MINERALOGICAL STUDY &
TREND SURFACE ANALYSIS
OF THE LAD GROUP
By: R.B.Findlay , 1968
(Part of Thesis)

Tom Adamson

2955 W. 31st Ave.,
Vancouver 8, B. C.,
March 27th, 1969.

Dr. W. H. Mathews,
Department Head,
Geology Department,
U. B. C.

Dear Sir:

This thesis "Mineralogical Study and Trend Surface Analysis of the Lad Group, Y. T." is submitted as partial fulfillment of the requirements for a B. A. Sc. degree at the University of British Columbia.

Respectfully submitted,

R. B. Findlay

R. B. Findlay.

RBF/FF

Mineralogical Study and Trend Surface Analysis of the Lad Group, Y. T.

Table of Contents

Table of Illustrations and Tables	i
Preface	1
Abstract	2
Introduction	3
Regional Geology	3
Grid Geology	4
Megascopic Description of Mineralogy	5
Mineralogy	5
Trend Surfaces	11
Comparison of Sixth Order Trend Surfaces - Test Area	14
Comparison of Second Order Residuals - Test Area	15
High Order Trend Surfaces vs. Hand Contoured Surfaces - Test Area	16
Low Order Residuals vs. Hand Contoured Surfaces - Test Area	18
Low Order Surfaces and Conclusions - Test Area	19
Application of Results to Remaining Areas	20
Conclusions	22
Bibliography	23
Appendix I - Geology map of Test and Central Areas	
Appendix II - Plan of Grid	
Appendix III - Maps from Test Area	
Appendix IV - Maps from Central and East Areas	

Table of Illustrations and Tables

Table 1 - Table of Geologic Formations 5

Table 2 - Field Description of Mineral Occurrences 7

Figure 1 - Vandeveer Diagram 12

Figure 2 - Textural Features 13

Preface

Claims of the Lad Group were staked originally by Atlas Explorations Ltd. (N.P.L.) in the fall of 1967. Since the summer of 1968 the Group consists of 208 contiguous claims located approximately at 132°14' W. Longitude and 62°56' N. Latitude. Extensive ground and airborne ~~work~~ surveys have revealed the presence of eleven mineralized showings. The thesis originated as a study of the mineral suite with particular emphasis on determining silver associations.

The writer spent approximately four days on the property while employed by Atlas Explorations in the summer of 1968 and carried out laboratory work during the last several months. Application of Trend Surface Analysis came at the suggestion of Dr. A. J. Sinclair.

I wish to acknowledge the assistance given me by Dr. A. J. Sinclair and T. J. Adamson, of Atlas Explorations Ltd.

Abstract

Polished section studies reveal a very simple mineralogy and paragenesis for the Lad Group. The minerals in order of deposition are pyrite, galena, sphalerite with exsolved chalcopyrite, chalcopyrite, tetrahedrite, pyrargyrite and native silver. Several replacement textures were found and the silver is believed to be associated primarily with the tetrahedrite. The case study area revealed that the best fit to known results was achieved through the use of low order residuals as opposed to high order trend surfaces. The results were applied to the remaining regions as a directive for exploration work and were found to correspond quite closely to known data. Trend surface analysis is believed to be a very important technique for exploration purposes.

succesion?

Introduction

The Lad Group, a block of 208 claims is approximately 65 miles north of Ross River, Y. T. at 132°14' W. Longitude 62°56' N. Latitude. More specifically it is on the south east slope of Mt. Selous. The property was staked originally in the fall of 1967 to cover three minor sulphide occurrences and was expanded to its present size in 1968. From July 23 to September 28, 1968 between five and fifteen men worked out of the camp involved with line-cutting, geological mapping and prospecting, geochemical and geophysical (ground and airborne) surveying, hand trenching and assay sampling. Geological mapping was done on a grid at a scale of 1" = 400'. The grid consisting of approximately 80 miles of line, was soil sampled every 100' and it is from these sample results that data was taken for the Trend Surface Analysis program. Mineralogy of the area will be discussed with respect to paragenesis, mineral association and origin.

