONAL EXPLORATION (TMGM) (Bogoljubov et al., 1978; Voroshilova, 1982)

The TMGM method is based on the selective extraction of bedrock-related metals associated with iron and manganese oxides and hydroxides (ferri-manganese forms). To extract these metals, primary magnetic minerals are first removed and the sample fired under reducing conditions. In the firing process, the secondary iron-bearing minerals are reduced to strongly magnetic compounds (magnetite, maghematite, wustite) which can be extracted from samples by magnetic separation. The extracted thermomagnetic fraction is analyzed for a wide range of elements using spectral, X-ray and other methods. On the basis of the upgraded contents of trace elements in the ther-

338031

momagnetic fraction of surface soil samples targets related to blind mineralization can be defined.

To illustrate the TMGM method, results over a tin deposit in the Far East are presented (Fig. 4). In this swampy area, tin mineralization in sandstone, beneath 30 m of Quaternary clays, was detected using the TMGM method. The mineralization was reflected by increased contents of Sn as well as the associated elements Pb, Ag and Sb. Examples also exist that show the successful application of the TMGM method in exploration for polymetallic, tungsten, gold and other types of mineralization beneath up to 100 m of uncon-

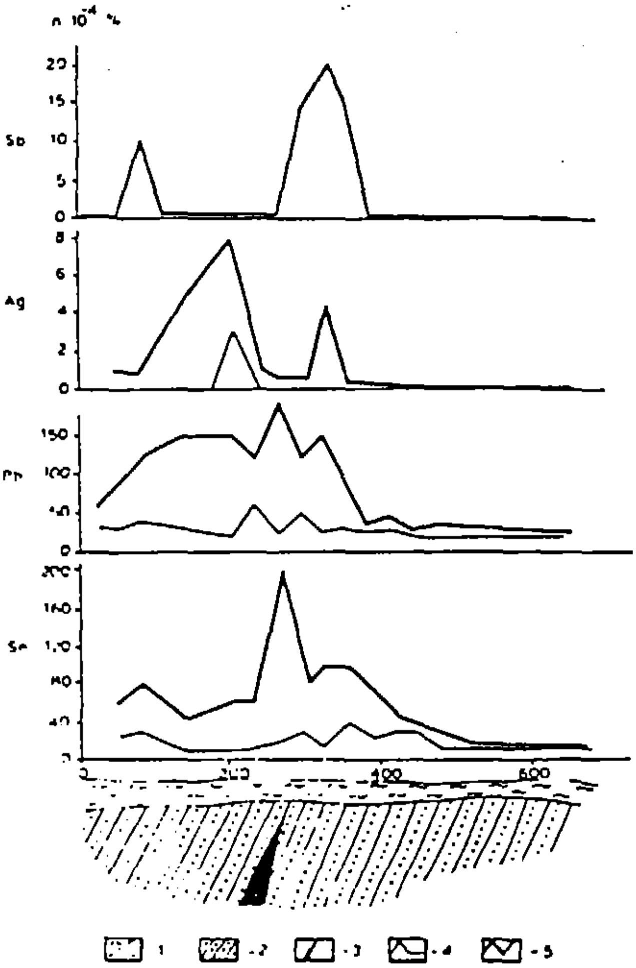

Fig. 4. A comparison between TMGM (4) results and lithogeochemical (5) results for antimony, silver, lead and tin over a tin-bearing zone covered by unconsolidated sediments. (1) Unconsolidated clay. (2) Sandstone. (3) Tin-bearing zone.

solidated overburden, as well as mineralization covered by up to 500 m of bedrock.

THE ELECTROGEOCHEMICAL METHOD OF PARTIAL EXTRACTION OF ELEMENTS (CHIM) Ryss and Goldberg, 1973; Goldberg et al., 1978)

The CHIM method enables the halo of the distribution of electromobile forms of trace elements in surface soils and rocks to be studied (Shmakin, 1985; Eng. Min. J., 1990). The elements are extracted into an element receiver consisting of a cylindrical polyethylene vessel with a capacity of 40 to 50 ml, covered on one end with an ion permeable membrane made of parch-

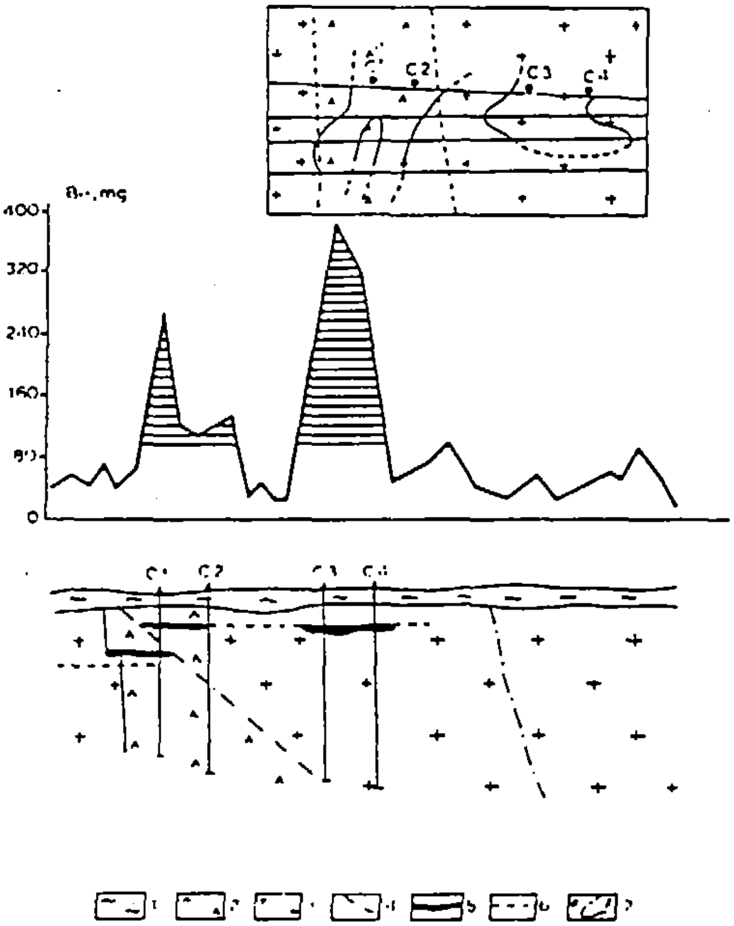

Fig. 5. Results obtained employing the CHIM methodology over rare-earth element mineralization. (1) *Glaciofluvial sediments.* (2) Diabase. (3) Granite. (4) Faults. (5) Rare-earth element mineralization containing beryllium. (6) Stringers of rare-earth element mineralization containing beryllium. (7) Contours of CHIM beryllium anomalies: (a) proven, (b) probable.

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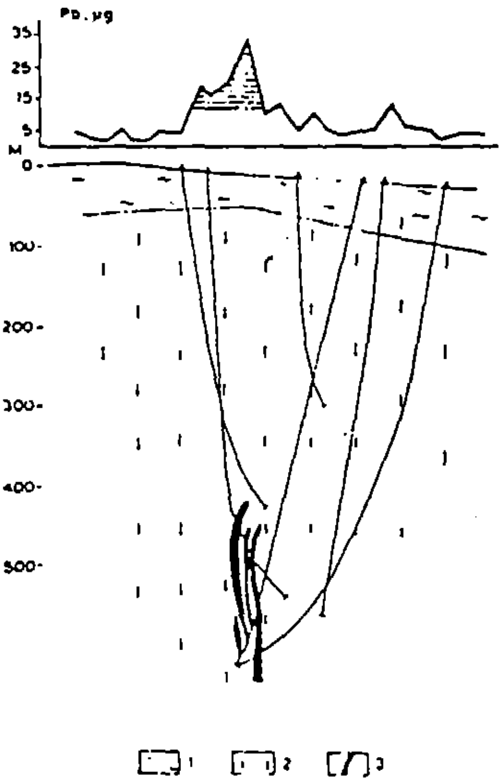

Fig. 6. Results obtained employing the CHIM methodology over polymetallic mineralization in Rudny Altai. (1) Unconsolidated sandy-clay overburden. (2) Volcaniclastic strata. (3) Polymetallic mineralization.

ment, into which is put an electrode and electrolyte solution (HNO_3). Extraction of ions into the element receiver can be done in either cathode or anode mode.

Currently, there are cathode extraction methods for Au, Pb, Cu, Zn, Fe, Ni, Co, Sn and an anode extraction method for Mo.

For selective extraction of the electromobile forms of elements and correlation of their quantities among element receivers an electrochemical process is chosen and the data normalized with regard to the time of collection and the intensity of the electric field used at each element receiver (Goldberg et al., 1978). The special CHIM Station used with the CHIM method provides simultaneous extraction of elements into 40 element receivers which can be placed along a profile or distributed over a promising site. Element receivers are commonly spaced 20 m apart but this may vary depending on the problem being addressed. The CHIM methodology is now being used in regional exploration for polymetallic, copper–nickel, gold, tin, molybdenum and other types of mineralization.

Results from the CHIM method, which detected deep-seated beryllium mineralization in Belorussia, are presented in Fig. 5. In this case, gently dipping mineralized lenses, which occur within a diabase dyke and metasomatized granite, are covered by unconsolidated overburden and bedrock totalling over 40 m. The CHIM method detected a Be anomaly over the known mineralization (drillholes C-1 and C-2). At the same time, a second similar anomaly unrelated to any known mineralization was obtained. Subsequent drilling (drillholes C-3 and C-4) revealed new Be mineralization beneath the second CHIM anomaly.

CHIM results over a polymetallic deposit in Rudny Altai are illustrated in Fig. 6. In this section, the mineralization occurs in volcaniclastic strata at a depth of 450 m. The area is covered by 60–80 m of sandy-clay overburden. A CHIM Pb anomaly occurs directly over the ore zone.

CHIM results obtained by geological organizations in the USSR confirm the potential of the method and its effectiveness in locating deep-seated mineralization buried beneath unconsolidated overburden is excess of 150 m and bedrock in excess of 400–500 m.

CONCLUSIONS

From the data presented and through experience in the practical application of the methods described, the following conclusions can be made:

Deep-seated and/or blind mineralization beneath overburden (in excess of 150 m) and bedrock (in excess of 500 m) can be traced at surface on the basis of trace element anomalies when the elements are in easily mobile and poorly bonded forms of occurrence such as in electromobile forms (CHIM); in fulvate-humate compounds (MPF); and, in secondary ferri-manganese compounds (TMGM). The elemental composition of the anomalies is determined by the composition of the mineralization. These new methods can be applied to regional exploration for various types of mineralization (copper-nickel, porphyry copper, polymetallic, rare-earth element, gold, and others).

Mineralization can be located under significant thicknesses of unconsolidated overburden (in excess of 150 m) regardless of the age and composition of the overburden. Trace element anomalies detected by the methods outlined (i.e. MPF, TMGM and CHIM) can be obtained for mineralization beneath very permeable overburden and dense clay (i.e. Quaternary moraines, river alluviums, glaciolacustrine sediments). Trace element anomalies over deep-seated mineralization can be located under various landscape-climatic situations such as: permafrost, swampy and boggy, arid and semi-arid landscapes etc. The similarities in the results obtained by these techniques (MPF, TMGM and CHIM) within a variety of geological and natural settings illustrates the universal character of the phenomena which give rise to the forma-

338035

tion of geochemical haloes at great distance above the buried mineralized source.

Anomalies obtained differ in a number of characteristics: (a) they are located over the head of deep-seated mineralization and have a local character; (b) the width of the anomalies depends on the depth of occurrence of mineralization to a small extent and as a rule, does not exceed the width of the mineralization by more than 2–3 times; (c) the magnitude of the anomalies in weight and concentration of elements within the same geochemical landscape is independent of the depth of occurrence of the mineralization.

The local character of the detected anomalies suggests the presence of channelways through which fast migration and streaming of elements occurs over great distances from depth to surface. In some cases, such streams are detected as anomalous quantities of the mobile forms of occurrence of elements (Antropova et al., 1980) in the transported sediments covering the mineralization. The possibility of detecting these new types of haloes by phase analyses offers a solution to the problem of exploration for blind mineralization beneath a thick cover of unconsolidated overburden.

The MPF and TMGM methods may be applicable at all stages of regional mineral exploration from reconnaissance level (1:200,000–1:50,000), identifying prospective target areas, to detailed follow-up level assessing mineralization. The CHIM methods is likely more applicable at the detailed scale of exploration (1:10,000 and more detailed), for classifying geophysical and geochemical anomalies, and at the assessment stage for verifying the anomalies detected in order to locate their epicentres.

Experience in applying MPF, TMGM and CHIM in various regions of the USSR shows that these new methods allow rational location of exploration drillholes as well as a significant reduction (up to 40%) in the number of holes required to assess a target. Overall, the geological and economic effectiveness of the exploration program increases. The greatest benefit has been achieved in regions with unconsolidated overburden in excess of 100 m.

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REFERENCES

Albul, S.P. et al., 1968. Sorption-saline method of regional exploration for ore deposits under of overburden in Almalyk. In a collection of articles: Lithochemical Exploration for Ore Deposits Based on their Hypergenic Haloes and Dispersion Streams. Alma-Ata, pp. 119–120.

Antropova, L.V., 1975. Forms of Occurrence of Elements in Dispersion Haloes of Ore Deposits. Nedra, Leningrad, p. 144.

Antropova, L.V. et al., 1980. Regional exploration for deep-lying gold deposits based on metal-organic forms of occurrence of elements. In a collection of articles: Methods and Techniques of Exploration, No. 136, ONTI VITR, Leningrad, pp. 22–29.

Bogoljubov, A.N., Voroshilov, L.N. and Voroshilov, L.N., 1978. Physicochemical basis of thermomagnetic geochemical method and a first experience of its application. In: Geochemical Basis for Exploration and Prediction of Ore Deposits. Nauka, Novosibirsk, pp. 168–170.

Dolukhanova, N.I., 1959. Soil-hydrochemical method of regional exploration for mineral deposits. Bulletin ONTI VIMS, No. 4.

Goldberg, I.S. and Ryss, Ju.S., 1968. A Method of Mineral Exploration. Author's certificate No. 237287.

Goldberg, I.S., Ivanova, A.V., Ryss, Ju.S., Veikher, A.A., Bakhtin, Yu.G., Alekseev, S.G. and Yakovlev, A.F., 1978. Exploration for Ore Deposits by the CHIM Method (Manual). ONTI VITR, Leningrad, 75 pp.

Grigorjan, S.V., 1982. Orogenic Geochemical Anomalies. M., Nedra, pp. 207.

Mayorov, N.F., 1972. An exploration method for copper-nickel deposits based on the superimposed saline dispersion haloes in moraine sediments in Kola Peninsula. In: Lithochemical Exploration for Ore Deposits. Alma-Ata, pp. 227–237.

Safronov, N.I., 1936. To the Dispersion Haloes of Mineral Deposits and their Application in Exploration. Problems of Soviet Geology, Vol. 6, No. 4.

Sayet, Ju.E. and Nesvizhskaya, N.N., 1974. Study of forms of occurrence of elements in the secondary dispersion haloes. M., VIEMS, Series III, pp. 1–14.

Voroshilova, L.N., 1982. A method of tracing poorly pronounced tin-bearing zones from the surface. In a collection of articles: Methods of Exploration Geophysics. Leningrad, pp. 48–61.

Vostroknutov, G.A. and Jushkov, Ju.N., 1968. The application of particle-phase analysis method in lithochemical regional exploration in the Urals. In the collection of articles: Lithochemical Exploration for Ore Deposits. Alma-Ata, pp. 124–125.

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338037

Preliminary studies of the CHIM electrogeochemical method at the Kokomo Mine, Russell Gulch, Colorado

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ABSTRACT

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The CHIM electrogeochemical exploration technique was developed in the former Soviet Union about 20 years ago and is claimed to be effective in exploration for concealed mineral deposits that are not detectable by other geochemical or geophysical techniques. The method involves providing a high-voltage direct current to an anode and an array of special collector cathodes. Cations mobile in the electric field are collected at the cathodes and their concentrations determined. The U.S. Geological Survey started a study of the CHIM method by conducting tests over a precious- and base-metal-bearing quartz vein covered with 3 m of colluvial soil and weathered bedrock near the Kokomo Mine, Colorado.

The tests show that the CHIM method gives better definition of the vein than conventional soil geochemistry based on a total-dissolution technique. The CHIM technique gives reproducible geochemical anomaly patterns, but the absolute concentrations depend on local site variability as well as temporal variations. Weak partial dissolutions of soils at the Kokomo Mine by an enzyme leach, a dilute acetic acid leach, and a dilute hydrochloric acid leach show results comparable to those from the CHIM method. This supports the idea that the CHIM technique is essentially a weak in-situ partial extraction involving only ions able to move in a weak electric field.

INTRODUCTION

In 1989, the U.S. Geological Survey (USGS) started a formal program to investigate the Russian electrogeochemical method *Ch*astichnoe *I*zvlechennye *M*etallov (CHIM), which means partial extraction of metals. The method is claimed by Russian researchers to be particularly effective in exploration

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for concealed mineral deposits that are not detectable by other geochemical or geophysical techniques. CHIM was developed by I.S. Gol'dberg and Yu.S. Ryss, principal investigators, and others at the National Institute for Exploration Technology in Leningrad about 20 years ago. Russian literature states that the method has been applied to exploration for base and precious metals and for deposits of Ni, Co, Mo, W, U, Sn, REE, Be, and oil and gas.

The method has received only minimal attention in the English-language literature. Shmakin (1985) and Antropova et al. (1992) gave a brief overview of the development and application of the CHIM technique in the former Soviet Union; Talapatra et al. (1986) discussed results of tests performed by the Geological Survey of India; and Xu et al. (1989) summarized the use of "electrogeochemical extraction" in gold exploration in China. The USGS has recently made available translations of several papers from the Russian literature on the application of the CHIM technique (Bloomstein, 1990).

The technique uses a DC electrical current introduced into the earth to draw mobile cations into specially designed cathodes. Ions collected in this manner constitute a geochemical sample of mobile ions extracted from soil in the vicinity of the electrode. The technique may be thought of as an in-situ partial chemical extraction.

Search for a local site where initial testing of the method and equipment could be made began in late 1989. Attention was focussed on the Central City and Idaho Springs mining districts, Colorado, where base metals accompany gold and silver in pyritic quartz veins. Base metals are associated primarily with the distal parts of the system, which contain pyrite, sphalerite, galena, chalcopyrite, and tennanite. The Frontenac–Aduddell–Druid–Kokomo vein system is well known in the area and contains base metals along the entire system. An area adjacent to the Kokomo Mine was selected for CHIM tests, and samples for geochemical analysis were taken from dumps on the property.

The purposes of the study were to test and develop equipment and procedures at a test site near Denver and to evaluate the CHIM method at a known site where transported overburden conceals a mineralized vein. The Russian literature available to us provided very little hard data in regard to comparisons of CHIM results with standard soil geochemical methods, the repeatability of CHIM surveys, and the spacial wavelength of anomalies with respect to thickness of overburden. Objectives of our CHIM surveys were to address aspects not adequately covered in the Russian literature that are essential for evaluation of the usefulness of the method.

CHIM testing started on May 22, 1990, and 11 separate tests were performed during the year. Testing ended November 19, 1990, when snow prevented further access. This paper discusses results of those tests.

THE CHIM TECHNIQUE

The CHIM technique can best be described as an electrogeochemical sampling method. It uses a DC electrical current to move mobile cations into special fluid-filled cathodes placed on the earth's surface. The cation-collector electrodes were designed and developed by the USGS. They are relatively easy to use and clean, hold liquid well, and have a transparent body so that field crews can monitor for leaks or other problems. The cation collectors used for the tests at the Kokomo Mine have an inside diameter of 1.625 inches (4.128 cm) and an operational capacity of 150 ml (Fig. 1).

Electrical contact to the ground is made through a disk of artificial parchment (type 1470) manufactured by the James River Paper Co., Parchment,

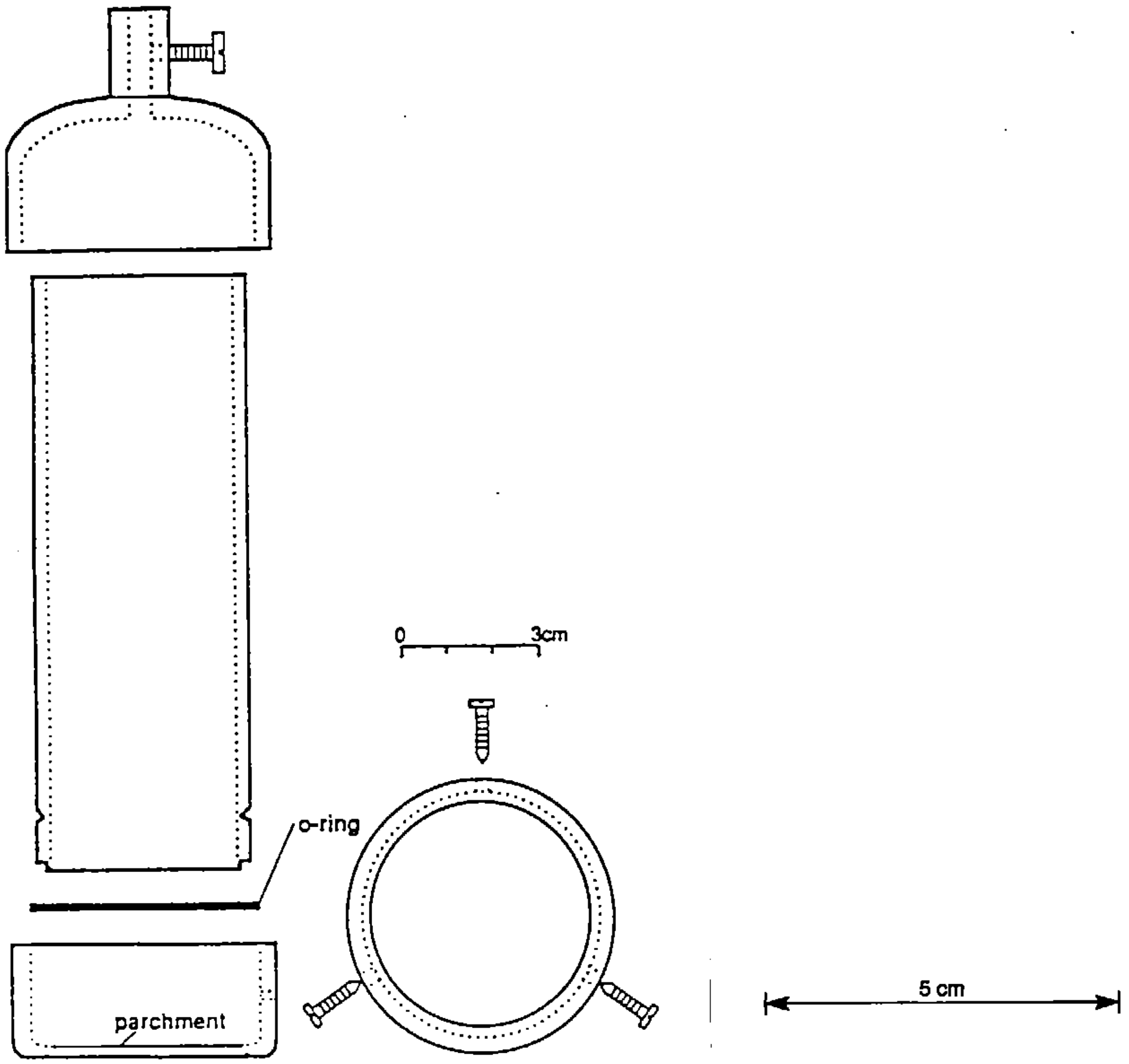

Fig. 1. Schematic drawing of the USGS 150 ml CHIM electrode. The central tube, cap, and bottom are made of standard PVC pipe and fittings available at most plumbing supply stores. Screws are made of acid-resistant plastic.

Michigan *. The parchment disks are cut to fit the lower cap and held in place by an O-ring seal (Fig. 1). In the absence of seal leaks, the electrode will lose about 5–10 ml of electrolyte through the parchment in 24 hours. A 99.6% pure titanium rod, 5 mm in diameter and 20 cm long, is used as the inner working cathode. The electrolyte used as the cation-collecting medium was 4N reagent-grade nitric acid.

The electrical current, generally ranging from 0.1 to 0.5 A, is conducted through the electrode for time intervals of several hours to several days. At the end of this time, the electrolyte and inner electrodes are collected and analyzed for elements of interest. An important aspect of the CHIM method is that it samples only ions mobile in an electric field as opposed to the total quantity of a particular element in the soil near an electrode. Where the mobile ions are related to a geochemical halo developed in cover above a deposit, CHIM samples may provide better definition of the concealed deposit than standard geochemical methods.

The equipment used in studies at the Kokomo Mine is generally similar to the Russian in electrical capacity, with the addition of a multichannel, recording, ampere-hour meter. The USGS system has a capacity of 31 channels, 15 kW, 1000 V, and 43 A. The principal components of the system are (1) power source, (2) ampere-hour recorder, (3) current control rheostats, (4) current distribution cables, and (5) cation-collector electrodes (Fig. 2). The power source is a 15 kW diesel motor generator providing AC power to a Zonge

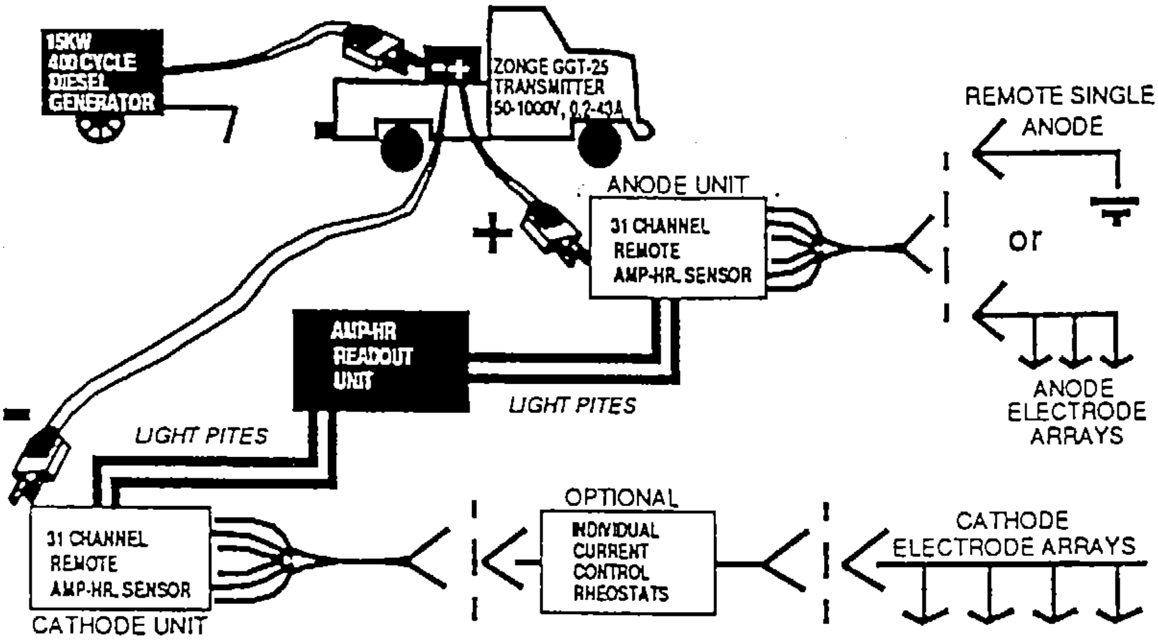

Fig. 2. Simplified block-diagram of the USGS CHIM system.

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*Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government

GGT-25 transmitter. DC power from the GGT-25 transmitter goes to individual anode and cathode ampere-hour sensor units where the power is split into 31 channels. Each of the 62 individual channels may be monitored for current, and the ampere-hours delivered to each channel are recorded. From the ampere-hour recorder, current goes to banks of rheostats that control current to each cation collector, and from the rheostat banks to multiconductor distribution cables. Take outs on the distribution cables then deliver current to individual electrodes. For studies at the Kokomo Mine, only cation collectors were used. The positive current conductor was directly connected to 3 or 4 graphite bars buried in the ground, salted, and watered. These were placed about 100 m from the cathode array.

GEOLOGIC SETTING

The test site at the Kokomo Mine is in the Central City Mining District, within the central part of the Front Range mineral belt (Tweto and Sims, 1963). Principal rock types in the district consist of folded Precambrian metasedimentary and metavolcanic units. Tertiary felsic intrusives, preore in age, cut the Precambrian metamorphic rocks as irregular dikes and small plutons. Post-intrusive faulting provided the principal paths for the mineralizing solutions.

Frontenac–Aduddell–Druid–Kokomo vein system

The Frontenac, Aduddell, Druid, and Kokomo Mines were developed along a single vein system that can be traced for more than 1.5 km (Fig. 3). The average strike of the veins is N50°E and dips range from 50° to 80° to the northwest. The Frontenac, Aduddell, and Druid mines worked two to three prominent sub-parallel veins in the system, whereas only a single vein was worked at the Kokomo Mine. The thickness of individual veins was variable but generally ranged from 1 to 2 m.

Mineralization in the veins includes an early pyrite stage followed by a galena–sphalerite stage. Some parts of the veins are principally of the pyrite type, whereas other parts are mixtures of the two types. Bastin and Hill (1917) give assays of ore for the various mines on the vein system. At the Kokomo Mine average grades were: Au—0.32 to 1.25 oz/ton, Ag—12.85 to 29 oz/ton, Cu—4 to 7%, and Pb—7 to 11%. Samples collected from the dump at the mine during this study contained as much as 2.6 ppm Au, 360 ppm Ag, > 970 ppm Cu, > 1.8% Pb, and > 1,100 ppm Zn. The water table is generally 15–45 m below the surface in this area (Lovering and Goddard, 1950).

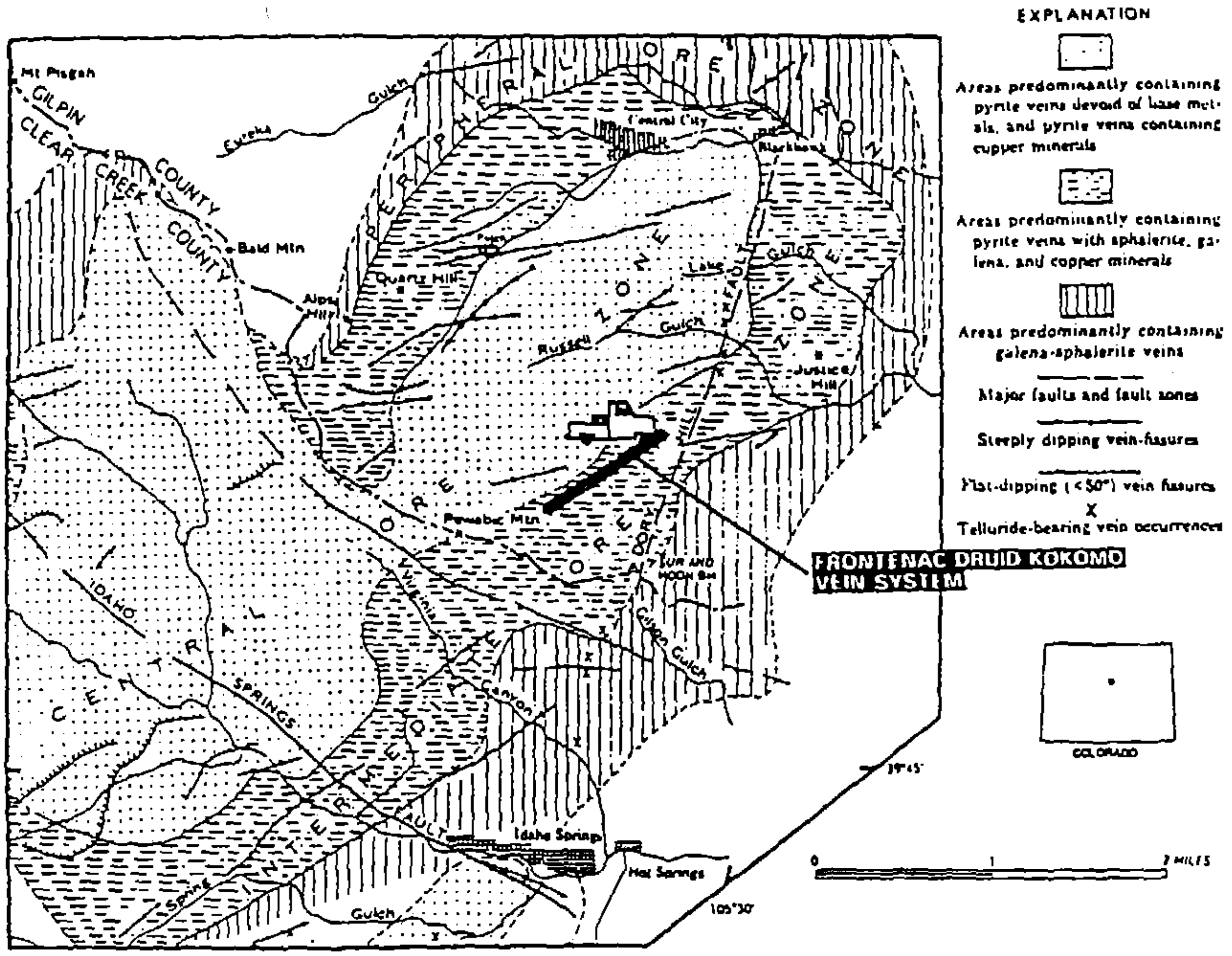

Fig. 3. Location of the CHIM test line on the Frontenac–Aduddell–Druid–Kokomo vein system, and mineral zonation within the Central City mining district (after Tooker, 1963).

FIELD PROCEDURES

The initial CHIM test line was selected normal to the vein system and 46 m northeast of the Kokomo Mine shaft. The line was positioned to avoid disturbed ground from prior mining activities. The zero position (site 00) was placed approximately on the northeast extension of the vein system that had been mined near the turn of the century. Sample sites along the line are located as distance, in meters, N or S of site 00. The line, on the wooded slope of Banta Hill, has a fairly uniform 16° slope to the north. Two roads cross the line at 10N and 80N. Transported material at these two positions is believed to represent the greatest source of contamination along the line.

In mid-May, 1990, a test line of 150 m was surveyed, and stakes were placed at 10-m intervals along the line. Self potential, gamma-ray, and electromagnetic surveys were run along the line, and soil samples were taken at each 10-m site. For testing of the narrow vein system at the Kokomo Mine, the full CHIM electrode array was not used. Test runs were made with only 12 cation collectors to shorten set-up and sampling time.

Upon completion of the CHIM tests, a backhoe was used to excavate a 10-m-long trench parallel to the test line and centered about 5 m southwest of site 00. The approximately 1-m-wide vein was encountered at a depth of about 3 m and was, as projected, below site 00. Soil material encountered above a depth of 180 cm was dominantly colluvium that appeared to have been transported several meters. Between 180 and 270 cm the soil consisted of fragments of weathered parent material (biotite schist) that had been only locally transported. Weathered bedrock was encountered at 270 cm. Composite samples were collected from each soil horizon in the trench.

Electrode site preparation

Shovels were used to remove soil and prepare holes at each site for placement of the cation collectors. Holes were about 30 cm in diameter and 10–25 cm in depth. A soil sample was collected below the organic-rich surface layer in each hole. When soil-moisture conditions permitted, a small portion of the material near the bottom of the hole was sieved to −2 mm to remove coarse fragments which could puncture the parchment of the collector. The sieved material was returned to the hole and spread to create an even surface. About 150 ml of deionized water was added to the sieved material to improve electrical contact and to produce a "soil paste" on which the cation collector was placed. After gently pressing the collector into the soil at the bottom of the hole to ensure good contact, the collector was filled with 150 ml of 4N nitric acid. Electrical connection to the generator was then completed.

Nitric acid was chosen as the electrolyte for two reasons. First, the electrolyte had to be an acid because of the reduction that takes place at the cathode. This results in the liberation of hydrogen gas, a resulting surplus of hydroxyl ions, and an increase in pH with increasing ampere-hours. Eventually, insoluble metal hydroxides precipitate as the solution becomes alkaline. These coat and insulate the titanium rod causing the current to decrease drastically and the temperature of the solution to increase. A concentration of 4N ensured that the pH remained low even with runs of several hours at high (0.5 A) currents. Secondly, most cations form soluble nitrates, so precipitation of insoluble metal salts is not a concern.

CHIM procedures

Voltage, current, and ampere-hours were monitored on a periodic basis throughout each test. In the early stages frequent monitoring and adjustment of the current via the rheostat bank was required as the temperature of the soil increased around the cation collectors. Problems such as poor electrical contact with the soil, nitric acid leakage, or bad electrical connections were usually manifested at the beginning of the experiment. Once current had stabilized, electrical parameters were monitored less frequently. Data such as times of current shut-off and start-up for temporal sampling, significant loss of acid, replacement of acid, and observations of potential contamination of sample sites or cation collectors were recorded.

All of the CHIM experiments discussed in this report were conducted with as much consistency as possible. Current to each cation collector was approximately 0.5 A and the run time was about eight hours unless otherwise noted.

At the end of the experiment, or during the experiment if its purpose was to determine rates of accumulation of cations, samples of the acid were obtained from each cation collector. The cover of the collector was removed and a pipette with disposable tip was inserted into the acid to collect 10-ml samples for temporal studies. Ten ml of 4N nitric acid was then added to the collector to maintain volume and assure an acidic environment throughout the run. Samples at the end of a CHIM run were 60 ml. All samples were collected after the current had been off for approximately 5 minutes to ensure equilibrium between the acid and the titanium inner electrode. Electrolyte samples were stored in capped polypropylene tubes or nalgene bottles prior to analysis. The titanium inner electrodes were left in the cation-collector cap and returned to the laboratory for further processing.

SAMPLE PREPARATION METHODS

Soil samples were prepared in the laboratory by sieving to two size fractions: 20–80 mesh (850–180 μm), and <80 mesh (<180 μm). Samples of soil horizons collected from the trench were sieved to five size fractions: 30–80 mesh (550–180 μm), 80–150 mesh (180–106 μm), 150–200 mesh (106–75 μm), <200 mesh (<75 μm), and <80 mesh (<180 μm). Little variation in concentration of elements of interest was observed between the two size fractions for the soils or among the five fractions for the soil horizons. Therefore, we only show results for the <80-mesh (<180 μm) fraction in this report.

Titanium rods from the cation collectors were leached in boiling aqua regia. The rods were removed from the cation-collector caps and placed in disposable borosilicate tubes. Three ml of concentrated hydrochloric acid and 1 ml of concentrated nitric acid were added to the tubes and brought to a boil for 0.5 hr. The tubes were cooled and the rods removed and rinsed into the tubes with deionized water to bring the volume to 10 ml.

ANALYTICAL METHODS

Soils

Two types of analyses were performed on soil samples collected in this study. The first type involved a vigorous digestion procedure designed to dissolve many, if not all, of the mineralogical phases within the sample. The second type involved much weaker, partial-dissolution techniques designed to liberate only those metals that are weakly bound to soil constituents. These latter techniques are selective extractions that dissolve specific components of the weathering products in the soil. Chao (1984) presents a thorough discussion of partial-dissolution techniques and their application to geochemical exploration.

Partial-dissolution techniques were applied to soil samples from the CHIM test line to (1) determine if the buried vein could be detected at the surface by an anomaly related to the readily available metals and (2) elucidate the

TABLE 1

Summary of elements determined, analytical methods, and lower limits of detection (LLOD) for the different sample media analyzed in the CHIM tests at the Kokomo Mine

Matrix	Element	LLOD (μg/g)	Detection technique
Soils			
Partial extractions	Cu	0.13	ICP-MS*
	Pb	0.05	ICP-MS
	Zn	0.13	ICP-MS
	Ag	0.001	ICP-MS
"Total" digestion	Cu	2.0	AA**
	Pb	10.0	AA
	Zn	1.0	AA
	Ag	0.2	AA
	Au	0.05	AA
Electrode leach	Au	0.001	ICP-MS
Electrolyte (HNO_3)	Au	0.001	ICP-MS
	Cu	0.02	AA
	Pb	0.1	AA
	Zn	0.01	AA
	Ag	0.02	AA
	Al	0.08	ICP-OES***
	Ca	0.04	ICP-OES
	Fe	0.02	ICP-OES
	K	0.1	ICP-OES
	Mg	0.07	ICP-OES
	Mn	0.003	ICP-OES
	Na	0.1	ICP-OES
	Si	0.1	ICP-OES

* Inductively coupled plasma mass spectrometry.

** Atomic absorption.

*** Inductively coupled plasma optical emission spectrometry.

process/mechanism of the CHIM technique by comparing patterns generated by various modes of occurrence of the metals in the soil to those generated by the CHIM technique. Three mild extractants were used to dissolve metals having varying degrees of availability. The extractants, in increasing ability to dissolve metals, were (1) an enzyme solution (Clark et al., 1990), (2) a 2.5% acetic acid solution (McLaren and Crawford, 1973), and (3) a 0.1N hydrochloric acid solution (Sarenson et al., 1971). Separate splits of soil sample were used for each extraction. The enzyme dissolution liberated metals of interest at concentration levels about an order of magnitude lower than those dissolved by the other two partial-dissolution techniques which liberated 1 to 30% of the total metal contained in the soil samples.

Soils subjected to a total digestion were analyzed for Cu, Pb, Zn, Ag, and Au (Table 1). The digestion procedure for Au was a hydrobromic acid–bromine leach followed by solvent extraction (O'Leary and Meier, 1990). The procedure for Ag, Cu, Pb, and Zn involved a modification of a total digestion such that the final uptake is in nitric acid (Sanzolone and Chao, 1976).

Soils subjected to partial dissolution were analyzed for Cu, Pb, Zn, and Ag (Table 1). Both the 2.5% acetic acid and the 0.1N hydrochloric acid partial-dissolution techniques used a sample-to-extractant ratio of 1 g to 25 ml. The acetic acid dissolution was equilibrated for two hours on a shaker, whereas the hydrochloric acid dissolution equilibration was for one hour, both at ambient temperature. The enzyme dissolution used a sample-to-extractant ratio of 1 g to 15 ml and a reaction time of one hour.

Cation collector

The nitric acid solution and the titanium rod leach solution were analyzed directly with no additional treatment (Table 1). Early results with the CHIM technique indicated that Ag, Cu, Pb, and Zn partition strongly to the nitric acid solution very quickly after the current is stopped. We observed Cu plating on some of the titanium rods while the current was on. This plating dissolved within several seconds after the current was turned off. Results for these elements for the CHIM method are reported as total micrograms in 150 ml of nitric acid solution. The relatively small amounts of these elements found on the rods are not included in this total.

The nitric acid solutions were analyzed for the major soil constituents Al, Ca, Fe, K, Mg, Mn, Na, and Si (Table 1) by inductively coupled plasma atomic emission spectrometry (Church, 1981) to evaluate total element collection versus time.

Inductively coupled plasma mass spectrometry (ICP-MS) was used to analyze for Au in both the nitric acid solutions and the titanium rod leach. This method was also used to analyze for Cu, Pb, Zn, and Ag in the partial dissolutions of soil samples (Table 1). More fluctuation than usual was noted in the lower limit of detection due to the variable and complex nature of the solution matrix, the high sensitivity sought, and the variability of the blanks. An internal standard of In and Lu was used to moderate some of the matrix effects contributing to the variations.

We were not able to consistently detect Au with the CHIM procedure even though Au was detected in soils at 7 of the 12 sample sites along the CHIM line at concentrations ranging from 0.05 to 0.3 ppm. In the few instances Au was detected in the CHIM experiments, it was found in the titanium rod leach solution. This could be due to Au plating onto the rod as nitric-acid-insoluble native metal. Another possible explanation is that Au is 15 times more concentrated in the 10 ml of rod leach solution than in the 150 ml of nitric acid solution. Because of the very sporadic nature of our Au results for the CHIM technique, the only Au values reported are those for soil samples.

RESULTS

Gamma-ray and self-potential surveys

The gamma-ray data show a broad peak in K and Th centered over the buried vein; values abruptly decrease about 35 m north of the vein. This decrease suggests a change in lithology at that point.

If present, the expression of the vein in the self-potential survey is less than 5 mV, extending 60 m either side of the vein.

Comparison of CHIM results with soil geochemistry

Figures 4a–d show a comparison of Cu, Pb, Zn, and Ag patterns produced by the CHIM method on May 23 to patterns produced by the total dissolution of soils taken from the CHIM sample sites. Patterns for Cu (Fig. 4a) and Zn (Fig. 4c) from the CHIM test exhibit very strong, narrow anomalies over the vein at site 00. Patterns for Cu and Zn in soils show very weak, broad anomalies over the vein. Patterns for Ag (Fig. 4d) show anomalies with roughly similar contrast over the vein for both CHIM and soils with the CHIM anomaly being somewhat broader than the soil anomaly. Patterns for Pb (Fig. 4b) show no clear expression of the vein for either CHIM or soils, possibly because of the ubiquitous nature of Pb in the area. CHIM results for Pb were not reproducible in subsequent runs and therefore will not be addressed further in this report. Anomalous concentrations of all four elements were observed in soil samples from site 40N and have been observed in some of the CHIM experiments. This may indicate the presence of a second vein at this site.

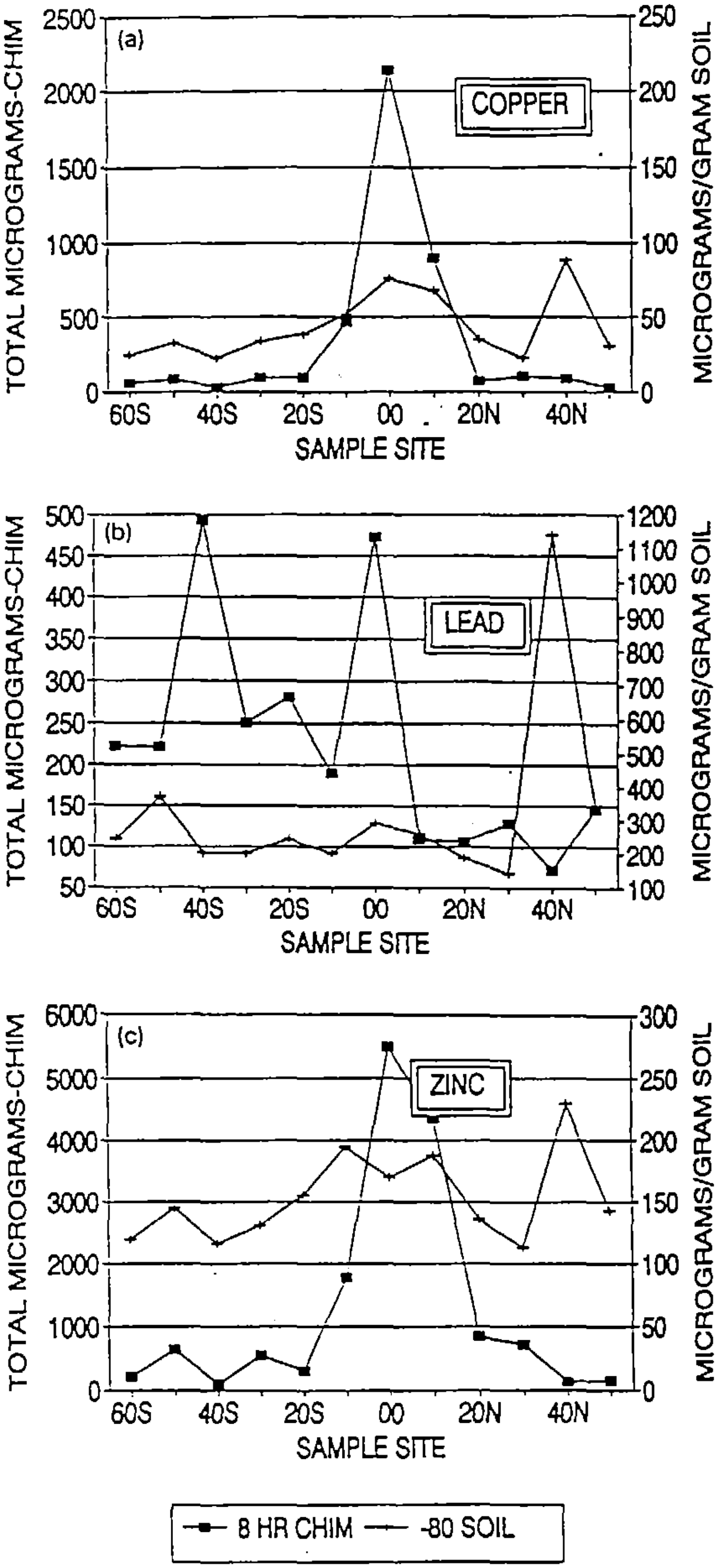

Fig. 4. Comparison of CHIM results (8-hr run) with soil geochemistry using total digestion of −80-mesh sample. (a) Cu; (b) Pb; (c) Zn; (d) Ag.

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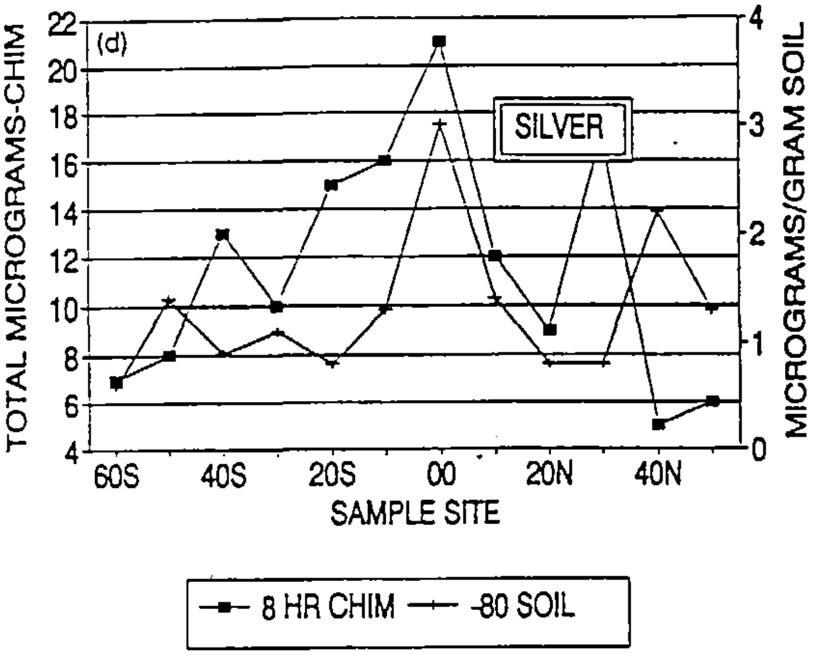

Reproducibility of CHIM results

One of the major concerns addressed in the CHIM experiments was that of reproducibility. We wanted to determine how results changed when different sample sites were used and how they varied over the entire summer when the same sites were used multiple times.

Variation due to sample site

A second CHIM line parallel to the first and offset by 1 m tested the local variability of CHIM results. Sites were prepared along line 2 at exactly the same spacings and in exactly the same manner as on the original line. A CHIM run was conducted on line 2 on May 24 with the same electric current and time parameters used along line 1 on May 23.

A comparison of results for these two runs shows a well-defined anomaly for Cu (Fig. 5) above the vein on both. However, the total amount of metal collected from anomalous sites on line 2 is significantly less than for equivalent sites along line 1. Similar results were found for Zn and Ag.

Variation with time

A comparison of CHIM runs at different dates throughout the summer shows that the vein was delineated on each run but with varying contrast (Fig. 6a,b). The contrast was lowest for both Cu and Zn on June 22. This variation in contrast seems to correlate with soil moisture. On May 23, snow melt made the soil very damp. By June 22, the soil had dried. On July 13, recent heavy afternoon thunderstorms had made the soil at least as wet as on May 23. More pathfinder ions are collected from wet soil than from dry soil. Similar observations have been noted in the Russian literature (Veikher et al., 1990).

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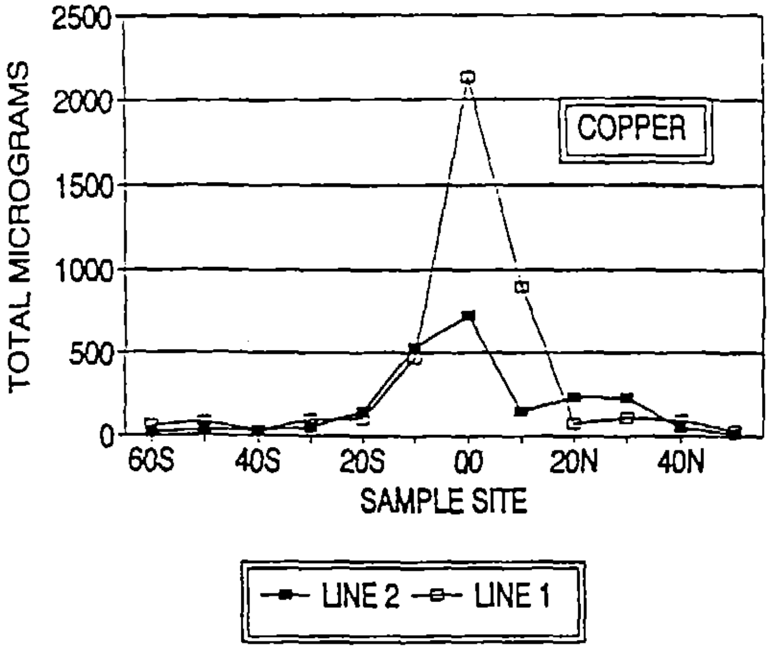

Fig. 5. Comparison of CHIM results for Cu along test line 1 with test line 2. Line 2 is parallel to line 1 and offset by 1 m from line 1.

Spatial wavelength of CHIM anomaly

A CHIM run with cation collectors spaced 2 m apart and centered over the vein at site 00 provided a more precise measurement of the wavelength of the CHIM anomaly on line 1. The anomaly is only 2–3 m wide (Fig. 7), comparable to the width of the vein itself. There is no obvious displacement of the CHIM anomaly downslope to the north.

Temporal studies

Gol'dberg et al. (1990) state that curves showing ion concentration versus time for specific ions collected in CHIM runs may be linear (constant rate of accumulation), concave upward (increasing rate of accumulation), or concave downward (decreasing rate of accumulation). They recommend that orientation tests be conducted in each region to determine the general shape of the concentration–time curve, and that generally the first linear segment should be chosen for routine operations.

A temporal study at the Kokomo Mine test site was conducted with samples taken from each cation collector after 4, 8, 14, 19, 23, and 25 hours. The results for Zn (Fig. 8) are similar to those for Cu and Ag. For each sample time a similar pattern is seen with an anomaly delineating the vein system at position 00. The 25-hr sampling has an anomaly:background ratio of approximately 12.7 (anomaly = 14,000 μm; background = 1,100 μg; whereas, the 4-hr sampling has a ratio of about 6.2 (anomaly = 2,500 μg; background = 400 μg). Thus, the 25-hr sampling only improves the contrast over the 4-hr sam-

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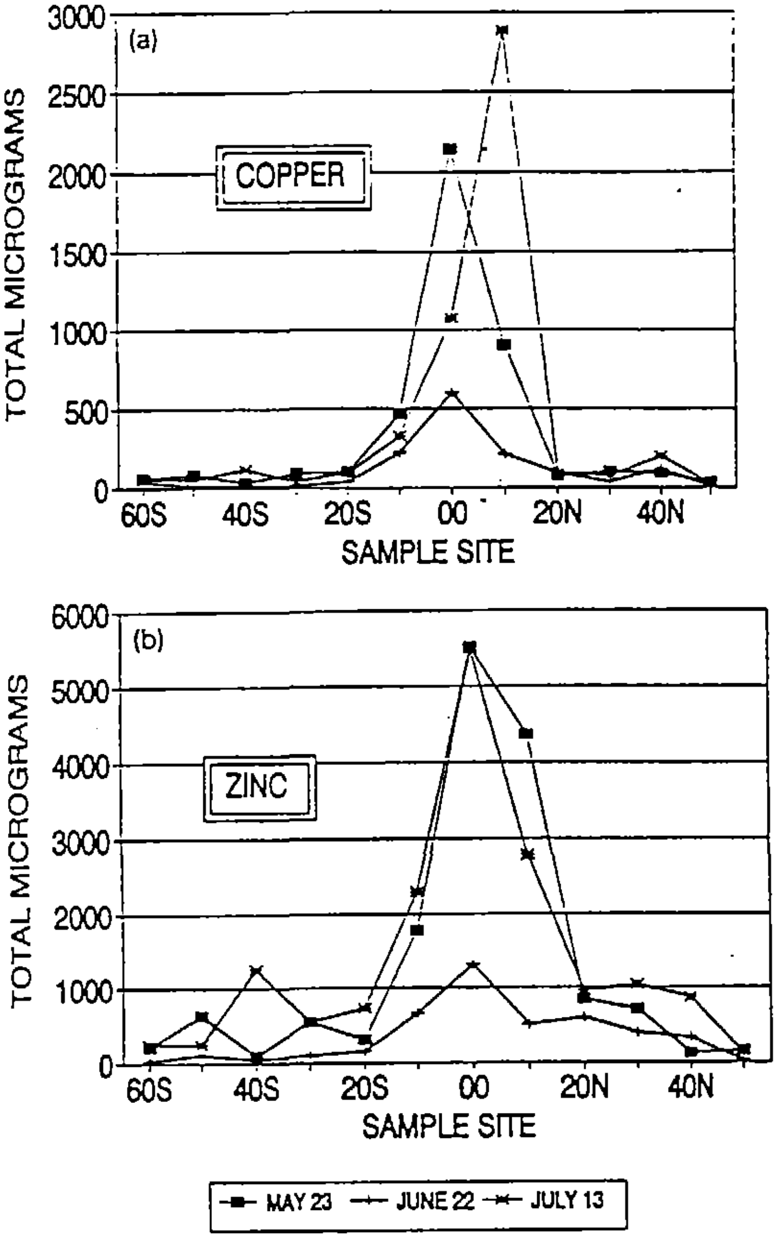

Fig. 6. Comparison of CHIM tests conducted on three different dates about 1 month apart. (a) Cu; (b) Zn.

pling by about a factor of 2. This implies that the run time only needs to be long enough for cations to accumulate in quantities enough above the lower limit of detection to offer good precision.

Less obvious in Fig. 8 is that Zn is collected at a rate which decreases with time. This is more clearly seen in Fig. 9 which shows the accumulation of Zn at positions 60S, 40S, and 20N as a function of time. Such behavior is typical for accumulation–time curves that we have observed at the Kokomo Mine test site. Less common are linear relationships through the origin. We have not observed curves that are concave upward.

Analyses for Na, K, Ca, Al, Si, Fe, Mg, and Mn showed a similar decrease in cation collection rate. We made calculations to determine the percentage

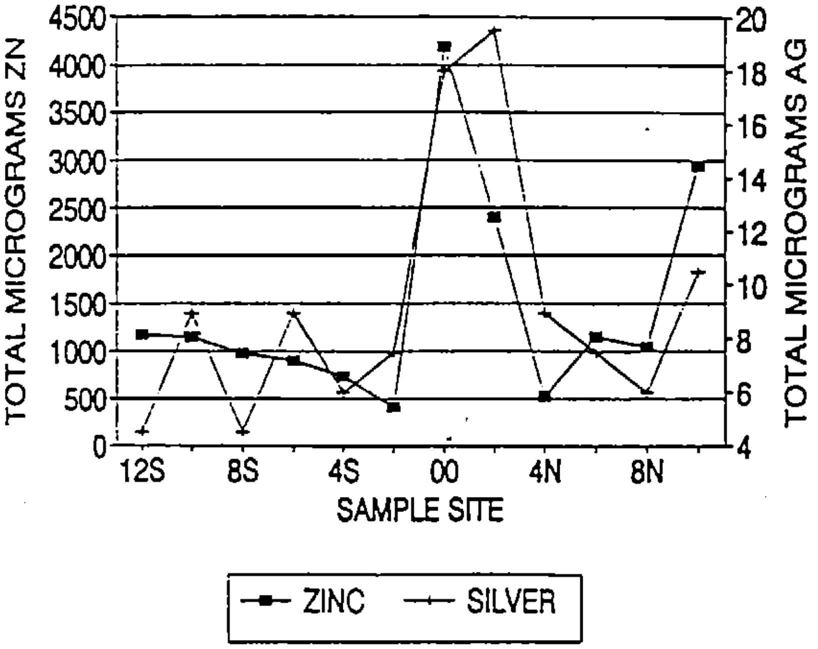

Fig. 7. CHIM results for a run with cation collector spacing at 2 m. The increase in both Zn and Ag at site 10N is probably due to contamination along a four-wheel-drive road at this site.

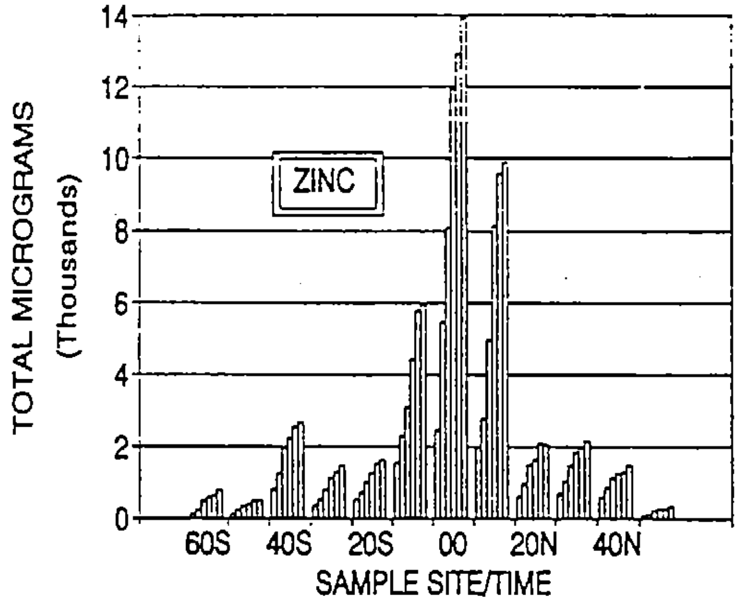

Fig. 8. Total Zn accumulation as a function of time and position along CHIM line 1. The bars at each sample site represent Zn concentration at the following sampling times: 4, 8, 14, 19, 23, and 25 hours.

of charge transfer due to the current that could be attributed to the analyzed ions, assuming the cations, on entering the electrode, had the following valences: Na^+, K^+, Ca^{2+}, Al^{3+}, Si^{4+}, Fe^{3+}, Mg^{2+}, Mn^{4+}, Cu^{2+}, Zn^{2+}, Pb^{2+}, Ag^+. The results showed that it required only 0.1% of the expended ampere-hours to account for these major and minor cations. It thus appears that the CHIM process is a very inefficient collector of cations.