Regional Geology

Lad Group is located slightly N.E. of a N.W. - S. E. trending lineament coicident with the S. MacMillan River valley. This zone bears resemblance to the Tintina Fault. The area is underlain by N. W. trending rocks, that are open to tightly folded. Within two miles of the Lad lies the Mt. Selous-Armstrong intrusive complex consisting of two major plutons that range from granodiorite to quartz diorite in composition. The Complex also trends N.W.-S.E. and is N.E. of the property. Two main stratigraphic units, Proterozoic and Devonian - Mississippian, are exposed within the area. The older unit is composed of quartzites, phyllites and limestones; the younger is primarily metasediments with graphitic cherts, shales and slates, and chert pebble conglomerates being the main rock types. A stratigraphic column is listed in Table 1.

Grid Geology

Exposures within the Lad group are restricted primarily to creek beds. As previously mentioned the area is underlain by Proterozoic rocks with attitudes 120° - 150°/ 49° - 90° N.E. with rare S.W. dips. Unit 1a of the stratigraphic column predominates and grades vertically upward from a clean blocky quartzite to a well bedded feldspathic micaeous quartzite to a quartzose sericite chert. Minor occurrences of limestone and phyllite of this age are present.

Devonian - Mississippian rocks previously mentioned have been infolded (?) into the Proterozoic materials. A small pluton and dike of orthoclase porphyry composition are also exposed. Although no detailed geology has been performed on the eastern portions, reconnaissance work indicates that it is similar. (See Appendix E, Fig. 1.).

Table I

Table of Geologic Formations

Cretaceous 11		Granitic Intrusives
		----------Intrusive Contact----------
Devonian-Mississippian (?) 3	3h	Chert; finely laminated, green and white chert and associated slates, green chert (Upper Devonian ?)
	3g	Red and green slates
	3f	Grey bedded chert (Upper Devonian ?)
	3e	Alkalic basalt (?)
	3d	Chert-pebble conglomerate, minor quartzite (Upper Devonian ?)
	3c	Phyllite, grey to green, indurated slates
	3b	Calcareous rocks; limestone, crystalline and argillaceous; calcareous argillite, chert-pebble limestone, minor dolomite.
	3a	Carbonaceous rocks; graphitic slates; black chert; graphitic argillite; poorly sorted feldspathic quartzites (graphitic greywacke) Mississippian (?) in part; clastic unit).
		-------Unconformity or Fault Contact----------
Proterozoic 1	1e	Chloritic schists, biotite quartzite, phyllite with interbeds of buff sandstone and quartzite.
	1d	Conglomerate; massive, quartz pebbles.
"Yukon Group"	1c	Phyllite and serecitic schists; occasionally gritty.
*Bostock	1b	Limestone; finely crystalline, banded to massive; minor quartz-pebble limestone.
	1a	Quartzite, feldspathic quartzite, minor sericite schist, phyllite and slate.

Note: Alphabetical designations ascribed to the various rock-units have no time or sequential significance.

Megascopic Description of Mineralogy

Mineralogy of individual field occurrences, of which eleven have been found to date, will be described briefly in Table 2. If polished section studies reveal separate pargenetic sequences for the showings individual descriptions will also be made on a microscopic scale. Otherwise a condensed description will be given.

Mineralogy

As mentioned in the previous section the mineralogy of the Lad Group is relatively simple and because the polished section studies revealed a similar pargenetic sequence and mineralogy for all of the showings on the property the results will be discussed as a whole rather than for the individual occurrences. Not all the minerals previously discussed were found in the polished section work, but the majority were. In order of overall abundance, they are pyrite, galena, sphalerite with chalcopyrite exsolved, chalcopyrite, tetrahedrite, pyrargyrite and native silver. Examination revealed that sulphides are most abundant in the skarns. Furthermore, sulphides are rare near the walls of veins. Within the central portion of the veins the mineralization is massive and gangue, either carbonate or quartz, is present in negligible quantities. Individual minerals will be discussed in order of their overall abundance for the area with no weighting on the basis of the size

Table 2

Field Description of Mineral Occurrences

Showing	Wallrock	Structure	Gangue	Sulphides
A	quartz sericite schist 130°/20°S	shear <1' wide 155°/20°S	quartz	galena sphalerite pyrite
B	quartz sericite schist	shear 3-5' for 30' 015°/20°E mineralization along footwall		chalcopyrite galena sphalerite pyrrhotite pyrite
C	quartzite 135°/20°S	vein 150°/20°S	quartz	chalcopyrite galena
D	quartzite	3' wide 030°/90°		pyrite, minor pyrrhotite and arsenopyrite
E	quartz sericite schist	2 veins conformable to wallrock	quartz	pyrite
F	quartzite with 35' wide zone of limestone	2 closely spaced veins in skarn 5' ave. width, open to west closed to east		chalcopyrite secondary copper min. galena sphalerite, to east chalcopyrite in quartz
G	similar to F	skarn adjoins veins		as above
H	skarny limestone	1' wide terminated by faults		chalcopyrite galena sphalerite
I	siliceous argillite	narrow discontinuous vein, good silver	quartz	galena
J		filling situation	quartz calcite	massive galena

Table 2 continued

Showing	Wallrock	Structure	Gangue	Sulphides
K		cross cutting (?) shear		chalcopyrite galena sphalerite pyrite

of the occurrence or the value of its assays.

Pyrite is by far the most abundant mineral present in the sections studied but is practically absent in sections from showings F to K. It is generally present as subhedral masses, separated from other sulphides by gangue or surrounded by or adjoining galena. Crystal shape and mineral association seems to indicate that this mineral was deposited first.

Galena is present in reasonable quantity in virtually all showings. Generally it occurs as euhedral masses but also is present as small veinlets cutting through the gangue. Texturally it occupies indentations in pyrite crystals and generally is associated directly with pyrite. Where not associated with pyrite, galena is interfingered with chalcopyrite and sphalerite. In several sections the chalcopyrite replaced small portions of the galena and in showings F and I galena has been replaced by tetrahedrite and rarely native silver. Showing of massive galena contained microscopic euhedral pieces of pyrite. Because of the textural conditions galena is believed to have followed pyrite in the paragenetic sequence.

Sphalerite almost always containing exsolved blebs of chalcopyrite occurs as anhedral masses interstitial to galena and chalcopyrite grains, and intergrown with chalcopyrite and galena. Exsolved chalcopyrite in sphalerite accounts for approximately 50% of all chalcopyrite present in specimens examined and is considered irrecoverable because of its very small size. Textural relationships indicate that the sphalerite with exsolved chalcopyrite probably was deposited approximately contemporaneously with galena and chalcopyrite.

Chalcopyrite, other than that exsolved from sphalerite, is associated with several other minerals. On several occasions it replaced very small portions of the galena but most commonly adjoined galena or sphalerite filling any interstices in the grain boundaries. Minor alteration of the chalcopyrite to azurite and malachite has occurred and one instance of chalcopyrite replaced by pyrargyrite was observed. Chalcopyrite is considered to have been deposited between galena and sphalerite in the paragenetic sequence although all three appear to overlap.

Tetrahedrite generally is associated closely with sphalerite or galena and has extensively replaced galena in some cases. It is also present as anhedral masses filling voids between sphalerite grains and gangue. In showing I it replaced galena up to 50%, while in showings F and B it occurred as interstitial masses. Tetrahedrite is believed to have followed the sphalerite in the sequence but after a depositional hiatus.