The general decrease in the rate of cation accumulation implies a depletion

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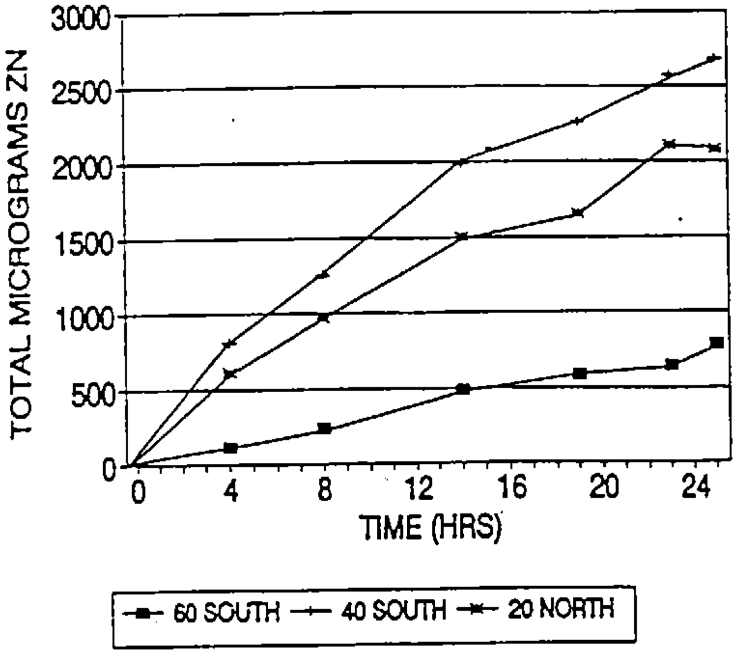

Fig. 9. Plot showing accumulation of Zn as a function of time at positions 40S, 60S, and 20N on CHIM line 1.

of cations, at least the mobile ones, in the vicinity of the collection electrode. However, the resistance in the earth circuit decreases during operation, with the greatest change occurring over the first few hours. This requires that the total quantity of mobile ions in the current path increases, or that net ion mobility increases. Although we have no definitive explanation for the decrease in the rate of cation accumulation, we suspect that it may be related to ionic processes within the vadose zone.

Comparison of CHIM results with partial dissolution of soils

Application of partial dissolution techniques to soil samples from the Kokomo Mine produces anomaly patterns that are comparable to those generated by the CHIM method (Figs. 10a–c). The anomalies show much higher contrast and define the vein much better than the total digestion procedure (Fig. 4a, c, and d). The enzyme, acetic acid, and hydrochloric acid dissolutions all generated strong anomalies in Cu and Zn that delineated the vein at site 00. The enzyme and hydrochloric acid dissolution also produced anomalies in Ag over the vein, but Ag was not detected in any of the acetic acid dissolutions. None of the partial-dissolution techniques give patterns for Pb that define the vein. Enzyme and hydrochloric acid patterns for Pb are similar to that shown by the total digestion but give much greater contrast. CHIM anomaly patterns for Pb are not consistent from run to run, and comparison to patterns from the partial dissolutions is difficult.

The good agreement between the partial-dissolution patterns and those produced by the CHIM technique supports the argument that the CHIM

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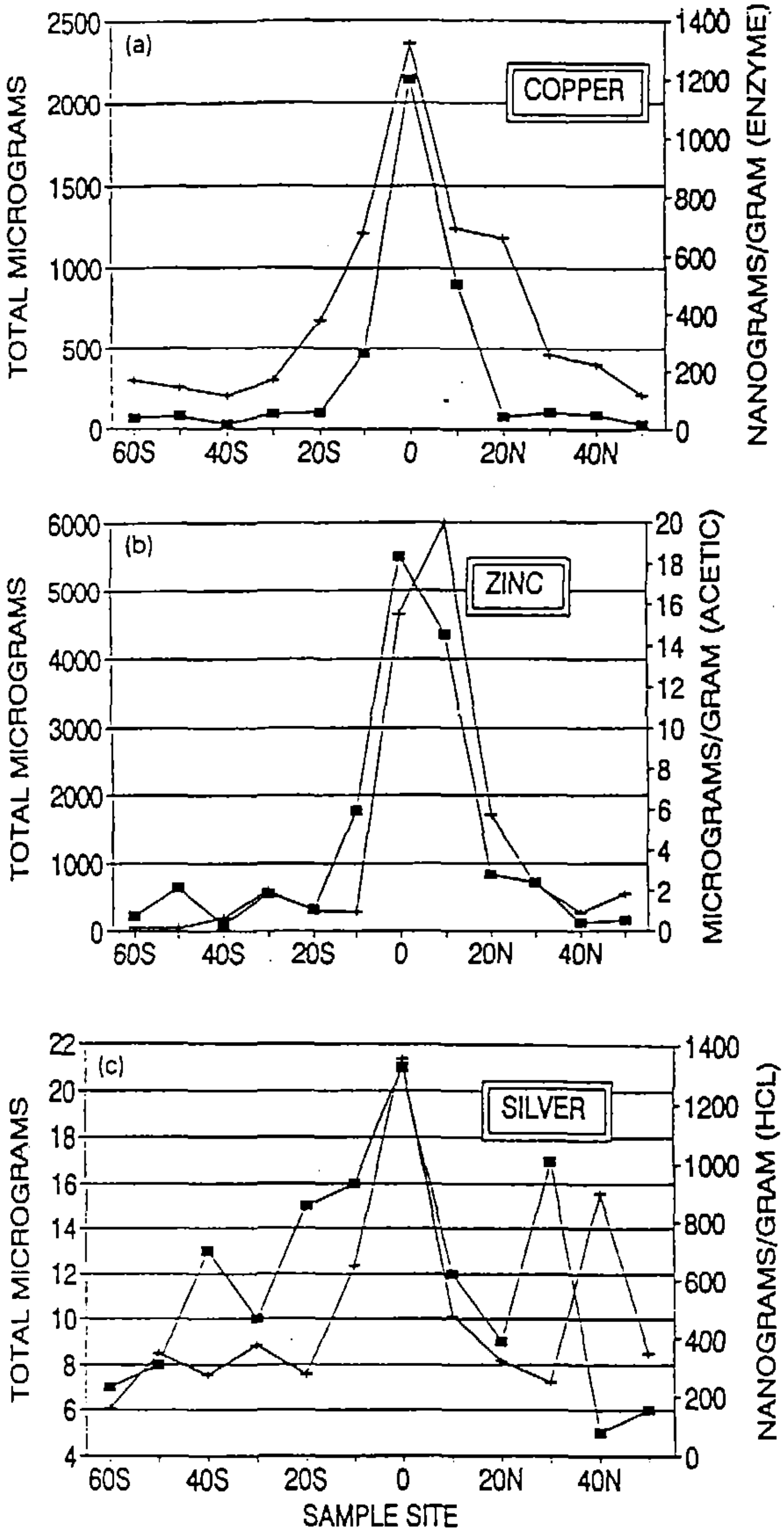

Fig. 10. Plots showing results of partial dissolution of −80-mesh soil samples (+) compared with CHIM results from May 23 (□). (a) Cu in CHIM and enzyme extraction; (b) Zn in CHIM and acetic acid extraction; (c) Ag in CHIM and 0.1N hydrochloric acid extraction.

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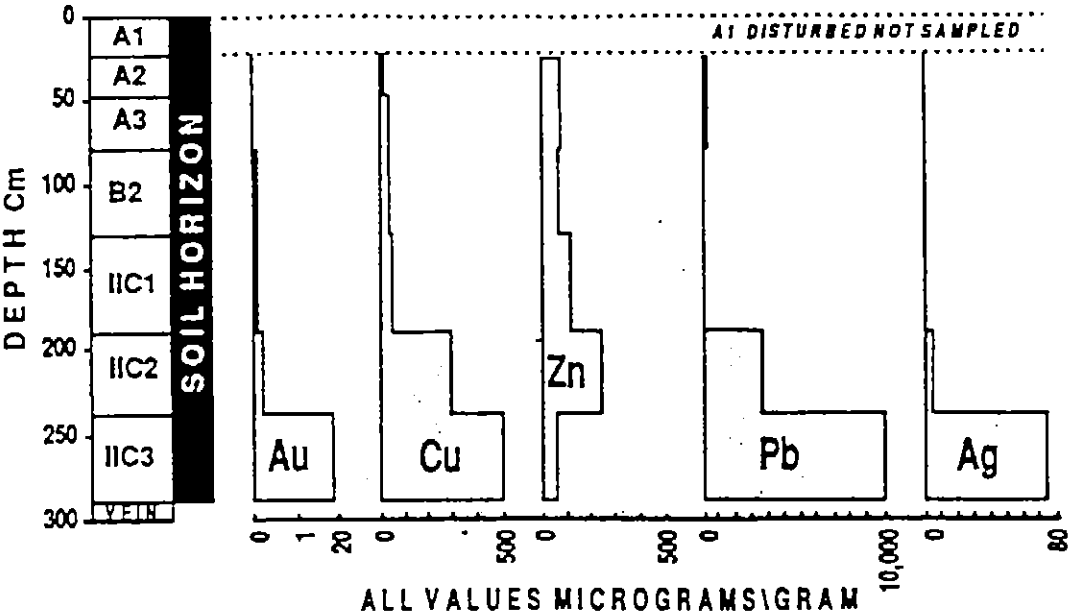

Fig. 11. Geochemistry of soil profile above the vein at site 00 on CHIM line 1.

method collects and concentrates available cations from the soil in the vicinity of the cation collector. At the Kokomo Mine test site, the partial-dissolution techniques generate much more definitive anomalies than the total digestions while offering operational and practical advantages over the more costly and time-consuming CHIM technique.

Soil horizons

Composite sampling of soil horizons along the 3-m vertical profile exposed in the trench dug near site 00 shows that Ag, Au, Cu, and Pb all reach maximum concentrations immediately above the vein (Fig. 11). Zinc has maximum concentration in the horizon that extends from 190 to 240 cm below the surface.

CONCLUSIONS AND REMARKS

A series of tests of the Russian CHIM method were conducted over a precious- and base-metal-bearing quartz vein with 3 m of colluvial cover near the Kokomo Mine in the Central City mining district, Colorado. These tests show that the CHIM method can better define this narrow vein than conventional soil geochemistry based on total-dissolution technique. However, weak partial extractions of soils produced results comparable to those generated by the CHIM method. This result seems to confirm that the CHIM technique, in effect, produces a weak in-situ partial extraction involving only ions able to move in a weak electric field. Our research has not yet progressed far enough to determine under what conditions the CHIM method may be superior to partial-dissolution techniques, or vice versa. The CHIM method may effectively sample a larger volume of soil than the few grams generally used for partial dissolutions and, as a result, may have advantages in certain environments or for certain elements.

Our tests have also shown that CHIM anomaly patterns are reproducible from run to run, but that absolute values at individual sites cannot be repeated. Because of this, it would be difficult to group data from runs made at different time periods. Variation in moisture content within the vadose zone, where collection occurs, appears to be one of the primary causes for these differences. This may obviate the application of CHIM to regional geochemical exploration.

Although our experience is limited, results support Russian investigations that show CHIM anomalies are narrow with respect to depth to source. At the Kokomo Mine, data generated from cation collectors at 2-m spacing show the anomaly is approximately the width of the vein (1–2 m), and in spite of the 16° slope, there does not appear to be any significant down-slope dispersion. Should this result be the norm, then mechanisms for charged ion migration within the earth need to be examined more thoroughly.

Many unsolved problems remain not only in the utilization of the CHIM method as an exploration tool, but also in the basic understanding of the physicochemical processes involved. The major issues, as we see them, include the following:

1. Anion collection. Pathfinder elements such as Au, As, and Sb may be present as anionic species in the near-surface environment (Stumm and Morgan, 1981; Mann, 1984; Webster, 1986). Russian literature translated in Bloomstein (1990) mentions briefly the importance of collecting and analyzing anions but does not give any data or case histories.

2. Ion mobility in the vadose zone. The mechanism of ion mobility in an electric field in dilute solution is well understood. However, in the vadose zone, where most CHIM collection occurs, and in the presence of clays and organic matter that adsorb ions, the process of ion mobility is not well understood. If relative mobilities in the unsaturated soil are significantly different than observed in dilute solution, selective collection could require alteration of conventional interpretation of CHIM data.

3. Processes at the soil–electrode interface. Elements present as either positive or negative complexes present problems for the CHIM technique. Such complexes are not stable over a wide range of pH. At the electrode–soil interface, these complexes may be destablized and thus prevented from entering the low-pH electrolyte.

4. Analytical methods. The nitric acid solution from a CHIM cation collector poses analytical problems because the sample contains very low concentrations of some important pathfinder cations such as Au in a matrix containing high concentrations of major cations such as Ca, Mg, Na, Fe, etc. As part

of our CHIM research, reference samples of the nitric acid solution from the CHIM runs have been prepared for interlaboratory comparisons.

5. CHIM vs. partial extractions. In the study at the Kokomo Mine, certain partial-dissolution techniques gave results at least as good as the more time-consuming and expensive CHIM method. More comparisons need to be made for various types of mineral deposits in a variety of geologic settings to determine if results from the CHIM method can be duplicated with partial-dissolution techniques.

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REFERENCES

Antropova, L.V., Goldberg, I.S., Voroshilov, N.A. and Ryss, Ju.S., 1992, New methods of regional exploration for blind mineralization: application in the USSR. J. Geochem. Explor., 43: 157–166.

Bastin, E.S. and Hill, J.M., 1917. Economic geology of Gilpin County and adjacentparts of Clear Creek and Boulder Counties, Colorado. U.S. Geological Survey Professional Paper 94, 379 pp.

Bloomstein, E., 1990. Selected translations of the Russian literature on the electrogeochemical sampling technique called CHIM (chastichnoe izvlechennye metallov). U.S. Geological Survey Open File Report 90-462, 172 pp.

Chao, T.T., 1984. Use of partial dissolution techniques in geochemical exploration. J. Geochem. Explor., 20: 101–135.

Church, S.E., 1981. Multi-element analysis of fifty-four geochemical reference samples using inductively coupled plasma-atomic emission spectrometry. Geostand. Newsl., 5: 133–160.

Clark, J.R., Meier, A.L. and Riddle, G., 1990. Enzyme leaching of surficial geochemical samples for detecting hydromorphic trace element anomalies associated with precious-metal mineralized bedrock buried beneath glacial overburden in northern Minnesota. In: Gold '90. Society of Mining Engineers, pp. 189–207.

Gol'dberg, I.S., Ivanova, A.V., Ryss, Yu.S., Veiker, A.A., Bakhtin, Yu.G., Alekseev, S.G. and Yakovlev, A.F., 1990. Exploration of ore deposits by the CHIM method. In: E. Bloomstein (Translator), Selected Translations of the Russian Literature on the Electrogeochemical Sampling Technique Called CHIM. U.S. Geological Survey Open-File Report 90-462, 172 pp.

Lovering, T.S. and Goddard, E.N., 1950. Geology and ore deposits of the Front Range, Colorado. U.S. Geological Survey Professional Paper 223, 319 pp.

Mann, A.W., 1984. Mobility of gold and silver in laterite weathering profiles: Some observations from Western Australia. Econ. Geol., 79: 38–49.

McLaren, R.G. and Crawford, D.V., 1973. Studies on soil copper. I. The fractionation of Cu in soils. J. Soil Sci., 24: 172–181.

O'Leary, R.M. and Meier, A.L., 1990. Determination of gold in samples of rock, soil, stream-sediment and heavy-mineral-concentrate by flame and graphite furnace atomic absorption spectrophotometry following dissolution by HBr–Br_2. In: B.F. Arbogast (Editor), Quality Assurance Manual for the Branch of Geochemistry, U.S. Geological Survey. U.S. Geological Survey Open-File Report 90-668, pp. 46–51.

Sanzolone, R.F. and Chao, T.T., 1976. Atomic absorption spectrometric determination of copper, zinc, and lead in geological materials. Anal. Chim. Acta, 86: 163–168.

Sarenson, R.C., Oelsligle, D.D. and Knudson, D., 1971. Extraction of Zn, Fe, and Mn from soils with 0.1 N hydrochloric acid as affected by soil properties, solution:soil ratio, and length of extraction period. J. Soil Sci., 111: 352–359.

Shmakin, B.M., 1985. The method of partial extraction of metals in a constant current electrical field for geochemical exploration. J. Geochem. Explor., 23: 27–33.

Stumm, W. and Morgan, J.J., 1981. Aquatic Chemistry. Wiley, New York, 780 pp.

Talapatra, A.K., Talukdar, R.C. and De, P.K., 1986. Electrochemical technique for exploration of base metal sulphides. J. Geochem. Explor. 25: 389–396.

Tooker, E.W., 1963. Altered wall rocks in the central part of the Front Range mineral belt, Gilpin and Clear Creek Counties, Colorado. U.S. Geological Survey Professional Paper 439, 102 pp.

Tweto, O. and Sims, P.K., 1963. Precambrian ancestry of the Colorado mineral belt. Geol. Soc. Am. Bull., 74: 991–1014.

Veikher, A.A., Tazeev, A.A., Gorbunov, V.A. and Memenko, A.I., 1990. Experience of finding gold deposits in western Uzbekistan using the CHIM method. In: E. Bloomstein (Translator), Selected Translations of the Russian Literature on the Electrogeochemical Sampling Technique Called CHIM. U.S. Geological Survey Open-File Report 90-462, 172 pp.

Webster, J.G., 1986. The solubility of gold and silver in the system Au–Ag–S–O_2–H_2O at 25°C and 1 atm. Geochim. Cosmochim. Acta, 50: 1837–1845.

Xu, B., Fei, X. and Wang, H., 1989. Electrogeochemical extraction technique in the prospecting of buried gold deposits. In: Xie Xuejing and S.E. Jenness (Editors), Geochemical Exploration in China. J. Geochem. Explor., 33: 99–108.

INTEGRATED METHODS IN EXPLORATION AND DISCOVERY

Conference Program and Extended Abstracts

Samuel B. Romberger and Darby I. Fletcher, Editors

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interlayered in colloform aggregates enclosing the sphalerite spherules or as separate crystal aggregates. Mineralization took place at temperatures of 100° to 260°C. Sphalerite salinities based on ice melting temperatures range from 20 wt % NaCl equiv. near the feeder structures to 7 - 8.5 wt % NaCl equiv. on the edges of the sulfide sheets. The decreasing salinities in fluids associated with the sphalerite suggest that at least 2 fluids, probably a hydrothermal solution and Carboniferous seawater or trapped diagenetic fluids, mixed within the system.

The CHIM Electrogeochemical Sampling Method - Understanding the Basics, Problems, and Applications

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The CHIM electrogeochemical method, developed in the former USSR over 20 years ago, combines theory and practices from electrical geophysical and geochemical methods. The term CHIM is an acronym derived from the Russian words "Chastichnoe Izvlechennye Metallov" meaning partial extraction of metals. Russian literature (Bloomstein, 1990) indicates that this integrated exploration method has advantages over conventional geochemical methods in exploration for covered deposits. In the former USSR, CHIM has been principally applied in exploration for base- and precious-metal deposits, although literature states that V, Co, Mo, U, Sn, Be, REE, as well as oil and gas deposits have also been investigated.

In 1989, the U.S. Geological Survey and Newmont Exploration began independent investigations of the CHIM method. Shortly thereafter both groups began conducting joint CHIM field tests. Results of the work are briefly described below.

In principle, the method is quite simple. A group (20 to 40) of specially designed sampling electrodes (element receivers in Russian terminology) are placed in shallow holes over the area of interest and DC electrical current is passed through the electrodes for periods from several hours to days. Typical electrode spacing is 20 m, with electrodes arranged in a linear or rectangular array. In normal operation, the sampling electrodes are cathodes (negatively charged) and thus collect cations from the soil moisture in the vicinity of the electrodes. The current is normally returned through a single graphite or steel anode well removed from the array of cation collectors.

The sampling electrodes are made from an inert plastic cylinder fitted on the bottom with a synthetic parchment membrane through which electrical connection to the earth is made. The cation collectors are filled with reagent grade acid electrolyte, commonly a 1 to 4 normal solution of nitric acid. A chemically pure graphite or titanium inner electrode is inserted into the acid and used to make connection to a source of electrical power. After a run is completed, the acid is removed from the cation collectors and analyzed for elements of interest.

Ideally, during operation cations in the soil moisture move under the force imposed by the applied electric field, through the parchment, and into the nitric acid. From Faraday's Law, the quantity of ions moved into a sampling electrode will be proportional to the charge transfer occurring at the electrode, i.e., the total ampere-hours delivered. The CHIM method, in effect, constitutes a very weak in-situ partial extraction.

An important aspect of the CHIM method is the volume of earth that can be sampled. Russian investigators note two types of CHIM extractions: 1) the halo CHIM method where ions are extracted from a local geochemical halo; and 2) the direct CHIM method where ions are said to be drawn directly from the deposit at depth. It is not believe that it is practically possible to collect ions from much more than a meter from an electrode. Sample volume does not appear to have been addressed directly by Russian investigators. Approximate measures may be obtained by calculating the number of chemical equivalents of ions present in the soil moisture in the vicinity of the electrode. Ideally, this is a volume containing a number of equivalents equal to the charge transfer in Faraday units. Alternatively, a geophysical approach may be used, and the transit time for an ion to move to the electrode under an applied electric field may be calculated to give a sample volume. For a homogeneous sample medium, and single ion type, the sample volume is given by the product of the ion mobility, the sample medium resistivity, and the electric charge expended. Under either approach sample volumes are typically less than 1 m^3. This conclusion, reached through the integrations of geophysical and geochemical expertise, focused attention on the nature and origin of the metal species in the soil being collected by the CHIM method and on alternative methods of identification and measurement of these species.

These estimated sample volumes are probably optimistic because, in practice, some hydrogen ion loss from the acid solution in the collection electrode occurs. This presents 2 significant problems. First, the positively charged hydrogen ions compete directly with the other cations present in the soil moisture. Second, the hydrogen ions may solubilize some elements from the soil, changing their mode of occurrence and their potential availability.

Conventional electric power sources used in CHIM work consist of high voltage (500-1000 V), high power (5-20 Kw) DC sources. The DC power is distributed by multiconductor cables to an array of cation collectors. Provisions for adjusting individual electrode currents and for measuring the currents are included in the source instrumentation. With such equipment, current to each electrode is normally set in the ige of 0.1 to 0.5 amps.

The USGS and Newmont Exploration recently introduced a modification to the conventional CHIM power source where individual 12 V batteries were used as current sources at each electrode (Hoover and others, 1992). In this variation, called APLOCHIM (from the Greek aplo meaning simple), the electrodes are operated at much lower currents, but collection time is normally increased. The use of small battery sources considerably simplifies the logistics of CHIM field operations, making the APLOCHIM technique a more practical field procedure.

Russian literature (Bloomstein, 1990) indicates that the CHIM method, in contrast to conventional soil geochemistry, is particularly effective at locating mineral deposits beneath substantial thickness of cover. This is presumably because weak geochemical halos developed through thick cover are more easily identified by the CHIM technique. USGS and Newmont Exploration research (Smith and others, 1991; Hoover and others, 1992; Smith and others, in press) examined the relationship between CHIM data and various types of soil extractions at sites in Colorado and Arizona. This work clearly showed a close correspondence between the CHIM and APLOCHIM elemental data and weak partial extractions of the same elements from near-surface horizons of transported overburden. A similar correspondence is not evident between the CHIM and APLOCHIM data results and more conventional "total" digestions of these soil samples. These observations have important implications with respect to: 1) the understanding of geochemical processes that are apparently operative in the subsurface; and 2) through the exploitation of these processes, the development of effective geochemical exploration methods for use in areas of barren and/or transported cover.

The reproducibility of the CHIM methodology has also been addressed by our research. For any given series of sites, and for a given charge, expended anomaly patterns are reproducible. However, the absolute quantity of cations collected may vary from run to run. The amount of soil moisture present during a run appears to be important in determining the quantity of ions collected.

Studies have also been made of the rate of accumulation of ions with time under constant current operation. Typically the accumulation rate of elements such as Ag or Cu falls off significantly after 3 to 4 hr of operation. The cause for this is not adequately understood, but it does not appear to be related to soil properties existent prior to operation. The effects of this change in ion accumulation rate with time are seen when comparing conventional CHIM and APLOCHIM results. At the Kokomo mine, Colorado, an APLOCHIM run collected similar quantities of Ag, Pb, Cu, and Zn compared to a conventional run, but used about 1/30 of the total charge transfer.

Research to date at the Kokomo mine, Colorado, the Carlin area, Nevada and Johnson Camp, Arizona, has shown that the CHIM method: 1) can be an effective tool for identifying geochemical halos associated with buried deposits; and 2) provides better discrimination of such halos than the soil "total" digestion techniques now commonly used by industry. To date, it has not been shown that CHIM has advantages over carefully selected partial extraction methods. However, a potential advantage may be demonstrated in areas where the surface halos are weak. In such areas the larger in-situ sampling volume and concentration permitted by the CHIM method may identify halos not possible by sampling and analyzing small soil volumes.

References

Bloomstein, E., 1990, Selected translations of the Russian literature on the electrogeochemical sampling techniques called CHIM (Chastichnoe Izvlechennye Metallov): U.S. Geological Survey Open-File Report 90-462, 172 p.

Hoover, D. B., Coope, J. A., Lavin, O. P., Nabighian, M. N., Sanzolone, R. F., and Smith, D. B., 1992, Studies of the CHIM electrogeochemical method in Arizona and Colorado [abs.]: Abstracts, Society of Mining, Metallurgy, and Exploration Annual Meeting, Phoenix, Arizona, Feb. 1992.

Smith, D. B., Hoover, D. B., and Sanzolone, R. F., 1991, Development and testing of the CHIM electrogeochemical exploration method, in: Goad, E. E., and others (eds.), U.S. Geological Survey Research on Mineral Resources - 1991 Program and abstracts: U.S. Geological Circular 1062.

Smith, D. B., Hoover, D. B., and Sanzolone, R. G., in press, Preliminary studies of the CHIM electrogeochemical method at the Kokomo mine, Russell Gulch, Colorado: Submitted to Journal Geochemical Exploration.

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PATTERNS OF ELECTROCHEMICAL LEACHING OF ELEMENTS IN THE SIMPLEST PHYSICO-CHEMICAL SYSTEMS
(Report I)

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The electrochemical extraction of elements from rocks, the process upon which the CHIM method is based [1], consists of a combination of many interconnected phenomena: the solution of concentration and chemical conversion of components around the electrodes through which the electrical current is introduced into the rock, etc. In order to more thoroughly investigate phenomena which are interactive and simultaneously dependent upon many controlling factors associated with the process and also in order to begin to manage these phenomena, it is advisable to study the totality of these processes, beginning with the simplest physico-chemical system and then moving to more complex systems gradually approximating actual rocks.

The simplest model for electrochemical extraction of elements is a two-chambered cell containing different media separated by a membrane. Electrodes placed in the chambers introduce an electrical current into the system from an external source. All of the processes characteristic of electrochemicalextraction take place in such a model: the current passing through dissolves and transforms minerals, and ions are displaced and concentrated around the electrodes. By lowering the intensity of the current and the time of its operation, one can vary the intensity of the electrical action. Changing the composition of a medium allows one to investigate the effect of a current as well as effect of a texture and structure of the rock upon electrochemical extraction. Finally, changing the composition of the electrodes allows one to investigate the effect of the composition of the electrode reactions, which is especially important at the sites where the elements are concentrated - at the element-receivers (ERs). Actually, one chamber in the proposed model can be considered an element-receiver; the other is a simulation of the surrounding medium. During the time the processes are taking place, but while products of the electrode reactions have not yet arrived to the ER from the second supply electrode from the chamber simulating the surrounding medium, the results of the investigation correspond to phenomena taking place in the environment of the ER during CHIM surveys in the aureole version [1]. When products of electrode reactions from the second electrode arrive at the ER simulator, on the other hand, the phenomena observed correspond to the extraction of elements directly from ores. This manner of extraction is utilized during CHIM operations in general and in the logging versions.

The simplest model examined here has its applications in a study of various factors controlling the electrochemical extraction of elements. In the present article, we characterize the role of the acid in the element-receiver and its effect upon the intensity of the extraction and the reproducibility of observations using the CHIM method. Other results will be presented in subsequent reports.

As is well known [1], acid is introduced into element-receivers in order to neutralize OH- ions arising during the cathode dissociation of water. This is because the OH- ions move toward metallic cations approaching the ER and block their approach to the ER. In addition to neutralizing OH- ions, the acid present in the ER unavoidably results in the diffusion of acid into the surrounding medium. This has two negative consequences. In the first place, hydrogen ions removed from an element-receiver by the electrical current are turned back to the ER. In this way, the portion of current deployed for the transport of useful components is decreased. In the second place, hydrogen ions turning up in the rocks around the ER can cause dissolution of the rocks and can add recently dissolved components to the extracted elements, thus distorting the results of the strictly electrochemical extraction of elements.

Since the current action impedes the diffusion of hydrogen ions from the element-receiver, apparently one can select conditions for carrying out the processes under which hydrogen ions will not leave the range of the ER. Experimental and numerical simulation approaches can be used to solve these problems. The results of investigations using both approaches are presented below.

A diagram of the electrochemical cell in which the investigations were conducted is shown in Fig. 1. The cell consists of two chambers separated by a membrane (10). Chamber (4) simulates the ER and chamber (3), large in size, simulates the external medium. A platinum anode is placed at the butt-end of chamber (3) and a titanium cathode is placed at the butt-end of chamber (4). In order to decrease the convection of the solution, chamber (3) is partitioned by three membranes which, as in the case of the ER membrane, are cellulose films 80-mcm in thickness.

The cell is connected to a stabilized source of direct current which remains unchanged during each experiment. The observations are made in the form of geoelectrochemical accumulation-time curves (hodographs) [1]. After electrical current has been passed through chambers (3) and (4), the solutions filling the chambers are removed. The titanium electrode is washed off with hydrochloric acid (1:1). The quantities of the participated in the experiment elements in the solution are then determined.

Solutions of nitric acid, forming easily dissolved compounds with the majority of metals, were selected as the medium in the ER. This allowed elements to accumulate at the element-receiver.

Solutions of zinc sulfate were chosen for the simulation of the external medium: zinc ions do not interfere with the determination of nitrate ions in the samples (nitrate analysis is necessary in order to construct a complete balance for all carriers of current; moreover, there is a fast and sensitive methodology for zinc determination).

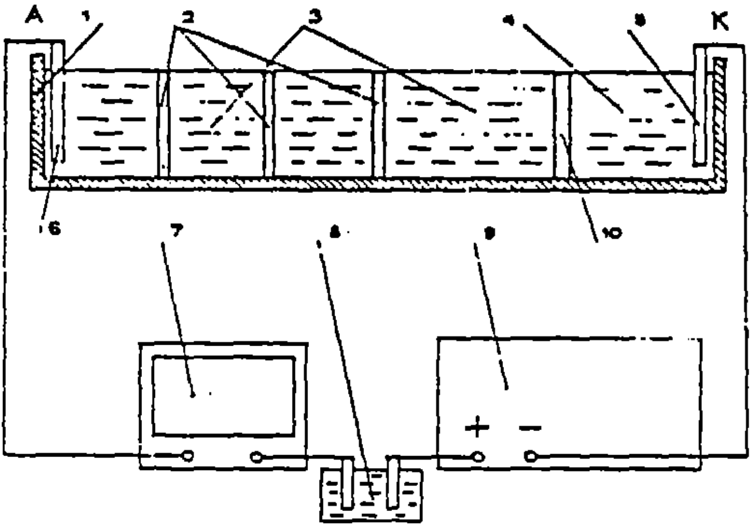

Fig. 1. Diagram of set-up for conducting the experiments: 1) electrochemical cell, 2) membrane on the anode side, 3) chamber simulating the external medium, 4) chamber simulating the element-receiver, 5) titanium cathode, 6) platinum anode, 7) ammeter, 8) coulombmeter, 9) direct-current source, 10) membrane of element-receiver.

The concentration of zinc was determined by a photocolorimetric technique using sulfarsecene on a FEK-56m instrument [5]. The control was implemented by polarographic technique on a FPL-1 instrument [1]. Both methods yielded results within margins of error not exceeding 10%. The concentration of nitrate ions was determined by the photocolorimetric method with phenoldisulfoxic acid [2]. It was first established that zinc lowers the values determined for quantities of nitrate ions at concentrations $Zn^{2+}:NO_3$ = 300:1 or more. Therefore, corrective coefficients obtained for reference solutions were introduced when determining NO_3^- in solutions with high concentrations of zinc. The concentration of hydrogen ions was measured by titration with a deci-normal solution of sodium hydroxide with methyl-orange indicator. The error of the analysis (coefficient of variance) was 10% for the control analysis of samples. The total volume of the control analyses was no less than 25-30%.

The effect of the concentration of acid in the ER upon the extraction of zinc was investigated in several sequential stages. First, a reference time for carrying out all experiments was established. This was necessary because an electrode process takes place at anode (which is placed in the external medium) involving the oxidation of OH- with the formation of hydrogen ions transported to the ER under the action of the electrical field. If the hydrogen ions reach the ER within the time of the experiment, a portion of the current will be deployed to transport them through the membrane (this results in a redistribution of the current between the other carriers). The contribution of hydrogen ions formed at the anode to the total quantity of current passing through the membrane is not subject to precise calculation, since hydrogen is present at the ER in a significantly higher concentration than that formed at the anode. It was simpler from a technical standpoint to limit the time the experiments were run, to establish a reference time when the hydrogen ions formed at the anode, still not having reached the membrane of the element-receiver and, consequently, still not having participated in transfer of current through it.

In order to determine the reference time, concentration of the zinc from a 0.1 N solution of zinc sulfate in 0.1 N HNO_3 was carried out at a current strength of up to 300 mA in a time interval of up to 8 hours. The results of the observations are presented in Fig. 2, where geochemical accumulation-time curves for the extraction of zinc are shown. Without current or with currents of 3, 10, or 30 mA, the increase in the mass of zinc per unit of time i.e., the rate of extraction, remains constant over the course of 8 hours. At currents of 100 and 300 mA, changes in the rate of the extraction of zinc take place at times of 5.5 and approximately 2.5 hours respectively. They are linked to the arrival of hydrogen ions formed at the anode, a fact indicated by the change in the pH value in the chamber simulating the external medium. The change in pH in the near-membrane zone on the side of the external medium shows that the acidity of the solution does not change for currents up to 30 mA, but that an acidic wave propagating from the anode reaches the element-receivers after 5.5 and 2.5 hours for currents of 100 and 300 mA respectively. We chose a reference time of 1 hour. During this time period, we studied the effect of acid concentrations in a range from 0.01 to 3 N upon the quantity of extracted zinc at current of 0 to 300 mA (TABLE 1).

For the quantity of zinc transported to the ER as a result of diffusion (without current), see TABLE 1, column 2. the current is shown in columns 3-7. The total quantity extracted (M) includes a migrational (M_m) and diffusional (M_D) components. The first component is associated with accumulation under the influence of the electrical-field gradient; the second is associated with the concentration gradient. Columns 8-2 contain data on the migrational component, defined as the difference: $M_M = M - M_D$.

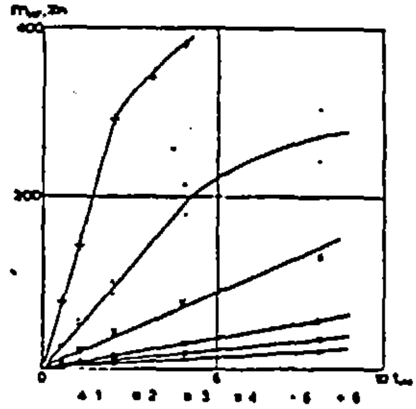

Fig. 2. Geoelectrochemical accumulation-time curves for the extraction of zinc; 10 without current; at currents of: 2) 3 mA, 3) 10 mA, 4) 30 mA, 5) 100 mA, 6) 300 mA.

For the quantity of zinc transported to the ER as a result of diffusion (without current), see TABLE 1, column 2. the current is shown in columns 3-7. The total quantity extracted (M) includes a migrational (M_M) and diffusional (M_D) components. The first component is associated with accumulation under the influence of the electrical-field gradient; the second is associated with the concentration gradient. Columns 8-2 contain data on the migrational component, defined as the difference: $M_M = M - M_D$.

(I) TABLE 1. Quantity of zinc accumulated at the ER.

Acid concentration in ER, N	M_D, mg	M, Mg					M_M, mg				
		Current strength, mA									
		3	10	30	100	300	3	10	30	100	300
0,01	1,7	3,2	6,7	17	55	160	1,5	5,0	15	53	158
0,1	2,7	4,0	7,1	18	46	143	1,3	4,4	15	43	140
0,3	4,6	5,0	5,5	11	49	133	0,4	0,9	6,4	44	139
1,0	9,6	10,0	10,0	11,5	17	135	0,4	0,4	1,9	7	125
3,0	12,5	–	13,0	13,5	18	38	–	0,5	1,0	5,5	25

By analyzing the data in TABLE 1, one can see that the mass of zinc increases with increasing current. The mass remains more or less high for each increase up to a certain concentration of acid. It then decreases sharply with increasing concentration of acid. With increasing current, the boundary between quantities of accumulated zinc (see TABLE 1) shifts to an area of higher concentrations: for 3-30 mA, a change in the quantities of extracted zinc occurs at 0.3 N. A change occurs at 1 N for a current of 100 mA and a change occurs at 3 N for a current of 300 mA.

The results of the experiments allow us to determine the portion of current involved in the transport of zinc or its transport number [3]:

$$n_1 = \frac{m_1}{K_1 I_t}, \qquad (2)$$

where n_1 is transport number of the i-th element, m_1 is the mass of the i-th element transported from one space to the other, I is the current in mA, t is the time in hours, and K_1 is the electrochemical equivalent of the i-th element. Calculated values for the zinc transport are shown in TABLE 2.

The data of TABLE 2 indicate that, within the region identified, the transport number is characterized by a constant value, 0.38, regardless of the level of current. In other words, 38% of the total current is used in the transport of zinc ions. The similar transport numbers for zinc in solutions of zinc nitrate and zinc sulfate are in agreement with tabulated data [4]. Within the region identified in TABLE 2, the transport number for zinc decreases approximately eight-fold and amounts to 0.05 on an average, i.e., all of 5% of the total current passing through the cell is involved in the transport of zinc. A decrease in the portion of current deployed in the transport of zinc should correspondingly lead to an increase in portion of current used for the transport of other ions. Under the conditions of the experiment, these ions would be nitrate or hydrogen ions.

TABLE 2. Transport Number for Zn^{2+} at Various Concentrations of HNO_3 at the ER.

Concentration of acid in ER, N	Current strength, mA			
	10	30	100	300
0,01	1,40	0,41	0,43	0,40
0,1	0,37	0,41	0,36	0,38
0,3	0,08	0,17	0,37	0,34
1	0,03	0,05	0,06	0,33
3	0,04	0,02	0,04	0,04

Data on the accumulation of NO3$^-$ in the chamber simulating the external medium are presented in TABLE 3.

TABLE 3. Mass of Nitrate Ions transported to the External Medium.

Concentration of acid in ER, N	M_D mg	M,Mg				M_K, mg			
		Current strength, mA							
		10	30	100	300	10	30	100	300
0,01	2	18	40	95	310	16	38	93	308
0,1	15	26	48	128	330	11	33	113	315
0,3	44	50	100	130	350	6	56	96	306
1,0	170	180	195	320	650	10	25	150	480
3,0	670	-	710	800	1185	-	40	130	415

It is evident from the table that, in contrast to zinc ions, the quantity of nitrate ions being transported under the influence of the current shows little dependence upon the concentration of acid. It follows from this that nitrate ions do not participate in the redistribution of ions among their carriers.

The results of the determination of the quantity of hydrogen ions in the external medium are presented in TABLE 4.

TABLE 4. Quantity of Hydrogen Ions Transported to the External Medium.

Concentration of acid, N	M, mg				
	Current Strength, mA				
	3	10	30	100	300
0,01	traces				
0,1	0,16	0,02	traces		
0,3	1,05	0,8	0,45	traces	
1,0	3,9	3,3	3,3	1,3	traces
3,0	13,8	13,5	13,4	11,8	11

The data in the table characterizes the mass of hydrogen in the external medium associated with hydrogen diffusion from the ER. For its determination, the quantity of hydrogen ions formed during the anode process are subtracted from the total mass of hydrogen ions:

$$M = M_{\Sigma} - M_{A}, \qquad (3)$$

where M_A is the mass of hydrogen ions formed at the anode (the value is determined by Faraday's Law), M is the mass of hydrogen ions associated with diffusion from the ER, and M_{Σ} is the total quantity of hydrogen ions determined in the external medium.

In TABLE 4, one can clearly distinguish an area in which hydrogen is either not fixed at all or is found at the trace level. It coincides with the area identified in TABLE 2 for zinc, and it is characterized by its high transport numbers. Where the transport number for zinc is minimal, hydrogen ions are present in the external medium in elevated quantities.

The inverse dependence between zinc and hydrogen indicates that a redistribution of current in favor of hydrogen ions takes place at certain levels and concentrations of acid. On the other hand, when the transport numbers for zinc are high, hydrogen plays almost no role in the transfer of current across the membrane. Such conditions could arise when the migrational flux of ions proves to be equal to or greater than the absolute value of the diffusional flux and opposite in sign.

$$\frac{dM_M}{dt} \geqslant \frac{dM_D}{dt} \qquad (4)$$

Under these conditions, hydrogen ions cannot cross through the membrane to the external medium and the mass of the extracted element from the external medium is maximum.

The diffusion equation for thin membranes in the absence of a convective flow takes the form:

$$\frac{dM}{dt} = D_H S \frac{C_1 - C_2}{l}, \qquad (5)$$

where dM is the mass of hydrogen ions crossing through a membrane of thickness l and area S during a time dt, C1 and C2 are concentrations of hydrogen on different sides of the membrane, and D_H is the diffusion coefficient for the hydrogen ions.

The velocity of migrational flux of hydrogen ions to the cathode side can be determined from the equation:

$$\frac{dM_H}{dt} = K_H I n_H, \qquad (6)$$

where dM is the mass of hydrogen ions crossing through the membrane to the ER during a time dt, I is the current strength, K_H is the electrochemical equivalent of hydrogen, and n_H is the transport number for hydrogen ions to a solution of nitric acid.

Substituting (5) and (6) into inequality (4), one can obtain the conditions for suppression of the diffusion of hydrogen ions from the ER as a result of electrical current by selecting the appropriate critical current I_K :

$$I_K K_H n_H \geqslant D_H \frac{C_1 - C_2}{l} S \qquad (7)$$

or, taking into account that $j_K = \frac{I_K}{S}$,

$$j_K \geqslant \frac{D_H}{K_H n_H l} (C_1 - C_2). \qquad (8)$$

By setting the coefficient $P=\frac{D}{K_H n_H l}$ and taking into account that a concentration of acid in the external medium did not exist prior to the beginning of the experiment ($C_2 = 0$), expression (8) can be represented in the form:

$$j_K \geqslant PC_1. \qquad (9)$$

The critical current density can be calculated if the diffusion coefficient of hydrogen ions is known for the medium being studied. The other parameters can either be determined from the conditions of the experiment (c_{H+}, S, l) or found from tabulated data (K_H, n_H).

The diffusion coefficient of hydrogen can be determined experimentally for the cellulose and parchment membranes [1] used in the CHIM method. The experiments were carried out in an electrochemical cell. A diagram of the cell is shown in Fig. 1. It was found that the diffusion coefficient is independent of the concentration of acid in the ER, the composition and concentration of electrolyte outside the ER, and the area and thickness of the membrane. The average coefficient of diffusion equals $6,0 * 10^{-3}$ cm^2/hr with a 12% margin of error.

Taking into account the value found for D_H, the coefficient of proportionality P *in equation (6)* can be quantitatively determined. The remaining parameters are: K_H- the electrochemical coefficient of hydrogen (0.00378 mg/mA); n_H - the transport number for hydrogen ions in nitric acid, equalling 0.83 [3]; l- the thickness of the ER membrane (cellulose and parchment membranes), equalling 8.10-3 cm. Then,

$$j_K \geqslant 25\ C_1 \qquad (10)$$

We attempted to use inequality (10) obtained for the simplest physico-chemical system, for complex systems and, in particular, for the extraction of elements associated with the use of the CHIM method in actual field conditions. The research was carried out in the Maritime Province (Far Eastern USSR) . At site 1[1], tin-rich ore stockwork occurs at a depth of 700 m hosted by interbedded sandstones and siltstones (Fig. 3). A tin ore body would not be noticeable on the basis of the results of a surface rock geochemical survey or trenching (see Fig. 3, graphs 1 and 2). It would not be determined by using the CHIM method if condition 10 (graph 4) were not fulfilled. If the required condition is fulfilled, on the other hand, the ore body would be discovered by CHIM survey (graph 5).

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[1] The Kavalerovo skarn type tin-polymetallic deposit

The small quantities of tin in mobile forms capable of moving under the influence of a current are so minuscule that the most favorable conditions would be necessary for the accumulation of tin in quantities sufficient for analysis. In accordance with inequality (8), such conditions can be realized in various ways. We used a change in j_k at the expense of the membrane area. For this, CHIM method observations were conducted at three different element-receivers with membrane areas equalling 60, 7 and 1 cm^2 for current densities of 1.5, 20, and 150 mA/cm^2 respectively. The calculated critical current density (j_k) equalled 37.5 mA/cm^2.

CHIM observations were carried out along three parallel sampling lines at intervals of 1 m along profiles used for the surface lithochemical survey; the outcrops along the profiles were examined also. Fig. 3 shows that no tin anomaly appears in the case (graph 3) when $j < j_k$; extraction of tin amounts to 1-1.5 microgram. In the second case (graph 4) when $j < j_k$, a weak tin anomaly of up to 4 microgram against a background of 2 microgram is noticeable within a projection to the surface of the ore stockwork. However, the anomaly has poor contrast and is indistinctly delineated against the overall background. Finally, in the third variant of the survey (Graph 5), $j \ll j_k$, a clear tin anomaly 250-m wide and coinciding with the projections to the surface of the ore body is obtained. Its intensity reaches 16 microgram against a background of 0.5-1.0 microgram.

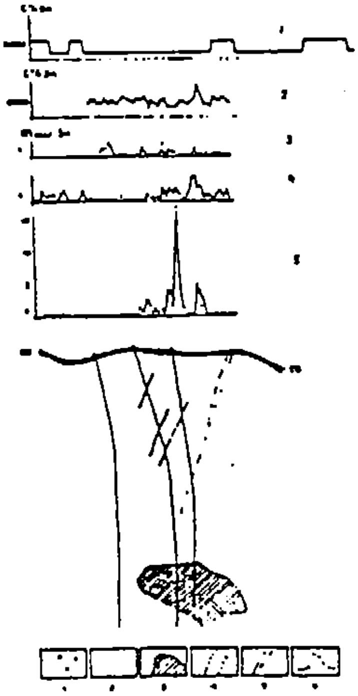

Fig. 3. Result of the CHIM survey at Site 1: 1) Quarternary deposits, 2) interbedded siltstones and sandstones, 3) tin-ore stockwork, 4) veins of tin mineralization, 5) veins of polymetallic mineralization.

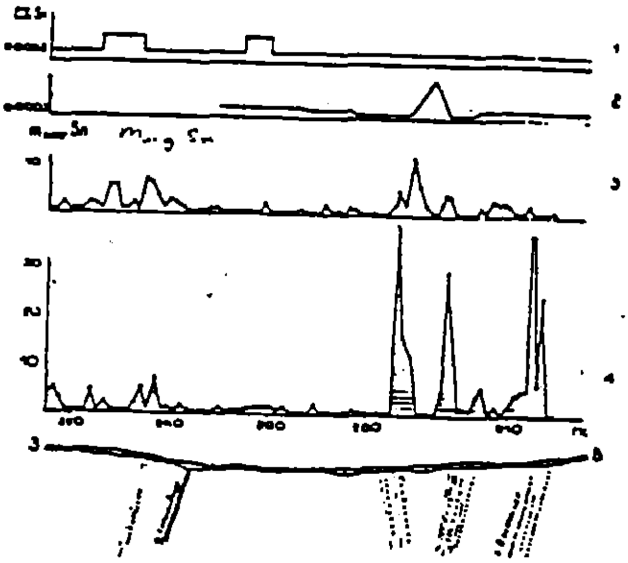

Fig. 4. Results of the CHIM survey at Site 11 (same legend as in Fig. 3).

Similar results were obtained at Site 11 (Fig. 4). the results of the soil survey and outcrops sampling are presented in graphs 1 and 2 respectively. The observations were carried out along two closely spaced lines: at one, the area of the ER was 7 cm^2 (Graph 3), at the other, the area was 1 cm^2 (Graph 4). Both in the first case ($j < jk$) and in the second ($j > jk$), two anomalous areas were noted on the profile: eastern and western. However, the intensity and contrast of the tin anomalies were significantly higher than when element-receivers with membrane areas of 1 cm^2 were used. The 1-cm^2 areas provided a current density for electrochemical extraction higher than the critical density; this was a higher current density than provided when using an element-receiver with a 7-cm^2 membrane. The 7-cm^2 membrane did not provide the required current density for the most favorable extraction of tin.

Investigation of the effect of the acid concentration in the ER upon the electrochemical extraction of metals characterizes one of the factors influencing the contrast and reproducibility of the results of observations using CHIM. Investigations of other factors will be discussed in subsequent reports.

LITERATURE CITED

1. I.S. Goldberg, et al., Manual "Exploration for ore Deposits Using the CHIM method", ONTI VITR (1978), p. 75.

2. Z. Marchenko, Photometric Determination of Elements [Russian translation], Mir Publishers, Moscow (1971).

3. V.V. Skorchelletti, Theoretical Electrochemistry, Khimiya Publishers, Leningrad (1974), p. 568.

4. A. Ya. Shatalov and I.K. Marshakov, Laboratory Course and Practicum on Physical Chemistry, Vysshaya Shkola (1968), p. 220.

5. M.A. Yagodnitsyn and V.N. Antonov, "Accelerated Photometric Determination of Copper and Zinc in Natural Waste Waters", in: Purification of Waste and Tap Waters Undertaken by Non-Ferrous Metallurgy Enterprises, Metallurgiya, Moscow (1971), pp. 117-119.

POSSIBLE USES OF THE CHIM METHOD FOR EXPLORATIONS OF COVERED GOLD DEPOSITS

S.G. Alekseyev, A.A. Veikher and I.S. Goldberg

A successful application of the aureole version of CHIM method in exploration for covered copper, polymetallic and nickel deposits located with unconsolidated overburden reaching 100-m in thickness suggests that this method could be used in search for gold deposits as well. The main difficulty with gold deposits using the CHIM method is the fact that gold content in the ore bodies and surrounding aureoles is low (four-five orders of magnitude lower than copper, nickel, lead, zinc, and a number of other metals). Overcoming this difficulty would be possible by increasing the sensitivity of gold analysis in samples from element-receivers and increasing the enrichment of samples during the process of electrochemical extraction. We undertook efforts in both directions. The results of our investigation are described below.

In order to increase the sensitivity of the gold analysis in the CHIM samples, we used a method of film polarography with accumulation on a solid graphite electrode. The ethyl ether of acetic acid (ethyl acetate) was used as the extracting agent. Extraction was carried out for 2 minutes on samples 10-ml in volume with the aid of 10 ml of ethyl acetate. Determination of the gold using film polarography with accumulation allowed us to concentrate the microquantities of gold at the graphite electrode's surface. This increased the sensitivity of the determination by a factor of 10-20. The use of a solid graphite electrode significantly simplified the technique of analysis over what was possible with the use of mercury electrodes. At the same time, we used a polarograph FPL-1 which was specially developed for field laboratories. The use of this polarograph may have also increased the sensitivity and productivity of analysis for each sample.

These measures allowed us to achieve a sensitivity of gold determination equal to 0.005 mcg/ml in the solution analyzed or a sensitivity of 0.01 mcg for the entire volume of the sample. The error of the determination was 30%. The gold analysis of CHIM samples for gold involved the following steps:

- The sample solution was evaporated to a volume of 10 ml and transferred to a separatory funnel;

- 5 ml of concentrated hydrochloric acid and 10 ml of ethyl acetate were added to this volume. Distilled water was then added up to a volume of 30 ml;

-extraction was carried out for two minutes;

- the aqueous phase was decanted, and the ethyl acetate was washed with 0.1 N hydrochloric acid;

- ethyl acetate was transferred to a heat-resistant 50-ml beaker; 2-3 drops of a 2% solution of NaCl were added and the mixture was evaporated to dryness in a water bath;

- the dry residue was dissolved in 0.5 ml of aqua regia, 3 drops of hydrogen peroxide were added, and the mixture was evaporated to moist salts;

- the moist salts were treated with 0.5 ml of concentrated hydrochloric acid and evaporated to a dry residue;

- the dry residue was dissolved in 2 ml of 0.1 N hydrochloric acid and transferred to a cell for polarography on the FPL-1;

- polarographic analysis of the solution was carried out in the regime: sedimentation (settling potential) - 0,7 V; sedimentation (settling) time - 10 min; scanning rate - 1.6 V/min; range of current recording - 2 mcA;

- a polarographic curve of gold-solution currents was recorded and the height of the maximum on the curve was measured;

- the concentration of gold in the analytical solution (2 ml) was determined according to a calibration graph;

- the mass of gold in the sample was calculated on the basis of the volume taken for the analysis of the sample.

A more detailed analytical methodology would require a special publication and is not discussed in the present article.

Using the analytical methodology just described, measures were taken to increase the concentration of gold in the samples during the process of electrochemical extraction. The investigation was conducted on one of the gold deposits where the gold mineralization is associated with a series of faults concordant with the bedding of host rock. The mineralization was covered by unconsolidated overburden up to 40-m thick.

During the first stage of the investigation, attempts were made to confirm the fact that gold is indeed extracted from soils when using the CHIM method. For this purpose, we selected a pediment area where the presence of gold was established in trench samples. For the electrochemical extraction, we used equipment normally used for CHIM surveys of copper, zinc and lead deposits. The experimental regimes were set up to clarify the gold extraction for various time periods, various strengths of electrical current, and , correspondingly, for various electric field strengths around the element-receivers. In addition, the gold extraction in the form of cations or anions was investigated by connecting element-receivers to a negative or positive pole of current source at the CHIM-10 station.

The results of the observations show that traces of gold could be found at sites where mineralized rocks outcrop directly under slope deposits only when using enhanced extraction regimes (a higher electric-field strength of ~1.0 V/cm and appreciable current - up to 400 mA). We were not able to determine gold at other current levels. Extraction of gold took place in cationic and anionic forms in approximately equal quantities.

The observations showed that increases in the level of current through the element-receivers caused increases in the quantities of gold accumulated. This led us to a conclusion that it might be possible to move from qualitative recording of traces of gold to actually measuring its amount by increasing the level of current (and, correspondingly, the electric-field strength).

When attempting to increase the current, however, it turned out that the standard element-receivers (in which the parchment membranes in contact with the soil have an area of 5 cm^2) heated up, and the membranes burned. Therefore, the element-receivers used would not allow passage of a current larger than 300-400 mA for the time period necessary (10-20 hours).

In order to raise the current through the element-receivers and avoid having the element-receivers heat up, it was necessary to lower ground resistance of the element-receivers. The latter goal was achieved by increasing the area of the membrane in contact with the soil. Element-receivers with membrane surfaces of 15, 40 and 300 cm^2 were tested. The current through the element-receivers was correspondingly increased to 400-600 mA under comparable conditions, and the masses of extracted gold increased to 0.015, 0.1, and 1.0 mcg respectively.

It follows from the data presented that one can anticipate extraction of measurable quantities of gold exceeding the reached limit of sensitivity for the analytical determination of gold (0.01 mcg) when using membrane-surface areas of 40 cm^2 or more. Using these element-receivers at a current of ~400 mA, we attempted to distinguish gold mineralization not only in shallow pediment conditions but also present at depth under clay-rich overburden with thicknesses of 10-20 and 40 m.

The results of initial and repeat observations during 1976 on one of the profiles where the thickness of unconsolidated overburden reached 20 m indicate (Fig.1) that two ore zones crossed by the profile are satisfactorily identified by anomalously high extraction of gold (see Curve 1). The repeat observations (Curve 2) coincide well with the initial ones. Some shift in the location of the anomalous samples is due to the non-uniform distribution of gold in soil and to the fact that the repeated observations were carried out along a profile offset from the first one by 2 m.

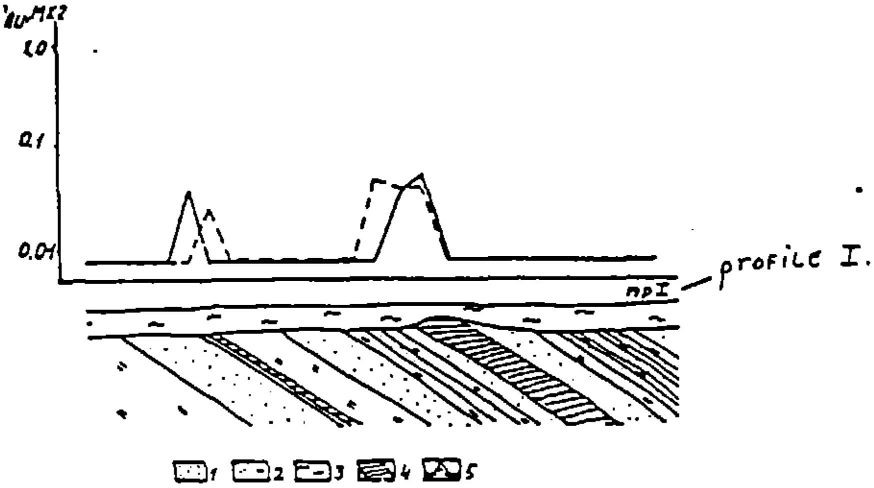

Fig. 1. Results of the CHIM survey. 1) sandstones, 2) siltstones, 3) clays, 4) zones of gold mineralization (gold content > 0.01 ppm), 5) curves of gold extraction.

In order to confirm the reliability of the results, the repeat sampling was conducted along a profile offset from the first one by 40 m along the strike of the ore zone. The repeat data (Fig. 2) show good correlation of zones of gold mineralization along strike.

In one year, control tests were made as to how reproducible the extraction of gold would be with changes in climatic factors and other environmental factors which are difficult to take into account. Measurements were made during a more humid and colder period of time than during the preceding year. In such circumstances, one would anticipate a change in the equilibrium between mobile and fixed forms of gold toward a decrease in the quantity of gold in mobile forms. The results of the measurements indicate that, in fact, extraction of gold was achieved only in isolated sample points in the anomalous zones and, second, there was an overall decrease in the amount of leached gold. Thus it became evident that the amount of leached gold necessary for satisfactory delineation of gold mineralization has to be increased to a higher level which would certainly exceed the climatic fluctuation in the mass of extracted gold. In fact, this makes one question the use of element-receivers with large membranes in the CHIM methodology.

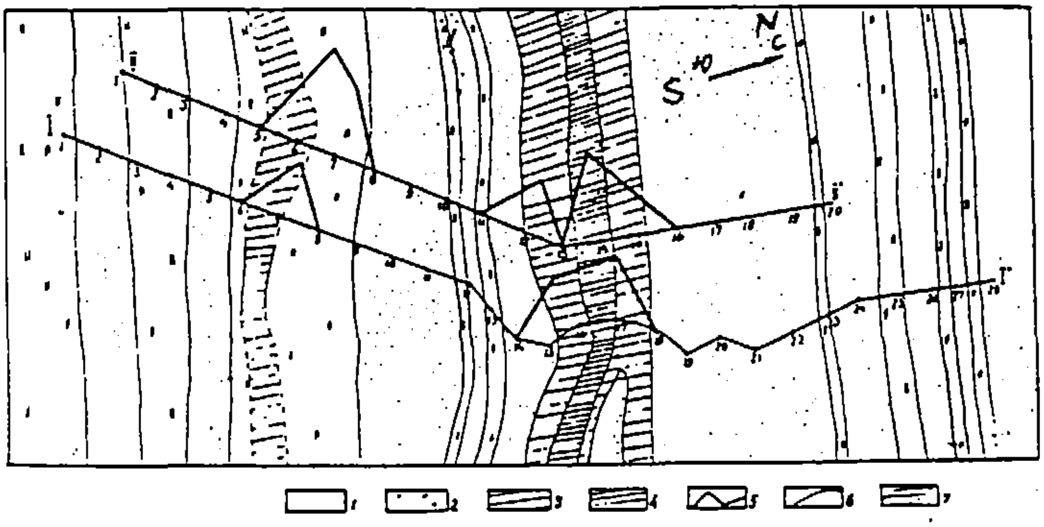

Fig. 2. Geological sketch of the CHIM surveyed area. 1) sandstones, 2) siltstones, 3) zone of gold mineralization (gold content 0.1-0.3 ppm, 4) ore bodies (gold content > 3.1 ppm, 5) gold-extraction curves, 6) sample profiles, 7) zones of gold mineralization suggested by the CHIM method.