Few occurrences of pyrargyrite and native silver were observed. The only occurrence of pyrargyrite appeared to be a replacement of chalcopyrite and those of native silver appeared to be the replacement of galena.

The paragenetic sequence indicated by textural relationships is thought to be pyrite to galena, chalcopyrite, and sphalerite with exsolved chalcopyrite to tetrahedrite to pyrargyrite and native silver and is shown in Figure 1. The presence of sphalerite with exsolved chalcopyrite suggests that the temperature must have been at least 350-400°C and this is supported by the presence of the skarn which adjoins the mineralization in most cases. A possible source of the mineralizing fluids is the Mt. Selous - Armstrong complex which lies to the N.E. of the area.

Before the area could be considered economical one must remember that less than 50% of the chalcopyrite present appears to be recoverable due to the fact that most of it is locked in a matrix of sphalerite. However, silver values appear to be associated with the tetrahedrite and native silver and are in general recoverable. Textural features are shown in Figure 2.

Trend Surfaces

Data used in trend surface analysis were taken from samples collected during the summer from the grid present on the Lad property. It was necessary to divide the property into three separate areas because of geographic distribution of data. Then, because of dimension limitations in the program used, (maximum of 500 stations) about one quarter of the data points in each area were used. (2, 1966). As a result of the tremendous quantity of computer out-put for each area it was decided that one of the areas would be chosen as a case study of the technique and the remaining areas would be discussed in the light of any conclusions drawn from the study. The choice of