The use of element-receivers with membrane surfaces of more than 100 cm^2 is associated with a number of difficulties: passage of the electrolyte, the complexity of construction, inconveniences with respect to transportation, etc. In order to increase the mass of gold leached, it is expedient to group together several element-receivers with a large membrane. The sample results along Profile I are shown in Fig. 3 for a grouping of four element-receivers with membrane areas of 40 cm^2 in the same area where in 1977 the gold extraction from one element-receiver was on the detection limit. A comparison of the data shows that the grouping of four element-receivers provides a satisfactory delineation of gold mineralization. The analytical data and quantities of extracted gold were reproducible.

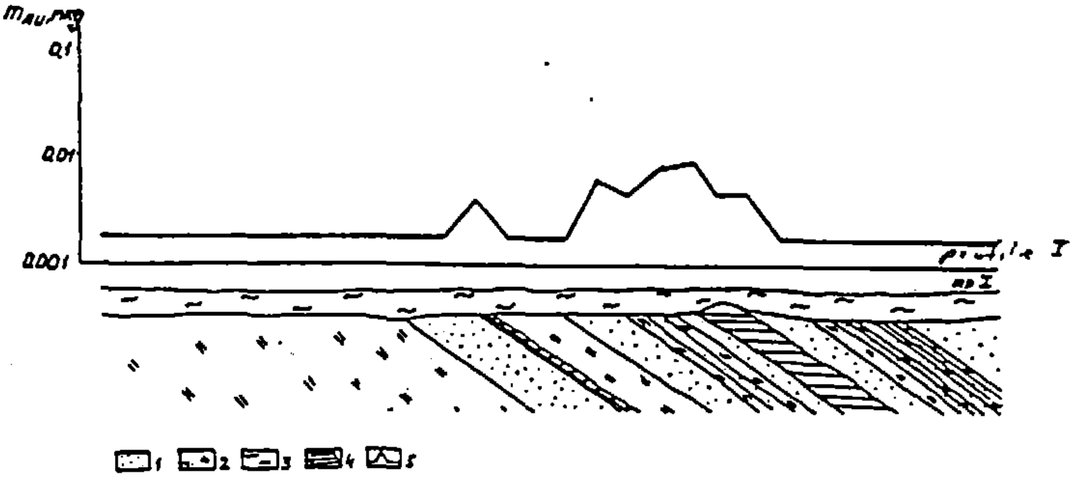

Fig. 3. The CHIM results based on combining of solutions from several element-receivers (for legend, see Fig. 1).

Thus the investigation lead to the following conclusions:

1. The CHIM method in the aureole version can be used to delineate gold mineralization under an unconsolidated cover, just as it can be used to delineate copper, lead, zinc, and other metals.

2. For successful determination of gold mineralization, it is necessary to use a high-power extraction regime (~0.5 A per element-receiver). This can be facilitated by enlarging membrane areas for the element-receivers and by grouping element-receivers together.

For the area of CHIM survey, the combining of solutions from 3-5 element-receivers with membrane areas of 40 cm^2 facilitated satisfactory delineation of gold mineralization under various climatic and environmental conditions. However, it is necessary to conduct an orientation survey for the selection of an extraction regime in each new area.

Additional case history.

The CHIM survey to trace gold mineralization covered by unconsolidated overburden (Fig. 4) was conducted in the test area using the extraction conditions described above. At sites where the cover was not thick, the gold mineralization was outlined by trenching and pitting.

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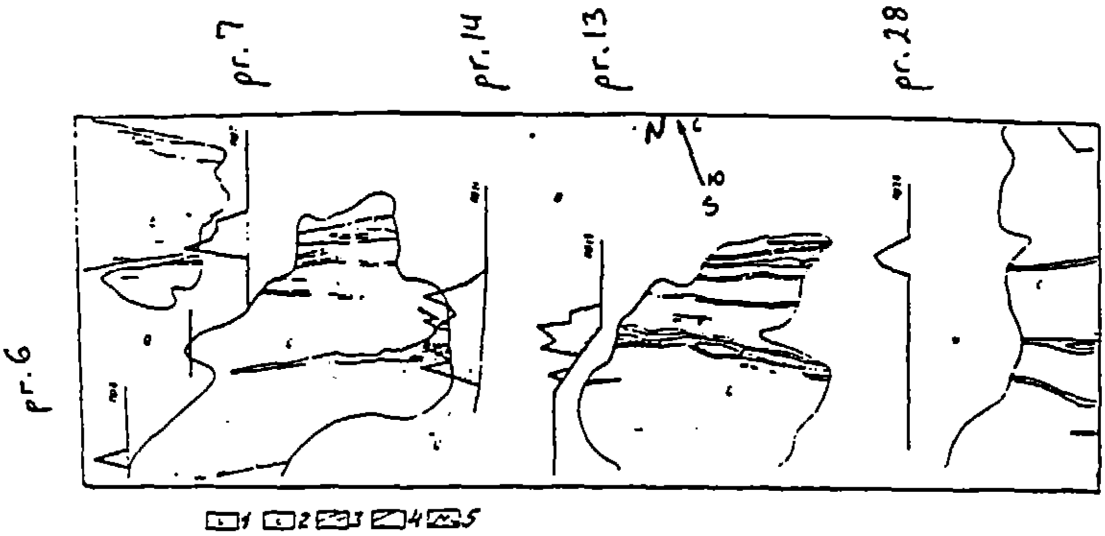

Fig. 4. Geological sketch of the CHIM survey area. 1) Quarternary alluvium, 2) Early Carboniferous sedimentary formation, 3) zones of gold mineralization (gold content 0.1-3.0 ppm), 4) ore bodies with gold contents > 3.2 ppm, 5) gold-extraction curves.

It is evident from Fig. 4 that high grade mineralization occurs in the central portion of the area. Two ore zones covered by unconsolidated overburden can be delineated here. The northern zone probably extends beyond Profile 14 to Profile 7, gradually becoming too low-grade in a northwestern direction. Low grade is also noticeable within this zone in the opposite direction, beyond Profile 28. The southern zone has a limited high-grade area. Its distribution to the northwest and southeast was not known before the start of the CHIM survey.

The results of the CHIM survey along Profile 14 and 18 allow us to confidently outline the southern zone in covered area between two outcrops in the central part of the area. A continuation of this zone was not found on profiles 28 and 6. Thus the ore zone established at the outcrop can be satisfactorily traced under alluvium and can be contoured from the northwest and southeast. The northern zone was not found on profiles 18 and 14, but is well delineated on profiles 28 and 7. From what has been said, we can conclude that this zone has a high-grade portion in the vicinity of Profile 18 and that the zone outcrops at the surface to the northwest. Further to the northwest, the zone becomes low-grade, but it again becomes high-grade near the Profile 7. The high-grade portion of the zone is limited in extent along strike. Such limitation was also noted in the area of Profile 28.

Besides the northern and southern zones traced by the CHIM method, high quantities of gold probably outlining still another gold-zone extending further to the northwest were extracted on Profile 6.

The results obtained by the CHIM method serve as a basis for drilling priorities in the southern zone.

The survey results within this area showed promising possibilities for using the CHIM method to trace gold mineralization beneath the unconsolidated cover. However, the methodology of field operations using the CHIM method in exploring for gold under various geologic, geomorphologic, and climatic conditions requires further development. Nevertheless, the very fact that deep-covered high-grade gold mineralization can be delineated is significant and allows us to consider the CHIM method for the prospecting of vast covered areas and for evaluation of gold prospects already discovered.

338084

FINDING BURIED GOLD MINERALIZATIONS

S. G. Alekseyev and I. S. Goldberg

The problem of finding a buried gold mineralization arises in several situations, typically, during 1) exploration of the flanks of known deposits; 2) in the process of prospect evaluation; 3) in correlating of ore zones uncovered in neighboring areas but separated by alluvial cover. It becomes all the more important the richer the discovered portion of the mineralization is and the more promising the undiscovered portion of a gold deposit appears to be. Tracing gold mineralization takes on a special significance when exploring covered areas. In such areas significant amounts of drilling can be used up. This is especially true in districts with complex geology and complicated ore grade distribution. This article discusses testing of the CHIM method to determine whether it is an easier method than drilling for tracing gold mineralizations under unconsolidated overburden.

The survey area is classified as a poorly exposed; 30-40% of the area is covered with transported unconsolidated overburden up to 70-100-m thick. Since such overburden is not ubiquitously present, the task of finding gold-bearing outcrops and subcrops is facilitated by the geological mapping on the scale of 1:50,000 and smaller, and surface geochemical surveys. Gold-oriented soil geochemistry is usually used.

Gold prospects and/or zones of mineralization are trenched and, in completely covered areas, they are drilled. The drill grid is usually 200x20-40 m with an average depth of 50-70 m.

In the area of the CHIM testing, the sedimentary formations are mainly represented by sandstones and siltstones. The rocks are graphitized to a significant degree, and thick, deep zones of chemical weathering and oxidation develop within them. The ore-hosting structures are tectonic zones striking north-west and dipping north-east. The primary ores are silicified sulfidized sandstones and siltstones. The gold in the primary ores exists in the form of admixtures in pyrite and arsenopyrite; a small amount of free gold is also present. In the supergene zone, the primary ores were completely oxidized. According to the fire assay and metallurgical test data, all of the gold in the oxide orebodies exists as a free gold. The oxide orebodies occur in a linear belt and are of significant width and length. The contacts of the orebodies are indistinct and can be mapped only on the basis of assay data.

It was shown before [1] that similar ore bodies and zones of gold mineralization can be delineated by the CHIM method if the thickness of unconsolidated overburden is about 20-m. The survey was conducted under the following conditions. Gold was extracted at element-receivers (ERs) with large membrane areas, 40 cm², in a high-power regime (300-400 A through each ER) at an average electric field strength of 2 V/cm. The extraction time was 10 hours. The element-receivers were distributed along the profile at steps of 7.5 m. The contents from four element-receivers were grouped into a single sample so the quantity of extracted gold will exceed the minimum amount necessary for analysis. This method successfully delineates a gold mineralization by outlining anomalies with amounts of gold exceeding 0.01 ppm. The anomalies are satisfactorily reproduced during repeated observations and are spatially distributed directly above the tops of the ore bodies. Mineralized zones with noncommercial gold concentrations are characterized by anomalies with less than 0.1 ppm. They are not always reproducible during repeated observations, since the quantity of gold extracted within such anomalies is too near the limit of sensitivity for the analysis (0.003-0.005 ppm).

The proposed methodology for CHIM was used to trace gold mineralizations at two gold prospects in Eastern Kazakhstan.

Prospect I (Fig. 1). The exposed portions of the area contain several zones of mineralization. High gold values were found in several of them on the basis of individual samples. The zones are 'lost' under unconsolidated overburden 50-70 m thick. They can be outlined by the CHIM method. The profiles and their relationship to the zones on outcropped hills is shown in Fig. 1. Three levels of gold extraction were established on the basis of the results. The most intense extraction is characterized by masses of more than 0.01 ppm. These are first-order anomalies; they were found on profiles 58, 66, 67, and 72. The anomalies were spatially combined into three anomalous zones, which have been named the Northern, Southern, and South-western zones. The Southern zone can be traced from the east to the west along several profiles. Its width is 62 m on Profile 72. Further to the west, it can be traced through Profile 67, where it reaches a width of 100 m. On an outcropped portion of the area between these two profiles, the zone is visible in mine workings, and it is intercepted in drill holes. Thus, a zone of mineralization found in the outcropped part of the prospect can be traced from the south to the west and to the east. In the west, it tapers out or the gold values within it diminish. To the east, however, the zone extends further than Profile 72.

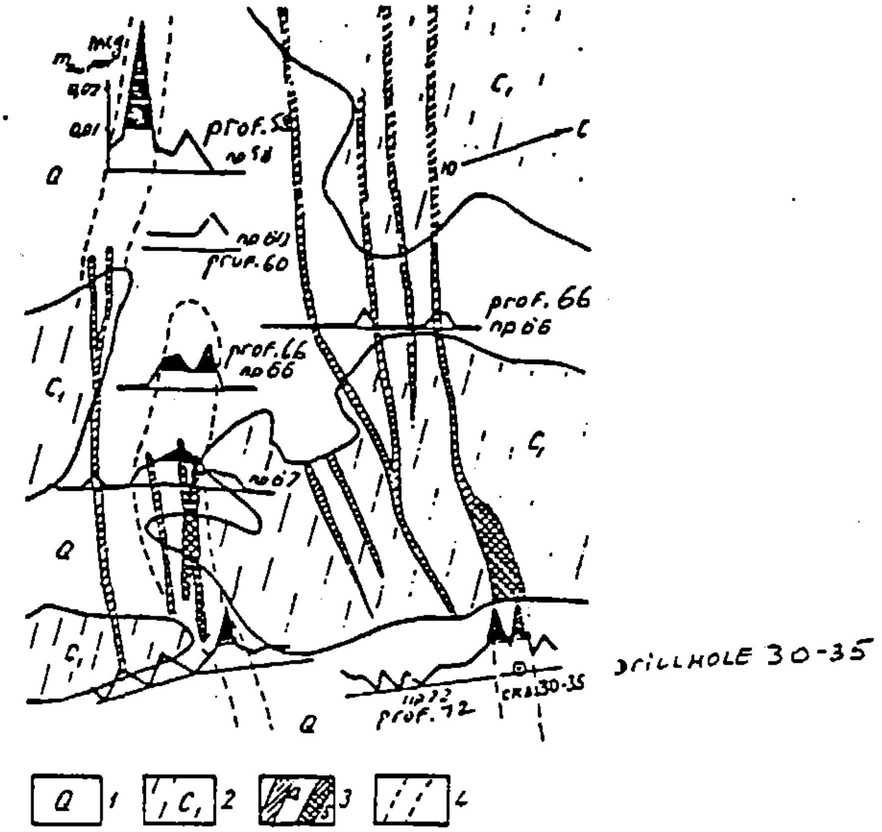

Fig. 1. Results from exploring the ore zones using the CHIM method. Prospect 1: 1) Quarternary unconsolidated; 2) Early Carboniferous sandstones and siltstones, 3) zones with noncommercial (a) and commercial (b) mineralization, 4) gold zones traced by the CHIM method.

To the south, the Southern zone abuts the Southwestern zone, which is noted on Profile 58. The Southern zone is confirmed here in an outcropped area which is also trenched. The zone continues to the east, where it can be traced by a weak CHIM anomaly. It can then be traced by trenches at a next outcrop and, still further to the east, again by a weak CHIM anomaly on Profile 72. It is necessary to note that the CHIM anomalies above the Southwestern zone are weak, with the exception of the anomalies in the western portion. This correlates with the small gold content in the outcropped portion of the zone.

The Northern zone is clearly delineated only on Profile 72. Its width is 100 m. The continuation of the zone to the west is apparently a zone of mineralization mapped and sampled in mine workings in the exposed portion of the area. Still further to the west in the area of Profile 66, according to the data from the CHIM method, the ore zone either tapers out or the gold values within the ore zone decrease significantly.

Thus, the anomalous zones which most probably contain gold mineralization within their contours can be traced at Prospect I using the CHIM method. The results of the CHIM operations at present are being verified along the Northern zone (Profile 72), where a zone of mineralization with an ore grade of gold was established by drillhole 30-35 (see Fig. 1) in the core of the CHIM anomaly.

Prospect 2 (Fig. 2). Several gold-bearing zones were discovered. A portion of these contain high grades of gold in the trenched part of the prospect. The CHIM results were obtained in the western and eastern parts of the area along four profiles in order to discover the extension of the zones under unconsolidated overburden. The thickness of the latter was 30-50 m.

According to the CHIM results, the major zones with commercial gold mineralization do extend beneath the unconsolidated areas. A zone exposed by trenches can be satisfactorily traced on Profiles 2 and 1 in the northeastern flank of the area. It apparently continues further in a southeasterly direction. This same zone extends to the northwest through Profile 4.

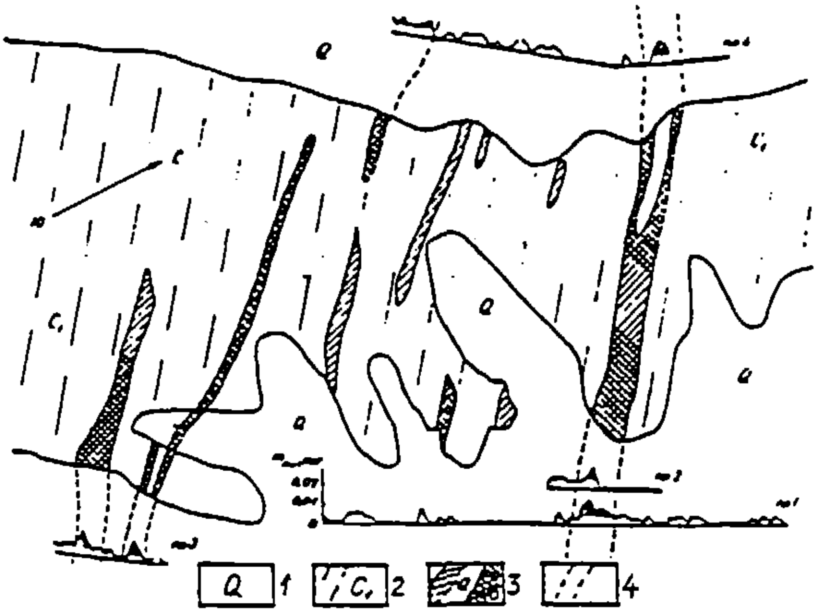

Fig. 2. Results from tracing gold mineralization using the CHIM method. Prospect 2: 1) Quarternary unconsolidated; 2) sandstones and siltstones (C_1), 3) zones of mineralization with low-grade (a) and commercial (b) mineralization, 4) ore zones traced by the CHIM method.

In analogous fashion, we can trace zones exposed in outcrop in the southeastern part of the area; they register well in the CHIM anomalies along Profile 3.

Still another anomalous zone extends into the northern part of the area cross-cutting the southern end of Profile 4. This zone has not been contoured and has a lower gold content than the other zones.

Besides the described first-order anomalies, the other weakly anomalous areas with 0.005-0.008 ppm extractions of gold were found on all of the profiles. Their lesser intensities indicate that, although gold values within such anomalies are higher than in the bedrock, the gold content at these sample sites is too low-grade.

We have discussed examples of tracing gold mineralization in the areas of low topography filled with unconsolidated Quarternary deposits. These examples illustrate the promise of the CHIM method. At the prospects surveyed by CHIM, the delineation of mineralized zones allowed us to decrease the amount of drilling by up to 60% as compared with the drilling needs predicted initially without the use of the CHIM method. We should add that tracing of the zones of gold mineralization at the two prospects mentioned took 1.5 months and significantly accelerated the exploration of these prospects.

LITERATURE

1. S. G. Alekseyev, A. A. Veikher, and I. S. Goldberg, "Possibilities of the CHIM Method for Exploration of Covered Gold Deposits", in: Methodology and Technology of Exploration, VITR (National Institute for Exploration Technology), Leningrad, (1978), No. 123, pp. 33-38.[In Russian]

CHIM SURFACE SET-UP FOR UNIPOLAR EXTRACTION.

Yu. S. Ryss and I. S. Goldberg.

In the set-ups shown on Figure 3, the auxillary grounding electrode is moved out of the survey area (to "infinity"). The primary ground is a system of element-receivers placed at points of intersection of concentric circles with radii or at points of intersection on a rectilinear grid of profiles. The dimensions of the grounding electrode are selected in accordance with the given depth of investigation. Depending upon the distribution of current flowing from the various ERs and the distance between ERs within the ground, the structure of the field within the volume of rock can be selected to be either homogeneous or central or of another type.

A set-up of the type involving a <u>charged body</u> differs from others in that the auxillary grounding is placed within the target object using boreholes or mine workings.

<u>Surface set-up for bipolar extraction</u>. In this set-up, the auxillary electrode is equipped with an ER, just as the primary ground is. Both grounding electrodes are arranged along the strike of the studied zone at a distance from one another which is determined by the actual goals of the study.

<u>The circular "aureole" set-up</u> consists of a central ER and an auxillary circular ground surrounding the ER. The volume being worked is determined by the size of the circle. When investigating aureoles, the radius of the circle usually amounts to 0.5-1 m.

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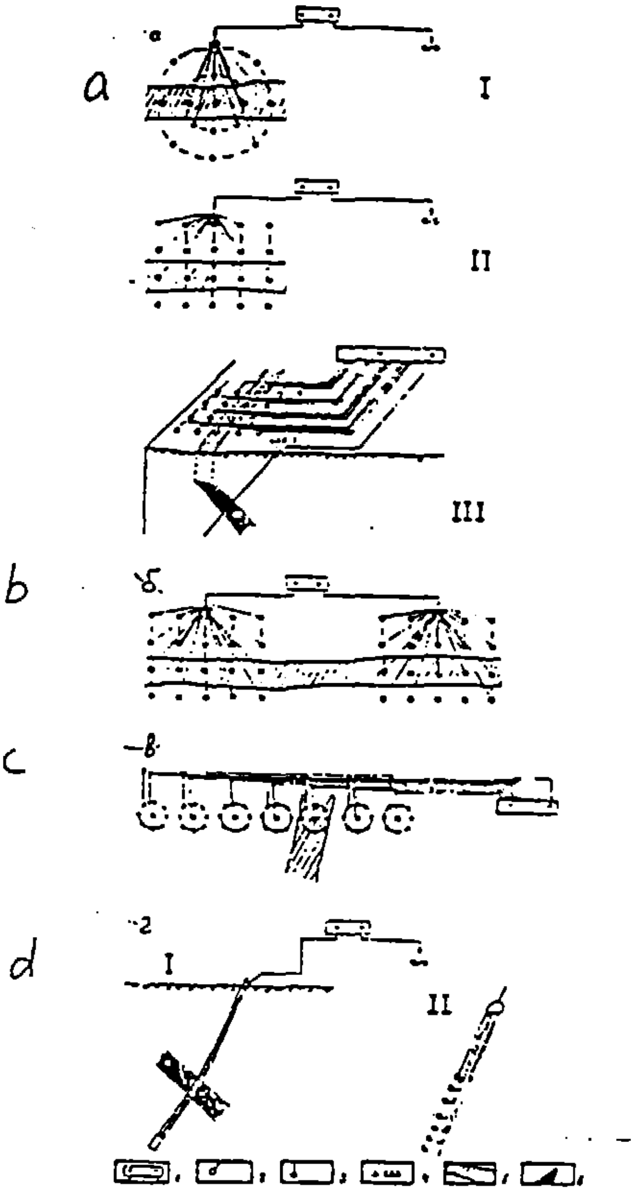

Fig. 3. Diagram of field set-ups in the CHIM method: a) surface set-up for unipolar extraction of metals (I: circular, II: rectilinear, III: by means of a charged body), b) surface set-up for dipole extraction of metals, c) "aureole" circular set-up, d) logging set-up (I: overall scheme, II: braided cable); 1) power source, 2) element-receivers, 3) auxillary electrodes, 4) boreholes, 5) projections of mineralized zones at the surface, 6) ore bodies.

In the Logging set-up, the primary ground takes the form of a chain (garland) of ERs lowered into the borehole on a multiple cable. The auxillary electrode is placed either in "infinity" or on the surface at the borehole opening (casing pipe can be used).

Observations using CHIM in 'aureole' version are the simplest. Circular surface set-ups by 20-30 pieces hooked up in parallel to the source are usually used. Set-ups are positioned along a profile or over a specified area. The ERs are joined to the negative pole of the power source, and the circular auxillary grounding electrodes are joined to the positive pole. One can use batteries of accumulators, rectifiers of alternating current, electromechanical assemblies, and other equipment with the power of 1 kilowatt or more as current sources. Electrical current is passed through the ERs for 1-2 days with periodic or one-time testing of the ER contents. In order to provide identical extraction conditions at each set-up within the circle, measurements of the electric field strength are made at specific points. The electric field strength is selected for all of set-ups at the site under investigation by varying the current passing through individual set-ups. The analysis of the contents of the ERs is carried out either by extraction of the solution or directly within the solution with the aid of chemical or various types of physico-chemical analysis.

Determinations of the metals present in the aureole, their relative quantities, and the positions of ore-bearing zones are usually involved in the 'aureole' version of the CHIM method. Taking into account the linear character of the dependence of the first branch of the accumulation-vs-time curve, graphs along the profiles under investigation are constructed with respect to the magnitude of dm/dt or values of m for a fixed t.

In Fig. 4, results are presented for extraction of nickel, copper, and cobalt at one of the copper-nickel deposits of the

Kola Peninsula. The mineralization is hosted by amphibolites interbedded with granito-gneisses and intruded by plagio-microcline granites. These rocks are covered by glacial moraine 8-12-m thick. Surface geochemical sampling established that the overburden has more or less identical concentrations of trace elements. No aureole was found above the mineralization. Electrochemical extraction from small surface set-ups 1-m in diameter resulted in the accumulation of mobile forms of nickel, copper, and cobalt at the ERs after current was passed for two days. Directly above the top portion of the mineralization, 150-200 mcg[1] of nickel was leached (in 2 days); above the buried portion and also outside the orebodies under the same conditions, 20-25 mcg of nickel were leached. Copper and cobalt were leached in quantities of 40-45 mcg above the mineralization and in quantities of 10-15 mcg at a distance from its upper portion. Thus, within the near-surface horizon of overlaying rocks, dm/dt, and, correspondingly, the contents of nickel, copper, and cobalt, are greater above the hanging wall of the mineralization than along both sides of the mineralized zone. During electrochemical extraction, an aureole was discovered above the mineralization which had not been identified on the basis of bulk sample analysis during the geochemical survey. The difference in discovering the aureole by total sample concentration or by electrochemical extraction is due to the fact that the electrochemistry facilitates the accumulation and selective determination of mobile forms of elements. These mobile forms apparently constitute a fraction in relation to other fixed forms. The masses of the fixed forms are greater than the masses of the mobile elements and are homogeneous over most of the profiles (and, apparently, within the area as a whole. The small changes in the amount of an element that are found during the bulk analysis go practically unnoticed. At the same time, such changes can be recorded very clearly in terms of their

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[1] mcg = microgram

intensified accumulations when using the CHIM method.

When using geochemical extraction, similar effects associated with the detection of covered aureoles can be observed in other areas. The profile of a polymetallic deposit is presented in Fig. 5. The ores here occur in a quartz-sericite altered zone covered by loose clay-rich overburden 40-50 m in thickness. According to the results of a soil survey, background concentrations of lead and copper are less than 10 ppm. During geochemical extraction from the same set-ups used at the preceding site, an aureole with a maximum extraction of lead reaching 90-110 mcg and a maximum extraction of copper reaching up to 360 mcg can be detected above the ores. Lead values of ~50 mcg and copper values of ~50-65 mcg were detected on the flanks of the deposit.

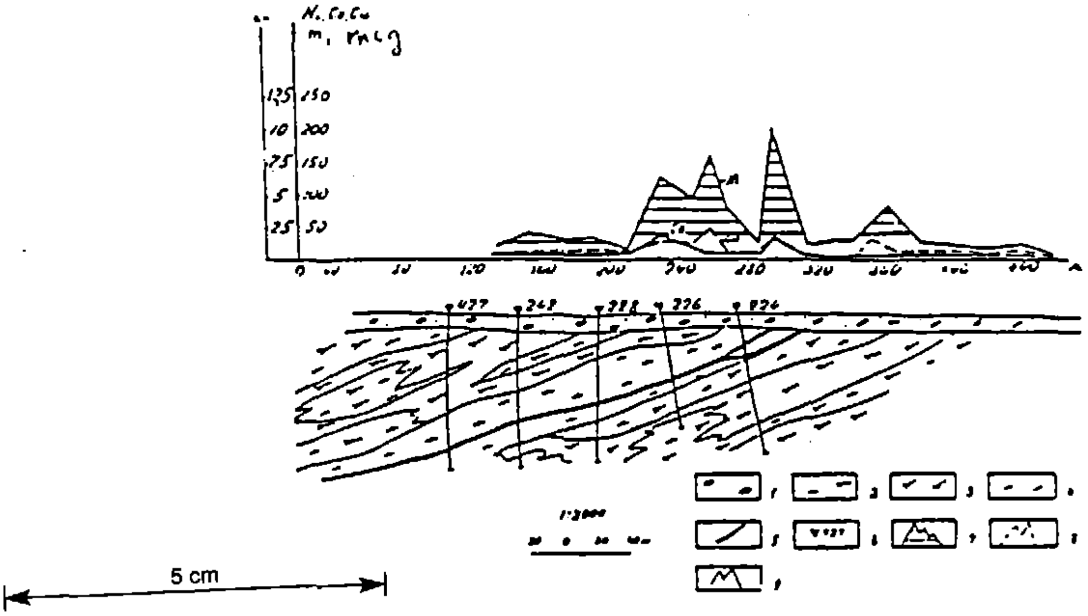

Fig. 4. The CHIM results for a copper-nickel deposit (Kola Peninsula): 1) moraine, 2) plagioclase-microcline magmatitic gneiss with amphibolite, 3) plagio-microcline granite, 4) feldspar amphibolite, 5) ores, 6) boreholes, CHIM graphs: 7) nickel, 8) copper, 9) cobalt.

On Fig. 6, we show an aureole detected during geochemical extraction under still more complicated conditions than those described above. The polymetallic mineralization occurs within volcano-sedimentary chloritized rocks covered by clays ~100-m thick. The mineralization itself does not subcrop under the overburden and occurs below the bedrock contact at a depth of 20 m. As is evident from the figure, 20-25 mcg of lead and 15-20 mcg of copper was leached above the upper portion of the ore. Outside the ore zone, 5-10 mcg of lead and copper were extracted.

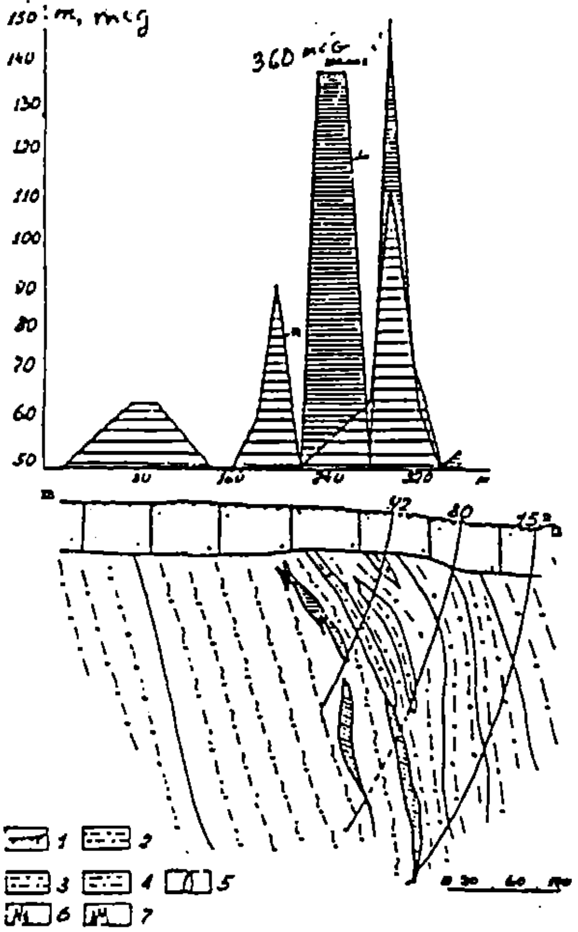

Fig. 5. Results of the CHIM method at polymetallic deposit I (Rudnyi Altai Mts.): 1) unconsolidated deposits (clays, loams), 2) schistose dioritic porphyries and microdiorites, 3) basalts, 4) sericite-quartz schists, 5) polymetallic ores, CHIM graphs:

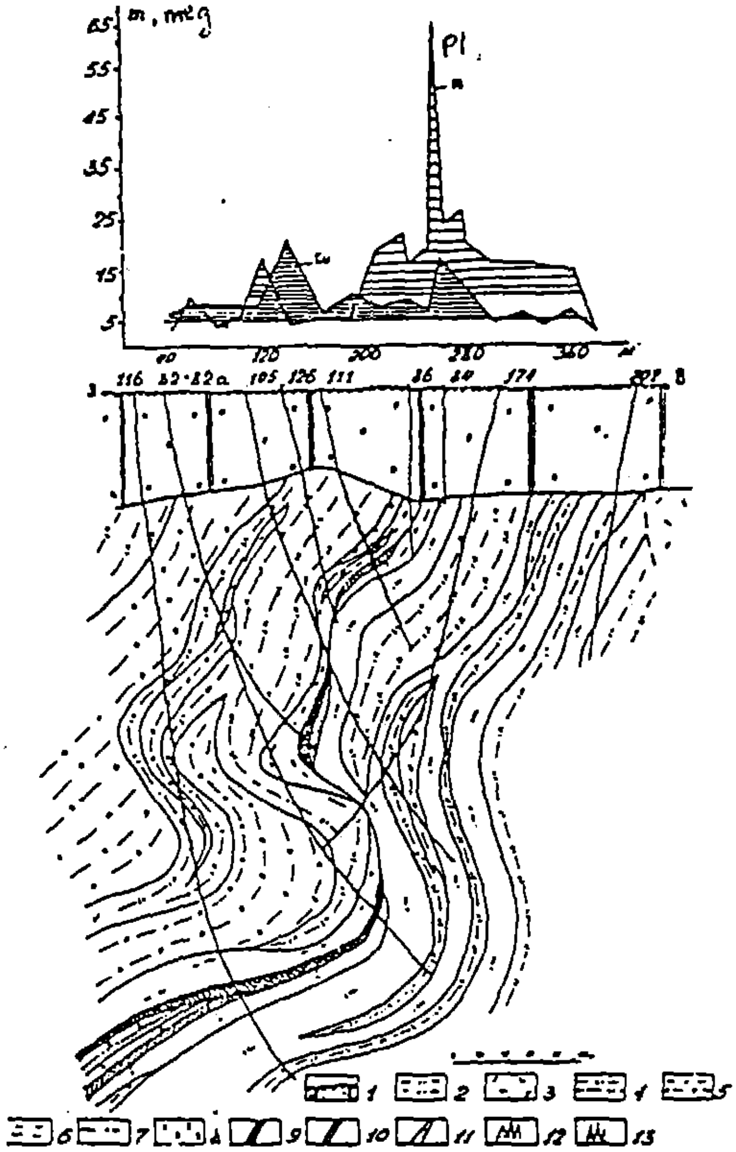

Fig. 6. Results of the CHIM method at a polymetallic deposit (Rudnyi Altai Mts.): 1) unconsolidated deposits (clays, loams), 2) siltstones, sandstones, tuffs, 3) tuffs of andesite composition, 4) tuffs of silicic composition, 5) basalts, 6) chloritized tuffs, 7) silicified mudstones, 8) disseminated polymetallic ores with chlorite, 9) massive copper-pyrite ores, 10) massive polymetallic ores, 11) veined-disseminated ores, CHIM graphs: 12) lead, 13) copper.

The results at the sites mentioned and also observations at other sites lead to the conclusion that geochemical extraction in the 'aureole version' allows one to detect weak aureoles not identifiable by bulk content of elements. As a result, the 'aureole' version of the CHIM method broadens the possibilities

The distribution of the total content can fluctuate not only depending upon migration processes but also depending on whether an element occurs in the lattice of a mineral.

The 'aureole' version of CHIM can be used, as can any other geochemical method, to test geophysical anomalies. As is well known, zones of conductivity are often represented by pyrite, pyrrhotite, and, more rarely, by polymetallic copper and copper-nickel ores. The detection of geochemical aureoles of high copper, lead and nickel on anomalies discovered by electrical geophysical methods substantially increases the chance of finding an ore deposit. On the other hand, an absence of geochemical aureoles can serve as a sign that the geophysical anomaly is not related to mineralization.

The 'aureole' version of CHIM proves useful in detailed exploration of deep-buried deposits and in testing of geophysical anomalies. Nevertheless, a basic shortcoming of any geochemical method remains in this CHIM method as well. The problem we are talking about is an inability of a geochemical method to evaluate the grade of an ore mineralization. A future 'fundamental' version of CHIM will permit one to record both the initial and the subsequent branches of the geochemical curve of accumulation vs. time (hodograph) which would help to overcome the problem.

The research in this direction is still in the early stages. An important inhibiting factor is the uncertainty associated with our conception of the velocities or mobilities of ions movement in rocks. Investigation of the mobilities of ions in various media [2, 3, 4] showed that mobility varies from thousandths to thousands of cm^2/volt-hour. The observed variations are caused by many factors which are extremely difficult to quantify. These include: the composition and concentration of pore solutions, the structure of the pore space, the composition of the solid phase, electrokinetic phenomena, etc. The totality and variety of effects of different factors makes experimental set-ups complex and lead to an uncertainty with respect to experimental results on account of one or another factor. It is quite obvious that practical implementation of the 'fundamental' CHIM version is possible in cases involving high mobility values. The conditions under which the mobility of ions in rocks exceeds units of cm²/volt-hour are not yet well known. Further studies and field experiments are needed in this direction.

The 'fundamental' or 'primary' version of CHIM is comparatively simple to implement during logging of a borehole. The close proximity of the element-receiver to the borehole walls allows to dissolve minerals from the borehole walls and accumulate elements at the element-receivers under a small electrical exposure over a brief period of time. A complete geochemical curve of accumulation vs. time for each element-receiver permits one to estimate the content of elements in the rock and to construct the downhole distribution curves of element concentrations for different depths. A qualitative concept of such a distribution can be achieved if we record the change in the mass m leached downhole over a fixed period of time corresponding to the branch of the accumulation-vs.-time curve. This qualitative concept would reveal any enriched intervals and show their pattern relative to one another. The results of the CHIM logging at one of the boreholes (Kola Peninsula) are presented in Fig. 7. As is evident from the figure, the ore interval at a depth of 20-21 m is well determined by high extraction of nickel, copper, cobalt, and iron against the low background associated with the extraction of these same elements in the host rock. Copper and nickel gradually decrease downward in the peridotite sequence and then abruptly decrease at the transition from ores to the underlying phyllites. At the point of maximum (20.5-20.7 m) of the extracted quantities of nickel and copper and at a depth of 25.1-25.3 m, we determined in the laboratory the contents of the indicated elements in ores and in mineralized peridotites and calculated empirical Q coefficients. A comparison of values found on the basis of the CHIM results and the laboratory analysis of the core indicates that they are satisfactorily similar. It follows that evaluation of the elements content on the basis of the CHIM data is quite realistic.

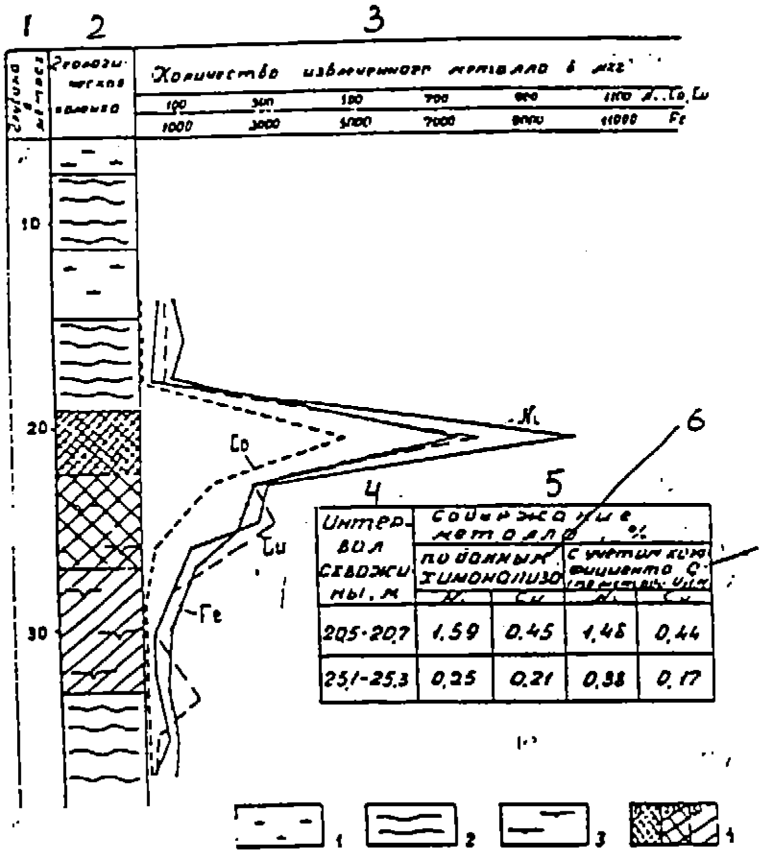

Fig. 7. Results of logging using the CHIM method (copper-nickel ores): 1) amphibolites, 2) biotite gneisses, 3) peridototites, 4) nickel content: 1) 1%, 2) 0.5-1.0%, 3) >0.5%.

Key: 1) Depth in meters, 2) Geological column, 3) Quantity of leached metal in mcg. 4) Interval of borehole, m, 5) Metal content, %; 6) Chemoanalytical data; 7) Taking coefficient Q into account (according to the CHIM method).

The sound principles of the CHIM method and the successful experience at applying the method offer several possibilities of using the chemical leaching for exploration and for economic geology. Deep-seated ore deposits covered with unconsolidated overburden up to 100-m in thickness can be detected by using the "aureole" version of the CHIM method. It is also possible to discover zones of mineralization through transported overburden. In the logging version, the CHIM method permits to determine the downhole distribution of elements and to determine the grade in certain beds of interest. In principle, it is possible to leach metals directly from deep ores. This problem is still in the initial stage of investigation.

EXPERIENCE OF ANALYSIS OF CHIM SAMPLES FOR GOLD

G. P. Fedorova, G. F. Vasilkova, A. Yu. Semova

The successful application of the CHIM method in the aureole version for exploration of deep-seated gold deposits is dependent to a significant degree upon the effectiveness and quality of analyzing the field samples. The difficulties which arise in this regard are due to the small quantity of gold in the rocks and ores. This results in interference effects from other elements extracted together with the gold. Several techniques have been developed to overcome the problem.

The primary type of analysis for CHIM samples is film polarography with accumulation [I] providing for a low detection limit. In order to record peaks involving nanogram quantities of gold, one can select polarography regimes and appropriate backgrounds allowing as low as 0.001 microgram of gold in the reference solution to be registered. The dependence of the height of the gold peak upon the concentration of gold in a pure solution without the presence of interferring elements is shown in Fig. 1. The polarographic background was 0.1 N hydrochloric acid of chemical purity. The potential of the gold solution was +0.85 V.

The graphs shown were obtained under maximally pure conditions for analysis. It follows from the graphs that polarography with accumulation can be used to determine gold in quantities of 0.001-0.003 micrograms. When interferring components are present in actual CHIM samples, however, the practical limit for gold detection can be found only after investigating the influence of extraneous elements on the results of the gold determination. We chose to study heavy metals in this regard, since they are most likely to be present in solutions of CHIM samples and most likely to have an effect upon gold determination. The studies showed that the widths and amplitudes of the maxima associated with gold-dissolving electric currents when the gold concentration is 0.01 microgram are unaltered in the presence of 1 microgram of Pb, 0.5 micrograms of Fe, 0.6 micrograms of Hg, 0.5 micrograms of Ag, 0.05 micrograms of As, 0.02 micrograms of Sb, and 0.01 micrograms of Cu in 1 ml of solution. An increase in the concentration of each of the elements mentioned leads to a decrease in the heights of the polarographic maxima associated with gold-dissolving currents. Within CHIM samples, the actual concentrations of the elements mentioned are substantially higher than those presented. It is necessary, in this connection, to carry out a selective separation of gold from other elements interferring with the gold determination.

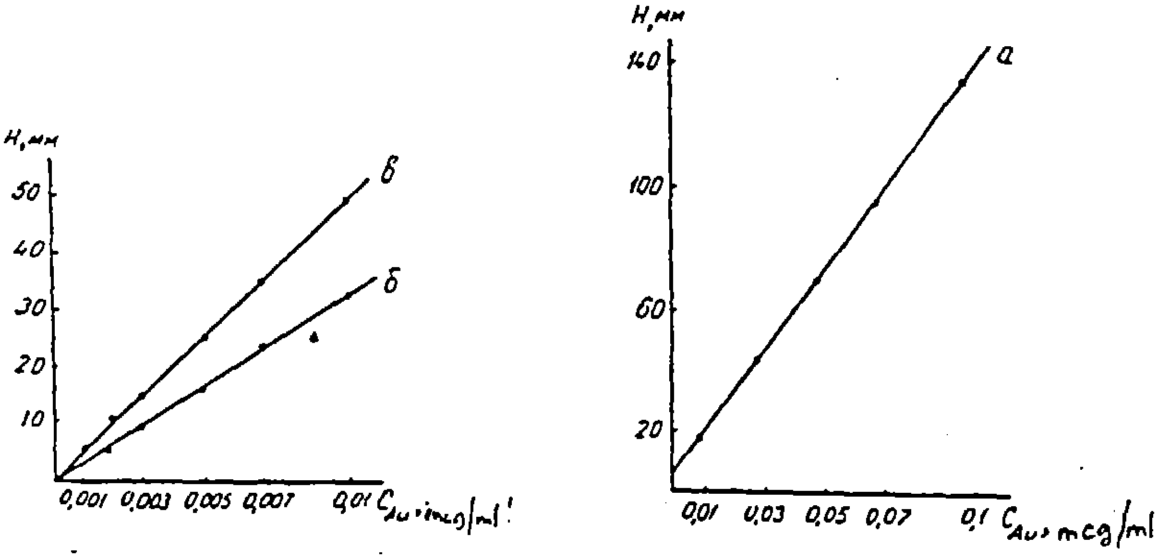

Fig. 1. Diagram of the height of the gold peak versus the concentration of gold in the solution: settling potential (φ_a)- 0.7 V, the scanning rate for the potential (V_φ)- 1.5 V/min, the settling time (T_{prec}): a) T_{prec} - 5 min., b) T_{prec} - 10 min, c) T_{prec} - 15 min.

One of the most simple and effective means of removing impurities is extraction of the gold by organic reagents. Gold is most completely and most selectively separated from other elements by dibutyl sulfide (DBS) and is separated somewhat less well by the ethyl ether of acetic acid (ethyl acetate).

An evaluation of the quality of the extraction is carried out with the use of mixtures of iron and gold solutions with these reagents. When the extraction is done using ethyl acetate, traces of iron can be detected in the extract. When the extraction is done using DBS, iron cannot be detected. Ethyl acetate is more suitable in the operation; it is inexpensive and has no disagreeable odor. It is therefore convenient to use ethyl acetate when small quantities of impurities are involved and to use DBS for the extraction when the samples contain significant quantities of admixture elements. It should be noted that extraction by organic reagents, besides removing interferring impurities, also allows one to concentrate the gold to a smaller degree, thereby improving the sensitivity of the analysis.

It is well known that natural organic complexes with gold are simpler compounds than are complexes with artificial organic extractants [3]. In view of the fact that natural organic compounds, gold itself and inorganic gold complexes, are extracted by the electrical currents into solution of element-receivers, it is necessary to treat the samples prior to chemical analysis so that the gold extracted in the form of natural organic compounds will not be lost. For this purpose, one must break down the compounds and convert them to simple ions by treating the samples with concentrated hydrogen peroxide. Several examples of detection of gold in natural organic compounds after treating the samples with hydrogen peroxide are shown in TABLE 1. Adjustments insuring optimal conditions for oxidation are made first.

TABLE 1.

Determination of Gold without Oxidation and with Preliminary Oxidation by Hydrogen Peroxide

Determination	Amount of gold, mcg			
	Sample 1		Sample 2	
	w/out treatment	after treatment	w/out	after treatment
First	0	0,050	0	0,030
Second	0	0,060	0	0,035
Third	0	0,050	0	-

It follows from the table that a treatment of the samples with hydrogen peroxide satisfactorily breaks down the natural organic compounds of gold and allows one to avoid a loss of gold during analysis of CHIM samples.

The use of extraction for the removal of impurities and the concentration of gold lead to the necessity of breaking down the artificial organic complex containing the gold and converting it to a background solution for polarography. Several variants of the decomposition process have been tested [2]. To keep the gold from escaping during the treatment and at the same time to oxidize it completely to the trivalent state, the organic layer was concentrated by evaporation with the addition of sodium chloride after the extraction. The dry sediment was treated with a mixture of hydrochloric and nitric acids in a 3:1 ratio with the addition of 30% hydrogen peroxide. Nitric oxides which would interfere with the polarography are removed by a further addition of concentrated hydrochloric acid twice. The polarographic analysis itself is carried out in a deci-normalized solution of hydrochloric acid.

The procedure for analyzing CHIM samples for gold:

1. The volume of the sample is measured. The sample is evaporated in a thermostable beaker until the volume reaches 10-20 ml. During the evaporation, 5 ml of 30% hydrogen peroxide is added.

2. When cooled to room temperature, the sample is quantitatively transferred to a separatory funnel.

In the case of extraction with ethyl acetate, 5 ml of concentrated HCl and 10 ml of ethyl acetate are added and the extraction is allowed to proceed for 1 min. The aqueous layer is discarded, but the organic phase is washed with 10 ml of 0.1 N hydrochloric acid for 30 sec.

When doing the extraction with dibutyl sulfide (DBS), 10 ml of concentrated HCl is added to the funnel; the mixture is then diluted to 100 ml with water. Next, 3 ml of a 0.1 molar solution of DBS in toluene (freshly prepared) is added and extraction is allowed to proceed for 3 min. An additional 3 ml of DBS is added after the extraction and the solution is mixed. The aqueous layer is poured off and the organic layer is washed twice with 50 ml of 0.1 N HCl for 1 min each time.

3. The organic phase is placed in a thermostable beaker, 3 drops of a 2% solution of sodium chloride is added, and the mixture is evaporated to dryness in a water bath.

4. To the dry residue in the hot beaker, 0,5 - 1,5 ml of a mixture $HCl:HNO_3 = 3:1$ (freshly prepared) is added along with 3 drops of 30% hydrogen peroxide.

When performing the extraction with ethyl acetate, the mixture obtained is evaporated in a water bath to the point of moist salts. To these salts, 0.5 ml of concentrated HCl is added, and the sample is evaporated to dryness. The operation is repeated twice.

When performing extractions using dibutyl sulfide, the mixture is evaporated to dryness. The samples are then treated twice by adding 1 ml of concentrated HCl each time, and the samples are evaporated to dryness.

5. The residue obtained is flooded with the polarographic background (2 ml of 0.1 N HCl), cooled, transferred to an electrolytic cell and subjected to polarography.

6. The polarographic determination is conducted in two regimes:

- sedimentation (settling) time 10 or 15 min, depending upon the anticipated gold content;

- sedimentation (settling)potential 0.7 V;

- rate of scanning of potential 1.6 V/min;

- limit of current recorded 2 mcA.

The working electrode (graphite) is cleaned mechanically prior to each analysis. Auxillary and reference electrodes are silver chloride.

The gold peak is fixed at +0.85 V.

7. The gold content is located on a calibration graph that shows how the height of the peak changes depending upon the gold content in the solution.

TABLE 2.

Reproducibility of Repeated Observations Using the CHIM Method
(Au in the sample volume, mcg)

Regions areas	Determinations 1	2	3
Rudnyi Altai	0,030	0,012	-
Area 1	0,020	0,030	-
	0,015	0,016	-
	0,012	0,014	-
	0,005	0,006	-
	0,018	0,017	-
Area 2	0,015	0,010	-
	0,012	0,020	-
	0,007	0,009	-
Uzbekistan	0,021	0,032	-
	0,005	0,005	-
	0,030	0,025	-
	0,007	0,005	-
	0,010	0,028	-
Yakutiya	0,035	0,040	-
	0,038	0,040	-
	0,090	0,075	0,165
	0,080	0,090	-
	0,040	0,050	0,060
	0,075	0,090	0,140

In order to construct the graph, a CHIM sample known not to contain gold is brought from the area being studied, reference solutions with known gold contents are added to it, and the mixtures are carried through the entire course of the analysis.

8. In order to avoid errors arising from contamination of the reagents used, analysis of a "blank" sample is performed first. Distilled water serves as a basis for the sample. The reagents to be used are added in the sequence provided for by the course of the analysis.

The correctness of the proposed methodology was verified during the analysis of actual samples using the method of additions. The relative standard deviation did not exceed 30% over the entire range (0.005-0.1 mcg) of gold contents studied. The reproducibility associated with repeated observations, including electrochemical extraction of gold along parallel profiles separated from one another by 3-5 m, is presented in TABLE 2.

The table shows that the error associated with the major portion of repeated observations under otherwise identical conditions in different regions did not exceed 40% (the deviation was more than 100% at individual points). The discrepancies are related either to departures from the analytical methodology or to errors associated with geochemical leaching. For conditions meeting the requirements for the analysis and the leaching of elements, the error for repeated observations was within a few tens of percents and provided satisfactory delineation of gold-bearing zones.

LITERATURE CITED

1. Kh. Z. Brainina, "Inversion Voltamperometry of Solid Phases", Khimiya, Moscow (1972), 192 pp.

2. R. Steinton, "Rapid Methods of Determining Traces of Elements During Geochemical Investigations", Mir, Moscow (1969), 136 pp.

3. E. I. Fisher, "Solution of gold under various oxidative-reductive conditions," Ph.D. Dissertation in Geology and Mineralogy, Riga (1974).

THE MOVEMENT OF IONS IN ROCKS UNDER THE INFLUENCE OF AN ELECTRICAL CURRENT (Part II)

M. A. Alekseyeva

The features of ion movements within the liquid phase which we discussed in Part I were confirmed by subsequent study of moist rock environments. As a model in the investigation, we used quartz sand 0.14-0.25 mm in diameter. The sand was moistened by 0.0001-4 N. solutions of potassium chloride at moisture W from total moisture capacity W ~19% to W ~2.3%. The methodology of the investigations was the same as used in Part I.

The experiments were conducted in heat-proof cuvettes made from transparent organic glass. The cuvettes were 5-22 cm long, 2 cm wide and 2.5 cm tall. The prepared sand with a set moisture and KCl concentration was loaded in the cuvette. A direct electrical current was passed through the sand with the aid of platinum electrodes glued to the butt-ends of the curvette. The current density was maintained at constant $j = 0.5$ mA/cm^2 in all of the experiments. At a concentration of pore solution $C \geq 1$n., the electric field strength E was measured on a V2-11 microvoltmeter. In the remaining cases, it was measured on a VK7-3 with input resistances of 300 and 1 MOhm respectively. The specific resistivity of the medium was $\rho = E/j$. In order to characterize the velocities of the ions H_3O^+ and OH^-, their movements l over a period of time t were measured. The mobility of the ions U was determined in terms of their velocities V $(V=l/t)$, $U = V/E$. The movement of H_3O^+ and OH^- ions was recorded by the shift of the color boundaries from the electrodes (where the above mentioned ions are being recreated at a constant rate j = const) to the center of the cuvette. In order to observe the shifts of H_3O^+ and OH^- ions, a universal pH indicator was added to the electrolyte solution which moistened the sand. Created at the anode H_3O^+ ions, interacting with the indicator, colored the sand red, while OH^- ions created at the cathode colored the sand violet and green. The positions of the color boundaries were noted at various times during the course of the experiment with the aid of scaled grid on the walls and lid of the cuvette. So that dilution of the pore solution at low moisture would not occur when the indicator was added, the indicator was first added to the sand in the quantity needed; then, after mixing and also during periodic remixings, the sand is dried in a thermostat at $t \leq 60°$ C. The required quantity of potassium chloride was added to the cooled sand. After a ten-minute remixing, the sand was loaded to the cuvette in small portions and tamped down. At the end of the experiment, several samples of sand were taken from the cuvette for a precise determination of the moisture at which the experiment was conducted. The difficulties associated with preparing a medium with a uniform moisture did not allow us to carry out experiments at moistures < 2%.

In a series of investigations, the rate of movement of the color boundary caused by differences in concentration of H_3O^+ and OH^- ions on both sides of the boundary was measured immediately after the current was switched off: $V_M = l_M/t_M$, where l_M is the length that the ions travel over a period of time t_M from the moment the current is switched off, and V_M is the rate of diffusion of H_3O^+ and OH^- ions without current (this characterizes the component of their movement due to diffusion during passage of the current). Values for V_M amount to several percent of the total rate of movement of ions in the case of 0.1 N KCl. These values did not exceed 20-30% at the highest concentration of KCl used, ~4n.

The processes taking place in the sand, both during the action of current and without current, are significantly more complex than in the case of a single liquid phase [1]. To the processes taking place in the solution itself, we must add the processes associated with the interaction of the solid and liquid phases. These processes lead to the formation of a double electrical layer at the phase boundary, a change in the overall given concentration of electrolyte and changes in concentration within pores at various distances from the solid phase, the solution of the solid phase under the influence of the current, the transformation of the double layers as a result of the solution process, the participation of the pH-indicator in their formation, etc.

As pointed out previously [1], the structure associated with ion movement when a single liquid phase is involved is different when the concentration of dissolved salt is more or less than 0.001 N. To be precise, at concentrations of KCl up to 0.001 N, the streams of H_3O^+ and OH^- ions moving toward each other occupy the whole cross-section of the cuvette. At potassium chloride concentrations higher than 0.001 N, they separate into layers with the flow of H_3O^+ moving on top and the flow of hydrogen ions moving beneath, underneath the flow of H_3O^+. With a shift in the flow structure, the variation in their velocities change with increasing concentration of KCl, and at the same time the mobility of the H_3O^+ and OH^- ions increases (Fig. 1). In the moist sand within the studied range of moisture between 2.3 - 19% at KCl concentrations of 0.0005-4 N., significant stratification was not observed. Nevertheless, variation in the velocities of the flows did occur, as did increases in the mobilities of the ions.

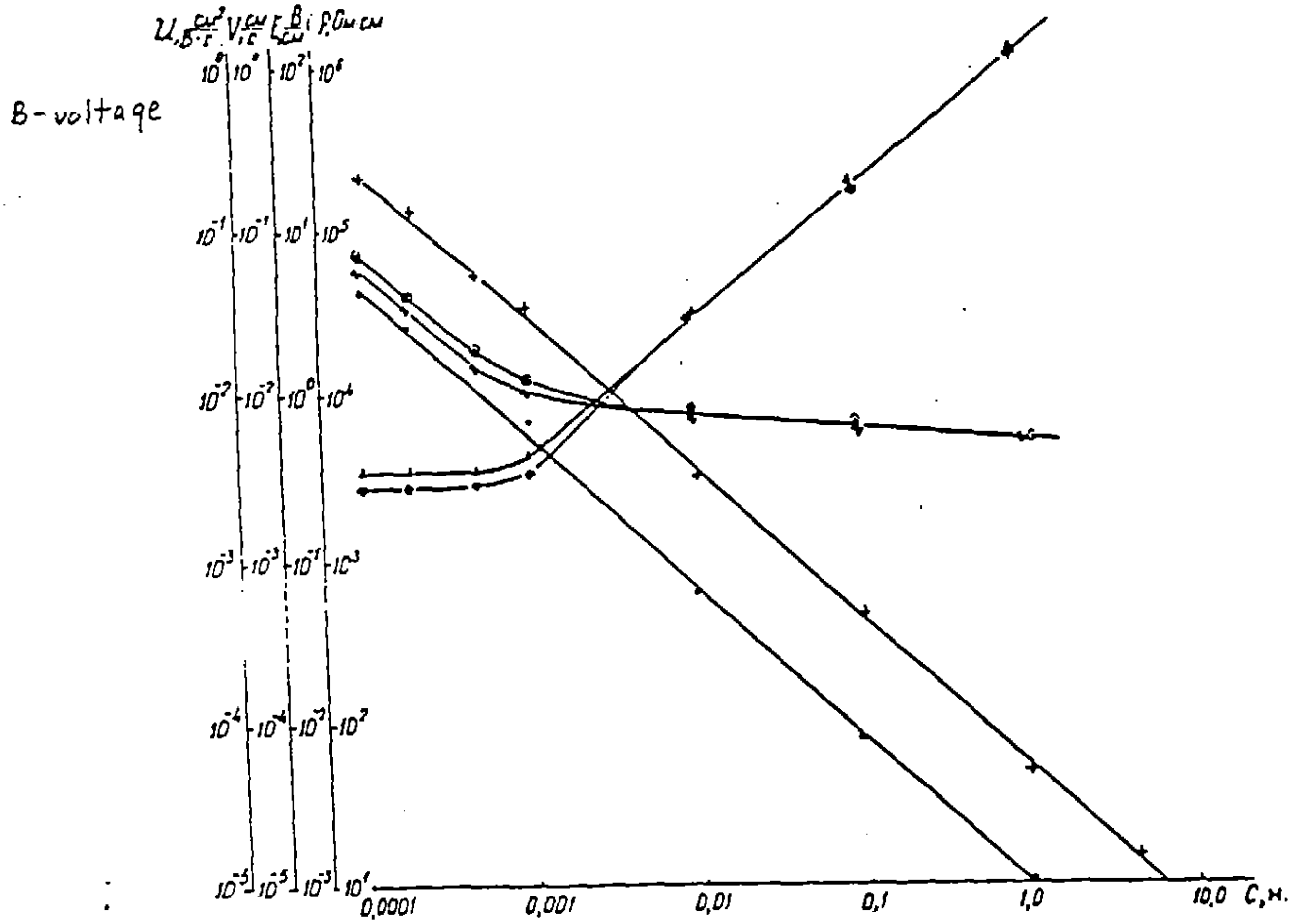

Fig. 1. Dependence of the solution resistivity ρ, electric field strength E, the velocity V, and the mobility of the ions U upon the concentration of KCl in the solution: x - E; • - ρ; ⊖ - $V^{H_3O^+}$; ▸◂ - V^{OH^-}; ▲ - $U^{H_3O^+}$; * - U^{OH^-}.