Fig. 1

Vandoveer Diagram

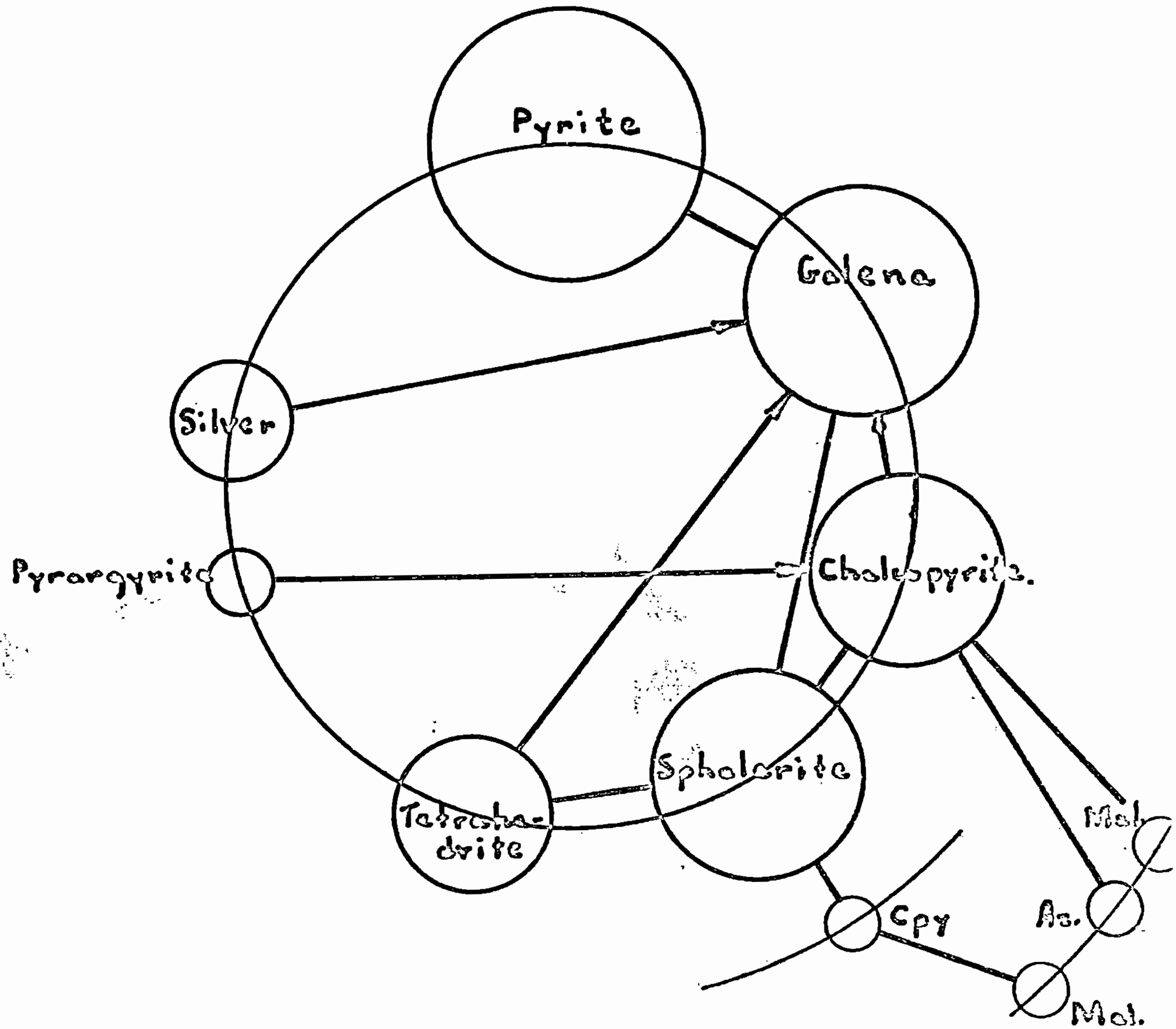
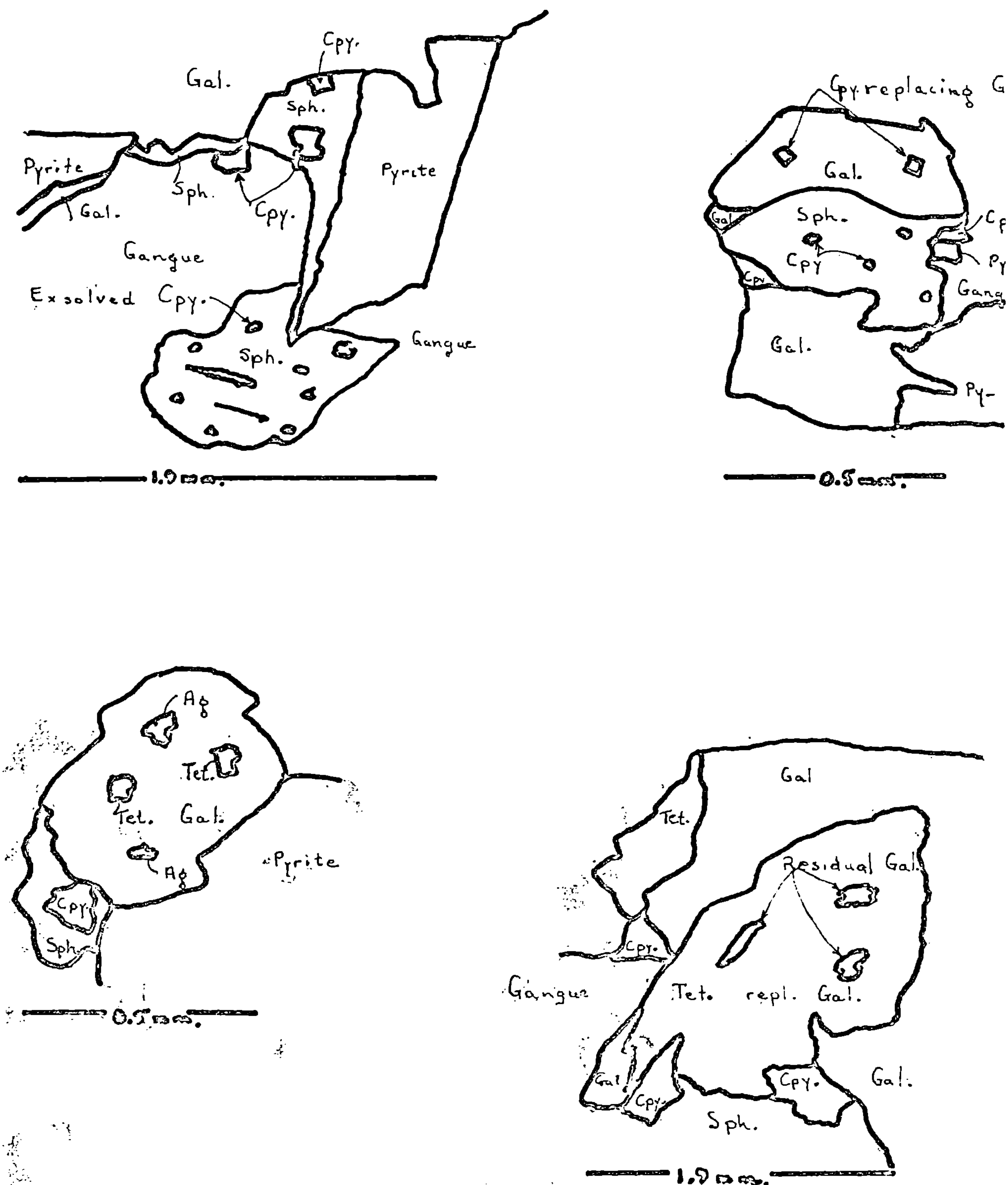