As can be seen on figures 2, 3, and 4, the specific resistivity of the moist sand and the electric field strength fall with increasing concentrations of potassium chloride when the density of current passing through is held constant. The rate of movement of H_3O^+ and OH^- ions decreases also. This decrease slows down when the concentration of KCl rises above 0.01-1.0 N. but the mobility of H_3O^+ and OH^- increases. The increase in mobility is greatest at KCl concentrations greater than 0.1-1.0 N. For a sand moisture of 19% (Fig. 2), the relationships between decreasing specific resistivity and electric field strength and increasing concentrations of potassium chloride can be represented by straight lines on a bilogarithmic scale. Slopes of the lines coincide with those for a single liquid phase. Values of ρ and E, however, are approximately 5 times higher in the sand than in the free KCl solution. The velocities of H_3O^+ and OH- ions, on the other hand, are lower in sand than in a unitary liquid phase. The decrease in the velocity during the transition from solution to sand varies at various concentrations of KCl, but exceeds an order of magnitude on an average. In the range of KCl concentrations from 0.0005-0.1 N, the velocity falls more sharply than within the range of KCl concentrations from 0.1-4.0 N. The change in the velocities of H_3O^+ and OH^- ions within the range of low KCl concentrations occurs under a different slope. The curves of variation V on the one side and variation of ρ and E on the other do not parallel one another as was observed in the unrestricted solution of potassium chloride.

In accordance with the change in the rates of movement of H_3O^+ and OH^- ions, their mobility changes in an analogous fashion by an order of magnitude. The mobilities of these ions are an order of magnitude less in sand than in solution and increase most sharply with increases in the concentration of KCl beginning at 1 N. It is important to note that the mobilities of H_3O^+ and OH^- ions at high KCl concentrations in sand exceed mobilities at low KCl concentrations in unrestricted solution.

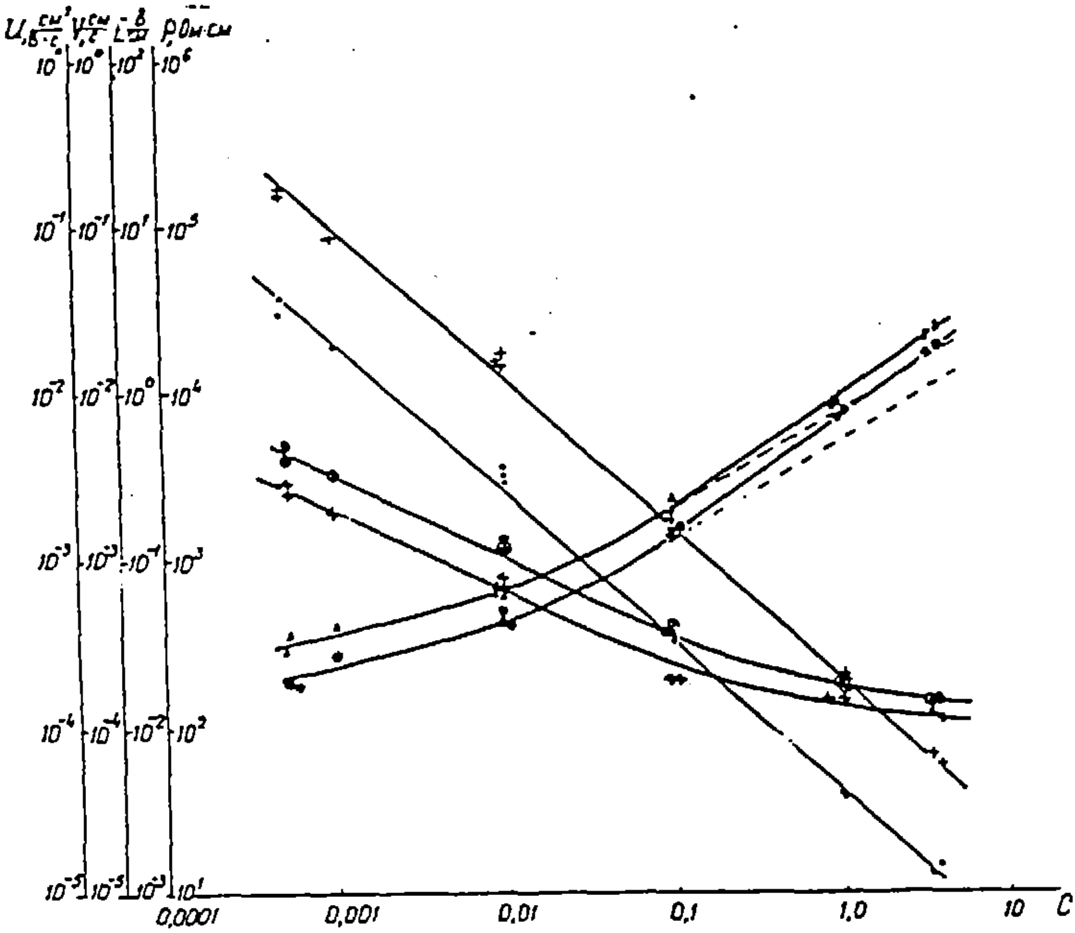

Fig. 2. Dependence of the specific resistivity ρ, the electric field strength E, the velocity V, and the mobility of the ions U upon the concentration of KCl - liquid phase at a sand moisture of 19.2%:
x - E; • - ρ; o - V^{H3O+}; ⊙ - U^{H3O+}; * - U^{OH-}; U is calculated according to the formula $V-V_M/E$.

At a 4.5% sand moisture (Fig. 3), the specific resistivity and electric field strength increase more compare to ρ and E in solution and sand under W = 19%. The increase of and E at W = 4.5% is ~1.5 orders of magnitude greater in relation to that for sand at W = 19%. The curves of specific resistivity and electric field strength change in slope with changing concentrations of potassium chloride. The slopes become more gentle. The slopes of the curves for ρ and E change positively. The dependencies discussed have a linear character only up to a KCl concentration C = 1 N. At higher concentrations of potassium chloride, the negative slope increases and becomes approximately the same as in the unrestricted solution and in sand with W = 19%.

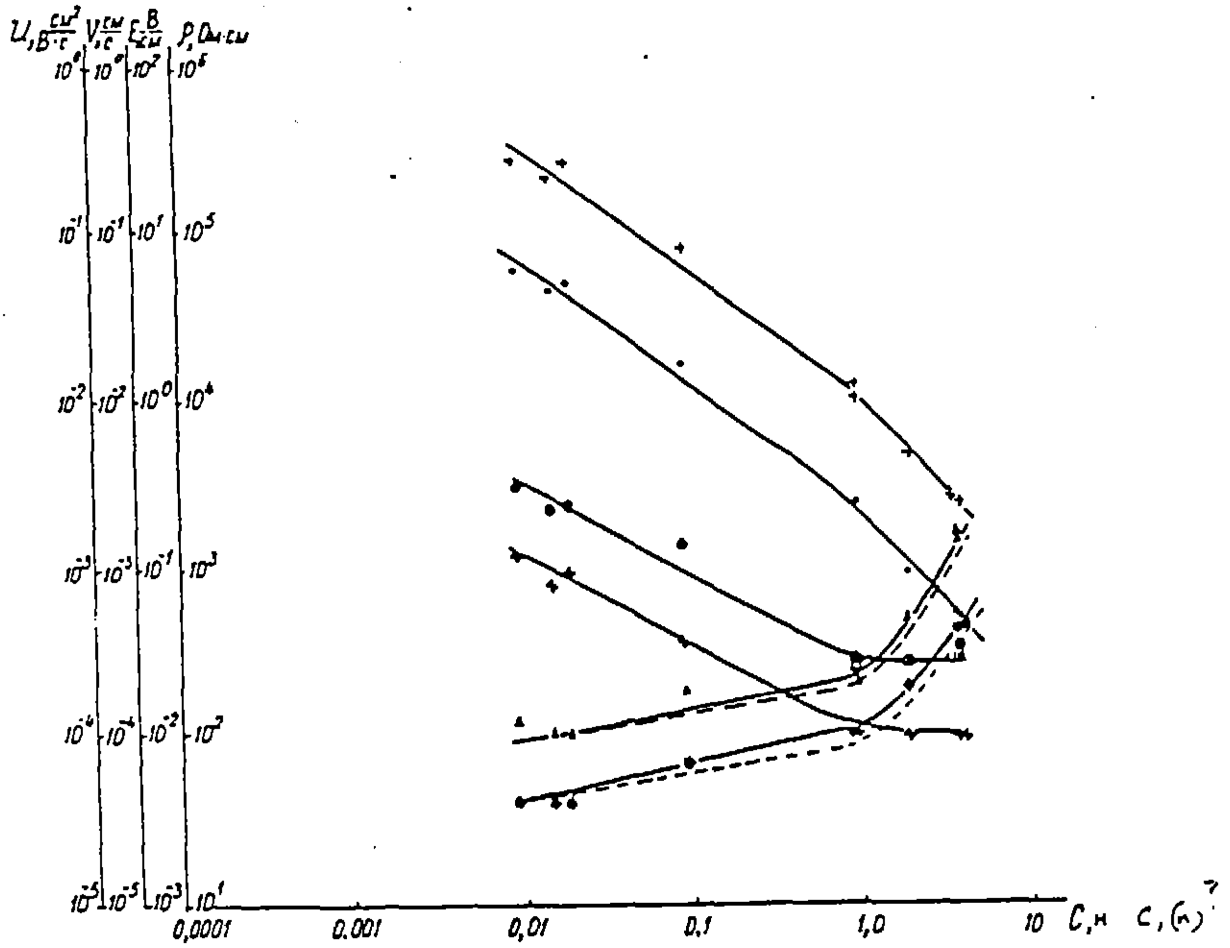

Fig. 3. Dependence of the specific resistivity of the solution, the electric field strength E, the velocity V, and the mobility of the ions U upon the concentration of KCl - liquid phase at a sand moisture of 4.5%: x - E; • - ρ ; ⊙ - $V^{H_3O^+}$; ●- - V^{OH^-}; ▲ - $U^{H_3O^+}$; * - U^{OH^-}; ----U is calculated according to the formula $V-V_M/E$.

In contrast to ρ and E, the rate of movement of H_3O^+ and OH^- ions does not decrease with decreasing sand moisture; it increases by a factor of approximately two. With increasing KCl concentrations (still less than 1 N), V, and E have similar slopes. The decrease in velocity slows abruptly at high concentrations. The mobility, on the other hand, generally increases with an increase in KCl concentration. The increase is most marked starting at $C \sim 1$ N. The mobilities in sand with W = 4.5% are 5-10 times lower than in sand with W = 19%. At C = 4 N, never the less, the mobility of H_3O^+ reaches a value similar to the value of U in dilute unrestricted solutions.

At a still lower sand moisture of 2.3% (Fig. 4), the specific resistivity and electric field strength become higher than at W = 4.5%. However, the increases in ρ and E are insignificant, 1.5-2-fold. The dependences of ρ and E upon C have a linear character in the 0.005-2 N range of KCl concentrations, and the slopes are more positive than at W = 4.5%. At KCl concentrations >2.0 N, the slopes of the dependences under discussion become more negative and approximate the slope values in an unrestricted solution and in sand with W = 19%.

The velocities of H_3O^+ and OH^- ions at W = 2.5% practically coincide with those for sand at W = 4.5%. Until they flatten out, the slopes of the curves for V on a bilogarithmic scale are similar to the slopes of the curves for ρ and E. The changes in the slopes occur at a KCl concentration of 2.0 N. The mobilities of the ions under investigation are 1.5-2 times less than the mobilities in sand with W = 4.5%. However, the values of U increase with increasing KCl concentrations and increase most sharply beginning at KCl concentrations of 2.0 N.

From a comparison of the results obtained, it is evident that the specific resistivity and electric field strength (at constant j) increase during the transition from unrestricted solution to moist sands. The velocities of the hydroxonium and hydroxyl ions drop sharply with the transition from solution to sands, but drop more or less identically at different moisture levels. At each value of moisture, the values of ρ, E, and V decrease with increasing KCl concentration, but the mobilities of the H_3O^+ and OH^- ions increase. Values of ρ and E in unrestricted solution and in sand at W = 19 % decrease identically with increasing concentrations of potassium chloride, but the decreases in ρ and E are different in regions of KCl concentration greater than or less than 1-2 N. At high concentrations, the degree of decrease of ρ and E is the same as in unrestricted solution and in sand at W = 19%; while at low concentrations, the degree of decrease is less than in sands at W = 4.5% and 2.3%.

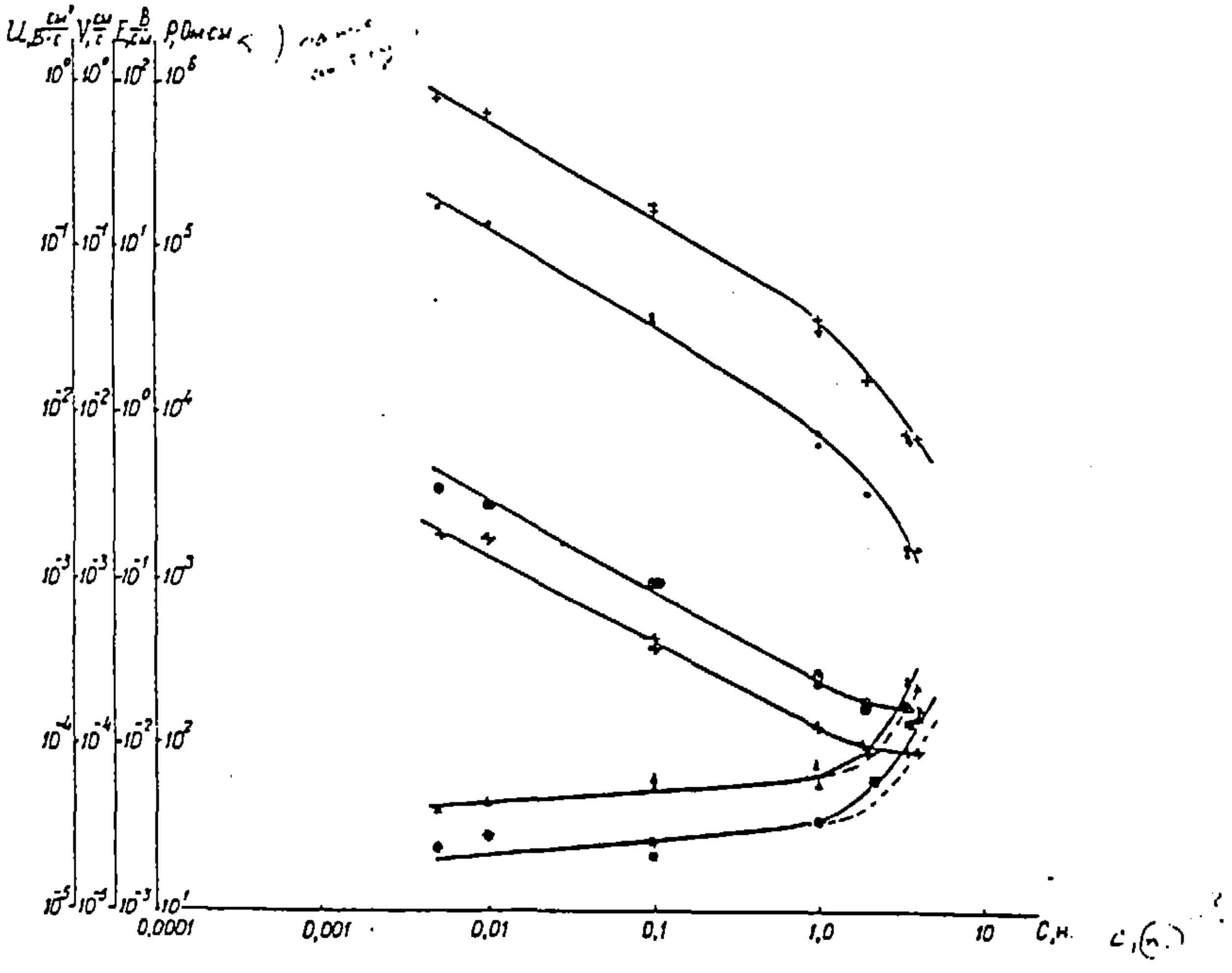

Fig. 4. Dependence of the specific resistivity of the solution ρ, the electric field strength E, velocity V, and mobility of ions U upon the concentration of KCl - liquid phase at a sand moisture of 2.3%: x - E; • - ; ⊙ - V^{H3O+}; ⋈ - V^{OH-}; ▲ - U^{H3O+}; * - $U^{)H-}$; ---- U is calculated according to the formula $V-V_{M}/E$.

In unrestricted solution and in moist sands, the decrease in the rate of movement of H_3O^+ and OH^- as a function of C can be divided into two parts. At KCl concentrations $C < 0.1-2.0$ N, the degree of decrease is greater than at $C > 0.1-2.0$ N. Levels of concentrations at which there are changes associated with the decrease in rate of ion movement increase with decreasing moisture of the sand. In the part of low potassium chloride concentrations, it is also true that the degree of decrease of V with an increase of C in moist sands is less than in unrestricted solution and is independent of the amount of moisture. The degree og decrease in ρ and E approaches this degree of decrease in sands with moistures of 4.5 and 2.3%. If the increase of ρ and E at the transition from unrestricted solution to sands with total moisture content is correlated with, but not proportional to, the decrease in V, then there is no clear correlation between the increases of ρ and E, on the one hand, and increases in the velocities of H_3O^+ and OH^- on the other.

The mobilities of H_3O^+ and OH^- ions differ, just as the velocities do, in areas of low and high KCl concentrations. The abrupt increase in mobility begins at higher KCl concentrations and lower sand moistures. The dependence of U upon C can be represented by the following empirical formulas:

	in sands with low C_{KCl}:	in sands with high C_{KCl}:
W=19%	$U_{H_3O^+} = 18,8 * 10^{-4} * C^{0,24}$;	$U_{H_3O^+} = 75 * 10^{-4} * C^{0,6}$
	$U_{OH^-} = 10,9 * 10^{-4} * C^{0,24}$;	$U_{OH^-} = 5,26 * 10^{-4} * C^{0,65}$
W=4,5%	$U_{H_3O^+} = 2 * 10^{-4} * C^{0,17}$;	$U_{H_3O^+} = 1,43 * 10^{-4} * C^{1,56}$
	$U_{OH^-} = 0,97 * 10^{-4} * C^{0,17}$;	$U_{OH^-} = 0,43 * 10^{-4} * C^{1,56}$
W=2,3%	$U_{H^+} = 0,63 * 10^{-4} * C^{0,08}$;	$U_{H_3O^+} = 0,35 * 10^{-4} * C^{1,19}$
	$U_{OH^-} = 0,36 * 10^{-4} * C^{0,08}$;	$U_{OH^-} = 0,24 * 10^{-4} * C^{1,29}$

Decrease in the mobilities of the hydroxonium and hydroxyl ions with decreasing sand moisture occurs to a less degree than the increase in ρ and E and the decrease in V. For 0.1 N KCl, the dependence U-W was investigated in more detail for W = 2.3, 4.5, 8.5, 11.2, 14, and 19 weight-percent. On a bilogarithmic scale, the mobilities of the ions investigated form straight lines (Fig. 5) as a function of W and can be calculated according to the formula $U = KW^{\alpha}$.

The empirical formulas obtained have the form:
$U_{H_3O^+} = 1,1 * 10^{-5} * W^{1.8} cm^2/V*c$; $U_{OH^-} = 0,62*10^{-5}*W^{1.8} cm^2/V*c$

Taking into account the changes in velocity and mobility of H_3O^+ and OH^- obtained, the specific resistivity and electric field strength at transitions from unrestricted solution to sands of various moistures and pore-solution concentrations, one can make several assumptions concerning the mechanisms of ion movement in porous media.

The sharp decrease in the velocities of H_3O^+ and OH^- at the transition from unrestricted solution to moist sands when there are significant increases of ρ and E indicates that an increase in the length of movement for ions in sands as compared to solutions has a substantial effect upon the mobilities and velocities of the ions. Since sands of the same fraction were used in the experiments, the increase in the length of travel at the transition from solutions to sands is greater than at a transition between sands of differing moisture. Probably, the rates of movement of ions in sands vary insignificantly with alterations in moisture and decrease sharply at the transition from solutions to sands. In addition, the specific resistivity increases with decreasing W, since not only the mobilities of the ions have effects on ρ but also the masses of the ions, which decrease with lowering of the moisture.

In areas of low but increasing KCl concentrations, the change in the slopes of curves for ρ and E on a bilogarithmic scale toward the decrease of negative slope and the change in the slope for the velocity of the ions, and also the approximation of the slope values at high KCl concentrations to its values in an unrestricted solution indicate the influence of an additional effect increasing the velocity and decreasing the specific resistivity. This is possibly a result of the influence of surface conductance. As is well known [3], the contribution of the surface conductance to the total conductance decreases with increasing concentration of pore solutions; this takes place at high C values. Thus, the rate of movement of ions in the areas of low concentrations of pore solutions is the sum of a component dependent upon the electric field strength and a component associated with the surface conductance.

For unrestricted solutions of KCl, it was demonstrated [1] that the motion of hydroxonium and hydroxyl ions in dilute solutions is primarily determined by the electric field strength and, at $C > 0.001$ N, by the hydrodynamic flows of the fluid caused by the electrochemical processes at the electrodes. The division associated with the changes in rate of movement of H_3O^+ and OH^- ions as a function of KCl concentration into parts in the areas associated with high and low concentrations (a partitioning observed in unrestricted solution and in moist sands) indicates the possible role of a hydrodynamic factor. This factor is apparently also present in the porous media, exerting a more significant effect upon the motion of ions at high concentrations of the liquid phase.

, Besides the increases mentioned above, there are probably also increases in the intrinsic electrical mobilities of H_3O^+ and OH^- ions with increasing concentrations of pore solution. For unrestricted solutions in the absence of convection, decreases in the mobilities of H^+, Li^+, K^+, OH^-, Cl^- and other ions by ~20%

are noticeable as the concentration increases from 0.001 to 0.1 N. With further increases in concentration from 0.1 N to 1 N, increases in mobility by ~20% occur (5). For porous systems, some data have been presented concerning the increases of mobility of K⁺, Cu⁺, and other ions when the concentration of the liquid phase increases [2, 8, 9]. One should also note the reference of Malerbi [6] to Maneke and Bonkhover, who obtained an increase of electrical conductance in ion-exchange membranes at the transition from 0.1 N solutions of KCl to 1 N solutions. The majority of researchers believe that ions move in a double layer with velocities less or equal to those in an unrestricted solution [7]. However, the hypothesis has been put forward that mobilities of ions in a double layer could be greater than in the unrestricted portion of the pore solution because of the presence of a regulated structure associated with the solution [4]. In the opinion of the author, this is also possible.

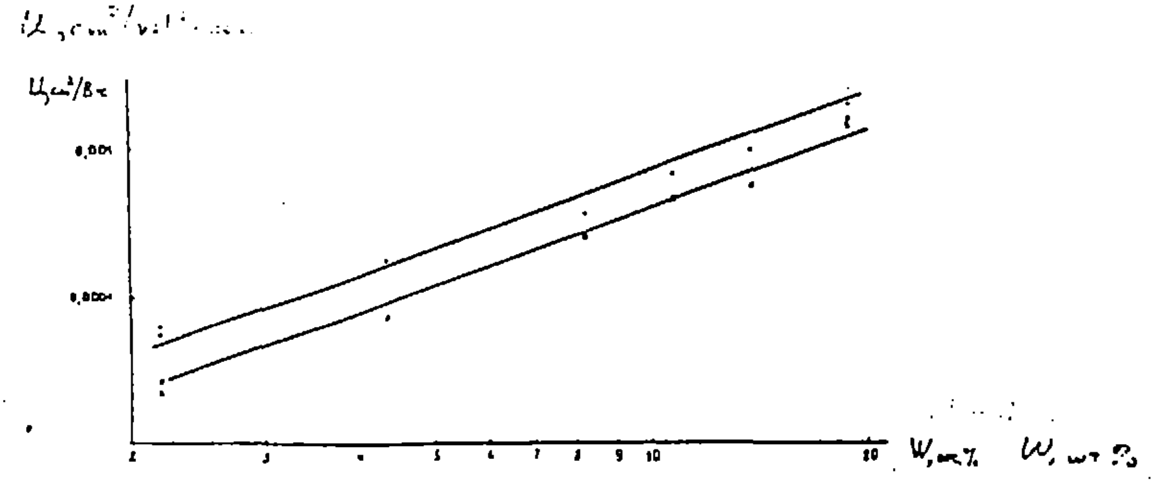

Fig. 5. Dependence of the mobility of ions U in sand with a 0.1 n. KCl solution upon moisture W: x - U^{OH^-}; • - $U^{H_3O^+}$.

The total mobility of ions recorded in the pore solution is a result of the simultaneous effect of many factors and several mechanisms. Practical application of the higher mobility of the ions requires the development of special instruments for differential recording of their movements and also further investigation of the mechanisms behind the transport of ions in porous media.

LITERATUTE CITED:

1. M. A. AlekseYeva and Yu. S. Ryss, "The movement of ions under the influence of electrical current in rocks (Part I)," in: Methodology and Techniques of Exploration [in Russian], ONTI of the National Institute of Exploration Technology (VITR), Leningrad No. 84 (1973), pp. 47-55.

2. I. S. Goldberg, "The mobility of ions in the field of an electrical current at high concentrations of solution in porous media," in: Methodology and Techniques of Exploration [in Russian], ONTI of the National Institute of Exploration Technology (VITR), Leningrad No. 65 (1969), pp. 43-47.

3. O. N. Grigorov, Z. P. Kozmina, A. V. Markovich, and D. A. Fridrikhsberg, "Electrokinetic Properties of Capillary Systems" [in Russian], Akad. Nauk SSSR, Moscow-Leningrad (1956), 216 p.

4. I. Klotts, "Water," in: Horizons of Biochemistry [Russian translation], Mir, Moscow (1964), pp. 399-419.

5. A. I. Levin, "Theoretical Basis of Electrochemistry," Metallurgiya, Moscow (1972), 83 p.

6. L. V. Malerbi, Manderslut, "Demineralization by the Method of Electrodialysis" (1963).

7. D. A. Fridrikhsberg, "Course in Colloidal Chemistry", Khimiya, Moscow (1974), 230 p.

8. N. Kamo, I. Toyoshima, H. Nozaki and I. Kobatake, "Kolloid.- Z. und Z. Polym," Vol. 238, Nos. 1, 2, pp. 914-921 (1971).

9. I. W. Lorimer, E. I. Boterenbrood, and I. I. Hermes, "Transport processes in ion-selective membranes," Disc. Faraday Soc., No. 21, p. 141 (1956).

EXPERIENCE OF FINDING GOLD DEPOSITS IN WESTERN UZBEKISTAN USING THE CHIM METHOD

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V. A. Gorbunov and A. I. Mernenko

Successful application of the CHIM method for discovery of covered polymetallic deposits in different regions of the USSR has led to the use of the method in exploration for gold deposits in Uzbekistan. The challenge to directly detect gold mineralization buried at appreciable depths increases in this region every year. The existing exploration methodology which consists of a combination of geophysical, geochemical, and geological methods and also drilling, becomes ever more expensive and labor-intensive with increasing depth of drilling. This expense is due to the following: 1) the need to replace surface soil sampling with deep lithogeochemical methods; 2) increased number of boreholes needed to be drilled to test geophysical anomalies verified by soil sampling and 3) use of in-hole geophysical methods at sites where surface methods are not capable of reaching the necessary depth. Under these conditions, it has become attractive to test the CHIM method since it allows to find covered ore deposits under unconsolidated alluvium more than 100-m thick during surface investigations.

It is difficult to use any new method. In addition, gold values in orebodies and geochemical anomalies are low in comparison to the contents of base metals in the same rocks. This requires special techniques for gold enrichment at the CHIM element-receivers and also the use of specific analytical methods for detecting the gold in the samples. All this is complicated by comparatively low sulfide content in the known gold deposits of Western Uzbekistan which are represented primarily by free gold disseminated in quartz-rich rocks. Such deposits provide very small quantities of gold in the mobile, water-soluble forms in which it can be leached by the CHIM method.

Another important feature for the field testing of the CHIM method in Uzbekistan is the abrupt change in moisture of the near-surface ground layer (it becomes very dry in the summer months) where the element-receivers (ERs) are set up. Fig. 1 shows that the specific resistivity of the soil from April to October in 1977 varied over an order of magnitude. This variation reflects the changes with respect to soil moisture and quantities of chemical elements in water-soluble forms in summer relative to the quantities of such elements in spring and fall. It is evident that these changes should be taken into consideration during the field work using the CHIM method.

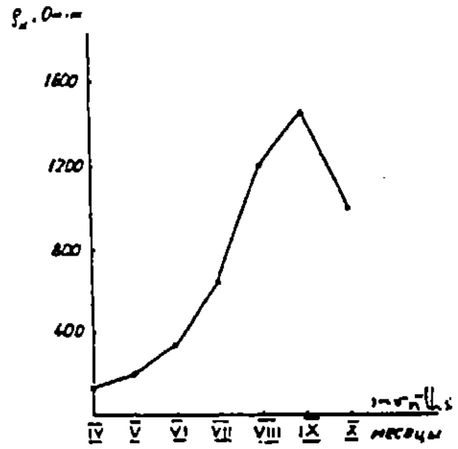

Fig. 1. Change in the specific resistivity of the soil with the seasons, 1977.

During the first stage of our CHIM survey, the possibilities for leaching gold in sufficient quantities for analysis were clarified and a correlation between zones of anomalously high gold leaching and known gold mineralizations. Operations were carried out at one of the known ore fields of Western Uzbekistan, Taking into account our experience with the CHIM method in tracing gold veins at Rudnyi Altai Mountains, we used element-receivers with membrane areas of 40 cm² allowing leaching to be carried out in a high-power regime of current: 400-600 mA through each element-receiver. Other measures were employed to decrease the resistivity of the total power circuit. In particular, the auxillary power ground (anode) was flushed with 1.5-2 m³ of water each day and carefully inspected for the presence of noticeably evaporating solution on the ER. In order to compensate for the evaporation on the ER, a portion of the solution was added periodically (after 5 hours). The shallow holes where the ERs were set up were carefully loosened and moistened with distilled water.

Investigations using the CHIM method were carried out at the first area in the middle of June. During the first days of the survey, the temperature was 25-30°C. The temperature then increased regularly; the original specific resistivity of the soil at 100-200 Ohm increased to hundreds and thousands of Ohm.

The results of the observations of gold-leaching during the first 10 hours and the next 10-20 hours along the first of the profiles (Fig. 2) indicate that the gold vein and the country rock adjacent to it could be satisfactorily delineated by anomalies of 0.03-0.04 mcg of leached gold relative to a background of 0.01 mcg during both tests. The leaching of gold differed at individual points, but anomalies generally coincided in space. The same situation was observed along other profiles. Graphs of CHIM constructed on the basis of the data of the first test are presented below.

Sampling repeated along a profile with an offset of 5 m from the first are shown in Fig. 3. From Fig. 3, it is evident that anomaly above the ore body was detected here at the same sampled in the late spring when the summer had just begun. The second profile was sampled when the hot summer had arrived. It is possible that it were these circumstances which brought about the change in the dimensions of the anomaly. Other causes are possible. Unfortunately, a profile was not completed during the third phase, the period of complete dryness. The need for such observations became apparent later, after measurements were carried out along other profiles and in other areas.

A second profile offset from the first by 80 m was sampled at a still drier time than Profile 1. Fig. 4 shows that the orebody was satisfactorily identified by gold CHIM anomaly. Its character is similar to that observed on the parallel Profile 1. Repeated observations along profiles 2 and 2', separated from one another by approximately 3 m, yielded the same correlation. However, it is necessary to note that the intensities of the anomaly and background decreased for Profile 2 in comparison to Profile 1, becoming 0.01-0.15 mcg and 0.0025 mcg respectively. In other words, the quantity of leached gold decreased by a factor of approximately 3-4 in more or less identical fashion both in the anomaly and in the background. The latter decrease, by the way, requires special investigation.

The decreases in the intensities of the anomaly and the background during the leaching of gold along Profile 2 relative to intensities along Profile 1 indicate that the cause is of a general character: a significant decrease in humidity. Features of the leaching due to changes in the gold content within the mineralization, for example, did not have a significant effect upon the change in the intensity of leaching, since they affected the anomaly and the background to more of less equal degrees.

On Profile 3, 100 m to the west of Profile 2, the gold-leaching anomaly presented in Fig. 5 has a lesser intensity than the ones along profiles 1 and 2. Moreover, the intensity of gold-leaching in areas of the profile with host rock remained the same as for Profile 2. This demonstrates that there are differences in the ore-grade and style of the mineralization and between these two profiles, and they caused the decrease in the intensity of the anomaly. Actually, Profile 3 was located at the marginal portion of the vein, where the gold content is less than in the vein's central portion and where the thickness of the cover is somewhat greater than over profiles 1 and 2, reaching 6-7 m, and, locally, 10 m.

Evaluating the results of the CHIM method at the first area, one can see that an ore body in the form of a quartz-gold vein can be satisfactorily delineated by the new method when using a high-power regime for leaching the gold (400-600 mA for an ER membrane area equalling 40 cm²). Climatic conditions lowering the quantity of gold leached during times of dryness had a substantial effect upon the CHIM results. For CHIM anomalies to be noticeable, it is necessary to leach the gold at high values of the current strength. The effect of the climatic conditions can be evaluated by their simultaneous effect upon the intensity of the anomaly and the background. The fact that the changes along the profiles are not identical indicates variations in geological styles of the mineralization and its bedding.

Further surveys using the CHIM method were carried out under conditions of low soil moisture in the area of unconsolidated alluvium several tens of meters thick at Area 2, which is underlain by sedimentary and volcanic sequences of the Lower Paleozoic age. Intrusive rocks, represented by granosyenites, syenites, granites, and syenite-diorites, are common in the area. Uuconcolidated deposits of Neogene-Quarternary age in the form of loesses and loess-like loams lie on an eroded surface of Paleozic rocks or on Lower Quarternary conglomerates. The thickness of the unconsolidated deposits varies from 0.3 to 40 m or more. The gold mineralization is is shown in Fig. 6. The thickness of the overburden of unconsolidated sediments amounts to approximately 20 m here. The results are presented in the form of two measurements along the first profile and along a profile parallel to the first but off-set by 3 m. The figure shows that the ore body makes a sharp, contrasting anomaly of up to 0.04-0.06 mcg for a background of 0.005 mcg. The background was characterized by a single point in connection with the small thickness (approximately 2 m) of the quartz-gold vein (the spacing of observations was 10 m) but reproduced well during repeated samplings. In this case, the anomaly delineated for a thickness of unconsolidated deposits equalling approximately 20 m is similar to that delineated when the thickness of such deposits was several meters (Site 1).

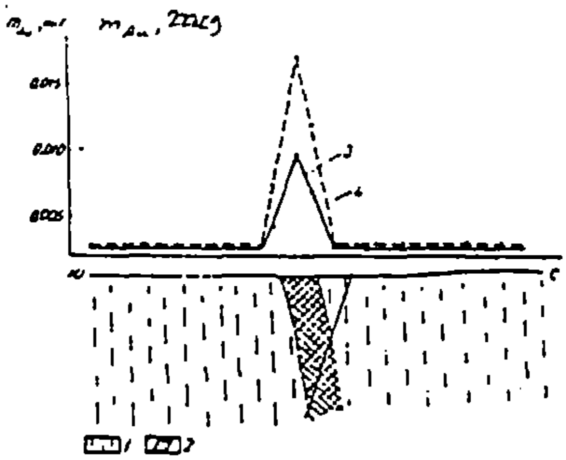

Fig. 4. CHIM results at Area 1. Profile 2: 1) host rocks, 2) ore body, 3) curve of gold extraction along the primary profile 2, 4) curve of gold extraction along the parallel profile offset from the primary one by 3 m.

Several hundreds of meters from that profile, CHIM testing was carried out along still another profile where the total depth of occurrence of the gold-quartz vein was approximately 40 m. The deposit at this location was hidden under conglomerates 10-20 m thick and loesses of the same thickness. The results of the tests, shown in Fig. 7, reflect a satisfactorily delineation of the gold vein under these conditions.

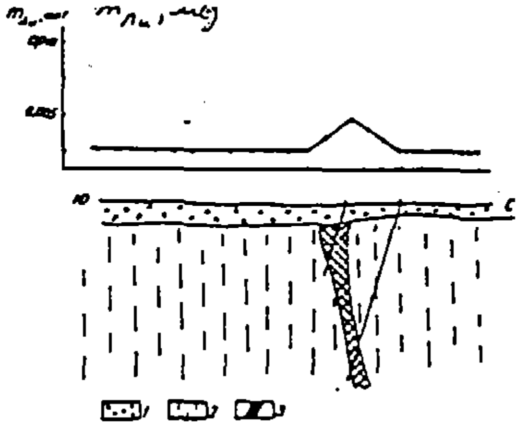

Fig. 5. CHIM results at Area 1. Profile 3: 1) alluvium, 2) host rocks, 3) ore body.

Thus, electrochemical leaching of gold using the CHIM method allows the discovering of gold objects covered by unconsolidated rocks tens of meters thick. Apparently, an approximately 40-m depth of occurrence of gold veins does not constitute a limiting depth for this method. Thus far, however, no veins have been found at greater depths. It is necessary to note that the thickness of the vein does not have a significant effect upon the detection of anomalies. Veins with thicknesses of either 2 or 10 m can be delineated during surface observations using the CHIM method.

The results of testing the CHIM method for discovery of gold mineralization covered by unconsolidated rocks in Western Uzbekistan, in principle, demonstrated a possibility for the use of this method. During the course of testing, several techniques were developed for conditions involving low or sharply varying soil moisture. The experience gained facilitated projects dealing with sorting of anomalies of electrical conductivity and consequent polarization which resulted in differentiation of areas containing gold from pyritized zones or other non-gold-bearing zones.

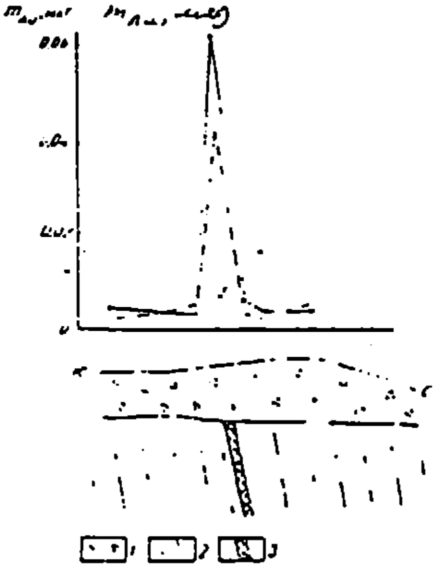

Fig. 6. Results of observations using the CHIM method at Site 2. Profile 1: 1) loesses, 2) host rocks; curves of gold-leaching on the first (4) and the parallel profile offset from the first by 3 m (5).

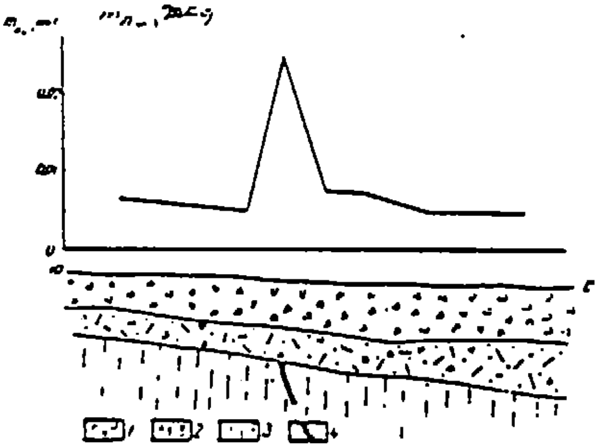

Fig. 7. Results of observations using the CHIM method at Site 2. Profile 2: 1) loesses, 2) conglomerates, 3) host rocks, 4) ore body.

LITERATURE CITED

1. Yu.V. Vyazovetsky and Yu. A. Kalashnikov, "An Experiment Using the CHIM Method for Sorting CP Anomalies During Surveys of Copper Deposits in Southern Kazakhstan," in: Methodology and Technology of Exploration, Department of Science and

Technology, ONTI of National Institute of Exploration Technology (VITR), No. 117, pp. 34-37 (1977).

2. Yu. S. Ryss and I. S. Goldberg, "Capabilities of the Partial Extraction of Metals (CHIM) for Surveys of Ore Deposits," in: Methodology and Technology of Exploration, Department of Science and Technology, VITR, No. 84, pp. 5-19 (1973).

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GOLD EXPLORATION IN SOUTHERN YAKUTIYA USING THE CHIM METHOD

A. A. Veikher

Two types of gold deposits are common in Yakutiya: high sulfide gold veins and the mineralized beds associated with ther (the Lebedinsky type), and gold-enriched weathered crusts, often karst limestones hosting stratiform occurrences of gol covered by unconsolidated overburden (the Kuranakh type). Exploration for both types of deposits utilizes a combination o many geophysical and geochemical methods together with geologica mapping and drilling [4]. Electrical methods are usuall included among the geophysical approaches when searching for th Lebedinsky type deposits. High-precision gravity surveys an magnetic surveys are used for targets of the Kuranakh type Over areas with thin unconsolidated overburden (up to 2-3 m) gold-oriented soil survey and other geochemical methods are use together with geophysics. With increasing thickness o overburden, however, surface geochemistry becomes ineffective Geophysical methods, indirect as they are, generally leav unanswered the question of gold potential in areas of know karsts with electro-conductive zones.

The effectiveness of exploration could be increased by method allowing for a direct delineation of gold-bearing veins mineralized beds, and karsts in covered areas. The positiv results achieved in the exploration for gold deposits i Kazakhstan and Uzbekistan [1, 2] using the CHIM method present promising opportunity to test the method's possibilities wit respect to gold deposits of Kuranakhskii and Lebedinskii types.

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[1] This project was conducted by the CHIM team of the Sixt Geophysical Expedition of the firm 'Yakutgeologiya' A.T. Indyukov, team chief; N.N. Nikulina, chemist.

Gold Deposits of the Kuranakh Type.

The district encompassing the group of gold deposits where we carried out the test of the CHIM method is characterized by the following principal geologic features. A thick (up to 600 m) carbonate sequence of the Lower Cambrian age is exposed over most of the district. The carbonates rest on an Archean crystalline basement. The carbonate rocks include interstratification of dolomites, limestones, and calcareous mudstones. A terrigeneous formation (up to 120 m thick) of the Lower Jurassic age lies unconformably upon an eroded and karsted surface of the Lower Cambrian. The rocks are sandstones, conglomerates, and silty shales. The post-Jurassic rocks are Neogene-Quarternary in age and range from several meters to tens of meters in thickness. Mezozoic magmatic rocks occur as isolated dikes, small stocks, and quartz veins of subalkalic composition. The dikes extend for hundreds to thousands of meters and have thicknesses of several meters. A few "sill-like" intrusions confined to the zone of stratigraphic contact between the Cambrian and the Jurassic.

The gold mineralization occurs as metasomatic strata-bounc deposits of an essentially potassic feldspar and pyrite-quart composition formed as a result of hydrothermal replacement of th Lower Jurassic sandstones and the carbonate rocks of the Lowe Cambrian. The widespread weathering and oxidation almos completely changed the primary ores. In their present state deposits of the Kuranakh type are products of weathering. Th ore is represented by loose gold-bearing limestones of kars cavities.

The mineralized karst formations consist of gold-bearin unconsolidated sand-clay material and bigger fragments of primar ore bodies - metasomatites. The linear zones of gold-bearin karst are confined to the stratigraphic contact between th rocks of the Lower Cambrian and the siliciclastic rocks of the Jurassic.

The age of the gold-bearing karst carbonates is accepted approximately as Late Tertiary. The karst-forming process, which began at that time, continues into the present [3]. Karst formation in limestones usually begins at the footwall of metasomatized limestones. Highly acidic groundwaters penetrating the carbonate rocks from an oxidation zone of metasomatic rocks lead to dissolution of carbonates. Closed karst cavities are formed as a result. With increasing karst development, the roof rocks cave in, oxidized gold-bearing metasomatites accumulate in the karst cavities along with Jurassic sandstones and conglomerates protected from erosion. Finally, the closed karst cavities transforme into the open ones.

In closed karst cavities, gold occurs in the form of free gold in the size fraction greater than 0.01 mm. The particles of the gold are flaky dendritic or lumpy. Silver, copper, lead, bismuth, iron, and arsenic are present as admixtures in the gold. Aluminum, titanium, manganese, and other elements are also present in small quantities. In the open karsts, some particles of gold are greater than 0.01 mm, but some in the clay fraction are less than 0.01 mm. In the clay fraction, the total content of gold is higher than in the coarser one. The presence of gold in the fine fraction within the open karst cavities is explained by the dissolution of the gold by ground waters during the open-karst stage, with subsequent sorption by clay minerals. Such gold can be present in ionic and colloidal states. In addition to karst cavities, higher gold concentrations have been noted in the soil directly above gold ore bodies where the thickness of the unconsolidated overburden does not exceed 1-2 m in situations involving open karsts [4]. Soils above the closed karst cavities do not contain high concentrations of gold. The CHIM survey was carried out on those mineralized zones where the thickness of overburden does not exceed ~3-5 m. The extraction was carried out at element-receivers with membrane areas of 40 cm². Complications arose when setting up the element-receivers in the soil. It turned out that the top layer of soil, with a depth of 0.1-0.3 m, has very high specific resistivity (from 12,000 to 20,000 Ohm). Such a soil resistivity does not permit the high-power regime necessary for gold extraction. Therefore, the ERs were placed in a second, deeper layer (~0.5 m) possessing a specific resistivity of 200-500 Ohm. These layers can be distinguished visually: the lower layer is denser and clay-rich compare to the upper, sandy layer. The necessary high-power extraction regime was achieved when setting up the ERs in the lower layer with lower resistivity: the electric field strength in the vicinity of the ER is ~2 V/cm at a current strength of 300-400 mA. The extraction time is 10 hours. The results of observations along one of the profiles are presented in Fig. 1. On the graph, one can conditionally distinguish several levels corresponding to different quantities of extracted gold: 0.3-1.0 ppm, 0.1-0.3 ppm and > 0.1 ppm. Maximum extraction of gold (0.3-1.0 ppm) corresponds to the outcrop projections of an ore body to the surface. Less intense anomalies were encountered above dikes containing anomalous gold.

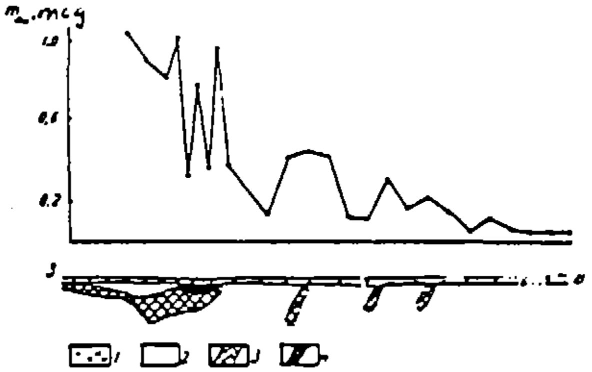

Fig. 1. The CHIM method results for deposits of the Kuranakh type: 1) unconsolidated Quarternary, 2) Lower Jurassic sandstones, 3) dike-related and low grade gold mineralization, 4) gold orebodies.

Thus, the CHIM method satisfactorily delineates the primary ore body and dikes with gold contents either lower than in the primary body or significantly higher than in the country rock.

Gold Deposits of the Lebedinsky Type.

Rocks of the Archean basement are a part of the geological structure of a district with the Lebedinskii type mineralization. Limestones and dolomites of the Lower Jurassic concordantle overlie the basement structure. The maximum thickness of the carbonate sequence is 200 m. The structure of the area is characterized by many high angle faults. The distribution and occurence of the gold are primarily determined by elements of high angle tectonics - vertical fissure zones in combination with stratabound zones of weakness. Ore bodies represented by steeply dipping quartz-sulfide veins are hosted by the lower Cambrian carbonates. Flat-lying ore bodies occur on several levels. The lower horizon of commercial mineralization is the footwall of the Cambrian limestones at the contact with the crystalline basement. The mineralogy of the ore is quartz, base metal sulphides, hematite and pyrite.

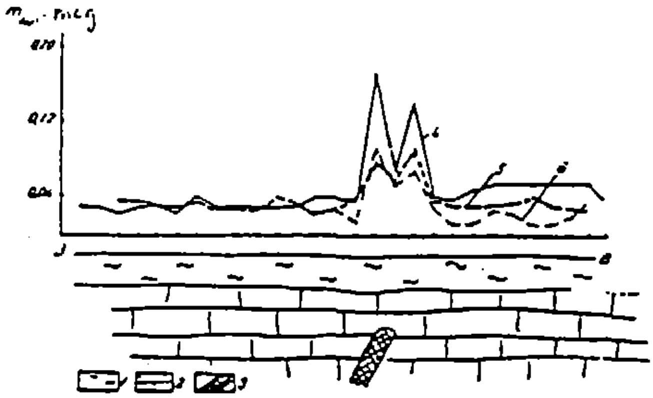

Fig. 2. The CHIM method results for deposits of the Lebedinsky type (Site 1): 1) Quarternary overburden, 2) limestones and dolomites of the Lower Cambrian, 3) gold-sulfide ore zone; gold-extraction curves using the CHIM method: first (4) and repeated (5, 6) observations.

A covered orebody hosted in dolomites at 40 m was successfully identified in a well studied part of the deposit where the CHIM method was used. The gold was extracted into the ERs with a membrane area of 40 cm². A high-power regime ensuring the current strength through each ER of 300-400 mA and the electric field strength of 2V/cm was set. The extraction time was 10 hours. The results of the experiment presented on Fig. 2 show that an elevated gold extraction was observed directly above the subcrop projection of the orebody onto the surface. The width of the anomaly along the profile was 60 m.

In order to evaluate the reproducibility of the observations, repeated measurements were carried out along the profiles which were offset parallel to the first profile by 2 and 3 m. The extraction regimes were identical. Figure 2 shows that anomalies are reproduced well with respect to width and position on the profile but not with respect to gold levels. In general, the results of the observations show that it is possible to identify gold deposits within limestone host rock at a depth of ¯40 m.

At another area with a similar geological environment, gold was extracted along two profiles located 150 m from one another on the slope of a hill. The gold mineralization within Profile I occurs in dolomites and represents two tube-shaped orebodies located close to each other. The ore bodies are blind and overlied by a bed of dolomites. Soils in the area have thicknesses varying from 0.5 to 2 m. At some places, the soils are rubbly containing coarse rock fragments. The element-receivers were set up along the profile in a humus layer at a depth of 5-10 cm. At locations where a great deal of rubble turned up under the ER, the soil was shifted through a screen with a 2-mm mesh and then moistened with distilled water. The gold was extracted at a current of 250-400 mA through each ER. The field strength was 2 V/cm. The extraction time was 10 hours for Profile 1 and 20 hours for Profile 2. There were two cycles of testing: 0-10 and 10-20 hours. The results are shown in Fig. 3, where the zone with gold-sulfide ore bodies is satisfactorily delineated by the CHIM method and can be traced well from profile to profile. Another anomaly located to the north of the first one was delineated on the basis of weaker but still satisfactory gold extraction. It corresponds to an unexplored gold mineralization intercepted by only a few drill holes and trenches. This new zone, as in the case of the first well studied zone, can be traced well from Profile I to Profile 2.

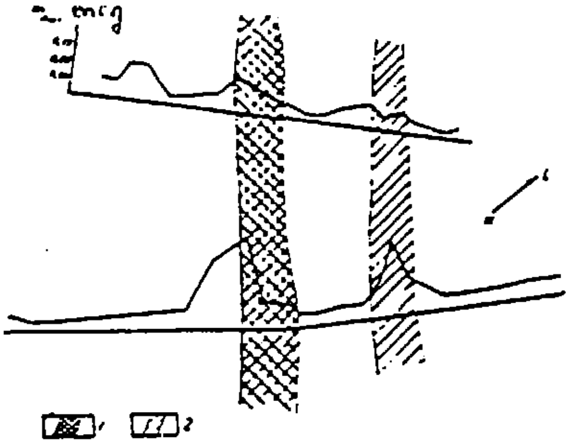

Fig. 3. The CHIM method results for deposits of the Lebedinsky type (Site 2): 1) well studied zone of gold mineralization, 2) new ore zone known from a few trenches and intercepted by drill holes.

In addition to these two anomalies, there is still a third anomaly located on Profile I to the south of the well studied ore zone. Its nature is unclear. It is possibly caused by an old mining road passing through the area, but it could be associated with unknown mineralization and requires special study. It should be first traced by the CHIM survey along the strike.

Not counting this third anomaly, the data obtained indicate a satisfactory identification of the gold mineralization of the Lebedinsky type by the CHIM method.

On the whole, the developmental work using the CHIM method for identification of a gold mineralization in Yakutiya shows the possibility of delineating gold anomalies under a cover up to 40-m thick . It could also be noted that the mass of gold extracted by the CHIM method was significantly greater than that extracted in Eastern Kazakhstan and Uzbekistan.

LITERATURE CITED

1. C. G. Alekseyev, A. A. Veikher, and I. S. Goldberg, "Possibilities of Using the CHIM Method in Explorations for Covered Gold Deposits," in: Methodology and Technology of Exploration, ONTI, VITR, No. 123, 33-37 (1978).[In Russian]

2. A. A. Veikher et al., "Experience of Finding Gold Deposits in Western Uzbekistan Using the CHIM Method," this volume, p. 34-38. [in Russian]

3. L. V. Rozin and I. S. Rozhkov, "Geochemistry of Gold in the Weathered Crust of Gold Deposits of the Kuranakh Type", Nauka, Moscow (1966), pp. 88-90. [In Russian]

4. A. A. Feldman, "Geophysical and Geochemical Studies Associated With Exploration For Gold Deposits of the Kuranakh Type," Trudy TSNIGRI, No. 73, 1-51 (1966). [In Russian]

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Appx 1 of

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APPENDIX 2

338144

A preliminary report on geolelectrochemical investigations in the area Zeehan (Tasmania). Area of investigations involves Henry River ETA 349, Mt.Zeehan ETA 348, Bluestone Creek ETA 344.

Prognostic Evaluation of the Territory
Stage II

Ionex
by Dr. I. Goldberg
1995

338145

TABLE OF CONTENTS

1. INTRODUCTION

1.1 General Principles of Geoelectrochemical Analysis and Peculiarities of Execution of Works in the Area.

The works were executed on the basis of a new technology, "Analysis of structure of geoelectrochemical systems". The technology is based on the analysis of distribution of a wide range of elements in energy fields of the Earth (and, in particular, with consideration for their possible electrochemical redistribution under the action of natural electric fields and transformation of petrophysical properties of geological medium). Brief statements of this model are given in the thesis for the Report, 17th International Geochemical Exploration Symposium, 1995.

In compliance with the model, the analysis of geochemical, geoelectrochemical data was carried out within systems, whose range as to conditions of their formation far exceeds the object of search. It enables the revealing of ore objects even in regional stages of work and to examine thoroughly their position in the system in more detailed stages.

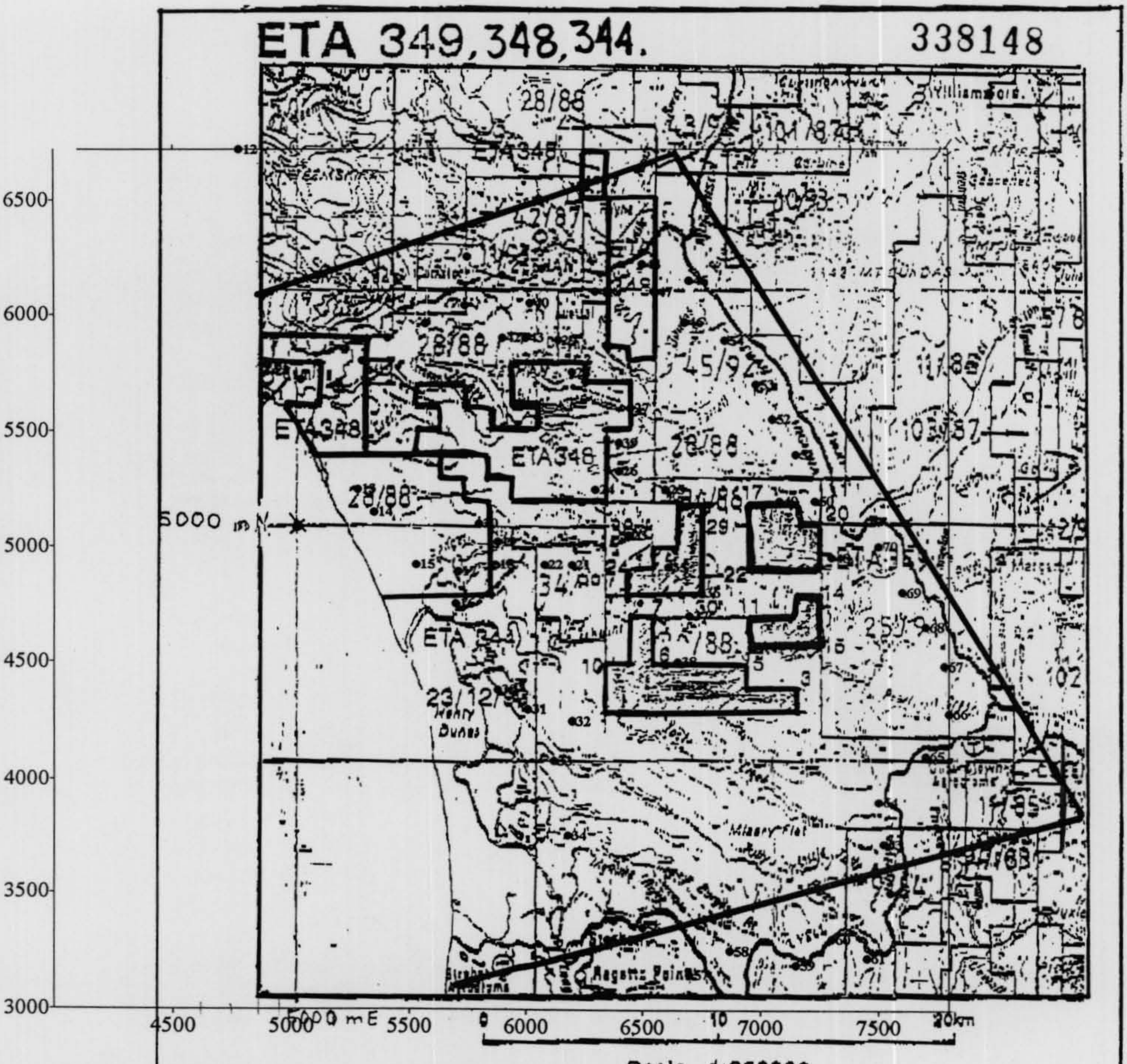
1.2 The Technology of Execution of Works Involves:

- field sampling in surface loose rocks and bedrocks (in open regions) or only use of loose rocks (in closed regions) including the CHIM method;
- analysis of samples, including soils, by special methods of selective (partial) extraction of elements (phase analysis) by MPF, TMGM;
- interpretation of results on the basis of geoelectrochemical model of the matter and structure of physical fields.

Employment of such technology is the most effective when stage-by-stage investigations are carried out. In this case, a large area is investigated in first stages. Then local areas are selected for subsequent evaluation.

In the given instance, our task was to evaluate approximately 9 - 10 small local areas united into 3 large areas: Henry River ETA 940, MtZeehan ETA 940, and Bluestone Creek ETA 944 (map 1b). Regional observations were necessary to be carried out for the provision of this strategy. Therefore, a territory of about 500km^2 was chosen involving all sections entering in the composition of ETA 348, 349, 344. Along with sampling in these sections, samples were also taken along state roads that made it possible to unite individual sections into a general system of observations.

Sampling



Map 1. The Samples' Location and Samples' Number.

Scale 1:250,000

0 5 10 15 20 km

TASMANIA DEVELOPMENT AND RESOURCES

FORMERLY PART OF E.L.34/88 (ALL MINERALS)

MINERAL RESOURCES TASMANIA

5 cm

Sampling was carried out from January 16 to January 21, 1995.

Altogether, 140 samples were taken. They include both splitted off samples of bedrocks (70 samples) and soil samples (70 samples). Position of points of observations are given in map No.1. The samples were taken along a route every 2 - 3.5 km, that corresponds to the density of the network of observations of about 7km. The density of sampling is irregular. It was condensed in areas of licences wherever possible. However, works have been fulfilled with money being available that was evidently insufficient for more regular network.

Study of the whole area in more detail necessitates much more time since most of the routes must be pedestrian.

Analysis of samples.

Only soil samples have been analysed by the geoelecrochemical MPF method. The analysis has been performed in a special laboratory in St. Petersburg.

Brief characteristics of the MPF method and kinds of analyses. The metalloorganic complex is selectively extracted by the MPF method. The extraction is made by sodium pyrophosphate. Normalisation of the metalloorganic complex is carried out after carbon (in percent) Me/C (where Me is any ore element). Mentioned relations reflect satisfactorily metal concentrations accumulated in the metalloorganic complex without distinct dependence on amount of organic compounds in soil. The analysis has been performed for heavy metals including Cu, Zn, Pb, Ag, As, Mo and carbon (C). The results are given in Appendix 1.

Interpretation of the results of analyses.

Data of the analyses characterise distribution of metals in weakly fixed metalloorganic compounds in soils. According to the conditions of the method, anomalous concentrations of metals correspond to the position of deep anomaly-forming objects without indication of the depth of their occurrence. Anomalies of metalloorganic forms of occurrence of corresponding metals in the soil give an indication of the projection of deep anomaly-forming objects on the Earth's surface.

Structural analysis of geoelectrochemical systems assumes use of data of chemical analyses of bedrocks and soil samples with the MPF method.

Terms of the contract did not allow us to perform the analysis of bedrocks. As a consequence, it is impossible to carry out such analysis completely within the framework of the given report.

Material represented in the report is given in various forms. Results of data processing are given for separate elements in three forms.

Contour maps, scale 1: 250,000. Boundaries of regions of various concentrations are determined, taking into account statistic distribution of every element using data catalogue in the MPF method on other regions.

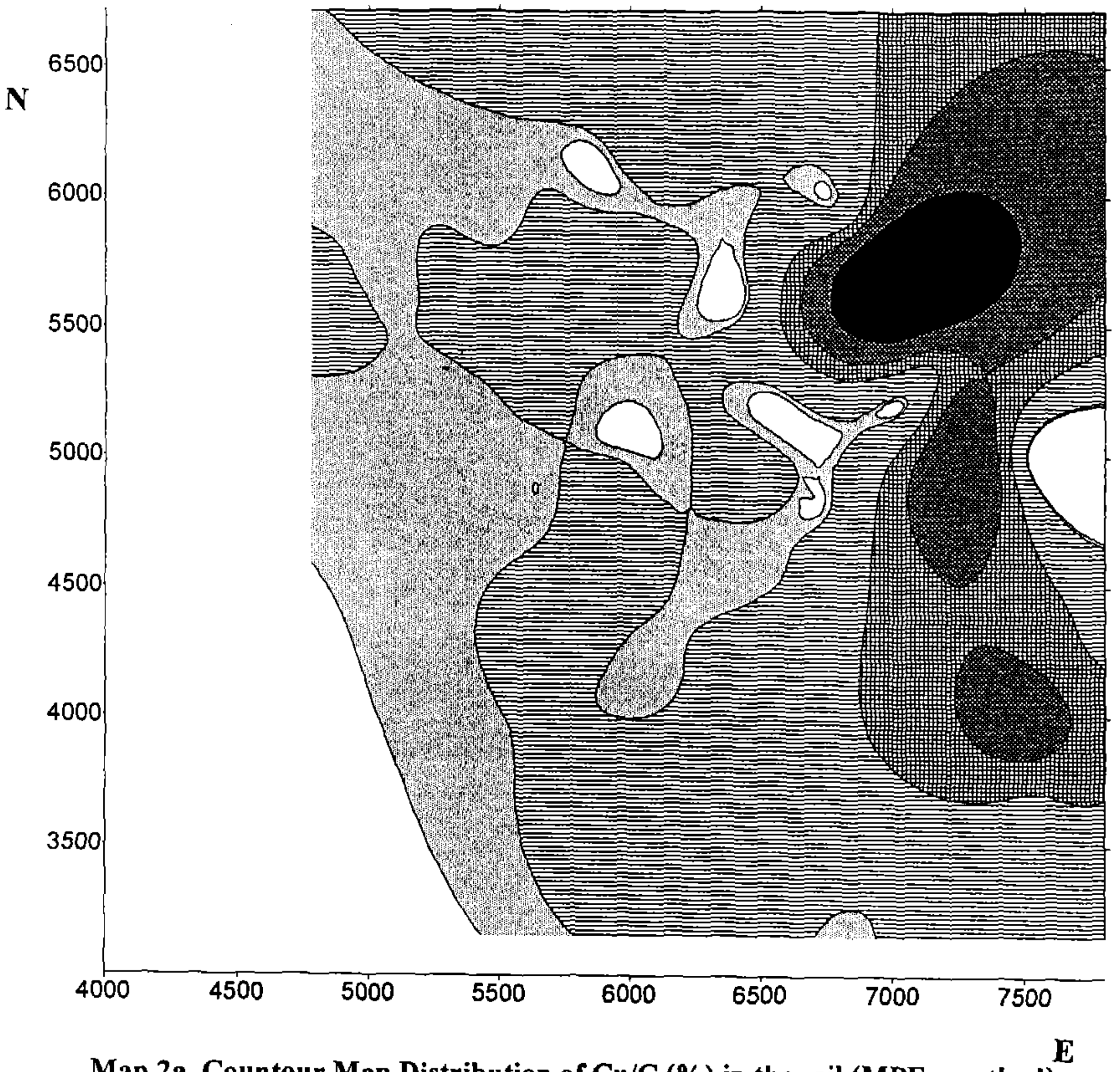
The model is constructed on the radial basis function;

$$B(h) = \sqrt{h^2 + r^2}$$

where h is the anisotropically rescaled, relative distance from the point to the node, R^2 is the smoothing parameter specified by the user. (Carlson, R.E. and Foley T.A., 1991a, "Radial Basis Interpolation Methods on Track Data". Lawrence Livermore National Laboratory UCRL - JC - 1074238).

The contour maps are given in two forms including transparent maps permitting correlation of a position of various anomalies between each other and geological and metallogenic data of the region of works.

For the purpose of more vivid presentation coincidentally with the contour map, maps of perspective projections are given also on 1: 250,000 scale.



Map 2a. Countour Map Distribution of Cu/C (%) in the soil (MPF - method)

1. ■ 2. ■ 3. ▩ 4. ▦ 5. ▤ 6. ░

Scale 1:250,000

0 5 10 15 20 km

5 cm

2. BRIEF CHARACTERISTIC OF RESULTS OF OBSERVATIONS

2.1 Copper

Map 2a. Contour map, distribution of Cu/C in the soil (MPF method) Scale 1: 250,000. 1. > 4%; 2. 2-4%; 3. 1-2%; 4. 0.5-1%; 5. 0.02-0.5%; 6. < 0.025%.

Map 2b. Perspective projection, distribution of Cu/C (%) in the soil (MPF method), scale 1: 250,000.

A submeridional zone anomalous in copper Cu/C% is distinguished in the eastern part of the area. It is traced within the limits of the studied area to 25km at a width of about 5km. This zone is not outlined in the east.

The most intensive anomaly occurs within the area bounded by coordinates 7000mE - 7500mE and 5250mN - 5750mN. This anomaly is the most distinct in map 2b.

Less intensive anomalous zone is confined to corridor 7000mE -7250mE in the interval 4000mN - 5000mN and involves the eastern part of the licence areas Henry River ETA 349 as well.

At least approximation of values adjacent to these sections evidences their possible prospects for copper.

A zone about 5-7.5km wide also of submeridional trend and with distinctly lower values of Cu/C% is distinguished in the western part of the area along the coast. The central part of the area is close to normal distribution.

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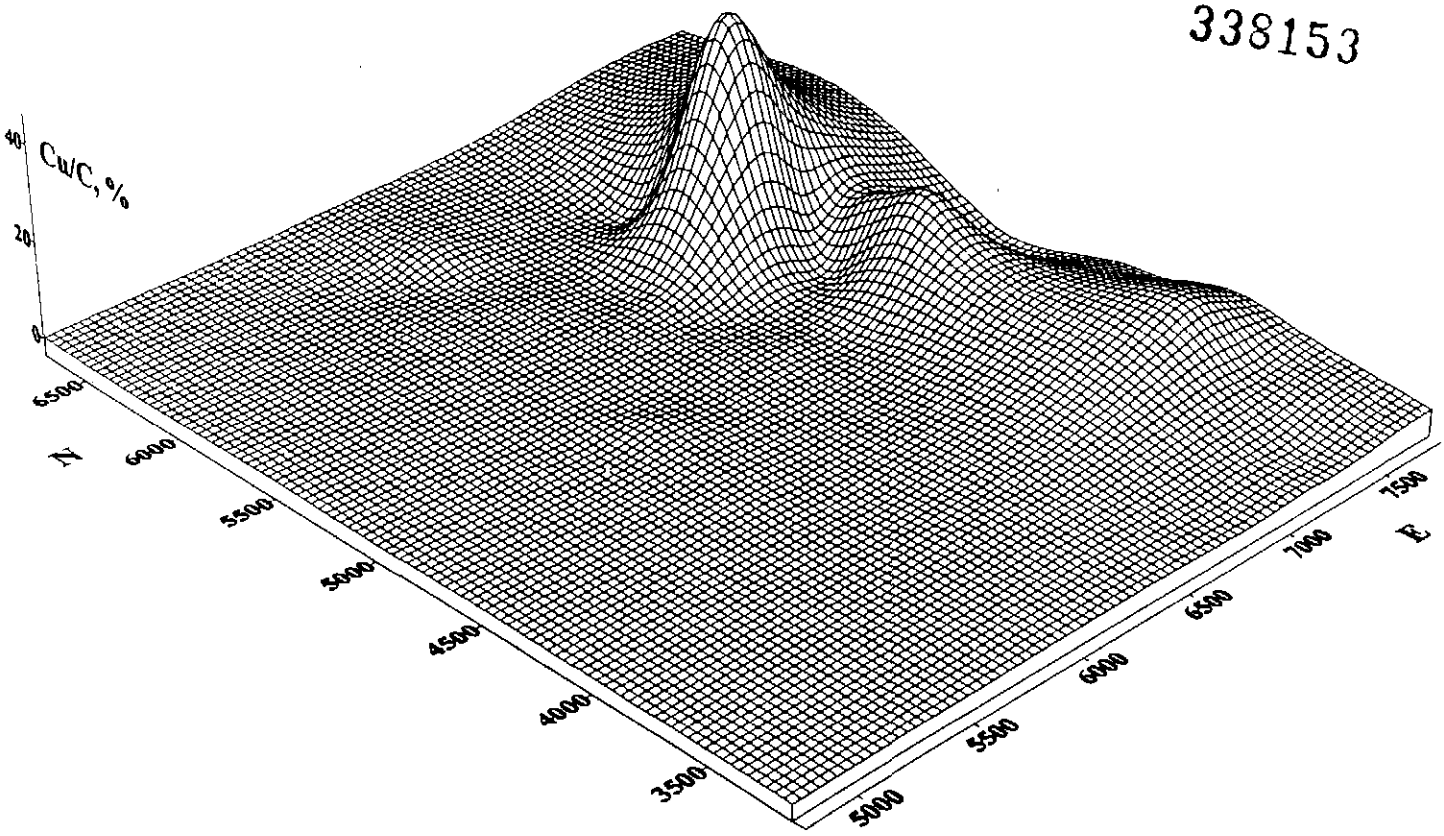
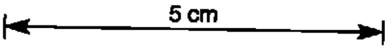


Map. 2b. Perspective projection, distribution of Cu/C (%) in the soil (MPF - method)

Scale 1:250,000



2.2 *Lead*

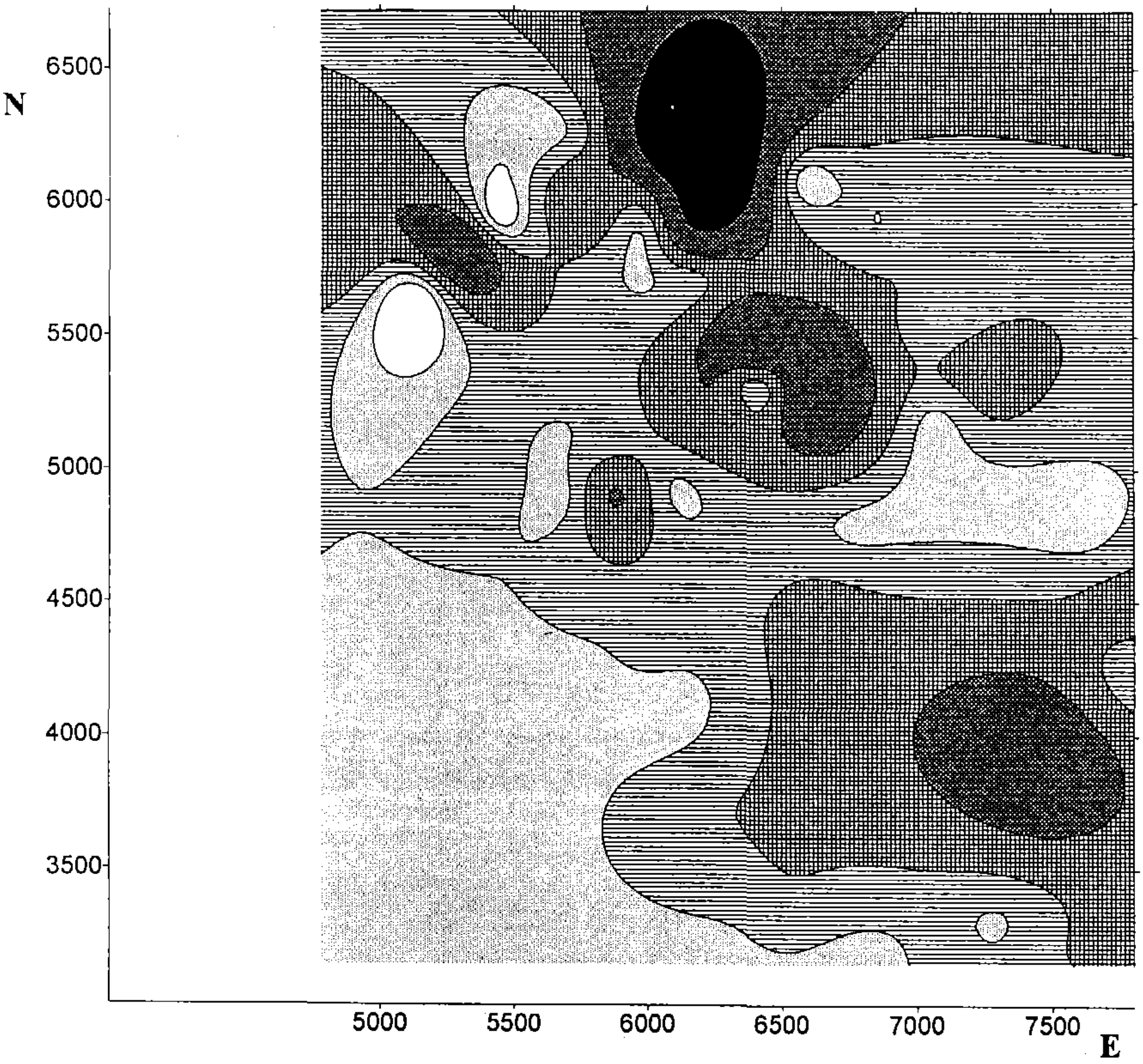
Map 3a. Contour Map, Distribution of Pb/C (%) in the soil (MPF method), scale 1: 250,000. 1. > 0.2%; 2. 0.1-0.2%; 3. 0.05-0.1%; 4. 0.05-0.02%; 5. < 0.02.

Map 3b. Perspective projection, distribution of Pb/C(%) in the soil (MPF method).

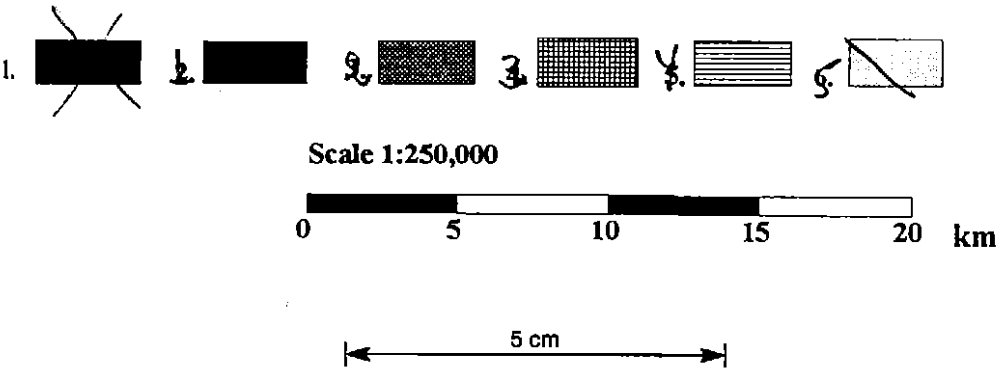
A zone anomalous in Pb/C% is distinguished to the west of the zone anomalous in Cu/C%. It extends from NW to SE.

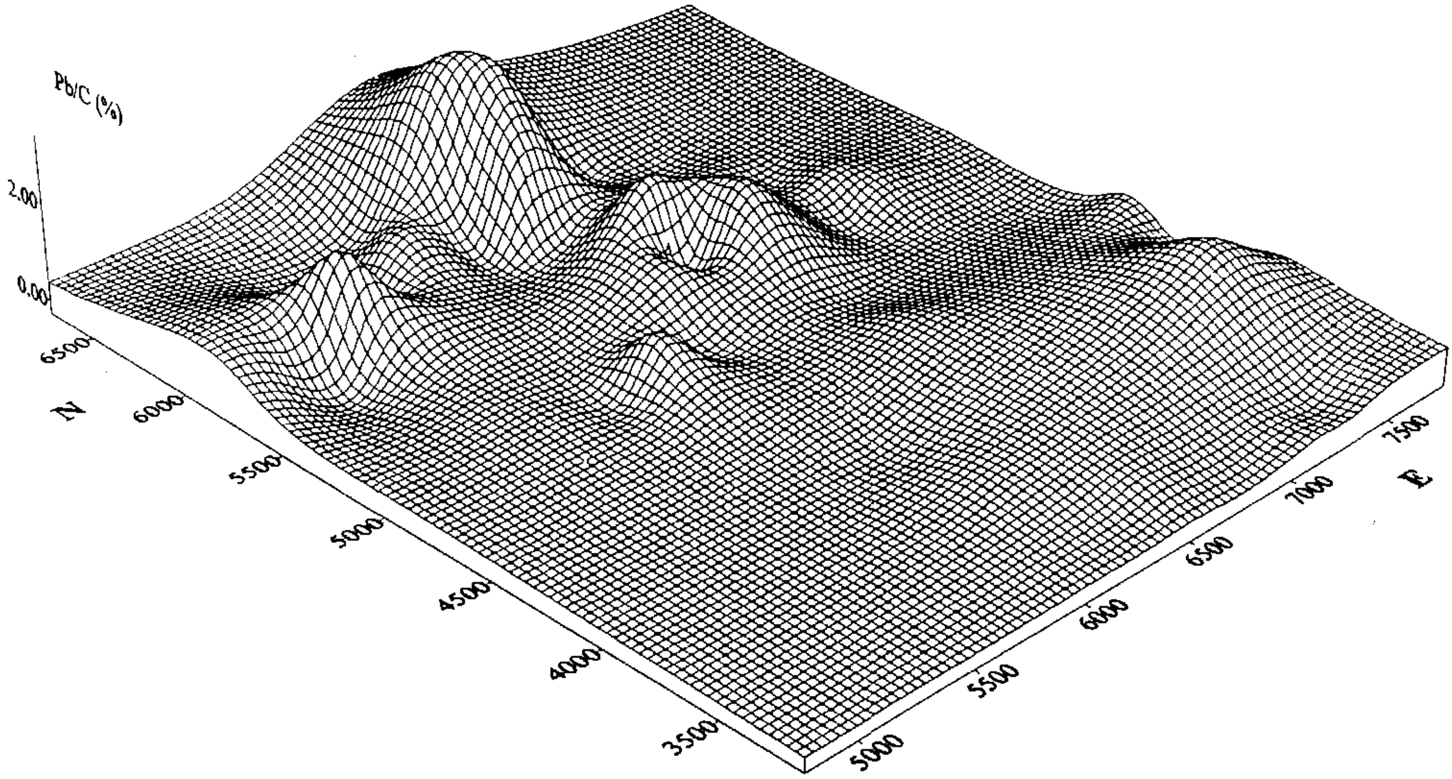
In the northern part, the centre of anomaly in Pb/C deviates from the centre of anomaly in Cu/C by 4-5km and is offset northward by 10km. In the south-eastern part, the anomalous zones coincide approximately at the intersection of coordinates 4000mN and 7250mE. Width of the anomalous zones is about 5 - 7.5km, its length is about 30km. A large region of lower values of Pb/C% is recorded in the south-western part of the area.

Position of anomalies Pb/C% relative to licence sections: The intensive lead anomaly coincides closely with the northern section of the licence Mt. Leehan ETA 348. However, more intensive part is confined to its western boundary. A rather considerable anomaly is confined to the southern and western section of Mt. Leehan ETA 348. In the southern part of the area, the anomaly Pb/C% occurs adjacent to the southern section of the Hanty River ETA 349.



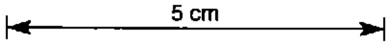
Map 3a. Countour Map Distribution of Pb/C (%) in the soil (MPF - method)





Map. 3b. Perspective projection, distribution of Pb/C (%) in the soil (MPF - method)

Scale 1:250,000



2.3 Zinc

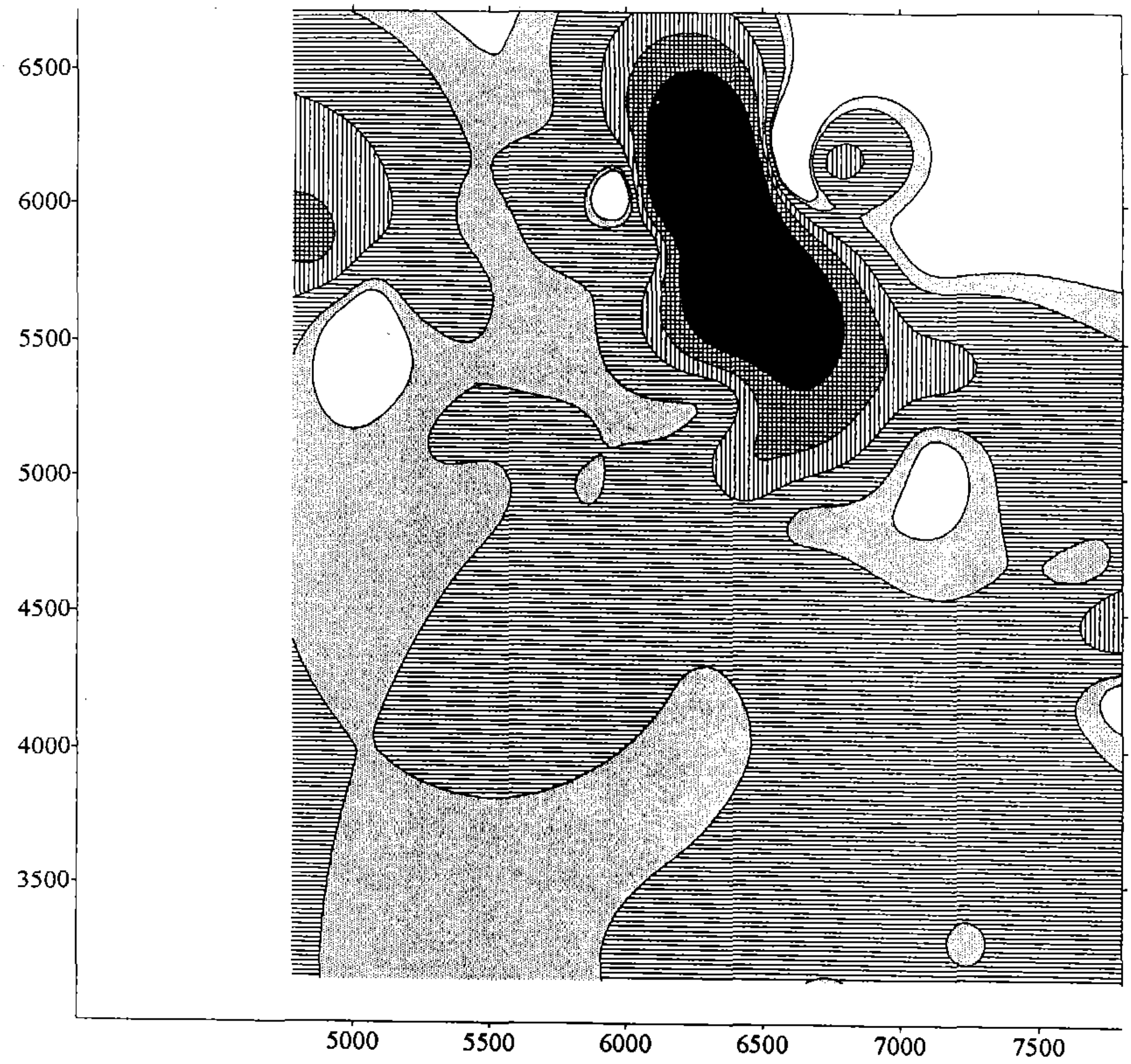
Map 4a. Contour Map, Distribution of Zn/C% in the soil (MPF method).

1. > 4%; 2. 2%; 3. 1-2%; 4. 0.3-1%; 5. 0.1-0.3%; 6. < 0.1%.

Map 4b. Perspective projection, distribution of Zn/C% in the soil (MPF method).

The intensive anomaly Zn/C% occurs in the north-eastern part of the area. It extends from NW to SE and is traced to 12km. The width of the most intensive region is from 4 to 5km. It spatially occurs between the anomalous zone Cu/C% in the east and anomalous zone Pb/C% in the west.

Position of the anomaly Zn/C% relative to the licence sections. The major anomaly Zn/C% overlaps the north-eastern section of the Mt. Zeehan ETA 348 and partially (in the eastern part) covers the southern section of this licence.



Map 4a. Countour Map Distribution of Zn/C (%) in the soil (MPF - method)

1. ■ 2. ■ 3. ▦ 4. ▦ 5. ☰ 6. ░

Scale 1:250,000

0 5 10 15 20 **km**

5 cm

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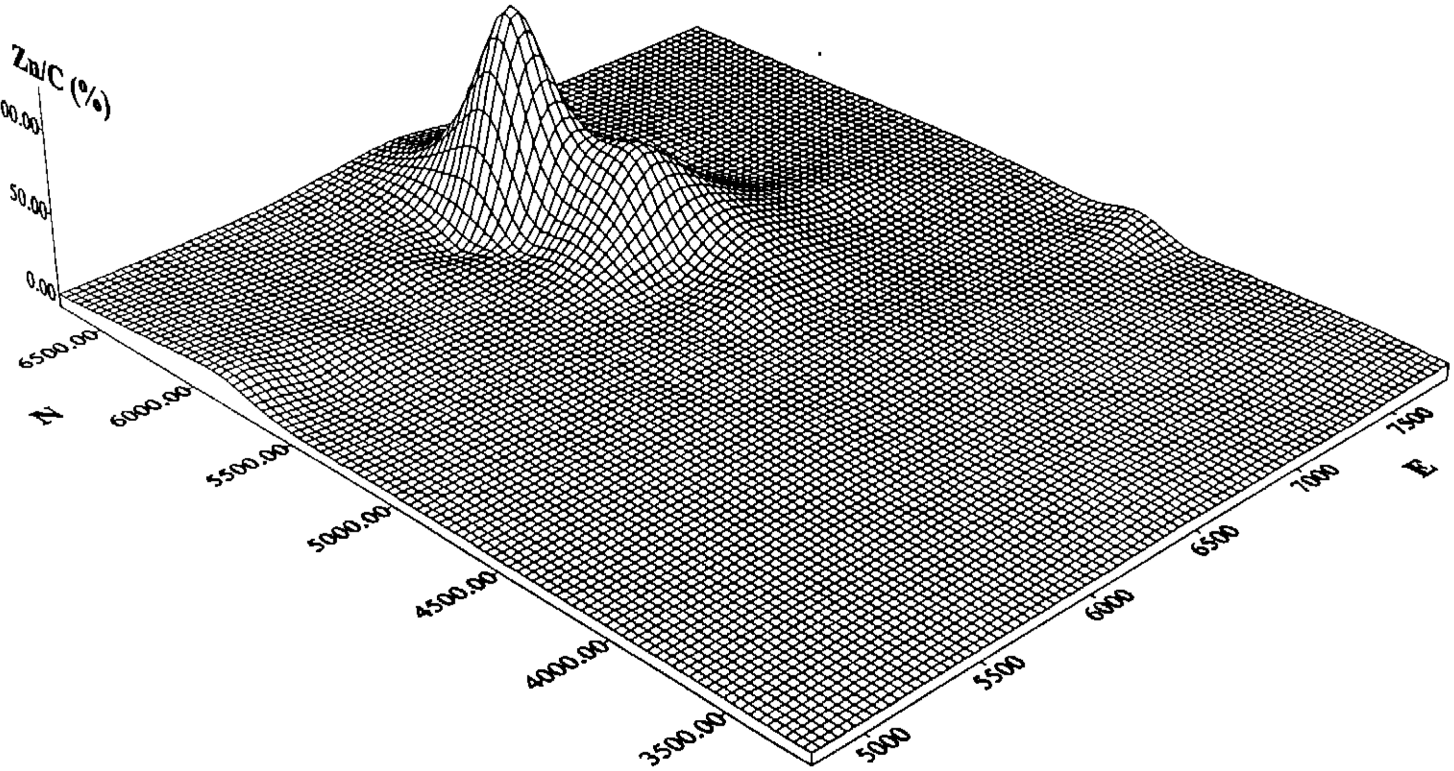


Map. 4b. Perspective projection, distribution of Zn/C (%) in the soil (MPF - method)

Scale 1:250,000

5 cm

2.4 Molybdenum

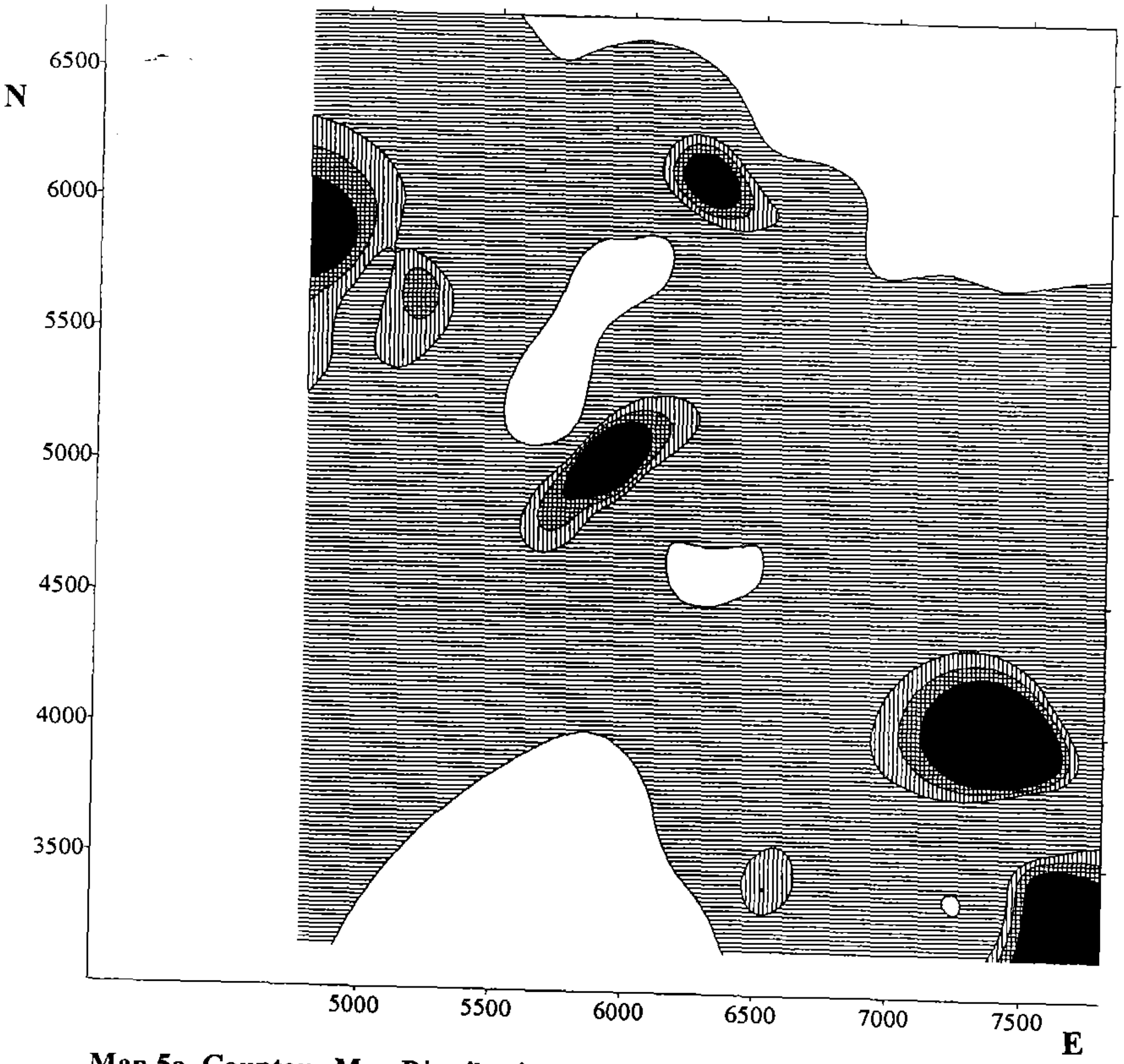
Map 5a. Contour map distribution of Mo/C (%) in the soil (MPF method), scale 1: 250,000.

1. > 0.15%; 2. 0.1-0.15%; 3. 0.05-0.1%; 4. 0.005-0.05%; 5. < 0.002%.

Map 5b. Perspective projection, distribution of Mo/C(%) in the soil (MPF method), scale 1: 250,000.

Anomalies of Mo/C% are of discontinued character. Area of separate intensive anomalies is about 5-6km^2. They mainly occur in the certain zone extended from NW to SE.

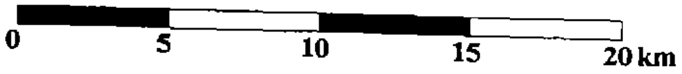
Position of separate anomalies relative to the licence sections. One of them occurs within the western section ETA 348, another occurs within the north-eastern section of this licence. An intensive anomaly occurs in the southern part of the area close to the southern section of the licence Henry River ETA 349.

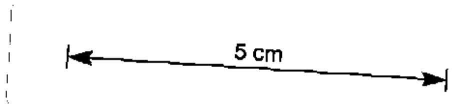


Map 5a. Countour Map Distribution of Mo/C (%) in the soil (MPF - method)

1. ■ 2. ■ 3. ▩ 4. ▦ 5. ▤ 6.

Scale 1:250,000





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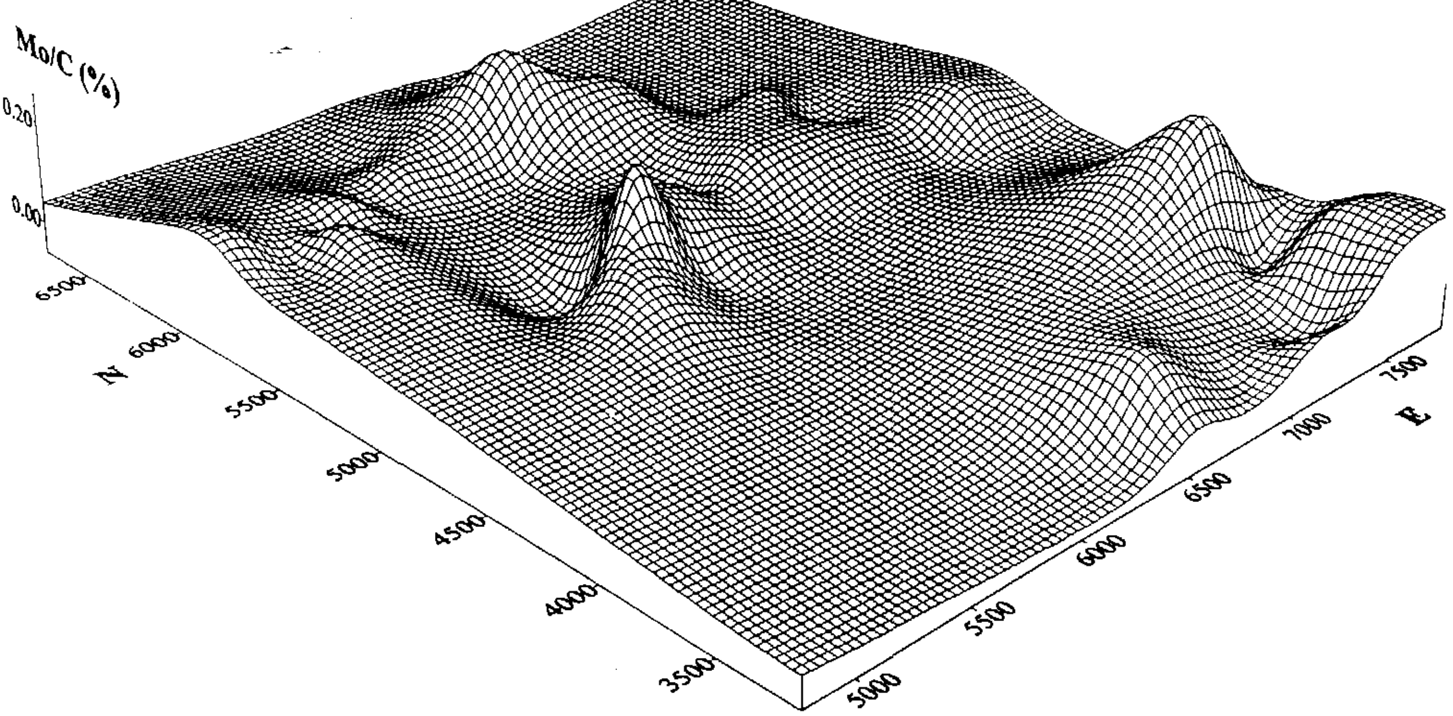


Map. 5b. Perspective projection, distribution of Mo/C (%) in the soil (MPF - method)

Scale 1:250,000

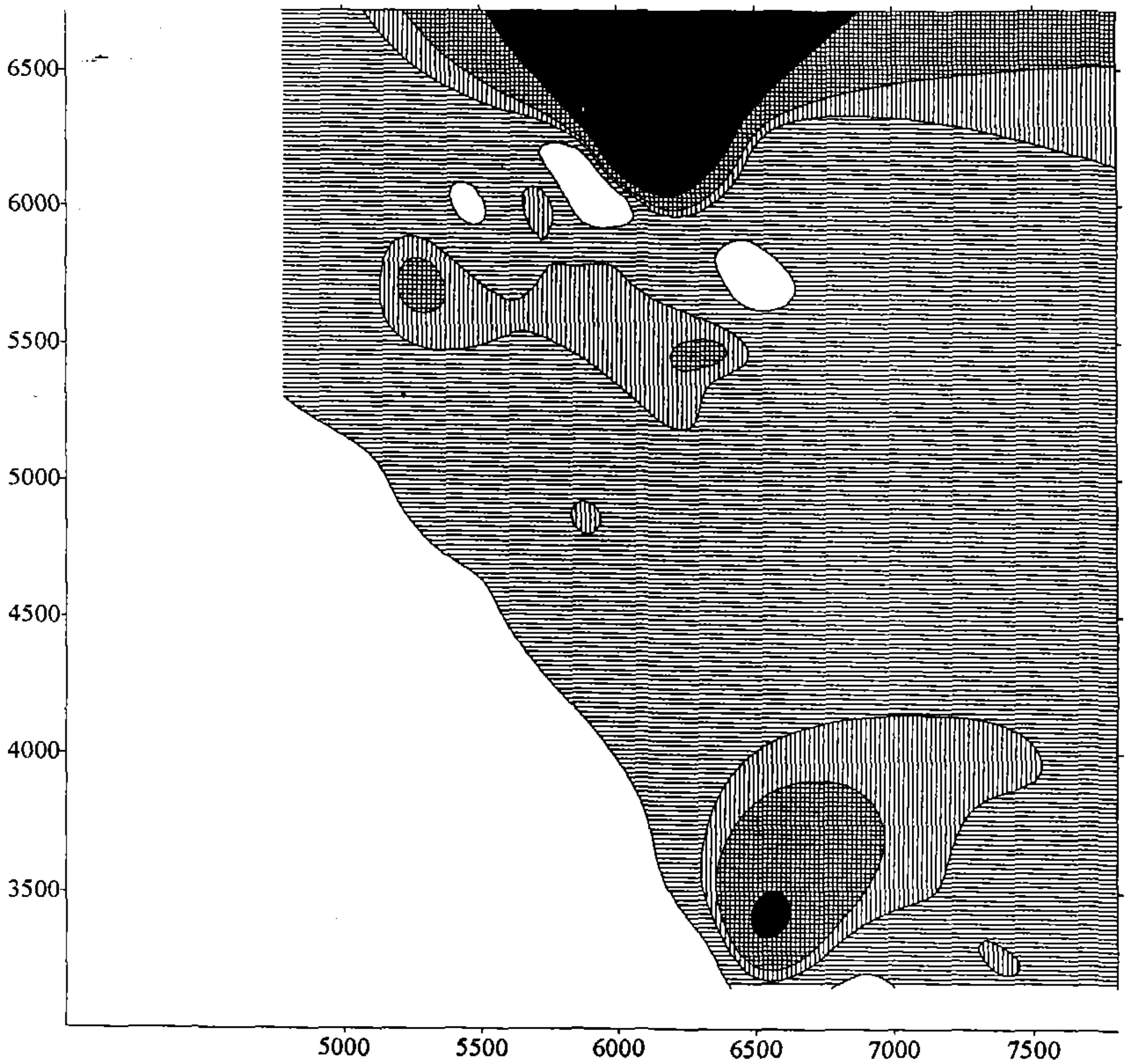
2.5 *Silver*

Map 6a. Contour Map, Distribution of Ag/C(%) in the soil (MPF method), scale 1: 250,000.

1. > 0.002%; 2.0.002-0.0006%; 3. 0.0003-0.0006%; 4. 0.0002-0.0003%; 5. < 0.0002%.

Map 6b. Perspective projection, distribution of Ag/C(%) in the soil (MPF method).

Two anomalies Ag/C% are recorded in the area. One of them is situated in the north of the area. It spatially coincides with the anomaly Pb/C%. Another, less intensive, occurs in the south. The anomalies has no evident association with other anomalies.



Map 6a. Countour Map Distribution of Ag/C (%) in the soil (MPF - method)

1. ■ 2. ■ 3. ▦ 4. ▦ 5. ▤

Scale 1:250,000

0 5 10 15 20 km

5 cm

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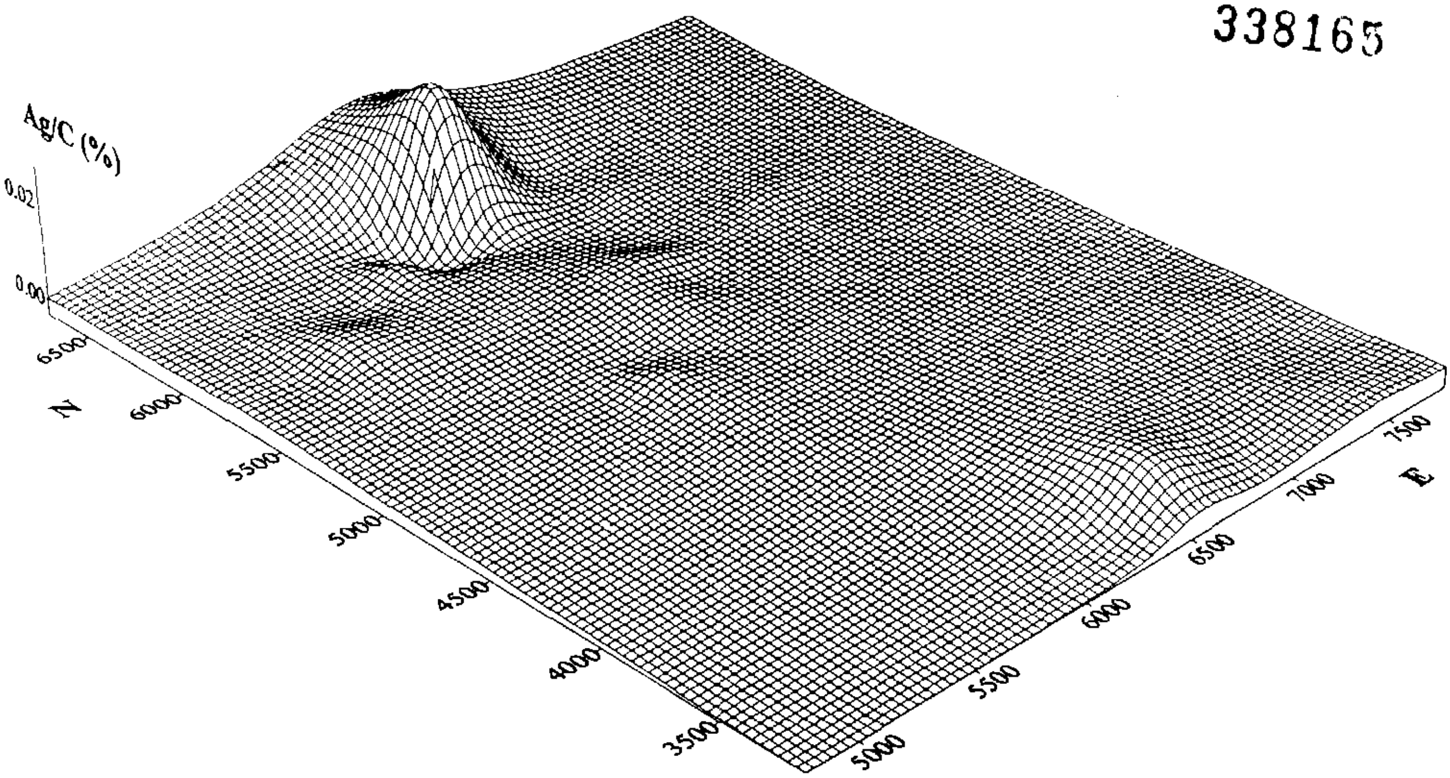
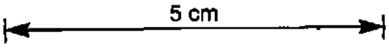


Map. 6b. Perspective projection, distribution of Ag/C (%) in the soil (MPF - method)

Scale 1:250,000



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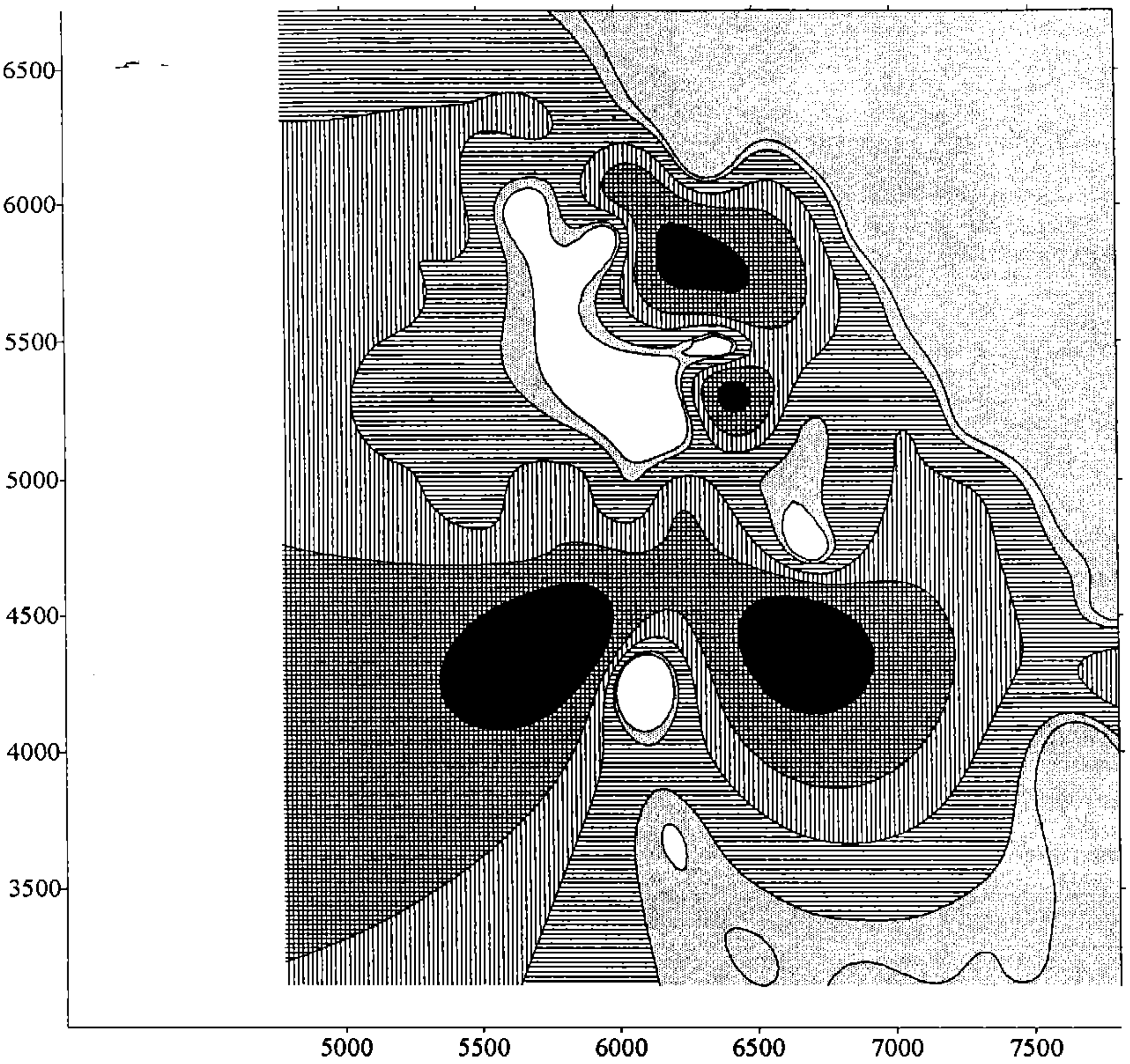
2.6 *Arsenic*

Map 7a. **Contour Map, Distribution of As/C(%) in the soil (MPF method), scale 1: 250,000.**

1. > 0.01%; 2. 0.01-0.05%; 3. 0.05-0.1%; 4. 0.1-0.2%; 5. 0.2-0.3%; 6. < 0.3%.

Map 7b. **Perspective projection, distribution of As/C(%) in the soil (MPF method), scale 1: 250,000.**

Arsenic anomalies has three local centres. Two of them overlap the northern section ETA 348 and southern section ETA 349. These two anomalies are traced as an anomalous zone closely coinciding with the anomalous zones Pb/C and Zn/C. Epicentres of separate anomalies are slightly shifted relative to each other, probably due to the zoning of the anomaly-forming objects in space.



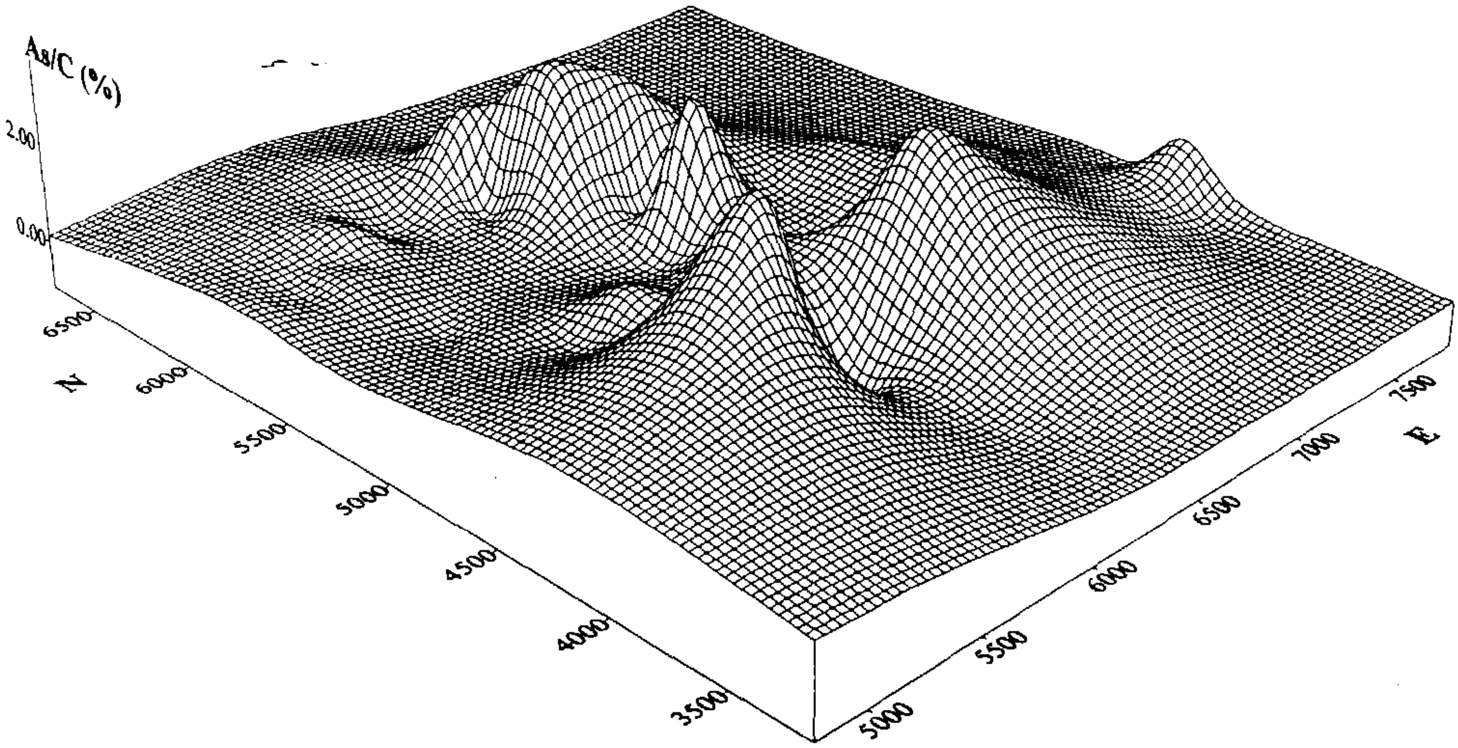
Map 11a. Countour Map Distribution of As/C (%) in the soil (MPF - method)

1. ■ 2. ■ 3. ▩ 4. ▦ 5. ▤ 6. ░

Scale 1:250,000

0 5 10 15 20 km

5 cm



Map. 7 b. Perspective projection, distribution of As/C (%) in the soil (MPF - method)

Scale 1:250,000

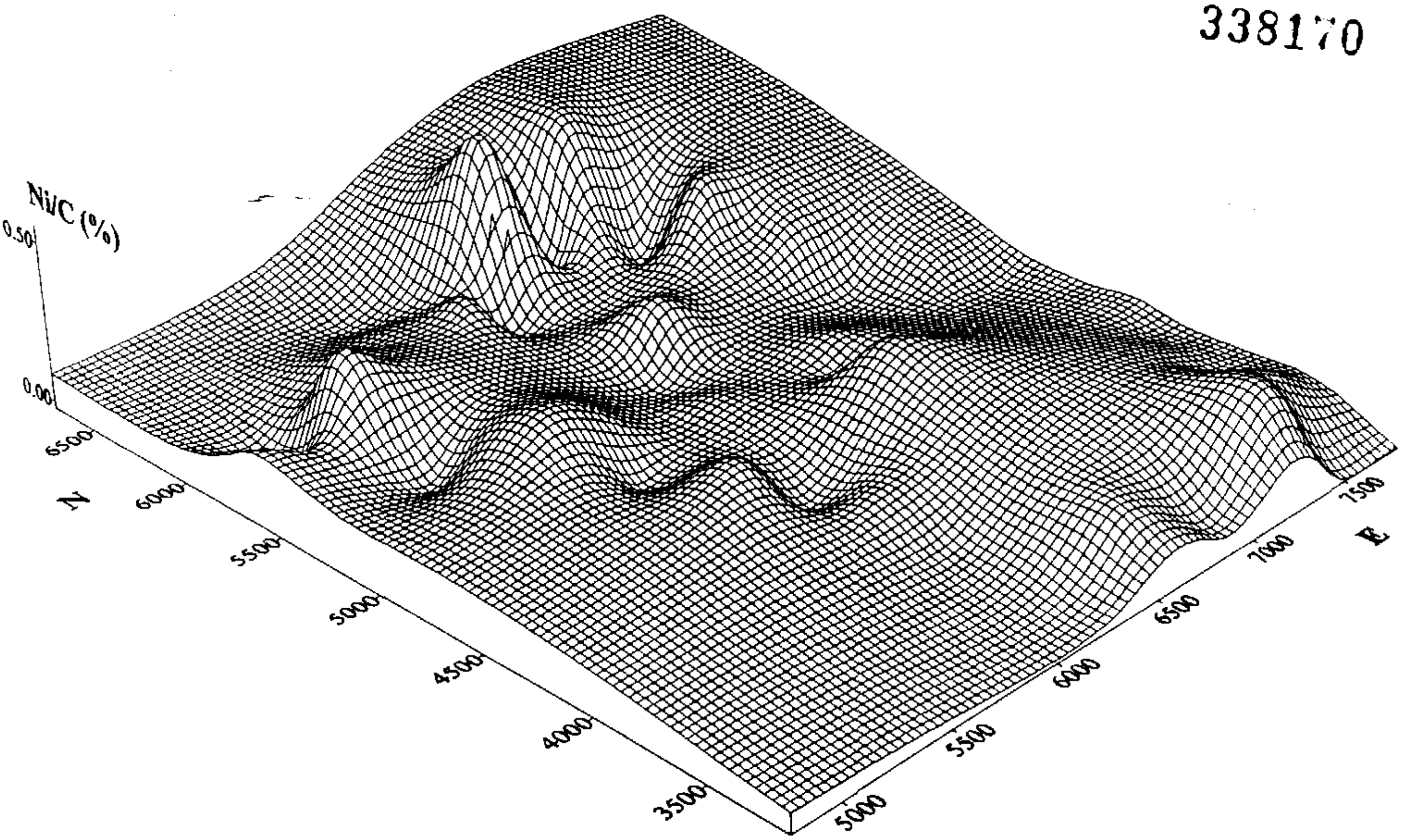
5 cm

2.7 Nickel and Cobalt

Map 8. Perspective projection, distribution of Ni/C(%) in the soil (MPF method), scale 1: 250,000.

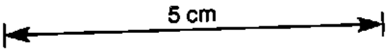
Map 9. perspective projection distribution of Co/C(%) in the soil (MPF method), scale 1: 250,000.

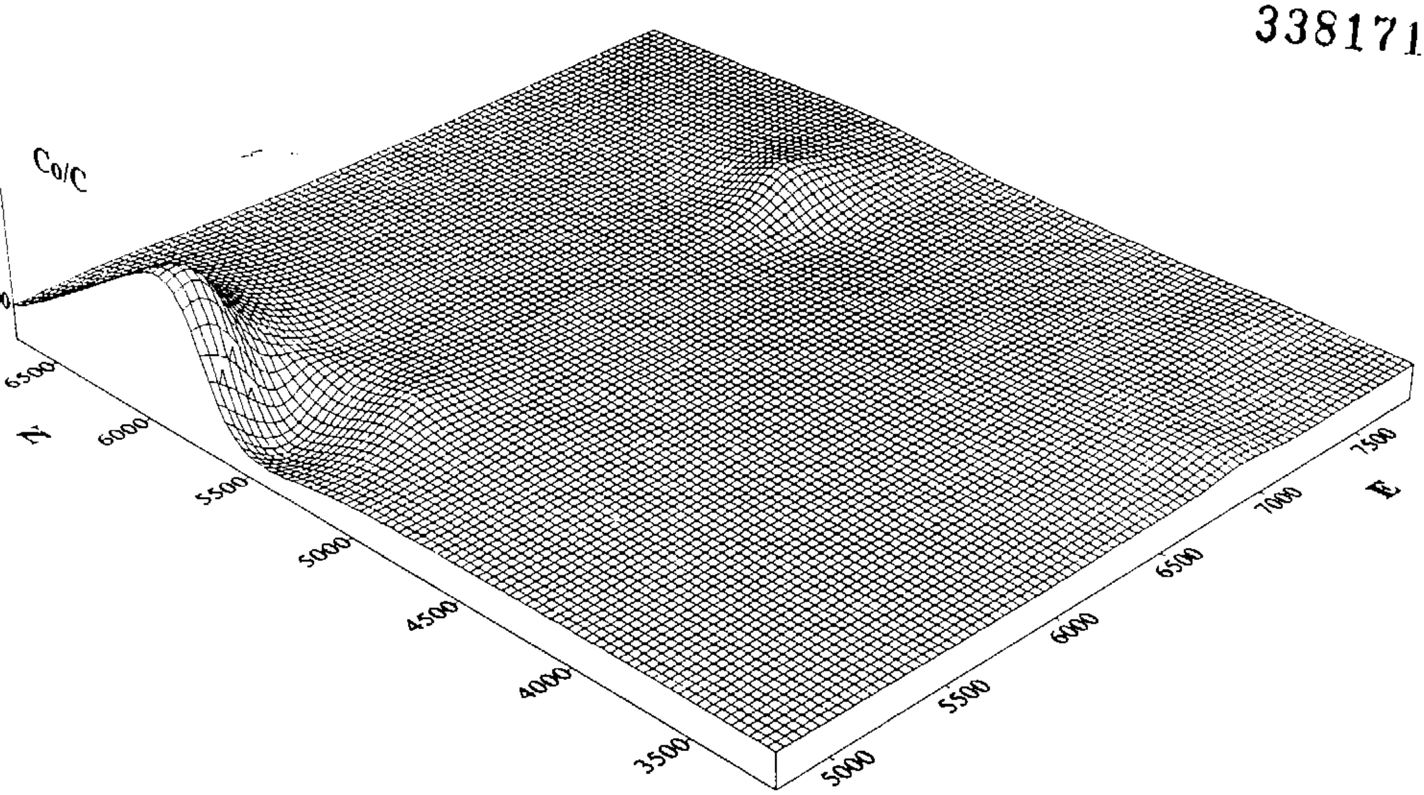
A structure of NW-SE trend is outlined in Co/C(%) and especially in Ni/C(%), which, to a certain extent is similar to molybdenum distribution. There are not any considerable anomalies in Ni/C and Co/C are recorded.