Fig. 2.



Textural Features

the test area was based primarily on simplicity of the trends developed by the program for each of the geochemical and geophysical variables. (See Appendix II, Fig.1.).

Within the area selected high (sixth) order trend surfaces were compared for similarities and low (quadratic) order residuals were treated similarily. Also the above were compared with hand contoured data to decide which method best defined and located known anomalous areas and known showings. Lower order trend surfaces were also studied to see if good definition could be obtained with surfaces less than sixth order. The conclusions reached were then briefly applied to the two remaining regions.

Comparison of Sixth Order Trend Surfaces - Test Area

A marked resemblance is notable among the trend surfaces developed by the computer for the geochemical surveys of copper, lead, and zinc. (See Appendix III, Fig.1-3.). The most obvious similarities are the presence of the central high and the surrounding lows. Aside from these, there are several areas of intermediate value interspersed with the above and it is because of this similarity in regional trends that this particular area was chosen for the case study. In apparent contrast to the geochemical data is the surface developed for the ground magnetometer survey. (See Appendix III, Fig.4.). However if examined carefully one will note a coincidence of location for geochemical highs and magnetometer lows. This is probably a result of the lack of pyrrhotite in any of the mineralized zones or the presence of magnetite in the host rocks. As a result of this coincidence the magnetometer survey will be examined for low values when compared to the geochemical data.

Comparison of Second Order Residuals - Test Area

As with the high order surfaces described above there is present a coincident regional trend for residual surfaces developed for the geochemical surveys. Unfortunately when studying the residuals of a quadratic surface the extremities of the area cannot always be considered valid. This problem arises because of the shape of the surface developed, which is generally a dome. Because of this shape the outer fringe of the trend surface is certain to be less than equal to the original data and thus will give rise to relatively strong positive anomalies in the residuals. The maps for this section have been contoured in terms of the standard deviation for the second order surfaces and only positive anomalies have been contoured. It was considered ineffective to contour negative zones as these would correspond to areas of background or less and would serve only to complicate the map. In general there are three anomalously high zones that coincide in this area for the copper, lead, and zinc surveys and the strongest of these lies in the central position of the map. The high residuals of the magnetometer survey tend to lie in the low or background areas of the soils surveys as they did in the high order surfaces. (See Appendix III, Fig.5-8.). One immediate advantage of this technique as opposed to the high order surfaces appears to be the better definition of shape and location of the anomolous zones present on the residual maps.