Map. 8 Perspective projection, distribution of Ni/C (%) in the soil (MPF - method)

Scale 1:250,000





Map. 9 . Perspective projection, distribution of Co/C (%) in the soil (MPF - method)

Scale 1:250,000

5 cm

3. PRØGNOSTIC EVALUATION OF THE REGION OF WORKS

Maps 2a-6a (contour maps - scale 1: 250,000.

Map 10 (metallogenic map, scale 1: 250,000)

3.1 Complex position of MPF anomalies in the area of works

Distribution of anomalies of metal concentrations possesses certain patterns in the area of works. A definite fan-like structure is outlined as to position of anomalies. Following zones can be distinguished from the east to the south: the copper zone (Cu/C(%), then the zinc zone (Zn/C(%), the lead zone (Pb/C(%)) and in the west the molybdenum zone (Mo/C(%)).

The angular of the position of the anomalous zones changes 45° from submeridional (369°) as to Cu/C(%) to NSW (about 310°) as to Mo/C(%). This zone is strengthened by a zone slightly anomalous in Ni/C (map 8). On the whole, a fan is formed with the centre in the south-eastern part of the section. Anomalies of essentially all metals mentioned above are recorded there.

Another anomalous zone is recorded in the north of the area, where divergence (spatial division of anomalies) takes place. Following anomalies show up there from the east to the west: anomaly Cu/C(5), then the anomaly Pb/C(%) + Zn/C(%) including the anomaly Ag/C(%), and in the west the anomaly Mo/C(%).

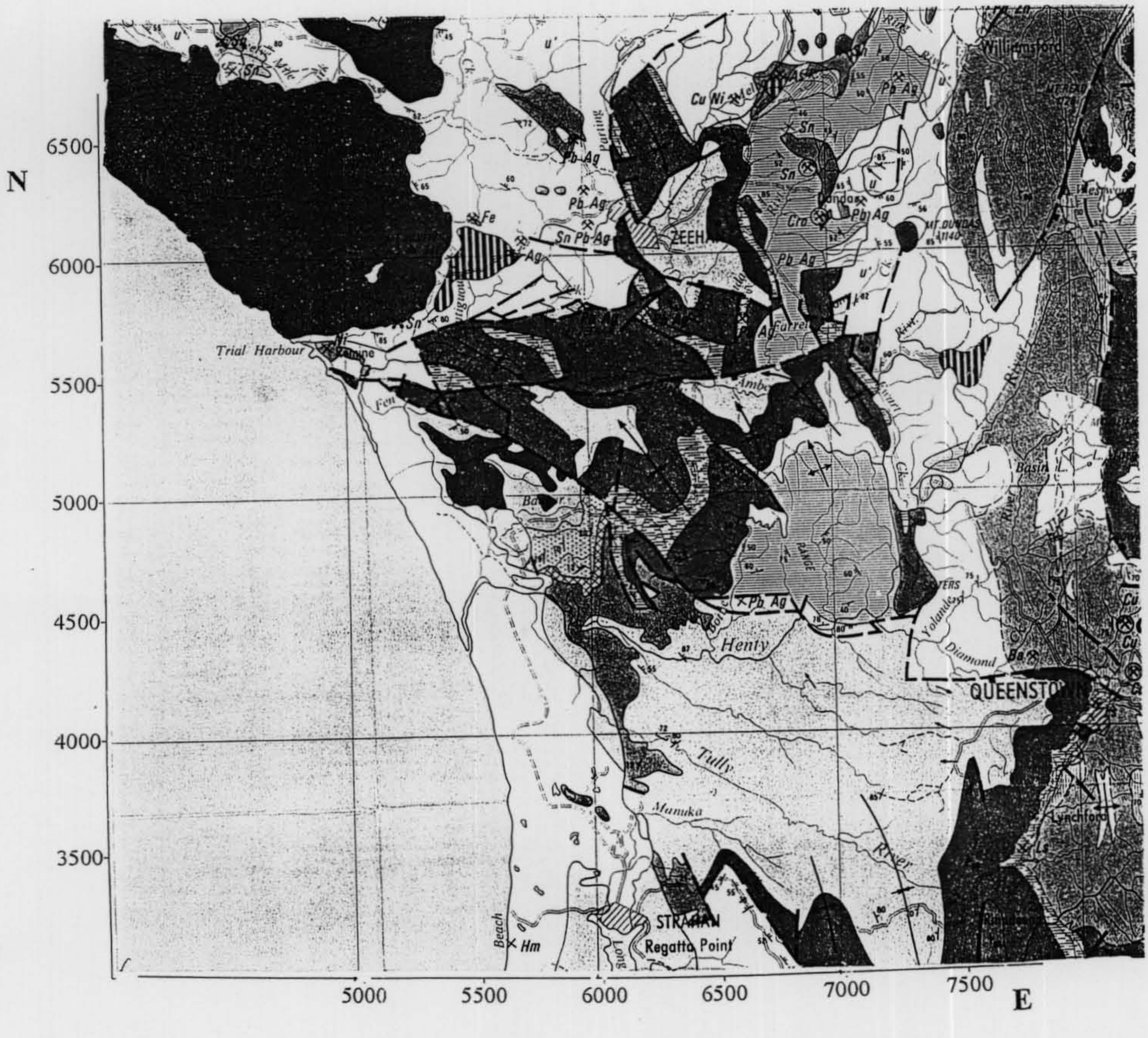
The case in point is the most enriched sections within the whole area. So, it is possible to speak of several of the most perspective regions in the area of the study.

3.2 Correlation between MPF anomalies with known geological and metallogenic data in the area under study.

The south-eastern anomalous region. Intersection of several faults of N and NW trend takes place in this region. Complex geological setting is observed there: combination of rocks of various composition and age. A show of barium is confined to this region; it also can be considered as a promising feature for occurrence of concealed mineralisation of complex composition.

In the northern section revealed anomalies occur within the limits of known objects, but each particular anomaly can be associated with a new deep object of different composition.

The distinguished anomalous zones call for additional more detailed investigations.



Map 10. Queenstown. Geological survey of Tasmania
- Department of mines Hobart.
Scale 1:250,000 Sheet SK55-5.

5 cm

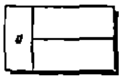
Scale 1:250,000

0 5 10 15 20 km

338174

COMPREHENSIVE REFERENCE FOR TASMANIA

HOLOCENE
PLEISTOCENE



Alluvium, sand, gravel and talus.
Till, fluvioglacial, periglacial and associated deposits

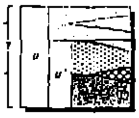
Erosional surface.

TERTIARY

Non-marine sequences (light); marine limestone (dark); basalt and related igneous rock types (orange).

Low angle unconformity.

TRIASSIC
PERMIAN
UPPER CARBONIFEROUS

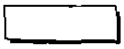


Fluvio-lacustrine sequences of sandstone, siltstone, mudstone (light) with carbonaceous sequences indicated (dark).
Fresh water sequence with some coal measures. } UPPER
Upper glacio-marine sequence of pebbly mudstone, pebbly sandstone and limestone.
Fresh water sequence with some coal measures.
Lower glacio-marine sequence of pebbly mudstone, pebbly sandstone, minor limestone, Tasmanite oil shale and basal tillite. } LOWER

PARMEENER SUPER GROUP

WESTERN TASMANIA

UPPER—MIDDLE DEVONIAN



Terrestrial cavern fillings. } EUGENANA BEDS

Unconformity attributed to Tabberabberan Orogeny.

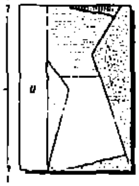
LOWER DEVONIAN — SILURIAN
ORDOVICIAN

Some quartz sandstone sequences (dark) and siltstone- shale sequences (light) indicated; Devonian limestone-siltstone (horizontally lined over-print). } ELDON GROUP AND CORRELATES; SPERO BAY GROUP

Limestone sequence with siltstone in some areas.
Siliceous terrestrial conglomerate, marine quartz sandstone and siltstone } JUNEE GROUP AND CORRELATES

Unconformity in northern Tasmania and parts of western Tasmania attributed to Cambrian movements; apparent conformity in Adamsfield region and parts of western Tasmania.

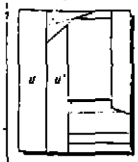
CAMBRIAN



Middle-Upper Cambrian fossiliferous usually greywacke turbidite sequences (horizontally lined overprint); acid with intermediate volcanic and associated rocks dominant (dark), and horizon with fossiliferous Upper Cambrian shallow water deposits (vertically lined overprint); basic-intermediate volcanic and associated rocks dominant (diagonally lined overprint); probably Cambrian unfossiliferous usually greywacke turbidite sequences (light); probably Cambrian unfossiliferous orthoquartzite sequence (dotted). } INCLUDING DUNDAS GROUP (fossiliferous); MT READ VOLCANICS AND OTHER FORMATIONS

Usually unconformity attributed to Penguin Orogeny but apparent conformity at Smithton and Pieman River.

PRECAMBRIAN



Comparatively unmetamorphosed sequences. Mudstone-sandstone sequences (u') – dominantly mudstone (light), dominantly orthoquartzite (dark), quartzwacke turbidite successions (small dot over-print), conglomerate (large dot over-print); dolomite (horizontally lined over-print); basalt lava (vertically lined over-print).

Metamorphic rocks. Pelitic sequences (dark); metaquartzite sequences (light) with some platy quartzite units indicated (vertically lined over-print); amphibolite (diagonally lined over-print). Garnet bearing rocks are indicated (g).

IGNEOUS ROCKS

TERTIARY	▨	*Basalt and related rock types.*
CRETACEOUS	■	*Syenite.*
	□	*Appinite.*
JURASSIC	■	*Dolerite and related rock types.*
LOWER CARBONIFEROUS – UPPER DEVONIAN	u ■	*Dominantly adamellite-granite; biotite-hypersthene-adamellite porphyry (diagonally lined over-print).*
	□	*Dominantly granodiorite.*
	□	*Dominantly diorite.*

CAMBRIAN	■	*Granitic rocks.*
	▥	*Coarser grained basic rocks.*
	▨	*Serpentinite, peridotite and associated rocks.*
	▨	*Acid with intermediate volcanic and associated roc*
	□	*Basic-intermediate volcanic and associated rocks.*
PRECAMBRIAN	□	*Granite.*
	□	*Dolerite.*

Undifferentiated rocks are indicated by the lightest colour and the letter "u" or "u'"
Blank boxes indicate absence of rock unit from this map sheet.

3.3 ~~General~~ Conclusion

Following conclusions about prospects of the licence sections can be drawn in this stage of investigation:

- All sections occurring in the eastern part of the area are promising for copper;
- sections in the north of the area, in its central region are promising for lead-zinc mineralisation;
- sections in the north-western part are favourable for occurrence of rare metal mineralisation.

Appendix 1

Table. **MPF Method. Results of analysis samples of soil.**

NN	Coordinates		Me/C (%)									
	East	North	Cu	Pb	Zn	Ag	Mo	V	Ni	Co	Ga	As
1	6070	6200	0.244	0.293	1.951	0.0024	0.008	0.036	0.02	0.0005	0.0005	0.06
2	5900	6170	0.008	0.126	0.286	0.00005	0.006	0.027	0.009	0.0005	0.171	0.045
3	5750	6250	0.015	0.037	0.00005	0.002	0.073	0.006	0.0005	0.0005	0.05	
4	5740	6040	0.018	0.091	0.409	0.0002	0.006	0.027	0.013	0.0005	0.0005	0.0005
5	5570	5960	0.02	0.028	0.08	0.00005	0.004	0.06	0.015	0.0005	0.16	0.006
6	5410	5900	0.012	0.022	0.066	0.00005	0.009	0.04	0.019	0.0005	0.088	0.067
7	5300	5800	0.036	0.197	0.329	0.0003	0.007	0.03	0.02	0.0005	0.0005	0.05
8	5200	5700	0.027	0.038	0.204	0.0003	0.013	0.038	0.032	0.0005	0.0005	0.064
9	5040	5720	0.012	0.021	0.117	0.00005	0.009	0.141	0.005	0.0005	0.0005	0.054
10	4900	5780	0.025	0.082	0.909	0.00005	0.015	0.231	0.008	0.091	0.0005	0.077
11	4890	5650	0.036	0.045	0.255	0.00005	0.011	0.048	0.016	0.0005	0.0005	0.079
12	4780	6720	0.023	0.04	0.159	0.00005	0.004	0.019	0.009	0.0005	0.0005	0.013
13	5280	5250	0.02	0.02	0.075	0.00005	0.008	0.024	0.006	0.012	0.0005	0.024
14	5350	5150	0.018	0.026	0.128	0.00005	0.006	0.025	0.017	0.006	0.014	0.042
15	5530	4920	0.012	0.021	0.067	0.00005	0.005	0.068	0.027	0.003	0.0005	0.034
16	5700	4750	0.024	0.03	0.229	0.00005	0.012	0.05	0.008	0.0005	0.0005	0.083
17	5710	4890	0.014	0.02	0.194	0.00005	0.013	0.057	0.019	0.0005	0.0005	0.094
18	5870	4920	0.093	0.102	0.088	0.0002	0.017	0.038	0.013	0.002	0.035	0.064
19	5880	5020	0.015	0.061	0.085	0.00005	0.024	0.03	0.014	0.001	0.061	0.05
20	5800	5100	0.02	0.029	0.143	0.00005	0.005	0.021	0.018	0.0005	0.0005	0.036
21	6200	4920	0.018	0.023	0.173	0.00005	0.004	0.103	0.01	0.0005	0.0005	0.086
22	6080	4920	0.013	0.019	0.286	0.00005	0.005	0.035	0.008	0.0005	0.0005	0.027
23	6440	5050	0.05	0.071	0.929	0.0001	0.004	0.056	0.007	0.0005	0.0005	0.028
24	6300	5250	0.032	0.082	0.141	0.0002	0.008	0.094	0.006	0.0005	0.0005	0.059
25	6600	5250	0.035	0.17	1.6	0.00005	0.008	0.032	0.011	0.0005	0.0005	0.054
26	6400	5330	0.04	0.04	0.568	0.0001	0.001	0.01	0.019	0.0005	0.0005	0.227
27	6450	5600	0.023	0.127	5.455	0.00005	0.001	0.01	0.009	0.0005	0.0005	0.138
28	6200	5750	0.054	0.059	2	0.0001	0.001	0.01	0.005	0.0005	0.0005	0.231
29	6140	5890	0.025	0.175	1.25	0.00005	0.001	0.01	0.005	0.0005	0.0005	0.188
30	5880	4380	0.066	0.024	0.229	0.00005	0.001	0.217	0.02	0.0005	0.542	0.325
31	6010	4300	0.021	0.025	0.292	0.00005	0.001	0.01	0.005	0.0005	0.0005	0.0005

Appendix 1

Table. MPF Method. Results of analysis samples of soil.

NN	Coordinates		Me/C (%)									
	East	North	Cu	Pb	Zn	Ag	Mo	V	Ni	Co	Ga	As
32	6200	4250	0.023	0.023	0.092	0.00005	0.001	0.01	0.007	0.0005	0.0005	0.0005
33	6120	4080	0.014	0.01	0.07	0.00005	0.001	0.07	0.012	0.0005	0.084	0.0005
34	6180	3750	0.106	0.043	0.053	0.00005	0.001	0.039	0.005	0.0005	0.071	0.0005
35	6610	4910	0.04	0.045	0.19	0.00005	0.001	0.01	0.01	0.0005	0.0005	0.0005
36	6750	4800	0.009	0.016	0.044	0.00005	0.001	0.044	0.013	0.0005	0.053	0.0005
37	6700	4700	0.041	0.026	0.143	0.00005	0.001	0.01	0.01	0.0005	0.0005	0.0005
38	6650	4500	0.075	0.065	0.258	0.00005	0.001	0.161	0.027	0.0005	0.376	0.29
39	6400	5450	0.069	0.175	2	0.0003	0.001	0.01	0.018	0.0005	0.0005	0.0005
40	6020	6050	0.028	0.119	0.168	0.0001	0.006	0.07	0.014	0.0005	0.003	0.14
41	6300	6100	0.073	0.309	12.73	0.0007	0.018	0.01	0.055	0.0005	0.0005	0.0005
42	5900	5900	0.04	0.035	0.14	0.00005	0.001	0.01	0.017	0.0005	0.0005	0.0005
43	6000	5900	0.037	0.032	0.176	0.00005	0.001	0.01	0.019	0.0005	0.0005	0.0005
44	6500	6220	0.081	0.119	0.865	0.0002	0.001	0.01	0.022	0.0005	0.0005	0.0005
45	6700	6150	0.044	0.031	0.3	0.00005	0.001	0.01	0.038	0.0005	0.0005	0.0005
46	6680	5970	0.042	0.024	0.229	0.0001	0.008	0.036	0.02	0.001	0.0005	0.06
47	6550	6100	0.032	0.023	0.273	0.00005	0.006	0.027	0.005	0.0005	0.0005	0.045
48	7300	4950	1.815	0.012	0.046	0.00005	0.001	0.073	0.005	0.0005	0.086	0.05
49	7080	5200	0.109	0.014	0.127	0.00005	0.006	0.027	0.005	0.0005	0.0005	0.045
50	7230	5200	1.131	0.045	0.143	0.00005	0.004	0.06	0.005	0.007	0.045	0.0005
51	7150	5400	0.8	0.06	0.667	0.00005	0.001	0.01	0.019	0.033	0.0005	0.0005
52	7050	5550	3.5	0.025	0.5	0.0002	0.007	0.01	0.02	0.012	0.0005	0.0005
53	6980	5700	4.487	0.045	0.308	0.00005	0.001	0.01	0.032	0.0005	0.0005	0.0005
54	6850	5890	0.652	0.022	0.207	0.00005	0.001	0.141	0.005	0.0005	0.283	0.0005
55	6350	3300	0.085	0.023	0.215	0.00005	0.001	0.231	0.005	0.0005	0.215	0.0005
56	6500	3350	0.087	0.04	0.302	0.0006	0.011	0.01	0.016	0.003	0.0005	0.0005
57	6700	3150	0.025	0.01	0.089	0.00005	0.001	0.01	0.009	0.0005	0.0005	0.0005
58	6870	3250	0.024	0.018	0.165	0.00005	0.001	0.01	0.005	0.009	0.0005	0.0005
59	7150	3190	0.075	0.029	0.117	0.0001	0.006	0.01	0.017	0.0005	0.0005	0.0005
60	7300	3300	0.061	0.017	0.095	0.0002	0.001	0.068	0.027	0.0005	0.037	0.0005
61	7450	3220	0.117	0.042	0.233	0.0002	0.012	0.01	0.005	0.0005	0.0005	0.0005
62	7550	3500	0.377	0.066	0.358	0.00005	0.013	0.01	0.019	0.0005	0.0005	0.0005

Appendix 1

Table. **MPF Method. Results of analysis samples of soil.**

NN	Coordinates		Me/C (%)									
	East	North	Cu	Pb	Zn	Ag	Mo	V	Ni	Co	Ga	As
63	7520	3710	0.513	0.128	0.244	0.00005	0.001	0.01	0.013	0.006	0.0005	0.0005
64	7500	3900	1.2	0.17	0.24	0.0002	0.024	0.01	0.014	0.002	0.0005	0.0005
65	7700	4100	0.857	0.071	0.054	0.0001	0.005	0.01	0.008	0.0005	0.0005	0.0005
66	7800	4280	0.343	0.026	0.057	0.00005	0.001	0.103	0.01	0.0005	0.149	0.086
67	7780	4480	0.27	0.076	0.865	0.00005	0.001	0.035	0.008	0.0005	0.0005	0.0005
68	7700	4650	0.14	0.034	0.079	0.00005	0.001	0.056	0.007	0.0005	0.146	0.0005
69	7600	4800	0.047	0.009	0.165	0.00005	0.001	0.094	0.005	0.0005	0.047	0.0005
70	7500	5000	0.59	0.16	2.58	0.001	0.08	0.1	0.11	0.005	0.005	0.005

338179

96-3926B
Appx 2 of
96-3926

APPENDIX 3

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338180

ALLEGIANCE MINING N.L.

Preliminary MPF Electrogeochemical survey carried out by Ionex at E.L. 14-94 Zeehan, Tasmania

DATE: May,1996

Distribution:

Allegiance Mining N.L.
Anthony Howland-Rose
Ionex Technology

TABLE OF CONTENTS

LIST OF FIGURES

338182

1.0 INTRODUCTION

This report outlines an MPF Geoelectrochemical sampling survey carried out at EL 14-94 by Ionex on behalf of Allegiance Mining during period between 13th April-20th April 1996 at Zeehan,Tasmania.

In summary main objective during the implementation of this programme was to sample uncontaminated well developed rich soil horizons,which are pervasively distributed within E.L.14-94.As this method takes advantage in detecting higher concentrations of metals ions attached to carbon in soils,particularly with respect to non residual soils as it is the case at E.L.14-94.

2.0 GEOLOGY

Exploration Licence 14-94 comprises primarily a sequence of Devonian rocks, mainly black carbonaceous-shale -qtz sandstone,interspersed with silstone and limestone affinities, represented by Ag-Pb occurrences This type of mineralization style is stratabound and deemed to be of sediment hosted volcanic-exhalative type.

2.1 Regional Stratigraphy

The Precambrian age basement(Oonah Fm) lithology in Western Tasmania is comprised of lower sequence of quartz-wacke and mudstone,overlain by an upper sequence of dolomite-magnesite and basaltic volcanics.

After deformation in late Precambrian,there followed in late Precambrian-early Cambrian time a sequence of shallow water clastics and dolomite (Success Ck Group),in turn overlain conformably by mafic volcanics and limestone (Crimson Creek Formation).

Following erosion in early-mid Cambrian time ,a sequence of mudstone,lithic wacke,chert and conglomerate(Dundas Group),was deposited,coeval with a succession of rhyolitic to andesitic volcanics (Mt Read Volcanics),which formed an island arc setting further to the east.

Unconformably overlying these lithological units are a siliclastic sequence (Mt Zeehan Conglomerate) and a limestone sequence(Gordon Limestone),both of Ordovician age,in turn overlain conformably by siliclastics,mudstone and limestone (Eldon Group) in Siluro-Devonian time.

The mid Devonian Tabberabberan deformation (with maximum expression in Cambrian to early Devonian age lithologies), was followed in the mid-late Devonian by the emplacement of a group of high level,S type granitoid masses.

2.2 Regional Mineralization

Several metallogenic events are recognized, as follows:

Proterozoic (late) : volcanogenic massive sulphide-oxide deposits of pyrite -magnetite-Cu,Pb,Zn,Au (Savage River,Keith River).

Cambrian (? mid) : volcanogenic massive sulphides,both disseminated Cu Ag Au (Mt Lyell). and massive stratiform Zn Pb Cu Ag Au (Rosebery,Hellyer etc).

Ordovician (late) : stratabound and stratiform carbonated hosted exhalative Zn Pb (Oceana, Austral).

Devonian (late) : granitoid related Sn W greisen-skarn-carbonate replacement -vein (Renison,Bischoff,Queen Hill etc) with associated Ag Pb Zn vein style mineralization (Zeehan,Dundas,Magnet).

2.3 Mining history

Lead high grade ore material were discovered at Zeehan in 1882 and in the following 15 years some 200 lodes were discovered and mined in the district. An smelting plant was commissioned in 1896 and operated until 1913 when the mining field was more or less abandoned. In 1950 the Oceana mine was again reopened and yielded some 128,000 tonnes of ore up until 1960 when the mine was closed again. The average grade of the Oceana ore was 11.6% Pb and 4.6 ounces per tonne of Ag.

Historically it has been the lode and vein style Pb-Ag mineralization of the Zeehan and Dundas fields that have had prevailing interest.Lode style deposits at Zeehan is usually hosted within graphitic shears in Oonah and Crimson Creek Formations. These deposits are high grade,but narrow(typically 0.3m) and with short strike and depth extent (usually less than 100m) In the context of modern large scale mining practises,it is unlikely that such a target could be of economic significance on its own.

During the past 20 years or so, replacement-style Sn deposits have been considered to have some economic interest. West Tasmania is well equipped with these deposits,which include Renison Bell,Queen Hill,Mt Bischoff and Cleveland. At Renison Bell, most ore occurs as massive pyrite-pyrrhotite replacement of carbonate horizons,although a substantial amount of ore occurs within the Federal-Basset feeder zone. Source of mineralization is believed to be from Sn-rich fluids emanating from the underlying Devonian granite. A pre-mining resource mineralization is estimate at 42M @ 1.1% Sn(Collins ,1989).

Zinc mineralization in a pyrrhotite-serpentine skarn within the Oonah Fm carbonates was discovered by Renison Goldfields at Sylvester prospect,west of Zeehan in 1992. Resources are estimated to be 6M @5.5% Zn,3.3% Pb and 40 ppm Ag. The sphalerite is reported to be very high in Fe (around 18% Fe) which substantially lowers the quality of this style of mineralization.

3.0 PREVIOUS EXPLORATION AND MINING

3.1 Early Exploration and Mining

The Zeehan Mineral field has been incessantly prospected since 1870 by small miners in the search by tin mineralization, however they suddenly directed their efforts in the search for silver-lead mineral occurrences with the discovery of rich horizons containing argentiferous galena mineralization in 1882.

This intensive galena mineralization mining continued its development until 1898, nevertheless production declined gradually until 1910 when the majority of the mines were abandoned due to lack of shallow ore, as well as closure of the local smelting plant in 1913, which it was it main contributing factor for the cessation of mining activities in 1919.

Mining exploitation of about 200 lodes contributed a great deal to the production of 200,000 tonnes of Pb, and 27M ounces of Ag. A great deal of this production occurred during the period up to 1919, of which most (90%) derived from lode hosted by Proterozoic and Cambrian age lithologies; around 55% of the Pb mining production and 60% of the Ag production was coming from 4 deposits (Montana No 1, Western, Queen & Oonah).

3.2 Systematic Mineral exploration Programmes

What evolves during early detailed mineral exploration campaigns happened between 1919 and 1946 (eg tribute mining from the Nike and Swansea mines). when the current comprehensive exploration really commenced.

1946 - 1960 Zeehan Exploration P.L. (JV between Broken Hill and Broken Hill South), carried out several ground surveys to identify the extension of the Spray-Nubeena shear zone (including unsuccessfully perforating at the Spray mine) and implemented the BMR managed magnetic, gravity and electrical (SP, EM) geophysical surveys.

It appears that these surveys generally speaking unsuccessfully, viz - some of the gravity anomalies were due to concentrations of siderite, and the electrical surveys failed to produce distinctive signature responses over known mineralization.

Notwithstanding,drilling around the Oceana mine were encouraging, and after some rehabilitation work (including the sinking of a new shaft) the mine was reopened and yielded 129,000 tons of ore averaging 11.6% Pb and 4.79 oz Ag -ton during period corresponding 1954 - 1960.

During the period between 1966-1970, Placer Prospecting Pty Ltd carried out some exploration surveys within the Zeehan District their attention was aimed primarily at the Spray-Nubeena Shear Zone and work included soil sampling and a TURAM-EM survey over the Spray lode region. Limited drilling was also implemented at this prospect, however results were not encouraging.

During the period 1970-1972 Tenneco Pty Ltd appraised the old Spray mine area by sampling and further drilling. Five additional holes were perforated however most salient intercept (with a core hole) was only 0.2m of 16.8% Pb and 267 ounces per tonne Ag.

Tenneco also conducted a TURAIR airborne EM survey of the Gordon Limestone areas with follow-up gravity TURAM ground EM and SP surveys. These surveys generated several interesting anomalies, but follow-up work failed to unravel new orebodies.

The Mt Lyell Mining and Railway Co., and Renison Ltd had exploration titles covering most of Zeehan area as from 1974 to 1986. Initial exploration work included the testing of new airborne EM survey methods. Aeromagnetic field campaigns were also implemented. A number of conductive and magnetic signature anomalism were delineated.

During the period between 1982-1984 the companies defined the "Stonehenge" grid upon a prominent magnetic signature and consequently carried out bedrock geochemistry, ground magnetic,VLF EM and gradient array IP surveys over the area. Only one hole was drilled in the prospect, however results were of not economic significance.

Moreover work during 1983-1984 incorporated follow- up drilling to test several anomalies being identified by previous geophysical surveys. Low grade mineralized intercepts were encountered in holes perforated close to the old Sunshine, Tasmanian and Spray mines.

EM surveys implemented during 1984-1986 defined a large number of anomalism signatures which were associated with faults and-or black shales. One drill hole close to the old Sunshine mine was completed, however ore grade of some economic significance was not intercepted.

Amoco Minerals also had some exploration exposure within Zeehan district during the period 1978-1983. They focussed their attention on the Gordon Limestone sequence and in particular to areas encompassing the Oceana and Austral Pb-Zn workings. These field surveys consisted primarily of Gravity, magnetic, electrical and geochemical surveys which were conducted over the prospects. Further drilling defined a resource of some 4M tonnes of 19.4% Pb,4% Zn and 106 grams per tonne Ag at the Oceana. This type of mineralization is thought to be of at least Ordovician age and of sedimentary -exhalative type.

From 1983 a JV involving Amoco and EZ Co., implemented some further work in other areas around the Zeehan district. This various geophysical and geochemical surveys were confined mainly to areas south of the Oceana.Some early diamond drilling was carried out , however results were disappointed.

More detailed exploration work implemented by the JV later on , outlined zones of Zn-Pb mineralization in weathered(decarbonated) limestone. Such mineralization at Grieves prospect yielded values up to 19.5 % Zn and 2.4%Pb . Diamond drilling at the Grieves prospect also detected the existence of low grade stratiform zinc mineralization at the base of the Gordon limestone. Most salient intersection was 6.8m at 8.5% Zn.

4.0 CURRENT WORK BEING IMPLEMENTED

4.1 MPF Geoelectrical sampling programme

A geochemical sampling programme was carried out by Ionex at E.L.14-94 in April,96 which consisted mainly of soil sampling the entire Exploration Licence , 79 samples were collected approximately 500 mts apart,they were logged and forwarded to Geoelectrochemical Laboratory at Rudgeofizika,Russia to be analyzed by the MPF technique(Method of Prospecting According to the to the forms of elements) takes advantage of the fact that soil organics naturally capture mobile ions. Samples of the appropriate organic rich soil horizon are taken. Extraction of the metal-organic of interest is undertaken, their metal content is analysed and the result is normalised for the carbon content.

5.0 CONCLUSIONS

Exploration licence No.14-94 covers highly prospective mineral occurrences around Zeehan and its neighbourhood, such Oceana,Austral,Nubeena-Spray etc.

The Zeehan Mineral Field has had a proliferation of good size Pb-Zn-Ag-Sn ore deposits. High-technology exploration methods had contributed a great deal to augment the econcmical potential of these areas for various types of mineral occurrences.

It can also be concluded that most salient conceptual exploration targets for follow-up work in the future,pending favourable results from MPF analysis within E.L.14-94 are stratiform syngenetic Pb-Zn sulphide mineralization in Precambrian carbonaceous shale lithologies as well as Ordovician Gordon Limestone affinities. Unfortunately delineating such targets within these areas is somewhat intricate by the overprinting of Devonian hydrothermal mineralizing fluids and the poliphase deformational provenance of the Precambrian lithologies with its associated potential for remobilized sulphide bodies.

6.0 RECOMMENDATIONS

6.0 RECOMMENDATIONS

Pending results from MPF analysis beingcarried out in Russia,it is warranted to implement a detailed evaluative assessment of past field data within these areas(Zeehan Expl.,Electrolytic Zinc Co.,Placer Prospecting Pty Ltd., Amoco,Tenneco ,Renison,Mt Lyell etc),which evolves since 1944.Embracing inter alia geochemical sampling programmes,geological mapping,comprehensive geophysical surveys(Magnetic gravity,VLF-EM and gradient array,IP,SP MP etc,) concurrently with drilling campaigns which will augment a positive approach to define bona fide follow-up targets.

It is also recommended to carry out wacker sampling deep geochemistry within E.L. in order to determine extension and thickness of decarbonated limestone -carbonaceous shale which are ubiquitously distributed within area,as well as mapping accurately these prospective horizons.

Finally detailed field work should be focussed upon SW portion of existing E.L. whereby an interesting sinistral fault mineralized system trending NW-SE(King Fault covering Sunrise,King and Silver King mines) appears to dissect this area.

References:

Parkinson R.G.,	1992	E.L.28-88 Zeehan 9-11-91- to 9-10-92 CRA Expl. P.L. Report No.19284
Parkinson R.G.,	1993	E.L.38-89 Zeehan 1-3-92 -28-2-93 CRA Exploration P.L. Report No.18647
Summons T.G.,	1991	E.L.28-88- Zeehan Progress report for the period ending 9th November,1991. CRA Exploration Report No. 17636
Taylor S., & Mathison I.J.,	1990	Oceana Pb-Zn-Ag deposit.,AIMM Monograph 14,

APPENDIX

LITHOLOGICAL DESCRIPTION

Sample No.	Soil Logging description
T-96-1	Black loamy soil,clayey,abundant organic matter 65% sample depth taken 8-10cmts
T-96-2	Black grey loamy silty soil,abundant organic matter 60% ,sample depth taken 7-8 cmts
T-96-3	Black silty-loamy soil,abundant carbonaceous matter, organic matter 60%; sample depth taken 8-10cmts
T-96-4	Dark-grey to black loamy soil, clayey,copious organic matter,60%.depth of sample taken 6-8cmts.
T-96-5	Black peat,loamy at times, occasionally shale vestiges 80-90% organic matter,carbonaceous,7-9 cmts depth
T-96-6	Black peat,carbonaceous,clayey,abundant organic matter depth of sample taken 8-10cmts.
T-96-7	Dark-brown loamy soil,clayey,partly carbonaceous,copious organic matter 60%; occasionally shale fragments
T-96-8	Dark-brown to black loamy soil,partly carbonaceous, copious organic matter 60%; 8-10 cmt depth of sample
T-96-9	Dark-grey,less carbonaceous matter 55%; clayey,partly loamy copious organic matter,sample taken 7-9cmts.
T-96-10	Dark-grey to black loamy soil carbonaceous matrix, abundant organic matter 60%; sample depth 6-8 cmts.
T-96-11	Dark-brown clayey soil,partly loamy,carbonaceous fabric organic matter 60%; depth of sample 6-8 cmts.
T-96-12	Dark-grey black clayey loamy soil,carbonaceous,abdnt organic matter 65%; depth of sample 8-10cmts.
T-96-13	Dark-brown silty loamy soil,occasionally argillaceous ,qtz particles at random,,carbonaceous at times,devoid iron oxides,sample taken 8-10cmts.
T-96-14	Dark-brown to black loamy soil,partly carbonaceous, interspersed with abundant qtz crystals,clayey,copious organic matter 60%' depth of sample 8-10 cmts.
T-96-15	Dark-grey black clayey soil,abundant organic matter 60%, partly loamy, 6-8cmts depth of sample.
T-96-16	Dark-grey black loamy soil,clayey,carbonaceous,copious organic matter 60%; depth of sample 6-8 cmts.
T-96-17	Dark-grey black loamy soil, carbonacous matrix,clayey, abdnt peat material,organic matter 65%; depth of sample 6-8 cmts.
T-96-18	Dark-grey to brown loamy soil,clayey,abundant organic matter 65%; partly carbonaceous,depth of sample 6-8cmts.
T-96-19	Dark-grey-black loamy soil,clayey carbonaceous,copious organic matter 60% ;depth of sample 6-8 cmts.
T-96-20	Dark-brown-black soil,loamy partly clayey,carbonaceous fabric;organic matte 60%;qtz xls at times,depth of sample taken 7-9 cmts.

APPENDIX

LITHOLOGICAL DESCRIPTION

Sample No.	Soil Logging description
T-96-21	Dark-brown soil,loamy,partly clayey,carbonaceous spotted,abundant organic matter,60%; 8-10 cmts depth of sample taken.
T-96-22 -	Dark-grey loamy soil,interspersed with argillic,sub-fissile light-grey to dark-grey,slightly carbonaceous copious organic matter 65%; depth of sample 6-8cmts.
T-96-23	Dark-grey to black loamy soil, abundant organic matter 60%; carbonaceous,depth of sample 7-9cmts.
T-96-24	Black loamy soil,carbonaceous matrix,occasionally qtz fragments,abundant organic matter 65%; depth of sample taken 8-10cmts.
T-96-25	Brown to dark-brown loamy soil,slightly carbonaceous partly clayey;organic matter 55%; depth of sample taken 8-10cmts.
T-96-26	Dark-brown loamy soil,clayey,copious carbonaceous material;organic matter content 60% ;6-8cmts depth of sample taken.
T-96-27	Dark-brown loamy soil,slightly clayey;occasionally carbonaceous;copious organic matter 65%; depth of sample taken 7-9cmts.
T-96-28	Dark-brown loamy soil,clayey,partly carbonaceous, abundant organic matter 65%;depth of sample taken 8-10cmts.
T-96-29	Dark-grey loamy partly silty soil,carbonaceous at random, abundant organic material 60%; depth of sample taken 8-10cmts.
T-96-30	Dark-grey to black loamy silty soil,carbonaceous fabric, abundant organic material content 60%; depth of sample taken 8-10cmts.
T-96-31	Dark-brown clayey loamy soil,partly carbonaceous, copious organic matter 60%, depth of sample taken 8-10 cmts.
T-96-32	Dark-grey to black loamy soil,partly silty, partly carbonaceous;50% organic matter,depth of sample 8-10 cmts.
T-96-33	Dark-grey to black loamy soil,carbonaceous matrix, 70% organic matter,depth of sample 8-10 cmts.
T-96-34	Dark-grey to black loamy clayey soil,carbonaceous fabric, abundant organic matter,depth of sample 8-10cm.
T-96-35	Dark-brown to black loamy soil, partly clayey, carbonaceous,copious organic material content 70%; depth of sample taken 8-10 cmts.

APPENDIX

LITHOLOGICAL DESCRIPTION

Sample No.	Soil Logging Description
T-96-36	Dark-brown loamy soil,partly clayey,occasionally carbonaceous,organic matter content 60%;depth of sample taken 8-10cmts.
T-96-37	Dark-brown loamy partly silty soil,occasionally carbonaceous,clayey at times,organic matter 55%, depth of sample taken 5-8cmts.
T-96-38	Dark-grey loamy soil, partly carbonaceous,organic matter 55%, 7-8cmts depth of sample.
T-96-39	Red-brown to dark-brown loamy silty soil,partly clayey,occasionally iron stained,carbonaceous mottled, organic matter 45%;depth of sample taken 7-9cmts.
T-96-40	Dark-brown loamy soil, clayey,carbonaceous at random,organic material content 60%,depth of sample taken 7-10cmts.
T-96-41	Dark-brown loamy soil,slightly silty,occ.clayey, carbonaceous material at times, 55-60% organic matter, 7-9 cmts depth of sample.
T-96-42	Red-brown to dark-brown loamy silty soil,partly carbonaceous, clayey, abundant organic matter 55% ; sample depth taken 6-8cmts.
T-96-43	Rd-brown to brown silty soil,partly loamy,partly argillaceous, occasionally carbonaceous,organic matter content 50%; depth of sample taken 5-8 cmts.
T-96-44	Red-brown loamy soil,partly clayey,carbonaceous at random, 55%organic matter, depth of sample taken 7-9cmts.
T-96-45	Dark-grey to black loamy silty soil,carbonaceous matrix, organic material 50%; depth of sample taken 7-9 cmts.
T-96-46	Dark-brown loamy partly silty soil,abundant shale debris,slightly argillaceous, occasionally iron stained,copious organic matter, depth of sample taken 5-7 cmts.
T-96-47	Dark-brown loamy partly silty soil, qtz-xls at random, 50% organic matter content,6-8cmts depth of sample taken.
T-96-48	Dark-grey to black partly silty loamy soil,occ. carbonaceous,abundant organic matter 55%;depth of sample taken 7-8 cmts.

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APPENDIX

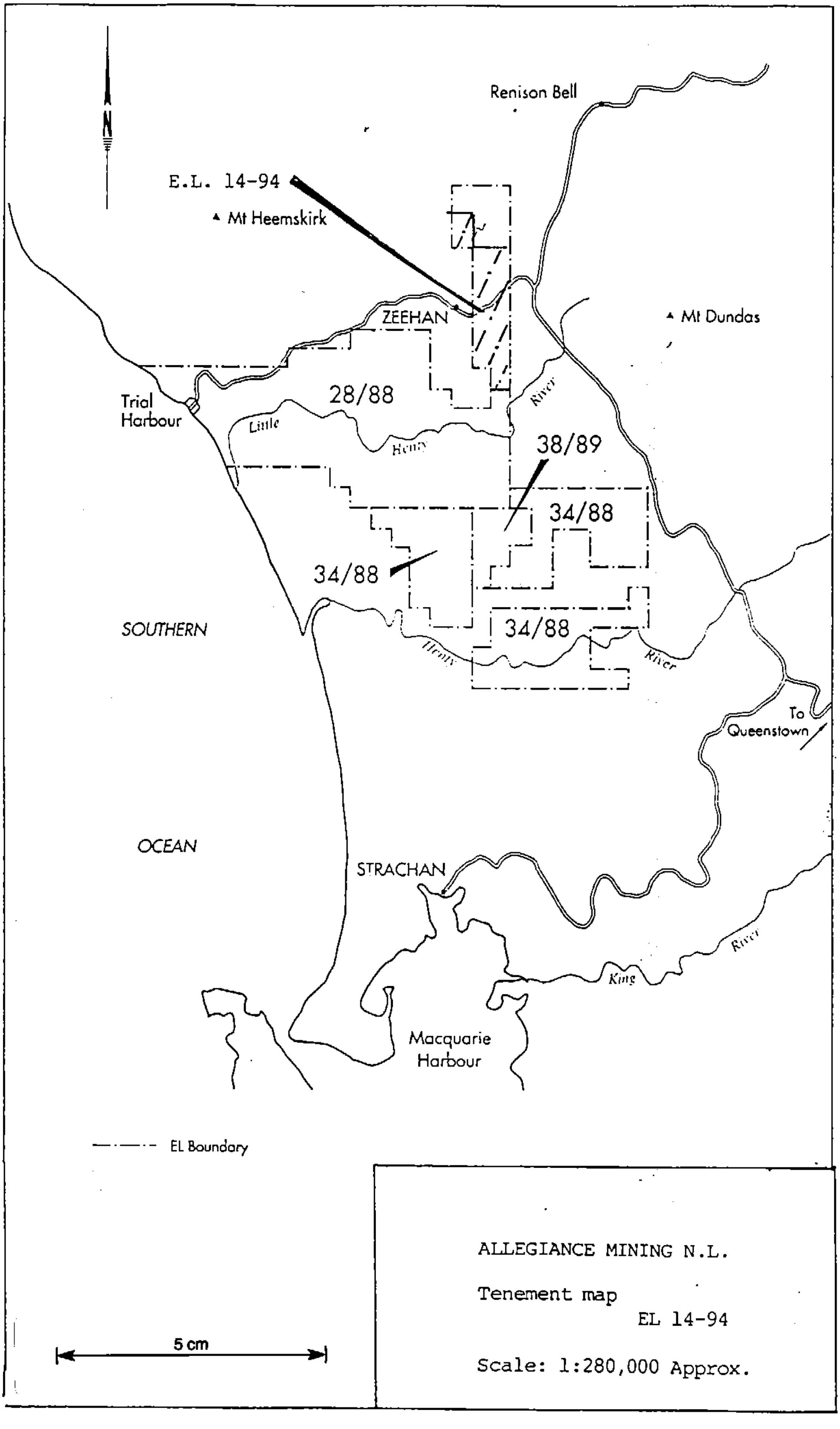
LITHOLOGICAL DESCRIPTION

Sample No.	Soil Logging Description
T-96-49	Dark-grey partly silty soil, interspersed with fine grained feldspathic sandstone,abundant organic matter 55% ; depth of sample taken 7-9 cmts
T-96-50	Grey-black partly sandy soil,feldspathic,occasionally carbonaceous,organic matter content 40%; 6-8 cmts dept of sample taken.
T-96-51	Dark-grey sandy silty soil, carbonaceous fabric, depth of sample taken 8-10 cmts.
T-96-52	Dark-grey sandy silty soil, partly carbonaceous,abunda qtz xls, organic matter 40%; 5-8 cmts depth of sample.
T-96-53	Dark-brown loamy soil,sandy silty at times,abundant shale fragments, partly carbonaceous, depth of sample taken 7-8 cmts.
T-96-54	Dark-grey loamy soil, occ.sandy-silty,calcareous at times, carbonaceous at random, 7-8 cmts depth of sample taken.
T-96-55	Dark-brown silty-sandy soil, carbonaceous matrix,abunda t organic matter 55%; depth of sample taken 7-9 cmts.
T-96-56	Dark-brown loamy silty soil,partly calcareous,carbonace us at times, organic matter content 50%,depth of sample taken 5-8 cmts.
T-96-57	Dark-brown loamy silty soil, partly calcareous,carb. at times, 60 % organic matter content, 7-10 cmts dept
T-96-58	Dark-brown loamy soil, partly calcareous,carb. at times 60% organic matter content; depth of sample taken 7-10cmts.
T-96-59	Dark-brown loamy silty soil, carb. fabric; organic matter content 60% ; depth of sample taken 5-8 cmts.
T-96-60	Dark-brown to black loamy silty soil,occ. sandy,argill. at times,partly carbonaceous,50% organic matter,depth of sample taken 5-7 cmts.
T-96-61	Dark-brown silty soil,partly arenaceous,abundant organi matter 55%; depth of sample 5-8cmts.
T-96-62	Dark-brown arenaceous soil,loamy at times, partly carb. abundant organic matter 55%; 5-8 cmts depth of sample.
T-96-63	Dark-brown arenaceous,partly silty soil,carbonaceous at times, copious organic matter 55%; depth of sample taken 7-9cmts. qtz xls vestiges.
T-96-64	Dark-brown to black loamy-silty soil,clayey,carb. at times, organic matter 55%; depth of sample 7-8cmts.

APPENDIX

LITHOLOGICAL DESCRIPTIONS

Sample No.	Soil Logging Description
T-96-65	Dark-brown silty loamy soil,,carbonaceous at times,60 organic matter content; depth of sample 5-8 cmts.
T-96-66	Dark-brown to black arenaceous soil,partly carbonaceo ,organic matter content 60%; depth of sample taken 7-8 cmts.
T-96-67	Dark-brown arenaceous material,carbonaceous at times abundant organic material 60%; depth 5-7 cmts.
T-96-68	Dark-brown loamy partly silty soil,clayey, organic matter content 70% depth of sample 7-9cmts.
T-96-69	Dark-brown loamy silty soil,occ. qtz-xls;partly carb., abundant organic matter 65%; 5-8depth of sample.
T-96-70	Dark-brown black loamy silty soil,partly carbonaceous abundant organic matter 55%; depth of sample 5-8cmts.
T-96-71	Dark-brown to black loamy silty soil,clayey,carb., at times,abundant organic matter 55%; depth of sample taken 5-8 cmts.
T-96-72	Dark-grey black loamy silty soil,clayey,occ. carbonac ous, copious organic matter 60%; depth of sample take 7-8cmts.
T-96-73	Dark-grey black loamy soil,clayey,partly silty,carb., at times, abundant organic matter 60%; depth of sampl taken 5-8 cmts.
T-96-74	Dark-grey black loamy soil, clayey,partly silty,carb. at random, copious organic matter 55%; depth of sampl taken 5-8 cmts.
T-96-75	Dark-grey to black loamy silty soil, argillaceous at times, abundant organic matter 55%; depth of sampl taken 8-10 cmts.



ALLEGIANCE MINING N.L.

Tenement map
EL 14-94

Scale: 1:280,000 Approx.

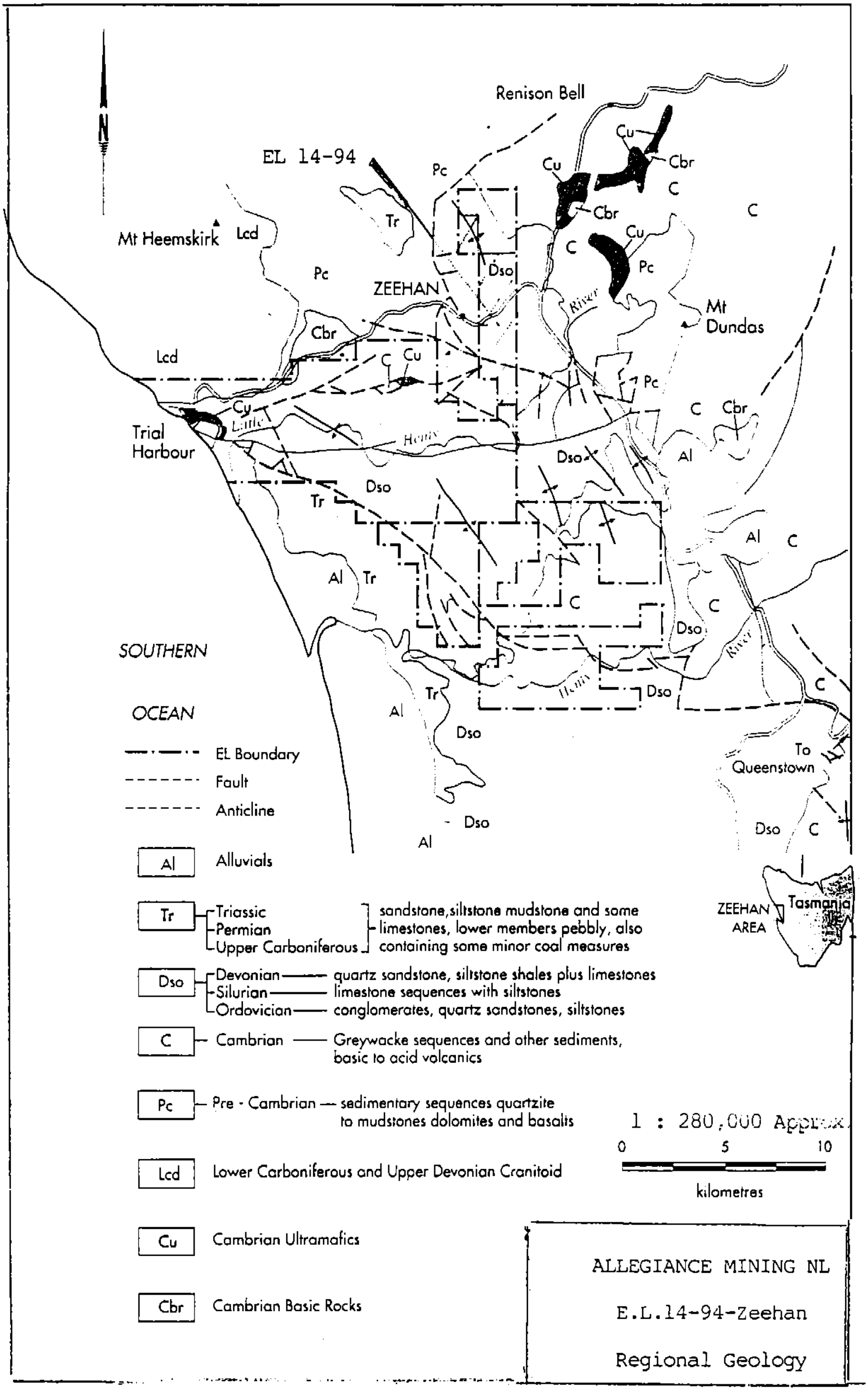


Fig. 1. EL 14-94 - Zeehan. Regional Geology. Scale 1:280,000

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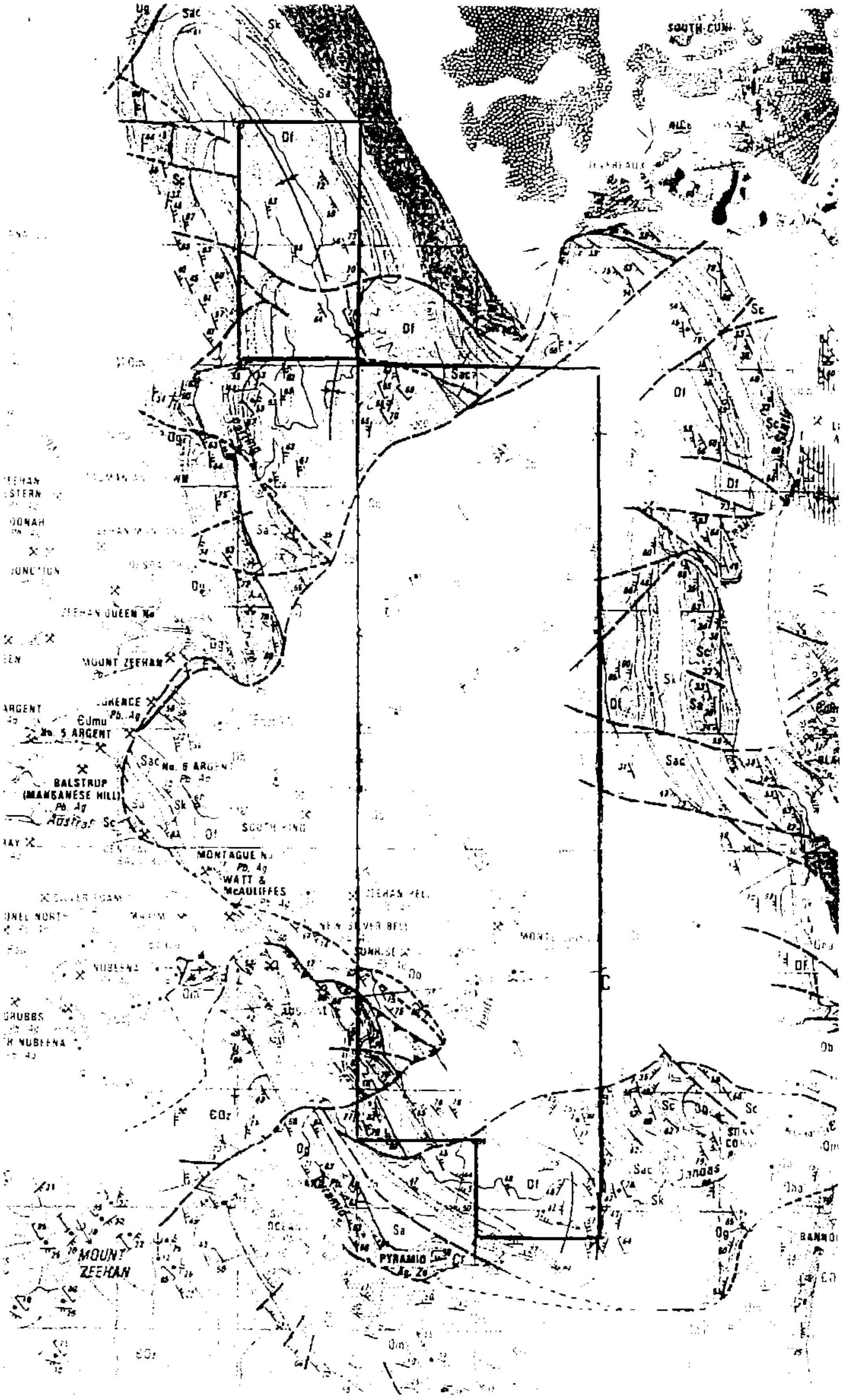


N

LEGEND

Quaternary:Qha
Alluvials

Devonian :Db,Df
Mdstn-Silstn qtz Ss

Silurian :Qg
Gordon Lstn

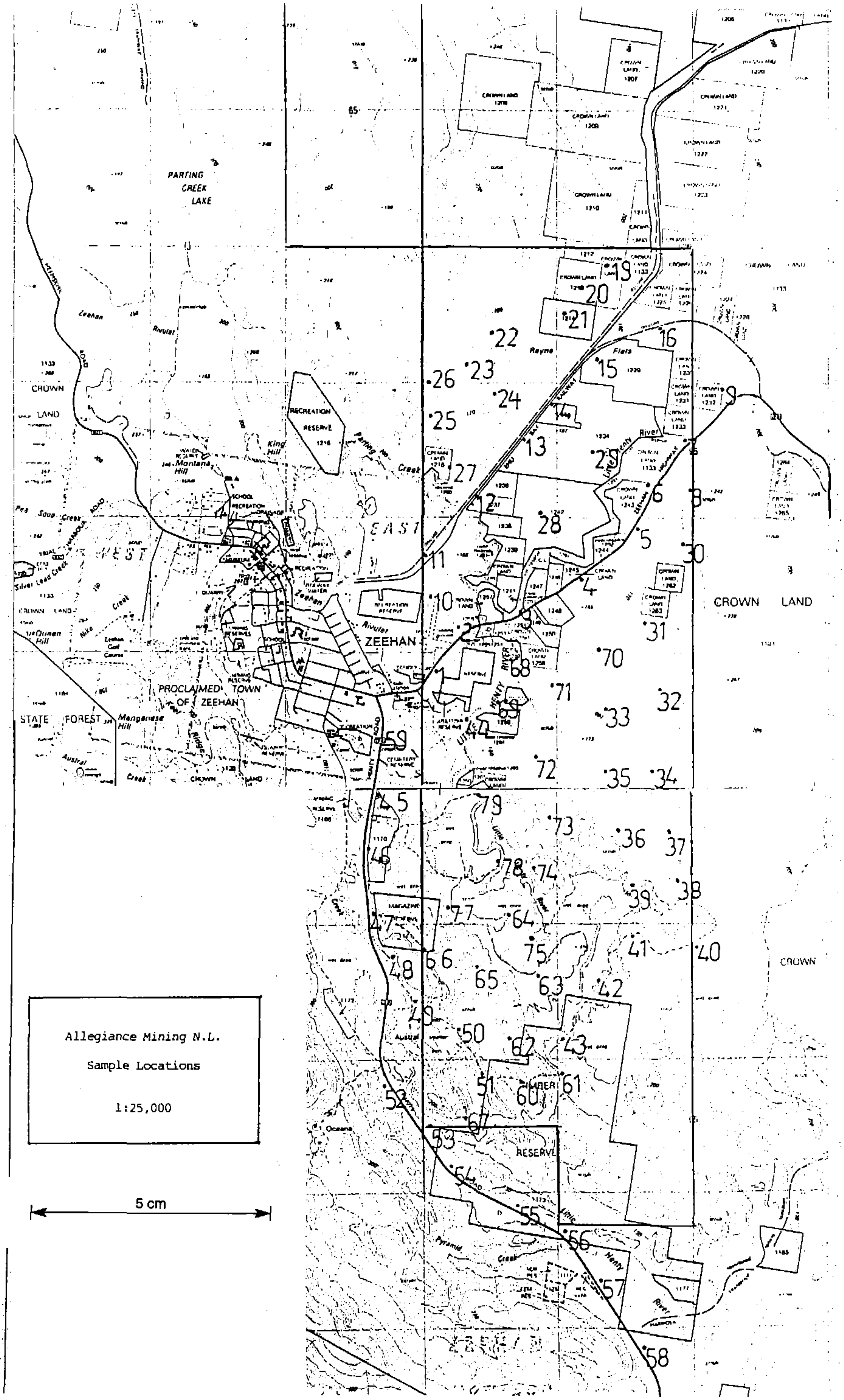
Fig. 2. EL 14-94 Geological Map. Scale 1:50,000

5 cm

LLEGIANCE MINING N.L.

.L. 14-94 Geological Map

Scale : 1 : 50,000



Allegiance Mining N.L.

Sample Locations

1:25,000

5 cm

96-3926 C
Appx 3 of
96-3926

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APPENDIX 4

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ALLEGIANCE MINING NL

Report of Geoelectrochemical Investigations in the area EL 14 / 94 Zeehan, Tasmania

IONEX
Dr I. Goldberg
Dr G. Abramson
Dr V. Los

August 1996

SUMMARY

An MPF Geoelectrochemical (GEC) survey carried out over EL 14/94 Zeehan Tasmania, has yielded anomalous Zn / Pb zones.

Their coincidence with depletion in the nickel and vanadium elements suggests a bedrock rather than a polution source.

TABLE OF CONTENTS

SUMMARY

ATTACHMENTS
- Figures Nos 1 - 21
- Appendix 1
- Appendix 2
- Appendix 3

1. Introduction

This report is based on analysis of samples using the MPF method [1]. The samples were taken from EL 14-94 Zeehan, Tasmania. This area was chosen after evaluation of the region (Stage II) [2].

The field survey was done by A. Galperine and M. Zapata over an area of about 20 km^2 in the middle of April 1996.

The main goals of the survey were to determine the prospectivity of this section and to choose the areas for further detailed work.

2. The methods of work

2.1. Sampling and analysis of samples

For solving these tasks, 79 geochemical samples were taken from the humic soil horizon at the depth of 6-10 cm. The average spacing between sampling points is 500 m. The location of each sampling point was determined by GPS, and is shown in Fig. 3. The analysis of samples was performed in the Virg-Rudgeofizika Laboratory Institute, in St Petersburg, Russia. The analysis was carried out at high sensitivity to allow the variations above and below the normal/average concentrations of elements in the lithosphere (i.e. to sub-Clark concentrations).

TABLE

Sentivity of Analyses

Chemical elements ppm											
Au	Ag	Pb	Zn	Cu	Sn	Mo	As	Ga	Ni	Co	V
A.A.S.		Spectral analysis									
0.00001	0.00005	0.4	0.4	0.4	0.4	0.2	3.0	0.2	0.4	0.4	1.0

2.2. Control analysis

The internal control of the sample analyses was undertaken. For this purpose 15 duplicate samples were taken, codified and sent to Virg-Rudgeofizika laboratory. The date is displayed in Appendix 2. The control demonstrated that analyses for lead, zinc, copper, tin, molybdenum, nickel and vanadium are quite reproducible and can be used. Analyses for other elements, particularly for gold and silver, area non-reproducible and require to be repeated.

Bearing in mind the results of the control analyses, this report does not discuss gold and silver. The report on gold and silver will be completed after special control analyses of the laboratory duplicates has been performed.

2.3. Data treatment and interpretation

The anomaly has been displayed both manually and by computer. The program ELAN-2 (V. Los, I. Gobernik, A. Ioffe, 1994) analyses statistic distribution of elements concentration, makes approximation model of geochemical fields (Appendix-3), and describes relationships between chemical elements and distinguishes generalized geochemical structures.

For data interpretation the authors used geological and geological-economical data presented in the report of Manuel Zapata (May, 1996) [3].

3. Results of geochemical investigations

3.1. General characteristics

Exploration Licence 14-94 comprises primarily a sequence of Devonian rocks, mainly black carbonaceous-shale-qtz sandstone, interspersed with siltstone and limestone affinities, represented by Ag-Pb occurrences. This type of mineralization style is strata bound and deemed to be of sediment hosted volcanic-exhalative type (Figs 1 and 2).

3.2. Structure of the geochemical fields

Below we will discuss the specific features of chemical elements distribution in the structure of the anomalous geochemical field of the area.

3.2.1. Lead (Pb) (Figs 4 and 5)

Lead (Fig 4) forms anomalies over almost the whole area under investigation. Here, the widest anomalous fields with high concentrations are located in the south-east and south parts of the area. The general direction of the structure is south-east (as seen on the approximation model, Fig 5). It is located on the south-east extension of the ore-bearing structure enclosing ore bodies Zeehan Bell, New Silver Bell, sunrise and other (Fig 2). Besides, local anomalous fields of north-west trend, having no closure in the north-west and west direction, are distinguished within the common south-east structure.

A small local lead anomaly (three anomalous samples) has been determined in the north part of the area.

Small anomalous fields with relatively low lead contents, that can be interpreted as "depletion zones" have been revealed in the limits of the area (mainly in the north part).

3.2.2. Zinc (Zn) (Figs 6 and 7)

Anomalous concentrations of zinc (Fig 6) occur over the whole area under investigation. The widest field with the highest concentrations is located in the south-east part, where it almost exactly coincides with the anomalous lead field. Here, one can notice elongation of the anomaly in two directions - south-east and north-west (Figs 6 and 7).

Individual lead concentrations occur in the north part of the area, where they partially coincide with lead anomalies.

3.2.3. Copper (Cu) (Figs 8 and 9)

Copper (Figs 8 and 9) forms a wide anomalous field essentially in the south-west part of the area, where it is located within the contours of lead and zinc anomalies.

3.2.4. Tin (Sn) (Figs 10 and 11)

Tin (Figs 10 and 11) form the anomalous field also essentially in the south-west part of the area, where it is located within the contours of the copper anomaly.

3.2.5 Molybdenum (Mo) (Figs 12 and 13)

Molybdenum (Figs 12 and 13) is concentrated in the area both in association with tin and copper and in the north part of area, where it is elongated as a narrow stripe of the north-west trend.

3.2.6. Nickel (Ni) (Figs 14 and 15)

Nickel (Figs 14 and 15) forms local zones of reduced concentrations (<0,02) over the whole area of the section. Here, in the south-west and central parts, the area of its reduced values essentially coincides with the area of basic metal accumulation. The lowest nickel values area noticed here (less that 0,01) which are interpreted as depletion zones.

3.2.7. Vanadium (V) (Figs 16 and 17)

Vanadium (Figs 16 and 17) forms a wide zone of reduced concentrations elongated in the south-east direction that essentially coincides with the base metals anomalies and perhaps the silver and gold (see above).

Other analysed chemical elements (Co, Ga, As) do not present any regular picture. Thus, they are not discussed in this report.

General

In such a manner, Pb anomalous field with regular behaviour of chemical elements, that corresponds to the Pb-Zn-Ag mineralisation developed here, has been detected in the south-west part of the studied area on the extension of the known ore-bearing structure (Fig 2).

This is also validated by the existence of close (more than 0,8) correlation between lead, zinc and copper (Figs 18-20). Lead and zinc area linearly dependent (Fig 18). Relationship between copper on one hand and lead and zinc on the other is exponential (Figs 19 and 20). The latter points to more local development of copper concentration over the studied area.

General regularities in distribution of Pb-Zn-Ag-elements-indicators of mineralisation in the anomalous field of the area are shown in Fig 21.

4. Conclusion

4.1. A high degree of differentiation between the analysed elements was observed within the survey area. This is demonstrated by:

(a) in the south-eastern sector of the grid, lead zinc and copper are superimposed, with tin and molybdenum being relatively displaced to south-east (Fig 22);

(b) nickel and vanadium form fields of reduced concentrations ("depletion zones") in the corresponding areas of positive anomalies of the elements - zinc and lead.

4.2. The anomaly pattern suggests the occurrence of mineralization in addition to the known showings (see Fig 3) within the south-west anomaly 8km^2 (+-), in coordinates 5361000N - 5356000N, 362500E - 364500E).

It is worth noticing that there is possible contamination of the area due to many years of mining activity. However, a high degree of differentiation of elements belonging to the iron group (nickel and vanadium), forming "depletion zones", associated with positive lead, zinc and copper anomalies also points to the presence of Zn, Pb mineralization in the area.

5. Recommendations

The following methods / procedures are suggested to follow up the anomalous Zn/Pb/(Ag?) Located in the survey area:

(i) Search of all records for data in the anomalous area, in particular drill holes, and any EIP surveying,

(ii) subject to the above, consider EIP surveys,

(iii) also short drill holes to bedrock in selected areas should be considered.

This deep sampling is proposed to avoid possible anthropogenic contamination. Any further Geochemical works should be performed only after geophysical investigations within the anomalous chemical zones. This will help to make geochemical work more focused and therefore decrease their extent and cost.

Respectfully submitted,

Goldberg

IONEX PTY LTD

References

1. L.V. Antropova, I.S. Goldberg, N.A. Voroshiliv and Ju S. Ryss. 1992. New Methods of Regional Exploration for Blind Mineralisation: Application in the USSR. Journal of Geochemical Exploration 43, 157-166.

2. I. Goldberg 1995. A Preliminary Report on Geoelectrochemical Investigation in the area *Zeehan (Tasmania). Prognostic Evaluation of the Territory Stage II.*

3. Manuel Zapata. May 1996. Preliminary MPF Electrogeochemical Survey carried out by IONEX at EL 14-94 Zeehan, Tasmania.

List of Figures

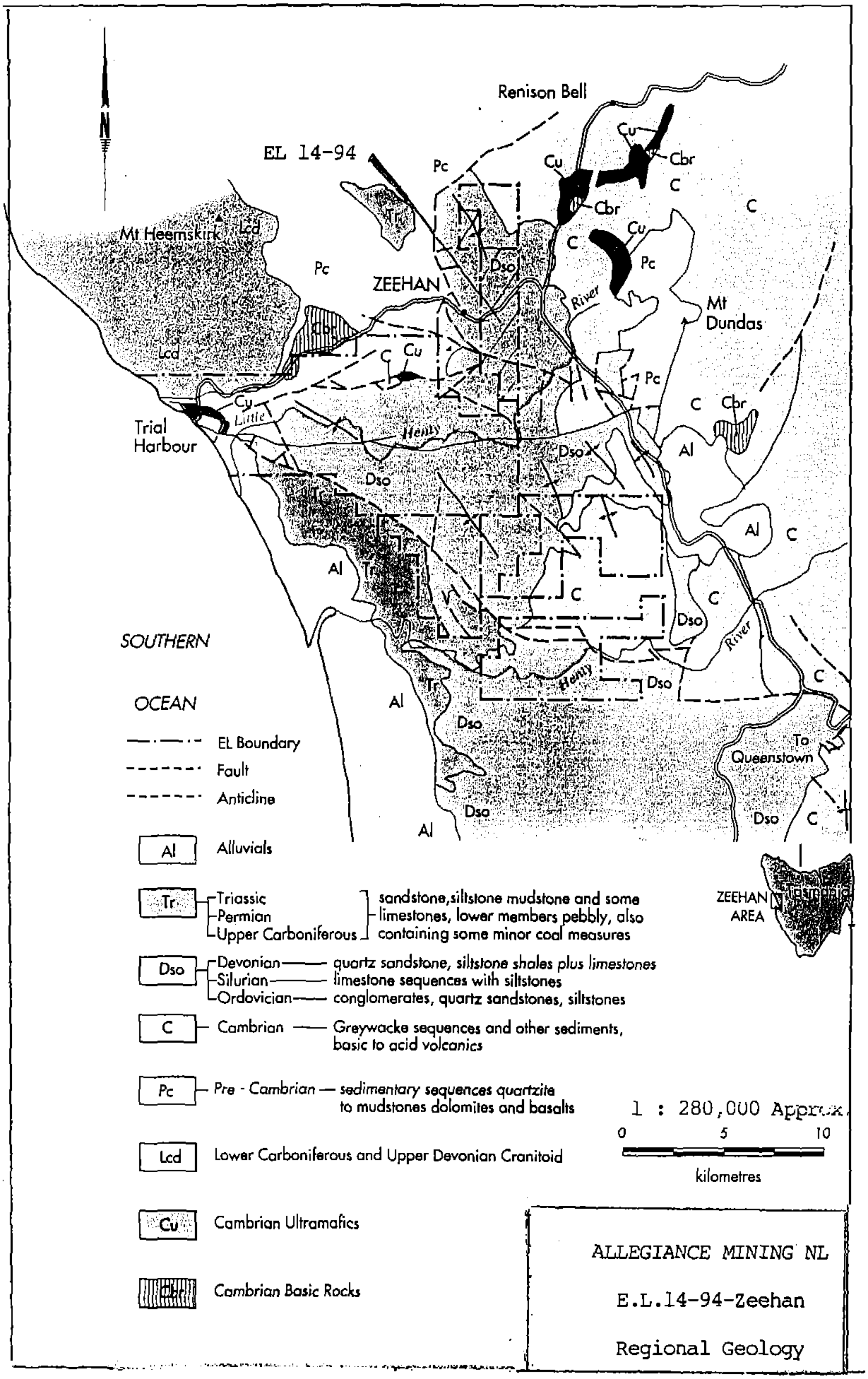

Fig. 1. EL 14-94 - Zeehan. Regional Geology. Scale 1:280,000

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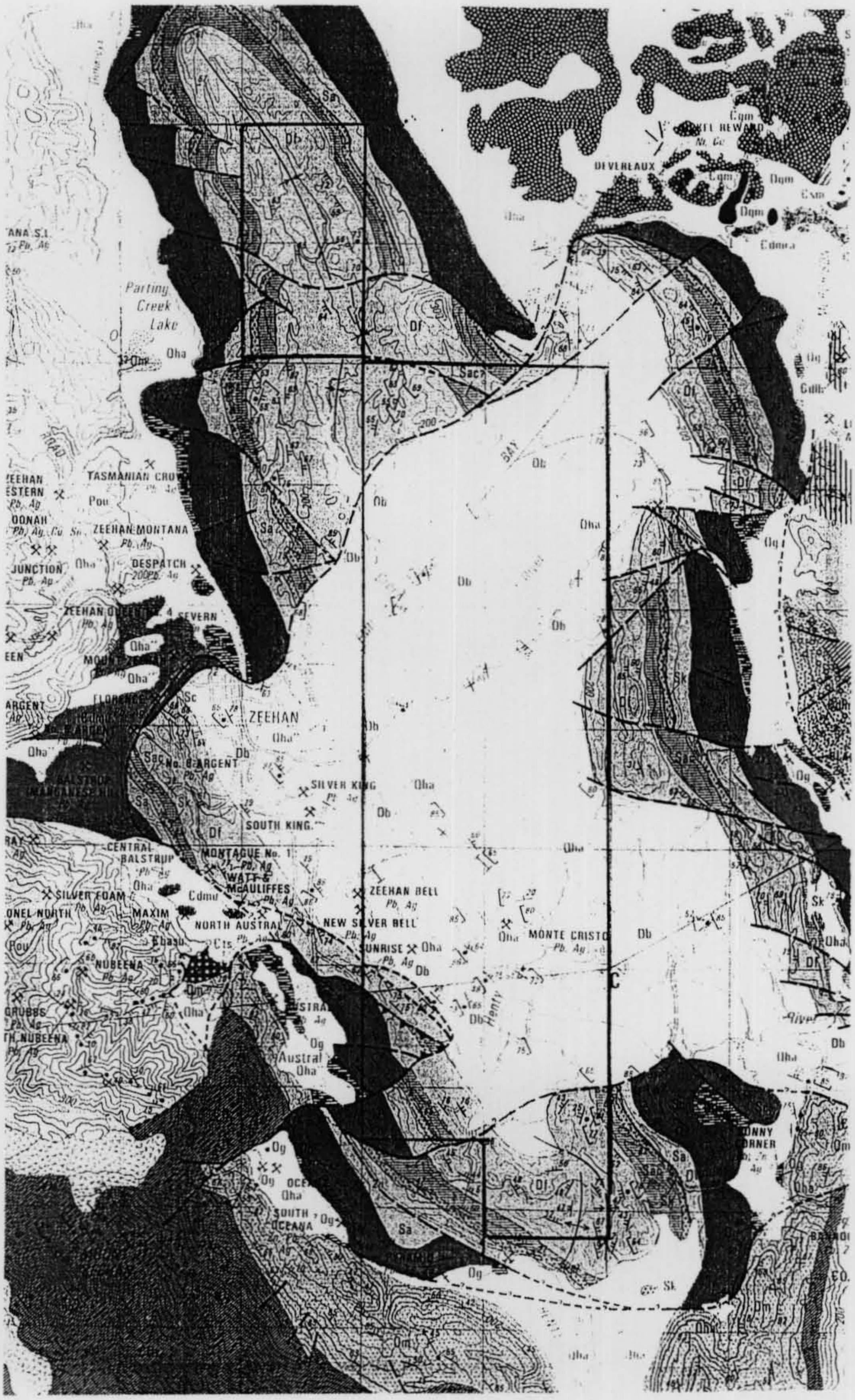


LEGEND

Quaternary:Qha
Alluvials

Devonian :Db,Df
Mdstn-Silstn qtz Ss

Silurian :Qg
Gordon Lstn

Fig. 2. EL 14-94 Geological Map. Scale 1:50,000

5 cm

ALLEGIANCE MINING N.L.

E.L. 14-94 Geological Map

Scale : 1 : 50,000

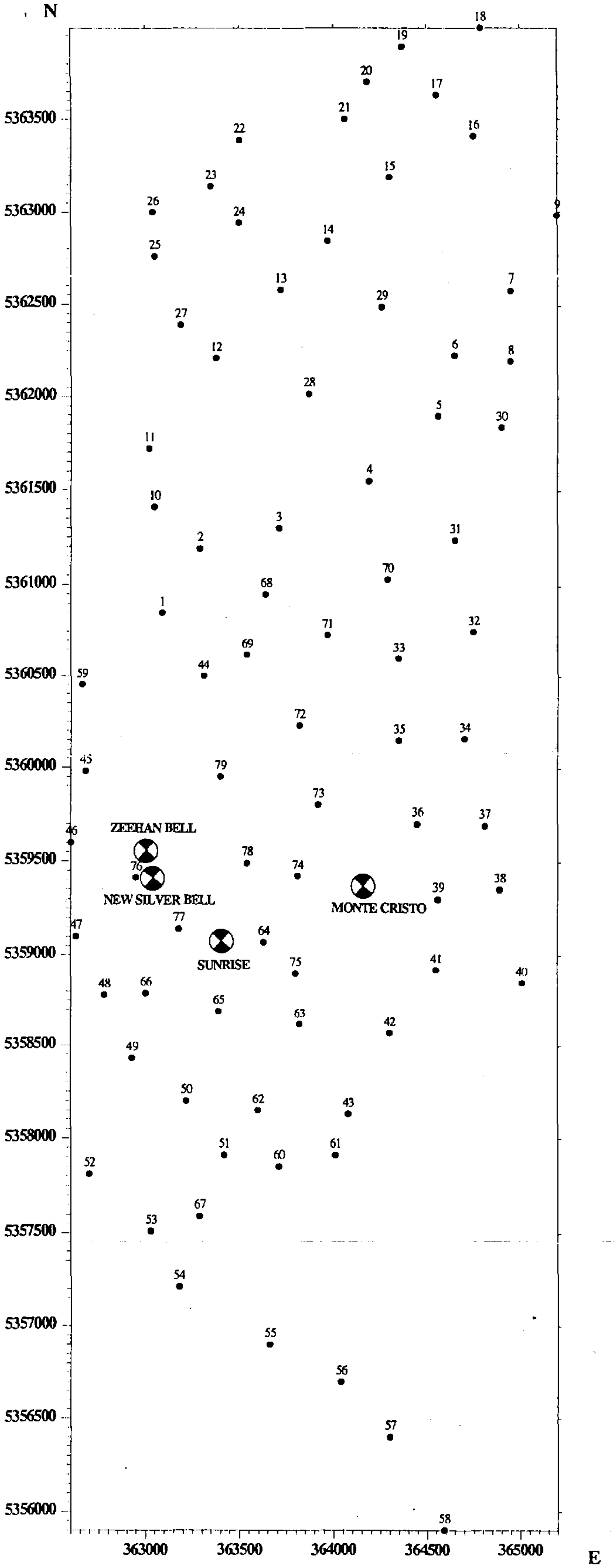


Fig. 3 Location of soil samples. Tasmania. Scale 1:25,000

⊗ – Ore deposit

5 cm

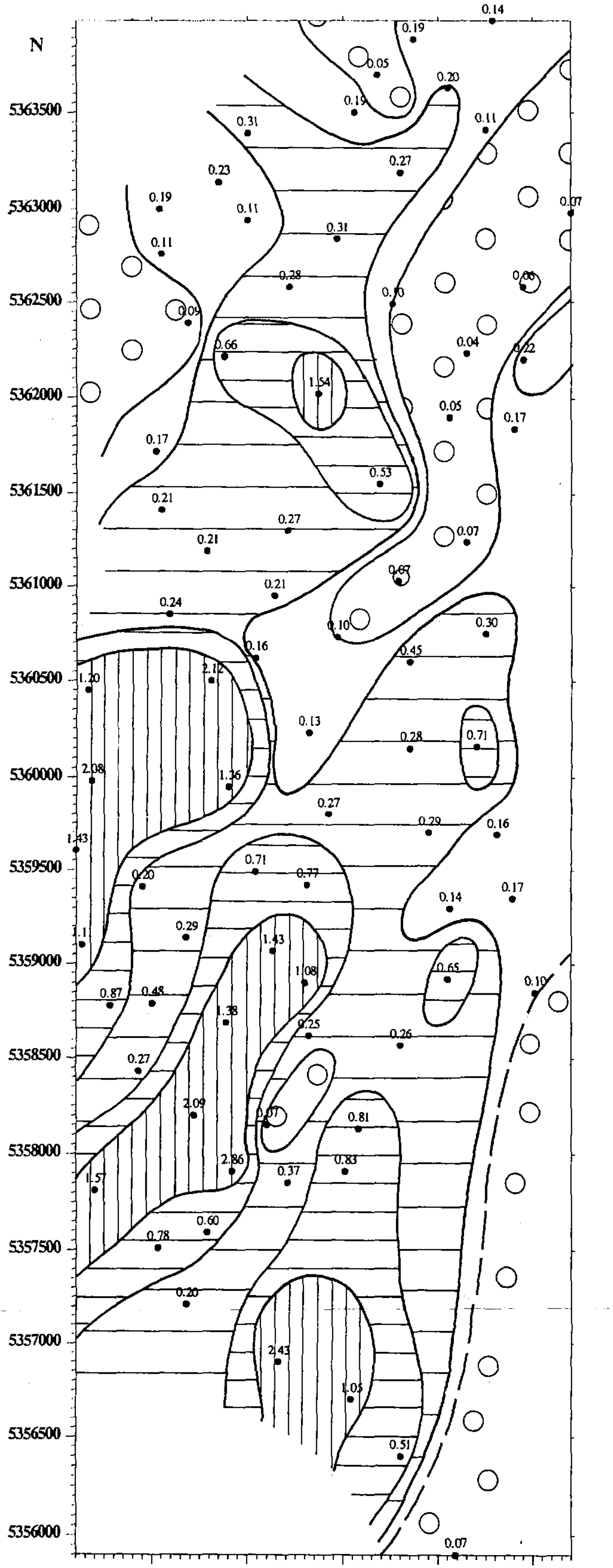


Fig. 4 . Distribution of Pb/C% in soil. Tasmania. Scale 1:25,000

▥ >1 ▤ 0.5 - 1 ☰ 0.2 - 0.5 ☐ 0.11 - 0.2 ○ ≤0.1

5 cm

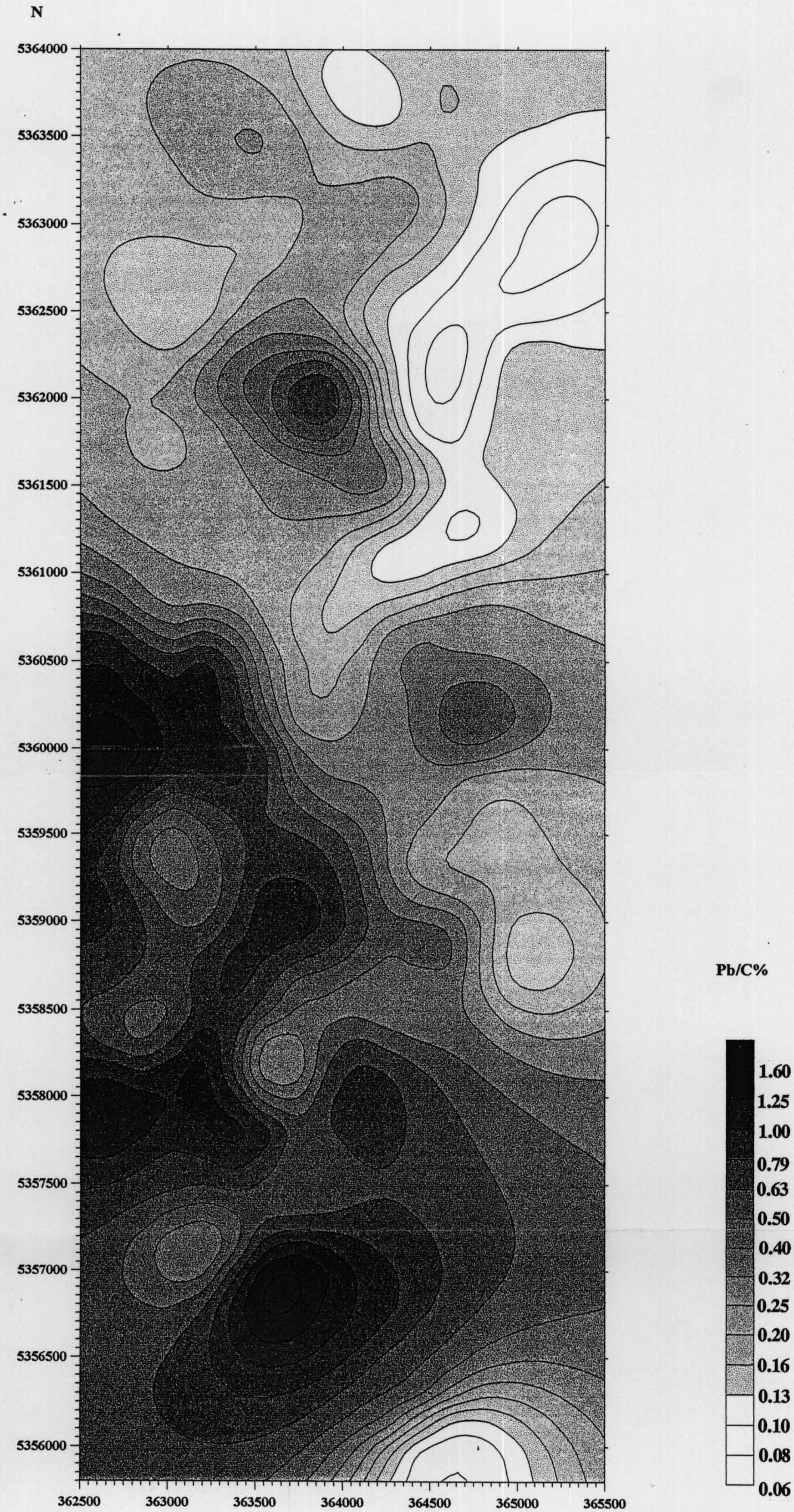


Fig. 5. Distribution of Pb/C in soil. Tasmania - Zeehan. Scale 1:25,000

5 cm

338214

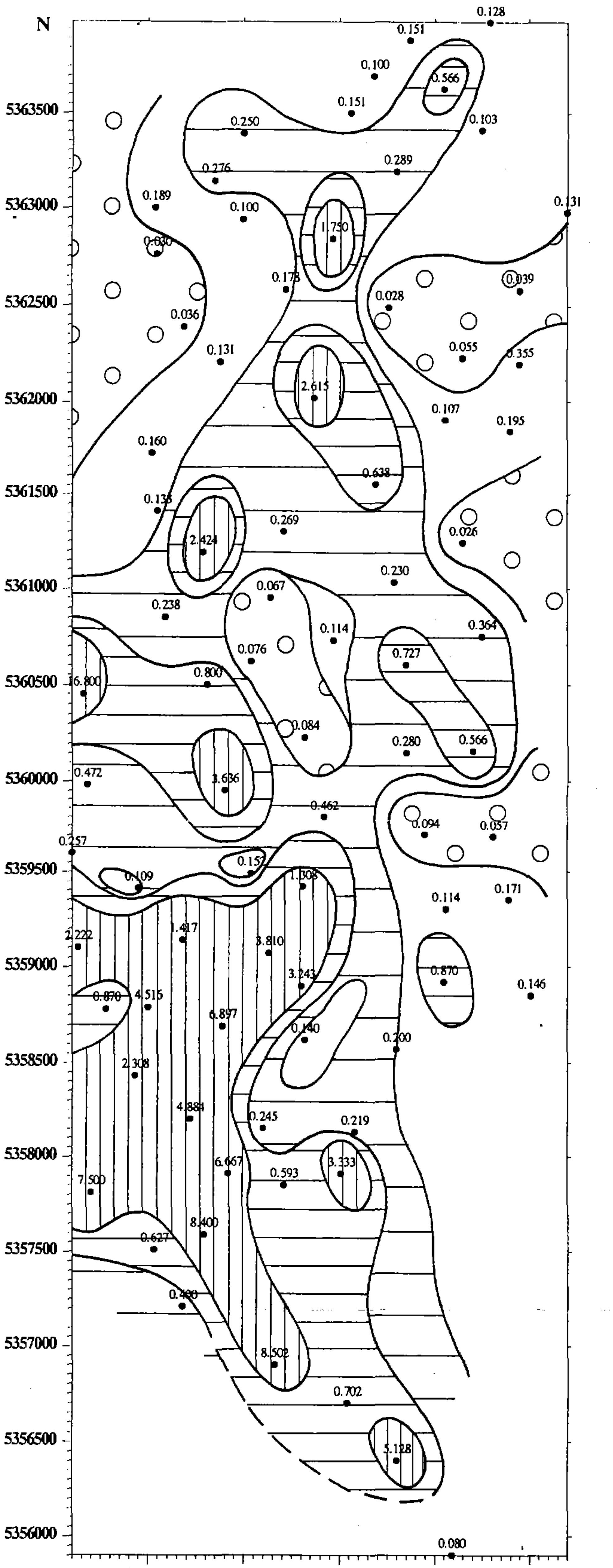


Fig. 6 . Distribution of Zn/C% in soil. Tasmania. Scale 1:25,000

▥ >1 ☰ 0.5 - 1 ☰ 0.2 - 0.5 ☐ 0.1 - 0.2 ○ <0.1

5 cm

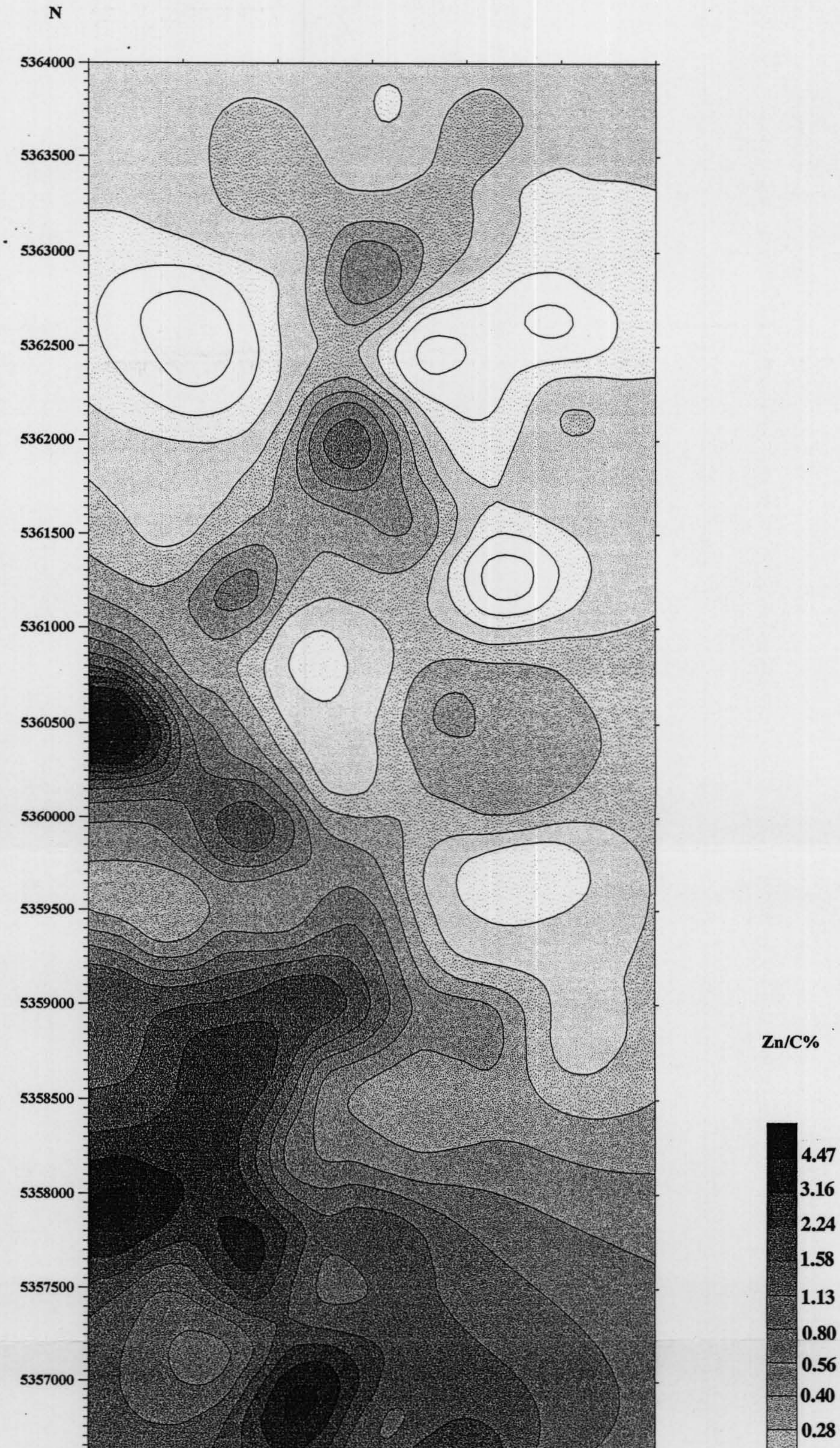


Fig. 7. Distribution of Zn/C in soil. Tasmania - Zeehan. Scale 1:25,000

5 cm

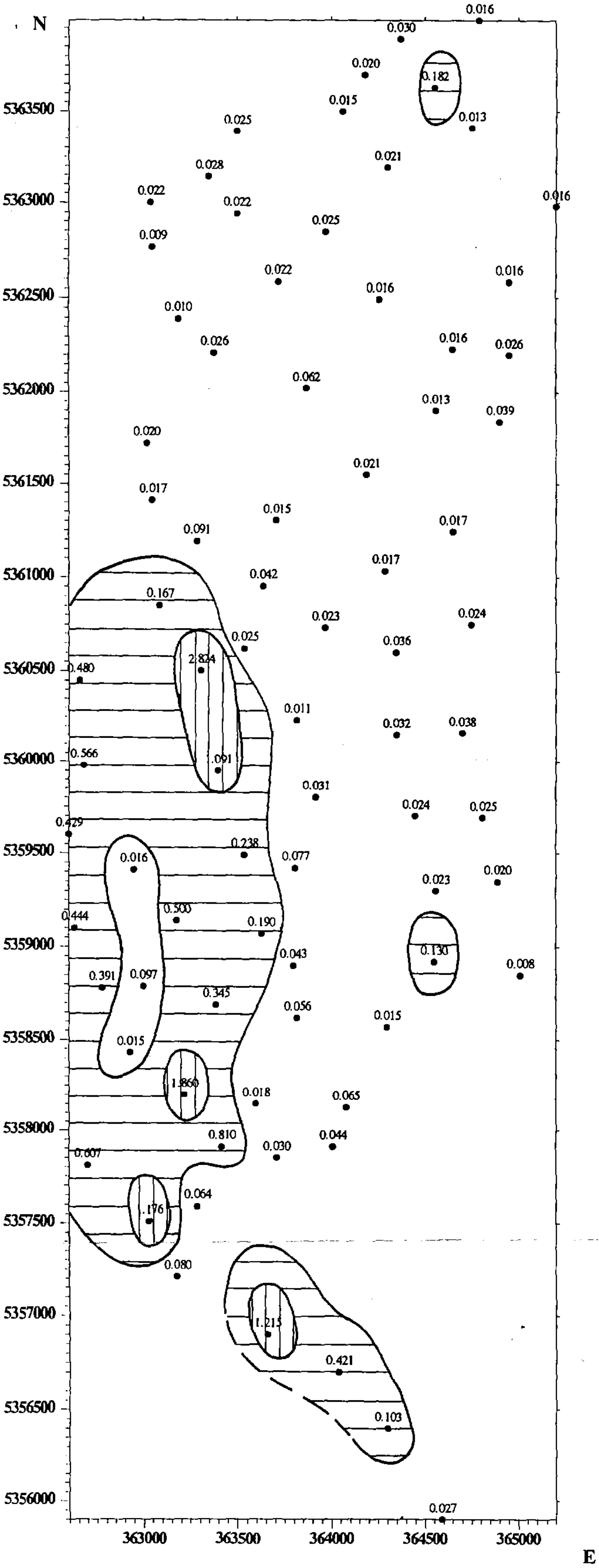


Fig. 8 Distribution of Cu/C% in soil. Tasmania. Scale 1:25,000

5 cm

▥ >1 ▤ 0.1 - 1 ☐ <0.1

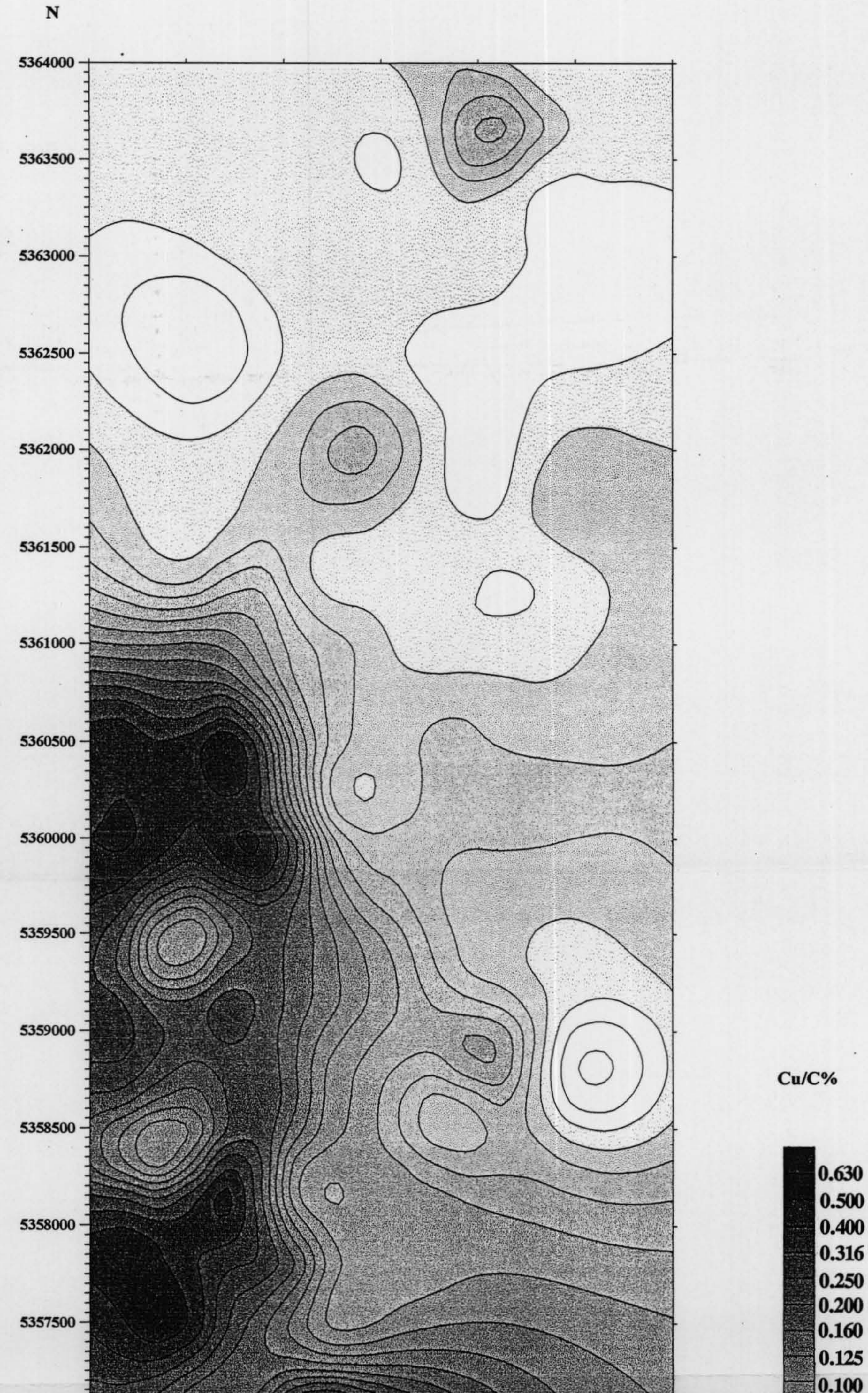


Fig. 9. Distribution of Cu/C in soil. Tasmania - Zeehan. Scale 1:25,000

5 cm

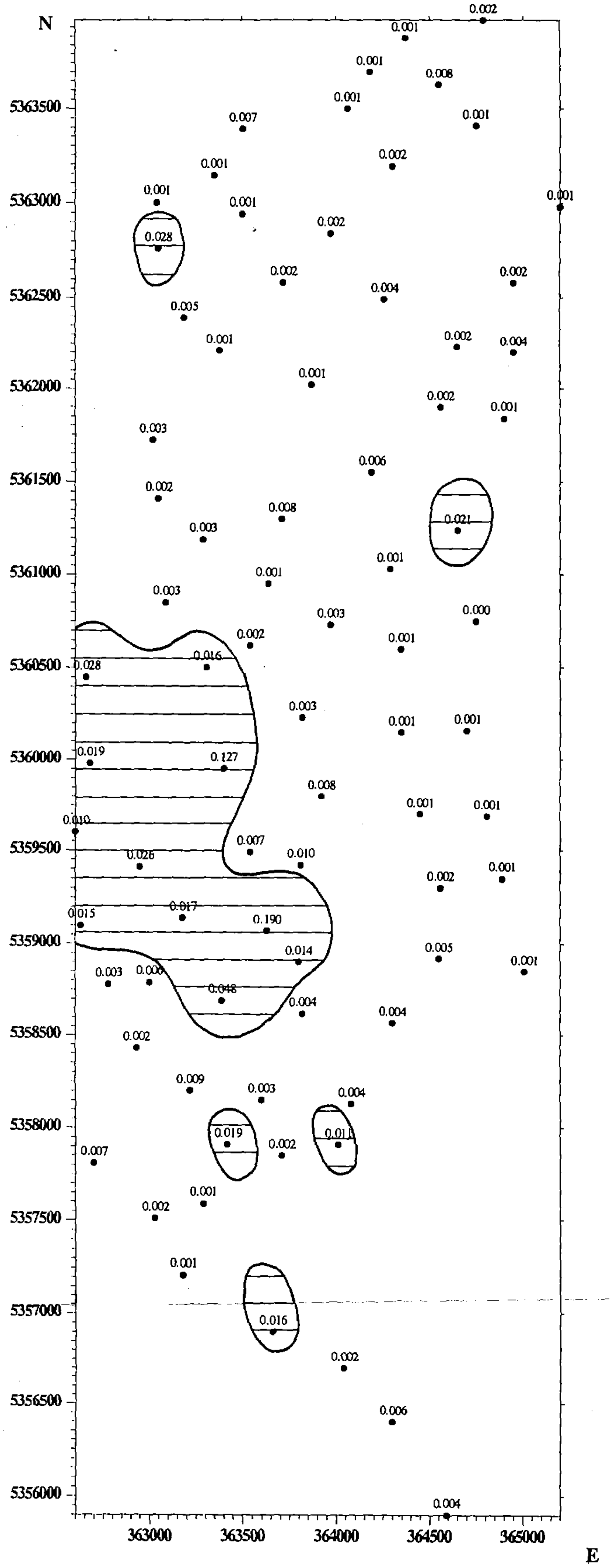


Fig. 10 Distribution of Sn/C% in soil. Tasmania. Scale 1:25,000

▤ >0.01 ☐ <0.01

5 cm

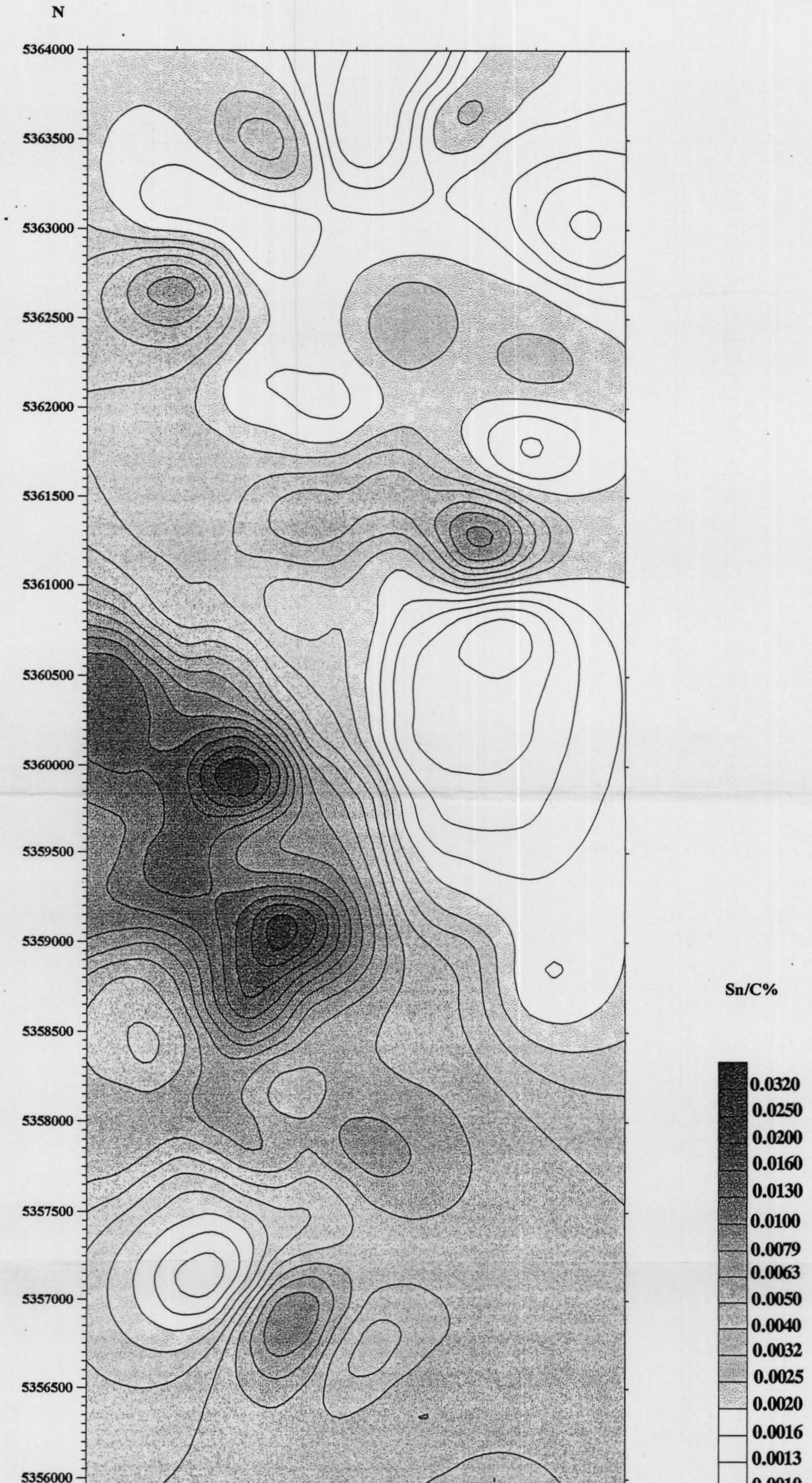


Fig. 11. Distribution of Sn/C in soil. Tasmania - Zeehan. Scale 1:25,000

5 cm

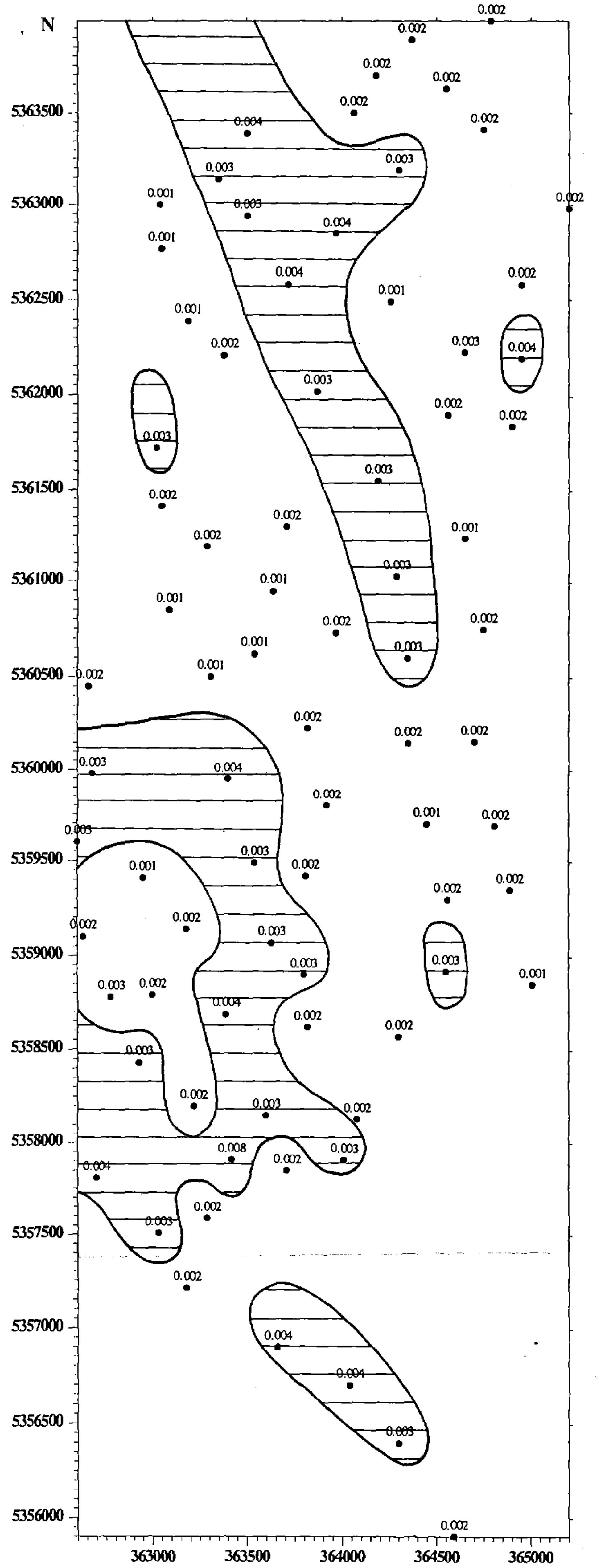


Fig. 12 Distribution of Mo/C% in soil. Tasmania. Scale 1:25,000

▤ ≥0.003 ☐ <0.003

5 cm

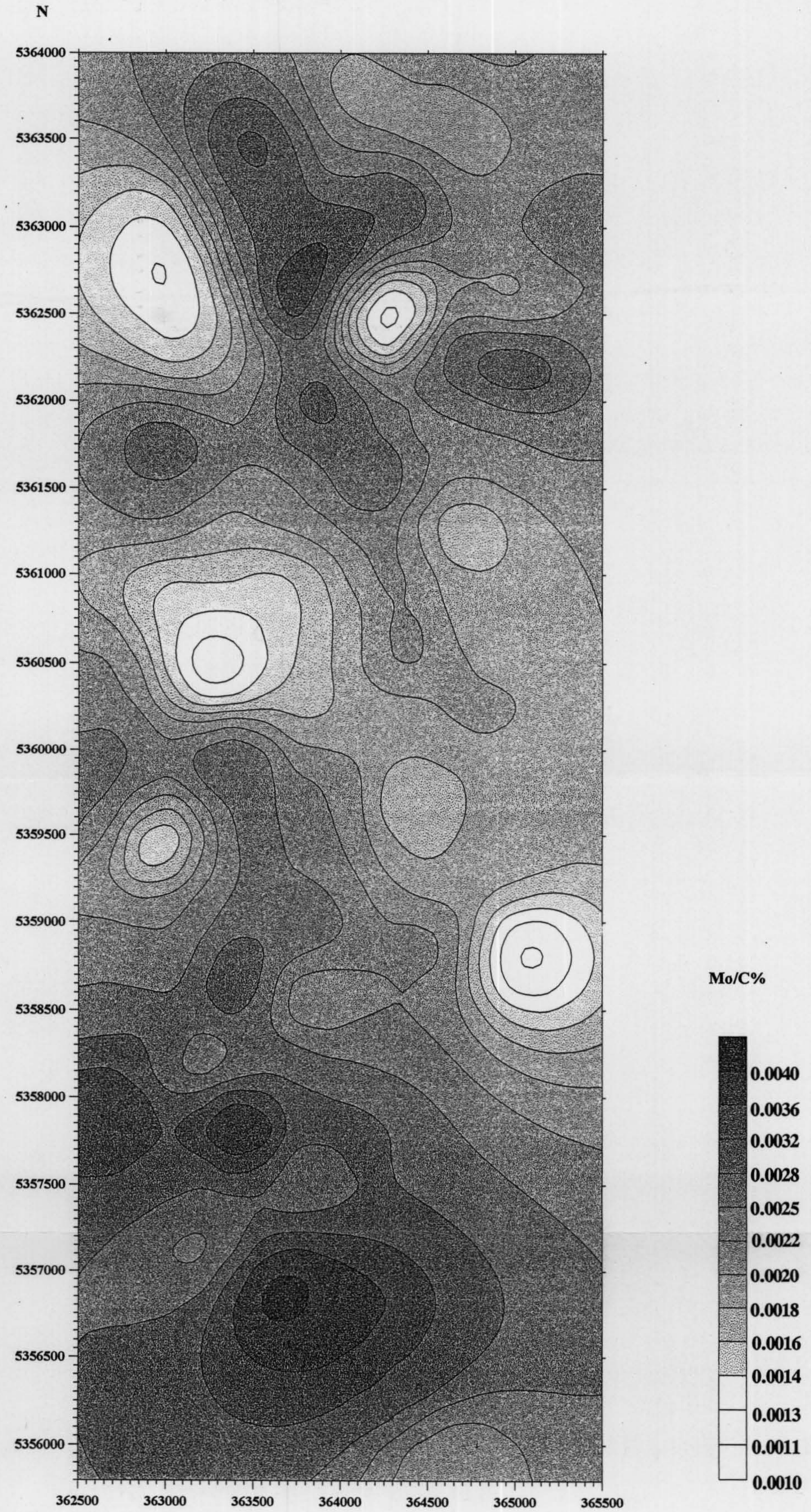
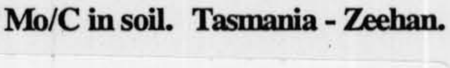


Fig. 13. Distribution of Mo/C in soil. Tasmania - Zeehan. Scale 1:25,000



338222

338223

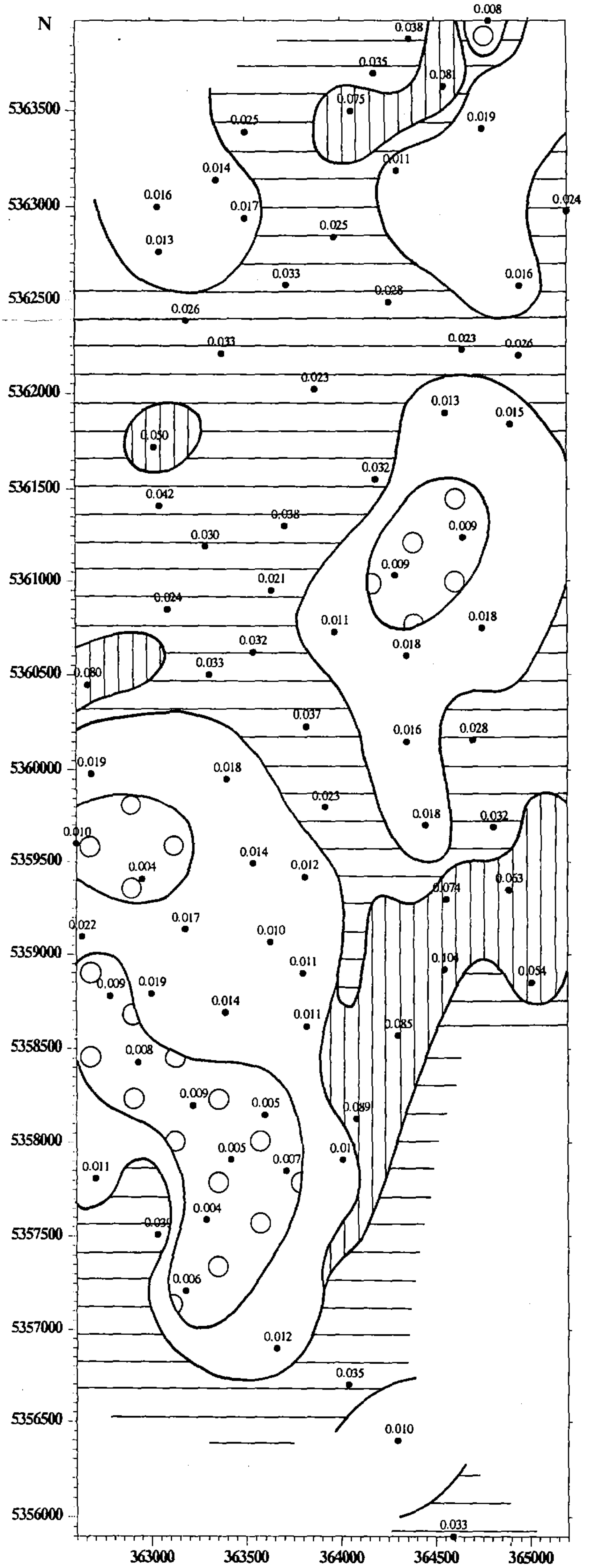


Fig. 14 Distribution of Ni/C% in soil. Tasmania. Scale 1:25,000

▥ >0.05 ▤ 0.02 - 0.05 ☐ 0.01 - 0.02 ○○ <0.01

5 cm

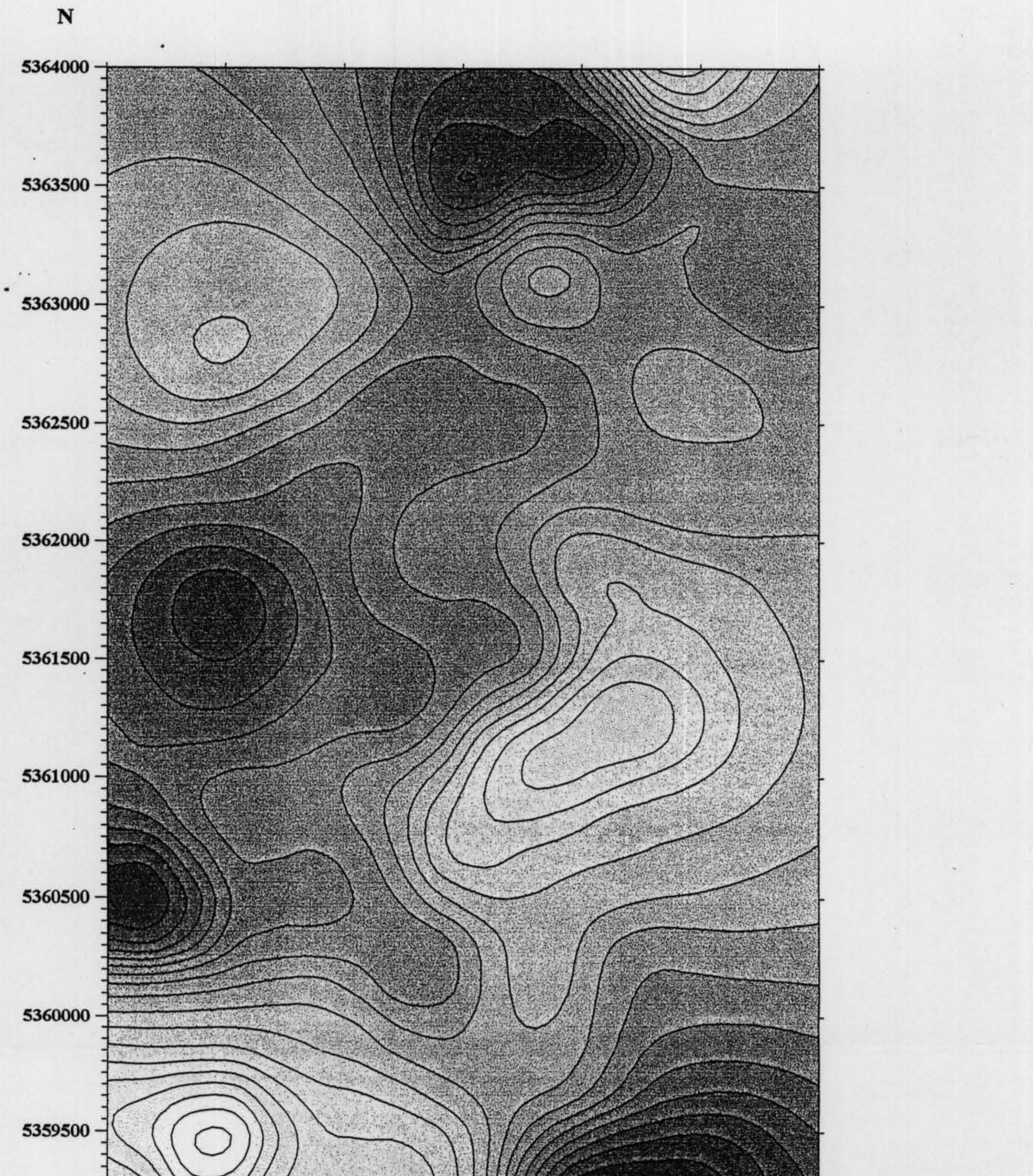


Fig. 15. Distribution of Ni/C in soil. Tasmania - Zeehan. Scale 1:25,000

5 cm

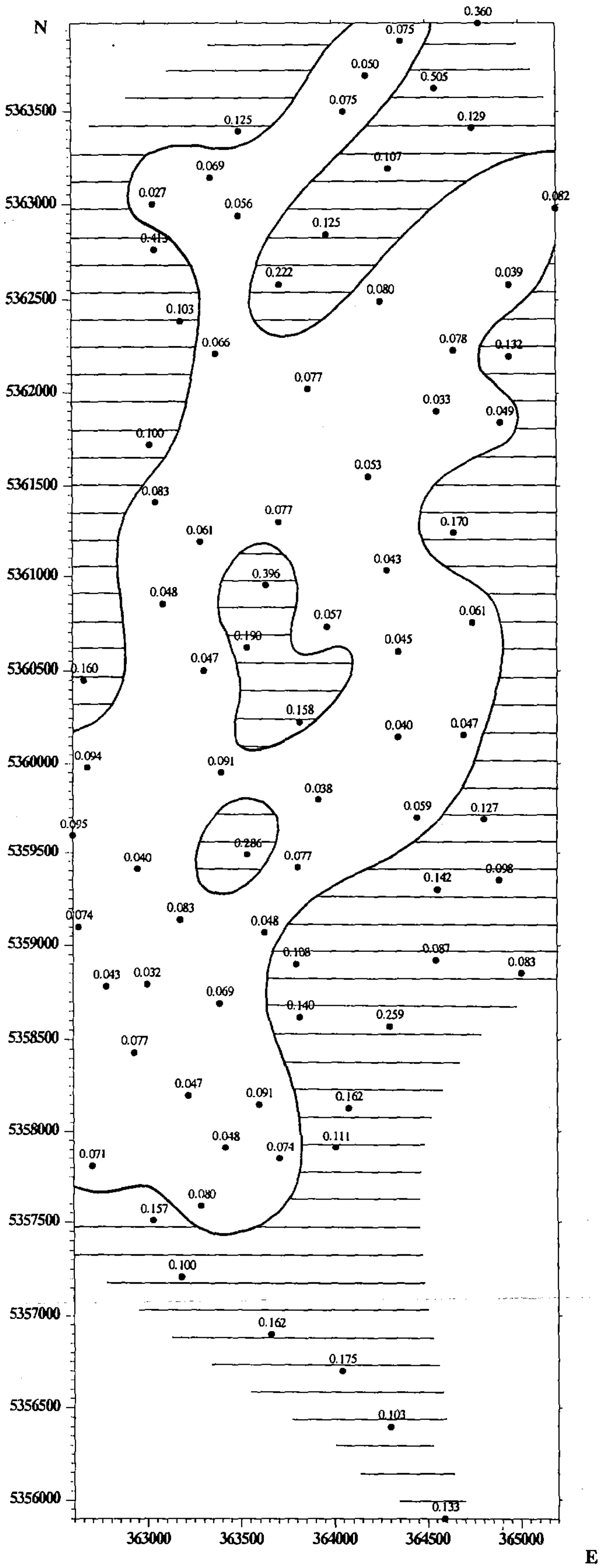


Fig. 16 Distribution of V/C% in soil. Tasmania. Scale 1:25,000

▤ ≥0.1 ☐ <0.1

5 cm

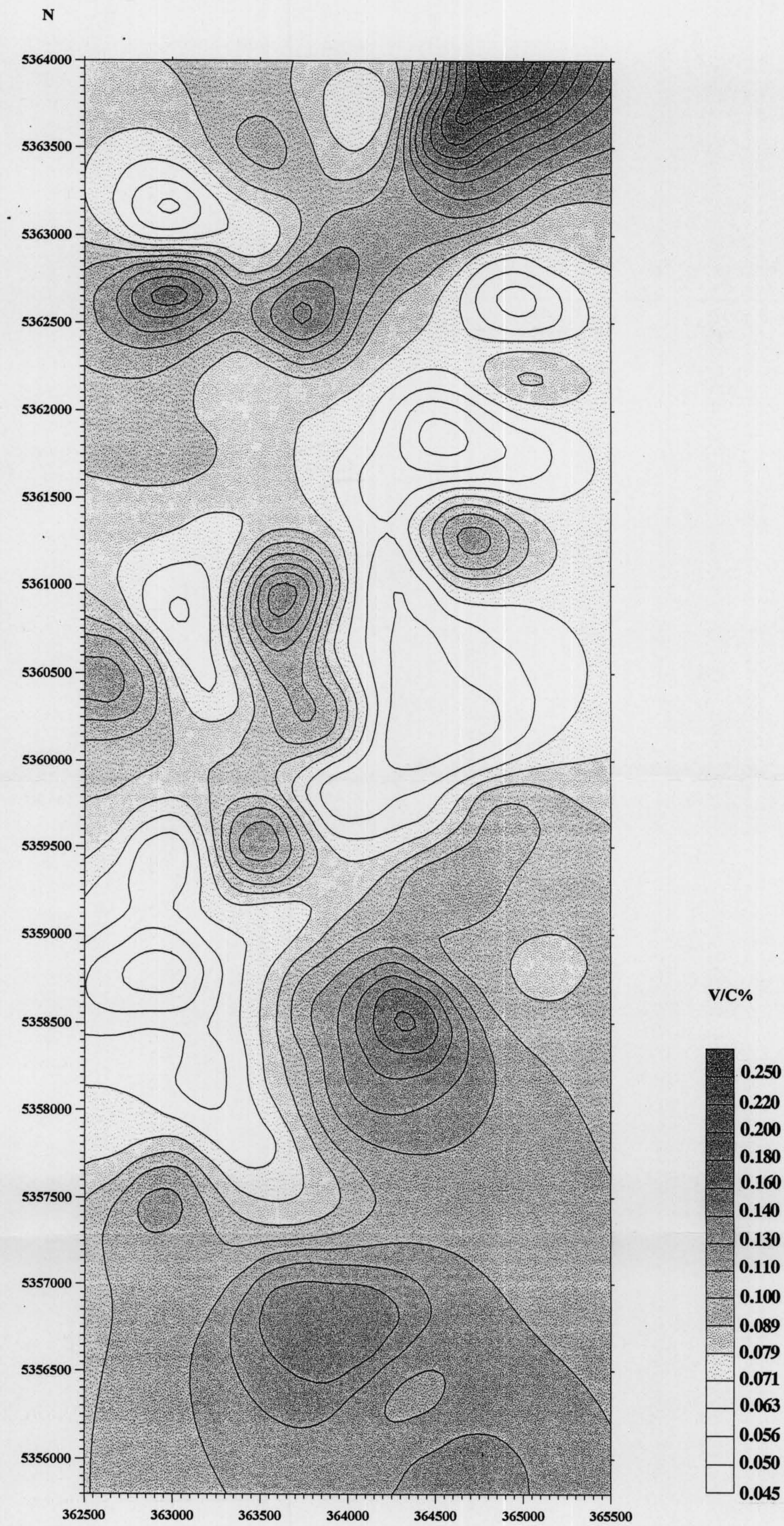
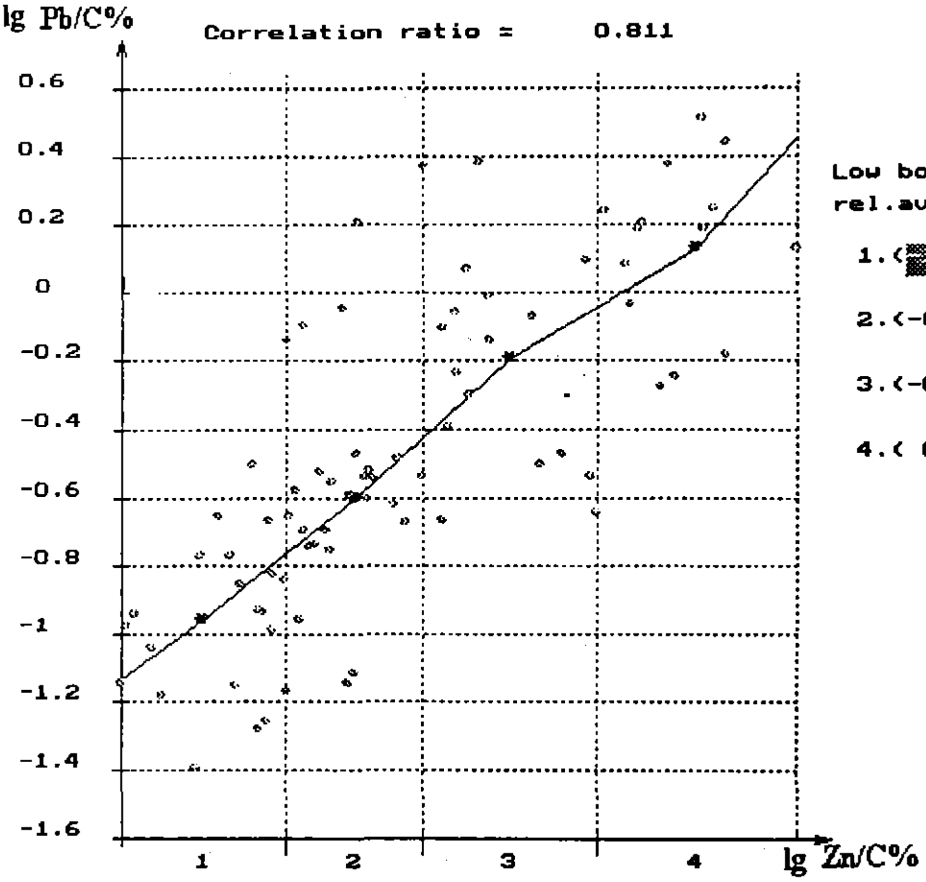