High Order Trend Surfaces vs. Hand Contoured Surfaces
Test Area

In order to maintain continuity, surfaces developed by the above two methods will be individually compared for each of the variables and the section will conclude with a summary of results. Each of the surfaces will be discussed with respect to the accuracy in locating and defining anomalous zones. Although the hand contoured surface may be biased, it is considered the best interpretation of the situation as it was compiled with the use of four times as much data. A map of known showings was also compared. (See Appendix III, Fig.9.).

The trend surface for copper is characterized by a large central anomaly which extends in a southerly direction. Comparison with the hand contoured results reveals that virtually all areas in excess of the threshold value of 55 p.p.m. copper are located within this zone. However, only the periphery of the zones is defined and none of the individual areas are outlined. (See Appendix III, Fig.1 and 10.).

The hand contoured data for lead has four major zones developed and the trend surface is characterized by three areas. The definition with respect to position is more accurate than for copper and in this case negative surfaces areas on the trend surface correspond to areas of less than the threshold value of 75 p.p.m. surrounded by zones above the threshold on the hand contoured map. One gross inaccuracy appears to exist on this map and this involves the relative magnitudes of anomalous areas. The central anomaly with a magnitude of 7500 p.p.m. is made to appear less than the area of 4150 p.p.m. lying to its east. This is a result of the sampling technique, because of which the highest sample from the central anomaly was not included. (See Appendix 3, Fig.2 and 11.).

As in the case of copper only one major anomaly is developed for zinc by the computer. The majority of the areas above the threshold are masked by the presence of the excessively high area in the center of the map. As a result of this, areas above the threshold value are found to lie in zones considered negative by the computer. (See Appendix III, Fig.3 and 12.).

The surface developed by the computer for the ground magnetometer survey is perhaps the most accurate of all discussed. Present on the hand contoured data sheet are many highs and lows and although these are not exactly located by the computer the relative magnitudes are quite well shown. (See Appendix III, Fig.4 and 13.).

In general this technique can be considered reasonably accurate provided excessive differences in value are not present on the map. If the above is true, fairly good definition with respect to magnitude and location may be achieved. If the above situation does not exist the results are invalid because the largest anomaly tends to mask all the others which may be present.

Low Order Residuals vs. Hand Contoured Surfaces
Test Area

The same criteria of comparison and method of approach will be employed here as was used in the previous section. As mentioned before the residuals of the second order surface have been contoured in terms of the standard deviation for the surface.

The correspondence obtained for copper between residuals and hand contouring is outstanding. Relative magnitudes of all anamalous areas are correct and in general all areas of threshold value are encompassed by zones of magnitude greater than one quarter standard deviation. Definition of location and shape of anomalies is good and had more data been employed areal extent would have been better defined for each anomaly. (See Appendix III, Fig.5 and 10.).

Results of lead are comparable, however, the delineation of areas exceeding the threshold was not as good as for copper. Shape and location are again accurate but some of the magnitudes are reversed between anomalies. This error is a result of sampling but can be accounted for if original data in the vicinity of the anomalies is examined. (See Appendix III, Fig.6 and 11.).

Coincidence of areas for the variable zinc are probably the poorest. Areas were neglected in the residuals until they lay approximately 50% in excess of the threshold value. However, location etc. of the zones delineated was quite accurate. The problem of magnitudes referred to above also existed here. (See Appendix III, Fig.7 and 12.).

Residuals for the magnetometer survey revealed very good correspondence with respect to location, shape and magnitudes. Low and high areas were very well defined and the results were probably as significant as those for copper. (See Appendix III, Fig.8 and 13.).

In general the contoured residual values displayed a much better correlation with known anomalies and mineral occurrences than did the high order surfaces. They tended to locate and define areas much better and also the relative magnitudes of anomalies were seen much more readily.