Fig. 17. Distribution of V/C in soil. Tasmania - Zeehan. Scale 1:25,000

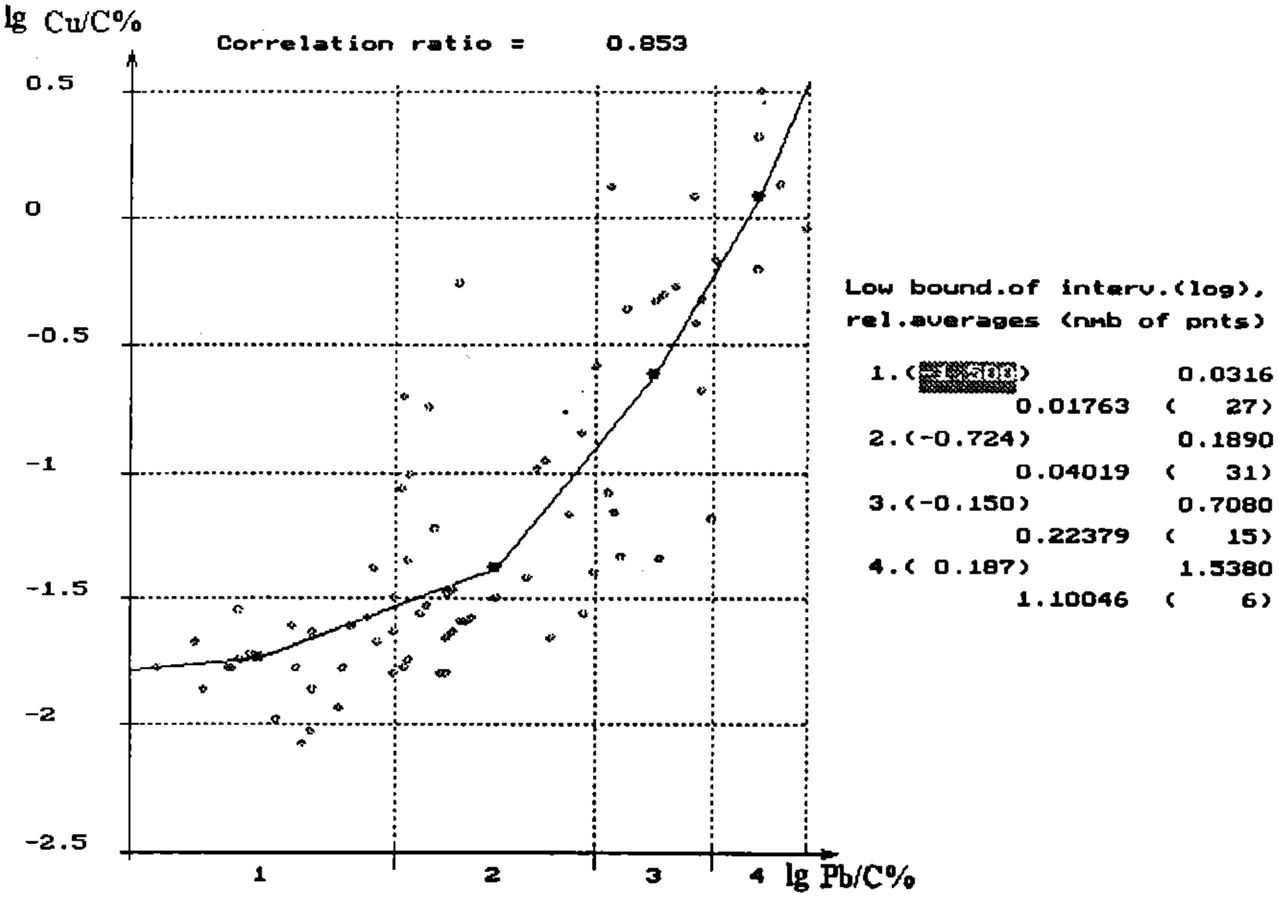
5 cm



```
Low bound.of interv.(log),
rel.averages (nmb of pnts)

 1.(-1.385)             0.0260
          0.10500  (    20)
 2.(-0.893)             0.1280
          0.23609  (    28)
 3.(-0.335)             0.4620
          0.58722  (    17)
 4.( 0.385)             2.4240
          1.21447  (    14)
```

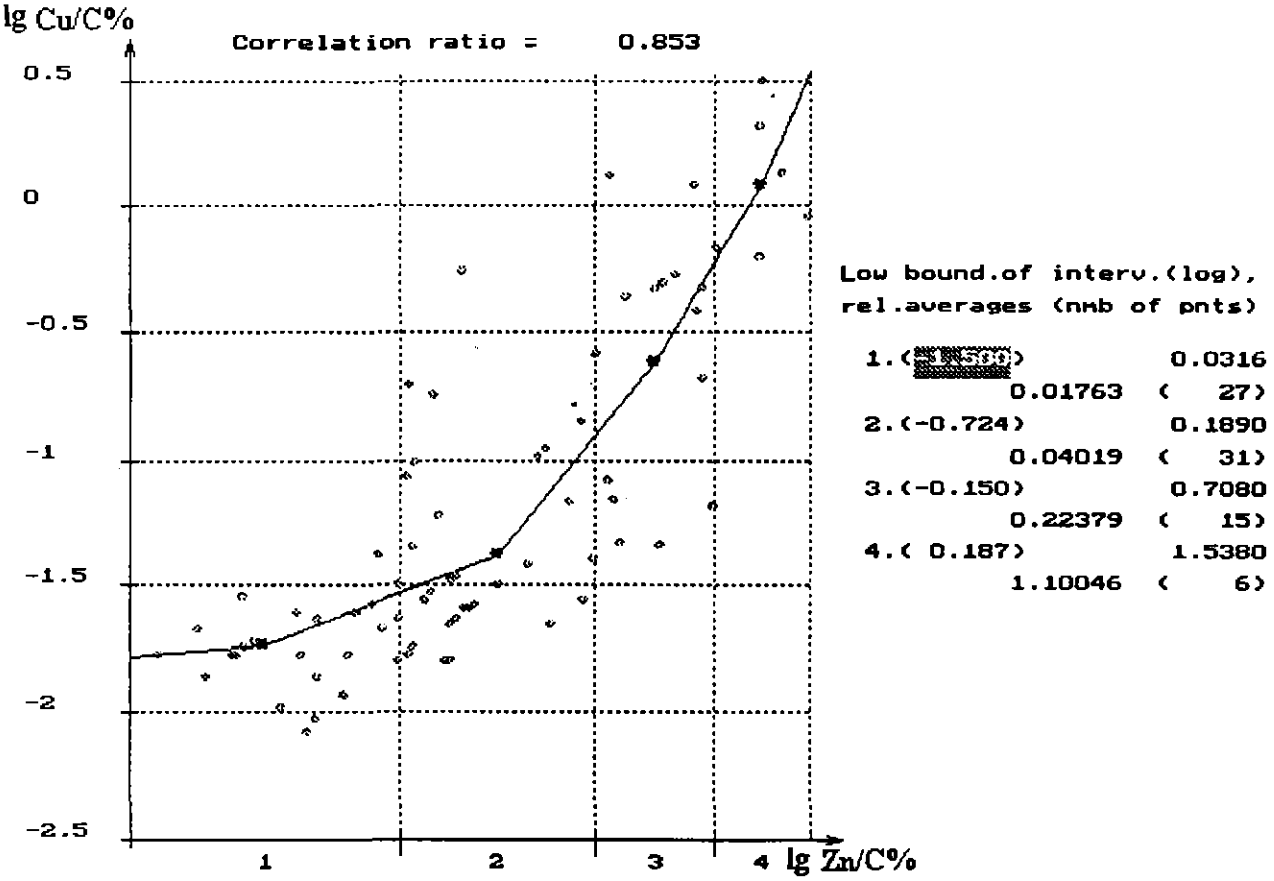
Fig.18. Correlation field Pb/C - Zn/C Tasmania - Zeehan.



```
Low bound.of interv.(log),
rel.averages (nmb of pnts)

 1.(-1.288)            0.0316
          0.01763  (   27)
 2.(-0.724)            0.1890
          0.04019  (   31)
 3.(-0.150)            0.7080
          0.22379  (   15)
 4.( 0.187)            1.5380
          1.10046  (    6)
```

Fig.19. Correlation field Cu/C - Pb/C Tasmania - Zeehan.



```
Correlation ratio =     0.853
```

```
Low bound.of interv.(log),
rel.averages (nmb of pnts)

 1.([redacted])               0.0316
          0.01763    (    27)
 2.(-0.724)               0.1890
          0.04019    (    31)
 3.(-0.150)               0.7080
          0.22379    (    15)
 4.( 0.187)               1.5380
          1.10046    (     6)
```

Fig. 20. Correlation field   Cu/C - Zn/C   Tasmania - Zeehan.

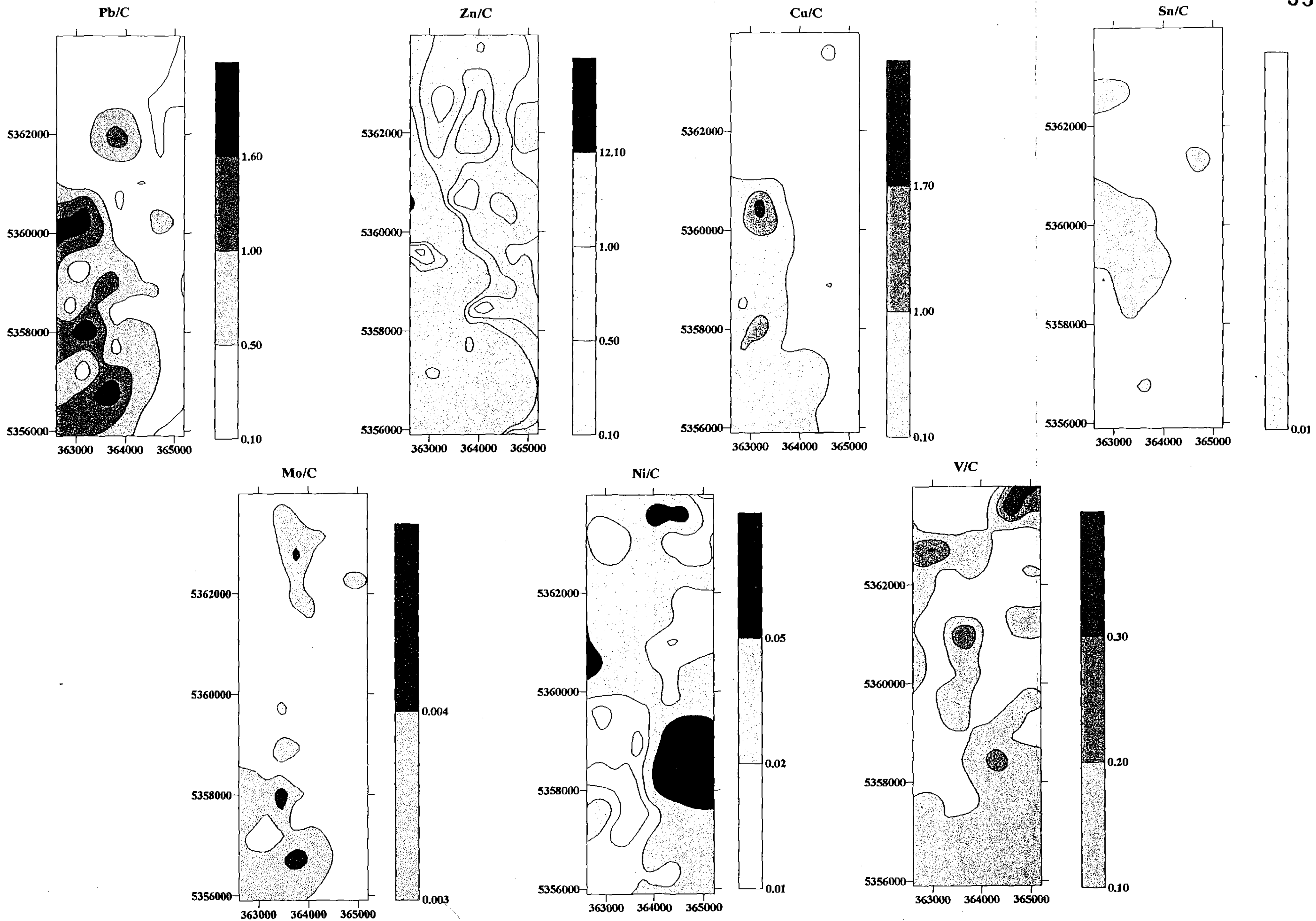


Fig. 21. Element - indicators of lead-zinc-silver ore deposit for the area EL 14-94 Zeehan, Tasmania.

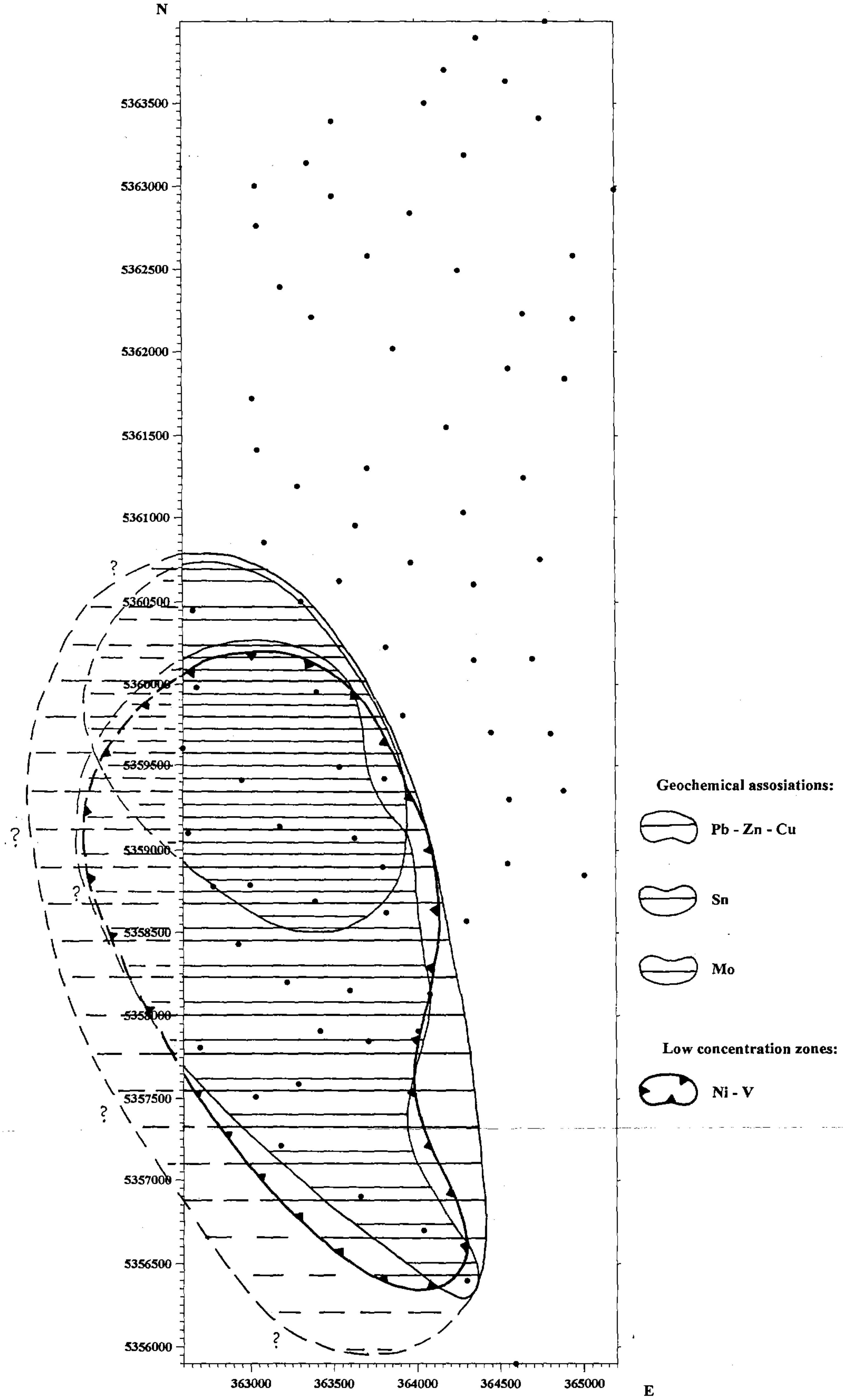


Fig. 22. Theoretic distribution of MPF elements. Tasmania. Scale 1:25,000

5 cm

Sample No	East	North	C ppm	Au/100000	Au/Copr*10000	Ag/100000	Ag/Copr*10000	Cu	Cu/Copr	Pb	Pb/Copr	Zn	Zn/Copr	Mo	Mo/Copr
				Metal, ppm, Metal(Me)/Carbon(C)%											
1	363090	5360850	420	1.40	0.033	66	1.57	0.70	0.167	1.00	0.238	1.00	0.238	0.006	0.0014
2	363290	5361190	330	2.70	0.082	4700	142.42	0.30	0.091	0.70	0.212	8.00	2.424	0.006	0.0018
3	363710	5361300	260	14.00	0.538	3900	150.00	0.04	0.015	0.70	0.269	0.70	0.269	0.006	0.0023
4	364190	5361550	188	2.10	0.112	34	1.81	0.04	0.021	1.00	0.532	1.20	0.638	0.006	0.0032
5	364560	5361900	300	3.70	0.123	66	2.20	0.04	0.013	0.16	0.053	0.32	0.107	0.006	0.0020
6	364650	5362230	256	1.80	0.070	340	13.28	0.04	0.016	0.10	0.039	0.14	0.055	0.008	0.0031
7	364950	5362580	256	3.30	0.129	45	1.76	0.04	0.016	0.16	0.063	0.10	0.039	0.004	0.0017
8	364950	5362200	152	4.00	0.263	45	2.96	0.04	0.026	0.34	0.224	0.54	0.355	0.006	0.0039
9	365200	5362980	245	0.12	0.005	75	3.06	0.04	0.016	0.16	0.065	0.32	0.131	0.006	0.0024
10	363050	5361410	240	2.00	0.083	54	2.25	0.04	0.017	0.50	0.208	0.32	0.133	0.006	0.0025
11	363020	5361720	200	6.50	0.325	130	6.50	0.04	0.020	0.34	0.170	0.32	0.160	0.006	0.0030
12	363380	5362210	305	2.40	0.079	51	1.67	0.08	0.026	2.00	0.656	0.40	0.131	0.006	0.0020
13	363720	5362580	180	1.70	0.094	110	6.11	0.04	0.022	0.50	0.278	0.32	0.178	0.008	0.0044
14	363970	5362840	160	1.00	0.063	43	2.69	0.04	0.025	0.50	0.313	2.80	1.750	0.006	0.0038
15	364300	5363190	187	1.50	0.080	42	2.25	0.04	0.021	0.50	0.267	0.54	0.289	0.006	0.0032
16	364750	5363410	310	2.10	0.068	58	1.87	0.04	0.013	0.34	0.110	0.32	0.103	0.006	0.0019
17	364550	5363630	495	1.20	0.024	170	3.43	0.90	0.182	1.00	0.202	2.80	0.566	0.008	0.0016
18	364790	5363990	250	0.90	0.036	300	12.00	0.04	0.016	0.34	0.136	0.32	0.128	0.006	0.0024
19	364370	5363890	265	0.12	0.005	100	3.77	0.08	0.030	0.50	0.189	0.40	0.151	0.006	0.0023
20	364180	5363700	400	0.72	0.018	100	2.50	0.08	0.020	0.20	0.050	0.40	0.100	0.006	0.0015
21	364060	5363500	265	1.20	0.045	82	3.09	0.04	0.015	0.50	0.189	0.40	0.151	0.006	0.0023
22	363500	5363390	160	2.60	0.163	77	4.81	0.04	0.025	0.50	0.313	0.40	0.250	0.006	0.0038
23	363350	5363140	145	2.10	0.145	24	1.66	0.04	0.028	0.34	0.234	0.40	0.276	0.004	0.0030
24	363500	5362940	180	1.50	0.083	33	1.83	0.04	0.022	0.20	0.111	0.18	0.100	0.006	0.0033
25	363050	5362760	460	2.20	0.048	190	4.13	0.04	0.009	0.50	0.109	0.14	0.030	0.004	0.0010
26	363040	5363000	370	1.90	0.051	91	2.46	0.08	0.022	0.70	0.189	0.70	0.189	0.004	0.0012
27	363190	5362390	390	2.70	0.069	190	4.87	0.04	0.010	0.34	0.087	0.14	0.036	0.004	0.0011
28	363870	5362020	130	3.90	0.300	75	5.77	0.08	0.062	2.00	1.538	3.40	2.615	0.004	0.0034
29	364260	5362490	500	0.12	0.002	320	6.40	0.08	0.016	0.50	0.100	0.14	0.028	0.003	0.0007
30	364900	5361840	205	2.40	0.117	260	12.68	0.08	0.039	0.34	0.166	0.40	0.195	0.004	0.0021
31	364650	5361240	235	2.00	0.085	130	5.53	0.04	0.017	0.16	0.068	0.06	0.026	0.003	0.0014
32	364750	5360750	330	1.10	0.033	36	1.09	0.08	0.024	1.00	0.303	1.20	0.364	0.006	0.0018
33	364350	5360600	220	3.50	0.159	160	7.27	0.08	0.036	1.00	0.455	1.60	0.727	0.006	0.0027
34	364700	5360160	212	3.70	0.175	52	2.45	0.08	0.038	1.50	0.708	1.20	0.566	0.004	0.0021
35	364350	5360150	250	1.50	0.060	49	1.96	0.08	0.032	0.70	0.280	0.70	0.280	0.004	0.0018
36	364450	5359700	340	4.20	0.124	80	2.35	0.08	0.024	1.00	0.294	0.32	0.094	0.004	0.0013
37	364810	5359690	315	1.30	0.041	90	2.86	0.08	0.025	0.50	0.159	0.18	0.057	0.006	0.0019
38	364890	5359350	410	2.70	0.066	35	0.85	0.08	0.020	0.70	0.171	0.70	0.171	0.008	0.0020
39	364560	5359300	352	3.30	0.094	93	2.64	0.08	0.023	0.50	0.142	0.40	0.114	0.006	0.0017
40	365010	5358850	480	1.00	0.021	140	2.92	0.04	0.008	0.50	0.104	0.70	0.146	0.004	0.0009

Sample No	East	North	C ppm	Au/100000	Au/Copr*10000	Ag/100000	Ag/Copr*10000	Cu	Cu/Copr	Pb	Pb/Copr	Zn	Zn/Copr	Mo	Mo/Copr
				Metal, ppm, Metal(Me)/Carbon(C)%											
41	364550	5358920	230	1.90	0.083	17	0.74	0.30	0.130	1.50	0.652	2.00	0.870	0.006	0.0026
42	364300	5358570	270	3.30	0.122	140	5.19	0.04	0.015	0.70	0.259	0.54	0.200	0.006	0.0022
43	364080	5358130	247	0.90	0.036	92	3.72	0.16	0.065	2.00	0.810	0.54	0.219	0.006	0.0024
44	363310	5360500	425	3.10	0.073	1200	28.24	12.00	2.824	9.00	2.118	3.40	0.800	0.003	0.0008
45	362680	5359980	212	3.10	0.146	100	4.72	1.20	0.566	4.40	2.075	1.00	0.472	0.006	0.0028
46	362600	5359600	210	0.93	0.044	70	3.33	0.90	0.429	3.00	1.429	0.54	0.257	0.006	0.0029
47	362630	5359100	270	0.51	0.019	55	2.04	1.20	0.444	3.00	1.111	6.00	2.222	0.006	0.0022
48	362780	5358780	230	1.90	0.083	72	3.13	0.90	0.391	2.00	0.870	2.00	0.870	0.006	0.0026
49	362930	5358430	260	1.00	0.038	65	2.50	0.04	0.015	0.70	0.269	6.00	2.308	0.008	0.0031
50	363220	5358200	430	6.60	0.153	710	16.51	8.00	1.860	9.00	2.093	21.00	4.884	0.008	0.0019
51	363420	5357910	210	6.00	0.286	300	14.29	1.70	0.810	6.00	2.857	14.00	6.667	0.016	0.0076
52	362700	5357810	280	1.50	0.054	100	3.57	1.70	0.607	4.40	1.571	21.00	7.500	0.011	0.0039
53	363030	5357510	255	2.50	0.098	150	5.88	3.00	1.176	2.00	0.784	1.60	0.627	0.008	0.0031
54	363180	5357210	500	1.20	0.024	150	3.00	0.40	0.080	1.00	0.200	2.00	0.400	0.011	0.0022
55	363660	5356980	247	8.10	0.328	54	2.19	3.00	1.215	6.00	2.429	21.00	8.502	0.011	0.0045
56	364040	5356700	285	0.55	0.019	120	4.21	1.20	0.421	3.00	1.053	2.00	0.702	0.011	0.0039
57	364300	5356400	195	1.80	0.092	100	5.13	0.20	0.103	1.00	0.513	10.00	5.128	0.006	0.0031
58	364590	5355900	300	2.20	0.073	52	1.73	0.08	0.027	0.20	0.067	0.24	0.080	0.006	0.0020
59	362660	5360450	250	2.10	0.084	410	16.40	1.20	0.480	3.00	1.200	42.00	16.800	0.006	0.0024
60	363710	5357850	270	4.10	0.152	640	23.70	0.08	0.030	1.00	0.370	1.60	0.593	0.006	0.0022
61	364010	5357910	180	0.81	0.045	24	1.33	0.08	0.044	1.50	0.833	6.00	3.333	0.006	0.0033
62	363600	5358150	220	0.80	0.036	96	4.36	0.04	0.018	0.16	0.073	0.54	0.245	0.006	0.0027
63	363820	5358620	285	3.30	0.116	64	2.25	0.16	0.056	0.70	0.246	0.40	0.140	0.004	0.0015
64	363630	5359070	210	1.40	0.067	140	6.67	0.40	0.190	3.00	1.429	8.00	3.810	0.006	0.0029
65	363390	5358690	145	2.10	0.145	76	5.24	0.50	0.345	2.00	1.379	10.00	6.897	0.006	0.0041
66	363000	5358790	310	1.10	0.035	130	4.19	0.30	0.097	1.50	0.484	14.00	4.516	0.006	0.0019
67	363290	5357590	250	3.40	0.136	900	36.00	0.16	0.064	1.50	0.600	21.00	8.400	0.006	0.0024
68	363640	5360950	480	1.80	0.038	86	1.79	0.20	0.042	1.00	0.208	0.32	0.067	0.006	0.0013
69	363540	5360620	315	0.50	0.016	150	4.76	0.08	0.025	0.50	0.159	0.24	0.076	0.004	0.0014
70	364290	5361030	235	1.50	0.064	44	1.87	0.04	0.017	0.16	0.068	0.54	0.230	0.006	0.0026
71	363970	5360730	350	0.47	0.013	14	0.40	0.08	0.023	0.34	0.097	0.40	0.114	0.006	0.0017
72	363820	5360230	380	0.75	0.020	98	2.58	0.04	0.011	0.50	0.132	0.32	0.084	0.006	0.0016
73	363920	5359800	260	1.90	0.073	47	1.81	0.08	0.031	0.70	0.269	1.20	0.462	0.006	0.0023
74	363810	5359420	260	2.70	0.104	9600	369.23	0.20	0.077	2.00	0.769	3.40	1.308	0.006	0.0023
75	363800	5358900	185	3.50	0.189	110	5.95	0.08	0.043	2.00	1.081	6.00	3.243	0.006	0.0032
76	362950	5359410	494	1.30	0.026	280	5.67	0.08	0.016	1.00	0.202	0.54	0.109	0.004	0.0009
77	363180	5359140	240	0.75	0.031	230	9.58	1.20	0.500	0.70	0.292	3.40	1.417	0.006	0.0025
78	363540	5359490	210	3.60	0.171	200	9.52	0.50	0.238	1.50	0.714	0.32	0.152	0.006	0.0029
79	363400	5359950	220	0.90	0.041	99	4.50	2.40	1.091	3.00	1.364	8.00	3.636	0.008	0.0036

Sample No	V	V/Copr	Ni	Ni/Copr	Co	Co/Copr	Sn	Sn/Copr	Ga	Ga/Copr	As	As/Copr
	Metal, ppm, Metal(Me)/Carbon(C)%											
1	0.2	0.048	0.10	0.024	0.004	0.0010	0.011	0.0026	0.006	0.0014	0.036	0.0086
2	0.2	0.061	0.10	0.030	0.004	0.0012	0.011	0.0033	0.024	0.0073	0.036	0.0109
3	0.2	0.077	0.10	0.038	0.004	0.0015	0.020	0.0077	0.003	0.0012	0.036	0.0138
4	0.1	0.053	0.06	0.032	0.004	0.0021	0.011	0.0059	0.003	0.0016	0.036	0.0191
5	0.1	0.033	0.04	0.013	0.004	0.0013	0.006	0.0020	0.003	0.0010	0.036	0.0120
6	0.2	0.078	0.06	0.023	0.002	0.0008	0.006	0.0023	0.003	0.0012	0.036	0.0141
7	0.1	0.039	0.04	0.016	0.002	0.0008	0.006	0.0023	0.240	0.0938	0.050	0.0195
8	0.2	0.132	0.04	0.026	0.002	0.0013	0.006	0.0039	0.003	0.0020	0.036	0.0237
9	0.2	0.082	0.06	0.024	0.002	0.0008	0.001	0.0006	0.006	0.0024	0.036	0.0147
10	0.2	0.083	0.10	0.042	0.002	0.0008	0.006	0.0025	0.006	0.0025	0.036	0.0150
11	0.2	0.100	0.10	0.050	0.002	0.0010	0.006	0.0030	0.003	0.0015	0.036	0.0180
12	0.2	0.066	0.10	0.033	0.002	0.0007	0.003	0.0010	0.006	0.0020	0.036	0.0118
13	0.4	0.222	0.06	0.033	0.004	0.0022	0.003	0.0017	0.006	0.0033	0.036	0.0200
14	0.2	0.125	0.04	0.025	0.002	0.0013	0.003	0.0019	0.003	0.0019	0.036	0.0225
15	0.2	0.107	0.02	0.011	0.002	0.0011	0.003	0.0016	0.003	0.0016	0.036	0.0193
16	0.4	0.129	0.06	0.019	0.004	0.0013	0.003	0.0010	0.003	0.0010	0.036	0.0116
17	2.5	0.505	0.40	0.081	0.016	0.0032	0.040	0.0081	0.700	0.1414	0.050	0.0101
18	0.9	0.360	0.02	0.008	0.002	0.0008	0.006	0.0024	0.700	0.2800	0.050	0.0200
19	0.2	0.075	0.10	0.038	0.028	0.0106	0.001	0.0005	0.006	0.0023	0.036	0.0136
20	0.2	0.050	0.14	0.035	0.004	0.0010	0.003	0.0008	0.013	0.0033	0.036	0.0090
21	0.2	0.075	0.20	0.075	0.004	0.0015	0.001	0.0005	0.013	0.0049	0.036	0.0136
22	0.2	0.125	0.04	0.025	0.002	0.0013	0.011	0.0069	0.006	0.0038	0.036	0.0225
23	0.1	0.069	0.02	0.014	0.002	0.0014	0.001	0.0010	0.006	0.0041	0.036	0.0248
24	0.1	0.056	0.03	0.017	0.004	0.0022	0.001	0.0008	0.006	0.0033	0.036	0.0200
25	1.9	0.413	0.06	0.013	0.004	0.0009	0.130	0.0283	0.006	0.0013	0.036	0.0078
26	0.1	0.027	0.06	0.016	0.004	0.0011	0.002	0.0006	0.006	0.0016	0.036	0.0097
27	0.4	0.103	0.10	0.026	0.004	0.0010	0.020	0.0051	0.006	0.0015	0.036	0.0092
28	0.1	0.077	0.03	0.023	0.002	0.0015	0.001	0.0011	0.024	0.0185	0.036	0.0277
29	0.4	0.080	0.14	0.028	0.006	0.0012	0.020	0.0040	0.024	0.0048	0.036	0.0072
30	0.1	0.049	0.03	0.015	0.002	0.0010	0.001	0.0007	0.006	0.0029	0.036	0.0176
31	0.4	0.170	0.02	0.009	0.002	0.0009	0.050	0.0213	0.006	0.0026	0.036	0.0153
32	0.2	0.061	0.06	0.018	0.004	0.0012	0.001	0.0004	0.013	0.0039	0.036	0.0109
33	0.1	0.045	0.04	0.018	0.002	0.0009	0.001	0.0006	0.013	0.0059	0.036	0.0164
34	0.1	0.047	0.06	0.028	0.004	0.0019	0.001	0.0007	0.024	0.0113	0.036	0.0170
35	0.1	0.040	0.04	0.016	0.004	0.0016	0.001	0.0006	0.013	0.0052	0.036	0.0144
36	0.2	0.059	0.06	0.018	0.002	0.0006	0.003	0.0009	0.090	0.0265	0.050	0.0147
37	0.4	0.127	0.10	0.032	0.004	0.0013	0.003	0.0010	0.044	0.0140	0.036	0.0114
38	0.4	0.098	0.26	0.063	0.006	0.0015	0.006	0.0015	0.006	0.0015	0.050	0.0122
39	0.5	0.142	0.26	0.074	0.002	0.0006	0.006	0.0017	0.120	0.0341	0.050	0.0142
40	0.4	0.083	0.26	0.054	0.004	0.0008	0.006	0.0013	0.090	0.0188	0.036	0.0075

Appendix 1

Sample No	V	V/Copr	Ni	Ni/Copr	Co	Co/Copr	Sn	Sn/Copr	Ga	Ga/Copr	As	As/Copr
	Metal, ppm, Metal(Me)/Carbon(C)%											
41	0.2	0.087	0.24	0.104	0.002	0.0009	0.011	0.0048	0.003	0.0013	0.036	0.0157
42	0.7	0.259	0.23	0.085	0.002	0.0007	0.011	0.0041	0.120	0.0444	0.050	0.0185
43	0.4	0.162	0.22	0.089	0.002	0.0008	0.011	0.0045	0.060	0.0243	0.036	0.0146
44	0.2	0.047	0.14	0.033	0.004	0.0009	0.070	0.0165	0.060	0.0141	0.036	0.0085
45	0.2	0.094	0.04	0.019	0.004	0.0019	0.040	0.0189	0.024	0.0113	0.036	0.0170
46	0.2	0.095	0.02	0.010	0.002	0.0010	0.020	0.0095	0.024	0.0114	0.036	0.0171
47	0.2	0.074	0.06	0.022	0.004	0.0015	0.040	0.0148	0.024	0.0089	0.036	0.0133
48	0.1	0.043	0.02	0.009	0.002	0.0009	0.006	0.0026	0.003	0.0013	0.036	0.0157
49	0.2	0.077	0.02	0.008	0.002	0.0008	0.006	0.0023	0.003	0.0012	0.036	0.0138
50	0.2	0.047	0.04	0.009	0.002	0.0005	0.040	0.0093	0.013	0.0030	0.036	0.0084
51	0.1	0.048	0.01	0.005	0.002	0.0010	0.040	0.0190	0.003	0.0014	0.036	0.0171
52	0.2	0.071	0.03	0.011	0.004	0.0014	0.020	0.0071	0.003	0.0011	0.036	0.0129
53	0.4	0.157	0.10	0.039	0.01	0.0039	0.006	0.0024	0.006	0.0024	0.036	0.0141
54	0.5	0.100	0.03	0.006	0.006	0.0012	0.003	0.0006	0.090	0.0180	0.050	0.0100
55	0.4	0.162	0.03	0.012	0.004	0.0016	0.040	0.0162	0.006	0.0024	0.036	0.0146
56	0.5	0.175	0.10	0.035	0.004	0.0014	0.006	0.0021	0.006	0.0021	0.036	0.0126
57	0.2	0.103	0.02	0.010	0.004	0.0021	0.011	0.0056	0.003	0.0015	0.036	0.0185
58	0.4	0.133	0.10	0.033	0.004	0.0013	0.011	0.0037	0.006	0.0020	0.036	0.0120
59	0.4	0.160	0.20	0.080	0.004	0.0016	0.070	0.0280	0.006	0.0024	0.080	0.0320
60	0.2	0.074	0.02	0.007	0.002	0.0007	0.006	0.0022	0.003	0.0011	0.036	0.0133
61	0.2	0.111	0.02	0.011	0.002	0.0011	0.020	0.0111	0.003	0.0017	0.036	0.0200
62	0.2	0.091	0.01	0.005	0.002	0.0009	0.006	0.0027	0.003	0.0014	0.036	0.0164
63	0.4	0.140	0.03	0.011	0.002	0.0007	0.011	0.0039	0.044	0.0154	0.050	0.0175
64	0.1	0.048	0.02	0.010	0.002	0.0010	0.400	0.1905	0.003	0.0014	0.036	0.0171
65	0.1	0.069	0.02	0.014	0.002	0.0014	0.070	0.0483	0.003	0.0021	0.036	0.0248
66	0.1	0.032	0.06	0.019	0.002	0.0006	0.020	0.0065	0.003	0.0010	0.036	0.0116
67	0.2	0.080	0.01	0.004	0.002	0.0008	0.003	0.0012	0.003	0.0012	0.036	0.0144
68	1.9	0.396	0.10	0.021	0.004	0.0008	0.006	0.0013	0.340	0.0708	0.036	0.0075
69	0.6	0.190	0.10	0.032	0.004	0.0013	0.006	0.0019	0.024	0.0076	0.036	0.0114
70	0.1	0.043	0.02	0.009	0.002	0.0009	0.003	0.0013	0.003	0.0013	0.036	0.0153
71	0.2	0.057	0.04	0.011	0.004	0.0011	0.011	0.0031	0.003	0.0009	0.036	0.0103
72	0.6	0.158	0.14	0.037	0.004	0.0011	0.011	0.0029	0.090	0.0237	0.036	0.0095
73	0.1	0.038	0.06	0.023	0.004	0.0015	0.020	0.0077	0.003	0.0012	0.050	0.0192
74	0.2	0.077	0.03	0.012	0.002	0.0008	0.026	0.0100	0.003	0.0012	0.050	0.0192
75	0.2	0.108	0.02	0.011	0.004	0.0022	0.026	0.0141	0.003	0.0016	0.036	0.0195
76	0.2	0.040	0.02	0.004	0.002	0.0004	0.130	0.0263	0.170	0.0344	0.036	0.0073
77	0.2	0.083	0.04	0.017	0.004	0.0017	0.040	0.0167	0.003	0.0013	0.036	0.0150
78	0.6	0.286	0.03	0.014	0.004	0.0019	0.014	0.0067	0.090	0.0429	0.036	0.0171
79	0.2	0.091	0.04	0.018	0.004	0.0018	0.280	0.1273	0.006	0.0027	0.036	0.0164

Appendix 2

Control of Analysis

Replicas of 15 basic samples were selected to control analyses for Tasmania-Zeehan. The basic samples and coded replicas were analysed as one set in "Rudgeofizika" laboratory (St. Petersburg). The results of basic and control analyses are shown in Table 1.

Root-mean-square divergence and value of correlation between basic and control analyses were calculated for estimation of reliability of the analyses results for different elements.

Root-mean-square divergence for all elements, except carbon, were determined by the formula:

$$S_{lg} = \sqrt{\sum (\lg X_i - \lg Y_i)^2/15},$$

where Xi and Yi are the results of basic and control analyses in the pair (i from 1 to 15).

Value S shows how many times basic and control analyses differ in average. S for carbon shows what the average difference (in p.p.m.) between basic and control results. S characterises random divergence between basic and control analyses systematic divergence between them is equal to zero under the test conditions.

The force of the linear correlation association (R) was determined with the help of correlation relationship. Value R shows how much information on concentration of mobile forms of elements in soil is contained in the results of the analyses. When R=O - the information is equal to zero; when R=1 - the information is maximum.

Comparison of basic and control analysis shows:

1. The results of analyses for Cu, Pb, Zn (main metals in the section Tasmania - Zeehan) contain reliable information on the concentration of these elements in soil ($R > 0.9$; $S < 2$).

2. The results of analysis for C, Mo, Ni, Sn are less reliable but they can be used to study the fields of these elements concentration ($R = 0.5 - 0.8$).

3. The results of analyses for Au, Ag practically do not carry information on these elements concentration in soil (R is near 0.S = 4-5), Figs 1 and 2.

The latter can be associated with two reasons:

- low quality of the analyses;

- very high heterogeneity of these elements distribution in soil and in sample material.

Results of main and control analysis. Tasmania - Zeehan

Table 1

Number	Sample control	Sample	East	North	C control	C	Au/100000 control	Au/100000	Ag/100000 control	Ag/100000	Cu control	Cu	Pb control	Pb
					Metal, ppm									
1	85	4	364190	5361550	230	188	2.1	2.10	47	34	0.04	0.04	1	1.00
2	90	7	364950	5362580	285	256	4.8	3.30	2400	45	0.16	0.04	0.5	0.16
3	80	8	364950	5362200	210	152	21	4	110	45	0.08	0.04	0.7	0.34
4	91	10	363050	5361410	304	240	2.6	2	82	54	0.08	0.04	0.7	0.50
5	92	11	363020	5361720	345	200	0.12	6.5	82	130	0.16	0.04	0.5	0.34
6	86	16	364750	5363410	490	310	0.81	2.1	23	58	0.08	0.04	0.34	0.34
7	93	27	363190	5362390	400	390	1.5	2.7	49	190	0.08	0.04	0.5	0.34
8	81	36	364450	5359700	330	340	2.9	4.2	410	80	0.08	0.08	0.7	1.00
9	82	41	364550	5358920	215	230	0.66	1.9	81	17	0.7	0.30	1.5	1.50
10	94	42	364300	5358570	275	270	1.8	3.3	360	140	0.08	0.04	0.7	0.70
11	87	46	362600	5359600	175	210	1.6	0.93	270	70	0.7	0.90	3	3.00
12	83	51	363420	5357910	255	210	2.6	6	120	300	1.7	1.70	3	6.00
13	84	72	363820	5360230	240	380	5.3	0.75	190	98	0.04	0.04	0.34	0.50
14	88	73	363920	5359800	170	260	1.9	1.9	960	47	0.16	0.08	1	0.70
15	89	78	363540	5359490	175	210	17	3.6	130	200	0.5	0.50	2	1.50

Results of main and control analysis. Tasmania - Zeehan

Table 1

Number	Sample control	Sample	Zn control	Zn	Mo control	Mo	V control	V	Ni control	Ni	Co control	Co	Sn control	Sn	Ga control	Ga	As control	As
			Metal, ppm															
1	85	4	1.2	1.20	0.006	0.006	0.2	0.1	0.04	0.06	0.004	0.004	0.006	0.011	0.003	0.003	0.036	0.036
2	90	7	0.24	0.10	0.0044	0.004	0.4	0.1	0.02	0.04	0.002	0.002	0.006	0.006	0.24	0.240	0.05	0.050
3	80	8	0.54	0.54	0.006	0.006	0.1	0.2	0.03	0.04	0.002	0.002	0.011	0.006	0.003	0.003	0.036	0.036
4	91	10	0.24	0.32	0.006	0.006	0.4	0.2	0.1	0.10	0.006	0.002	0.006	0.006	0.006	0.006	0.05	0.036
5	92	11	0.24	0.32	0.006	0.006	0.4	0.2	0.1	0.10	0.006	0.002	0.006	0.006	0.024	0.003	0.05	0.036
6	86	16	0.18	0.32	0.006	0.006	0.2	0.4	0.06	0.06	0.004	0.004	0.006	0.003	0.006	0.003	0.036	0.036
7	93	27	0.24	0.14	0.006	0.004	0.6	0.4	0.14	0.10	0.006	0.004	0.011	0.020	0.044	0.006	0.05	0.036
8	81	36	0.4	0.32	0.0044	0.004	0.6	0.2	0.06	0.06	0.004	0.002	0.011	0.003	0.09	0.090	0.05	0.050
9	82	41	3.4	2.00	0.006	0.006	0.1	0.2	0.02	0.24	0.002	0.002	0.014	0.011	0.003	0.003	0.036	0.036
10	94	42	0.32	0.54	0.006	0.006	0.6	0.7	0.03	0.23	0.004	0.002	0.006	0.011	0.24	0.120	0.05	0.050
11	87	46	0.7	0.54	0.006	0.006	0.2	0.2	0.04	0.02	0.004	0.002	0.014	0.020	0.003	0.024	0.05	0.036
12	83	51	14	14.00	0.011	0.016	0.1	0.1	0.02	0.01	0.002	0.002	0.026	0.040	0.003	0.003	0.036	0.036
13	84	72	0.32	0.32	0.006	0.006	0.2	0.6	0.04	0.14	0.002	0.004	0.011	0.011	0.024	0.090	0.036	0.036
14	88	73	0.7	1.20	0.008	0.006	0.1	0.1	0.02	0.06	0.004	0.004	0.014	0.020	0.003	0.003	0.036	0.050
15	89	78	0.24	0.32	0.006	0.006	0.6	0.6	0.02	0.03	0.002	0.004	0.011	0.014	0.06	0.090	0.05	0.036

Table 2

Comparision of control and main analysis. Tasmania - Zeehan

Elements	Slg	S.	R
C	-	80ppm	0.64
Au	0.6	4	0.25
Ag	0.69	5	0.029
Cu	0.306	2	0.93
Pb	0.2	1.6	0.95
Zn	0.18	1.5	0.94
Mo	0.07	1.2	0.76
V	0.3	2	0.5
Ni	0.44	2.7	0.55

Slg - root- mean-square divergence of concentration logarithms in basic and control analyses.

S - antilogarithm of Slg.

S for carbon - standard deviation in ppm.

R - force of the linear relationship between logarithms of concentrations in basic and control analyses.

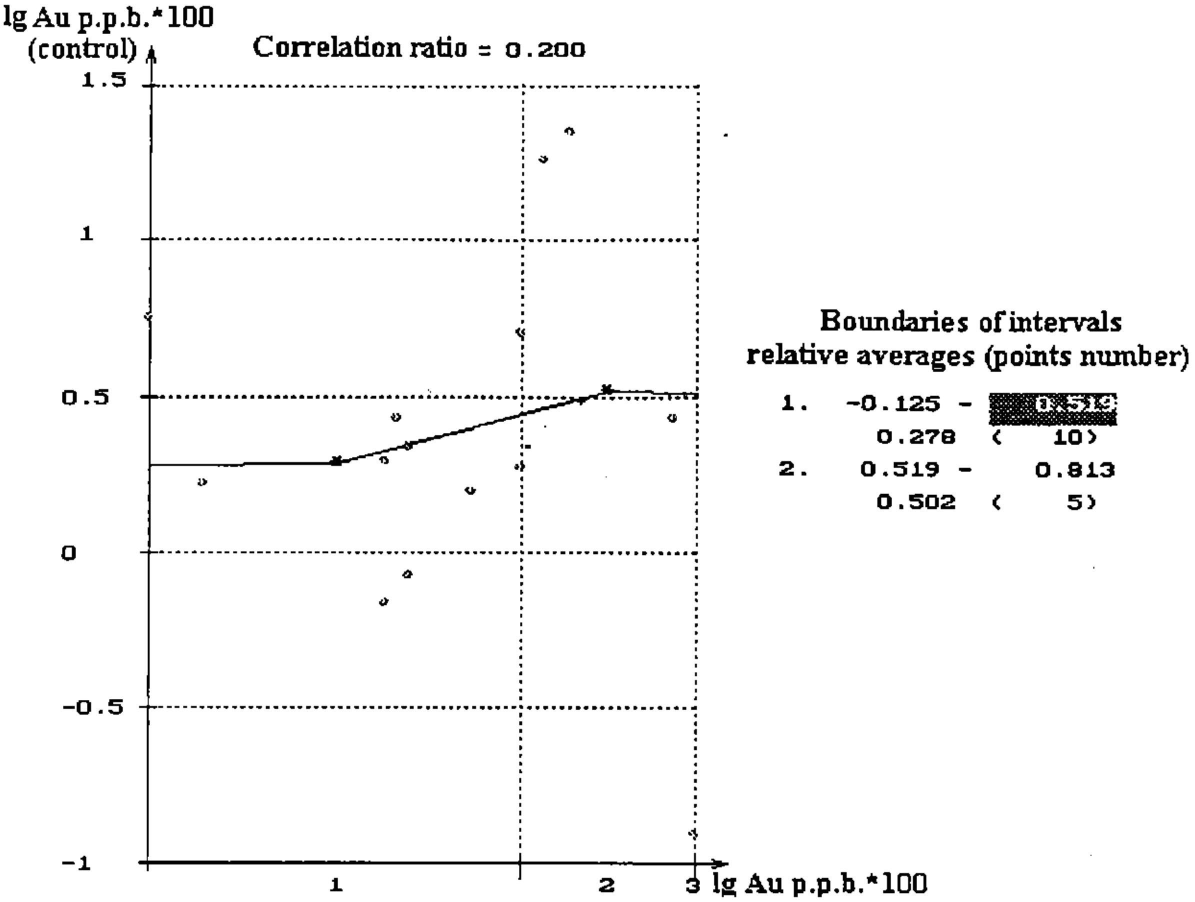


Fig. 1 . Correlation field of main and control analysis.
Au. Tasmania - Zeehan.

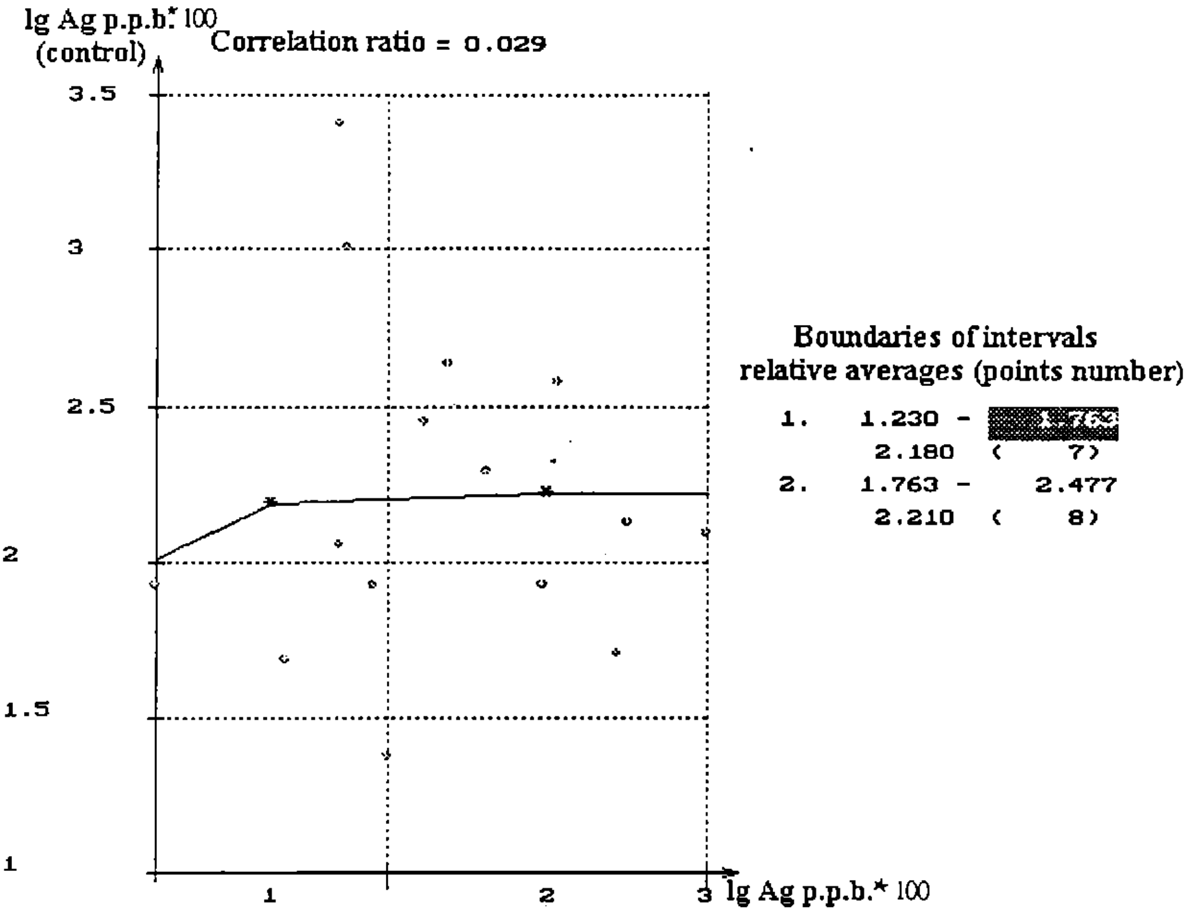


Fig. 2 . Correlation field of main and control analysis.
Au. Tasmania - Zeehan.

Appendix 3

A group of programs "ELAN" developed by Dr V Los "Mathematical methods of solving the problems of modelling and prognosis in geology" (Alma-Ata, Kazims, 1994) has been applied for the processing of data from analyses).

The maps are constructed on a basis of two approximation models using the approximation formula:

$$t\,(Z) = \sum_{i=1}^{n} w\,(Z;\,Z_i) * \; t\,(Z_i) \,/\, \sum_{i=1}^{n} w\,(Z;\,Z_i),$$

where $t\,(Z)$ are model values of characteristic of t in points with current coordinates ($Z \in V$, V is an area of modelling);

$t\,(Z_i)$ are measured values of the characteristic of t in points with coordinates Z_i (i from 1 to n where n is a number of points of measurements);

$w\,(Z;\,Z_i)$ is the "weight" of i-point of observation in the point with current coordinates Z.

The value $w\,(Z;\,Z_i)$ is defined by a special weight function:

$$w\,(Z;\,Z_i) = 1 \,/\, [1 + \lambda\,(R \,/\, \gamma)^{\alpha}\,],$$

where $R=R\,(Z;\,Z_i)$ is Euclidean distance between point i and the point with current coordinates Z;

Υ, λ, α are governing parametres.

Where parametre γ plays a role of a scale multiplier; parameter λ defines a degree of "smoothing" of the model field and the rank of distinguished structures ($R/\,\gamma > 1$); parameter α defines a value of the weight function of the nearest zone ($R/\,\gamma < 1$).

Quantitative indices $\gamma = 50$, $\lambda = 10$ $\alpha = 3$ have been used for construction the generalised approximation models which characterise the generalised pattern of the geochemical field.