Lower Order Surfaces and Conclusions

Although exceptionally good correspondence has been achieved by using low order, hand contoured residual values, it was believed possible that reasonably accurate results might be obtained by using trend surfaces of less than sixth order. However a study of such surfaces for each of the four variables revealed that no definition could be obtained with any surface less than fifth order. Since this is not significantly less, the idea was discarded and it was decided that results would be discussed only with respect to second order residuals.

Low order residuals were selected over high order surfaces for several reasons. First of all definition of location and shape is much more accurate and second the relative magnitudes of developed anomalous zones was correct with only a few exceptions. The greatest apparent error appeared on the lead and zinc maps with respect to the central and eastern anomalies, of which the magnitudes appear reversed when checked against the hand contoured data. This is a result of the sampling for computer data and the magnitudes are in fact correct for the data which the computer received. The only downfall of the residuals is concerned with the size of the anomalous areas developed. This again is due to sampling and would correspond more closely to the original data had more sample values been used in the program. The final reason for the choice is cost, for much computer time may be saved if it is necessary only to compute up to second order. The two remaining areas of the Lad will now be discussed, bearing in mind what has been learned to date. Only low order residuals will be considered.

Application of Results to Remaining Areas

For this part of the study three variables of the seven considered in the two remaining areas of the property will be discussed. They include lead and zinc of the eastern grid and lead of the central grid.

As discussed in the previous sections the various maps from the case study area which were examined revealed that the best fit to known results was in general obtained from the second order residual maps. Because of this the data referred to above will be studied through the use of residuals to determine which areas should receive attention. As a conclusion to the section the results will be compared to the original data and also a map of known showing locations. Residual value maps for lead samples collected from the east grid revealed the presence of several major anomalies, the greatest of which had a magnitude of approximately 800 p.p.m. This area lying to the south of B.L.1 should receive further attention. (See Appendix IV, Fig.4.). Zinc values from this area showed strong correlation to those for lead and again the strongest areas lie to the south (2400 p.p.m.). (See Appendix IV, Fig.4.). Residual lead values for the central grid indicated the presence of two anomalies. However, the limited extent of these zones seems to render them uninteresting. (See Appendix IV, Fig.7.).

Contoured residuals for lead of the eastern grid showed a close correspondence to hand contoured data for lead on this grid. However, in some cases the absolute peaks of the computer anomalies were displaced from their positions on the hand contoured maps but in general the areas tended to correspond overall. (See Appendix IV, Fig.1-3.). The results were not as good as those obtained in the case study but this was felt the result of sampling, that is, tending to omit high value samples and thus shifting the position or due to the close spacing of several areas of high magnitude. Zinc values were generally more accurate as shapes, locations and magnitudes corresponded to a much better degree. (See Appendix IV, Fig.1,4 and 5.). The results for lead on the central grid were probably the poorest in appearance obtained. The largest anomaly in the area was neglected and the other areas were only vaguely outlined. (See Appendix IV, Fig.6-8.). This was considered due to either of the problems discussed above. The greatest difficulty in comparing the results arises due to the sampling, that is, that certain samples are omitted. This omittance tends to either shift the position or distort the shape of the anomalies which result. However, if this fact is borne in mind the position of this technique as an exploration tool is not weakened.

Conclusions

The case study has served to reveal that very close correspondence to hand contoured data may be obtained through the use of second order residuals from the trend surface analysis program, and that only one quarter the amount of data was necessary. A technique such as this is deemed more economical with respect to time and finances than conventional methods. The economy lies in the fact that fewer samples need be collected and analyzed and that once analyzed, contoured results would be almost immediately available. Perhaps the only weakness of the method is that a case study should be performed in every area to which the method might be applied to ensure accuracy of results. However, it is my opinion that the technique will eventually hold a very relevant position in the mining industry as an exploration guide.

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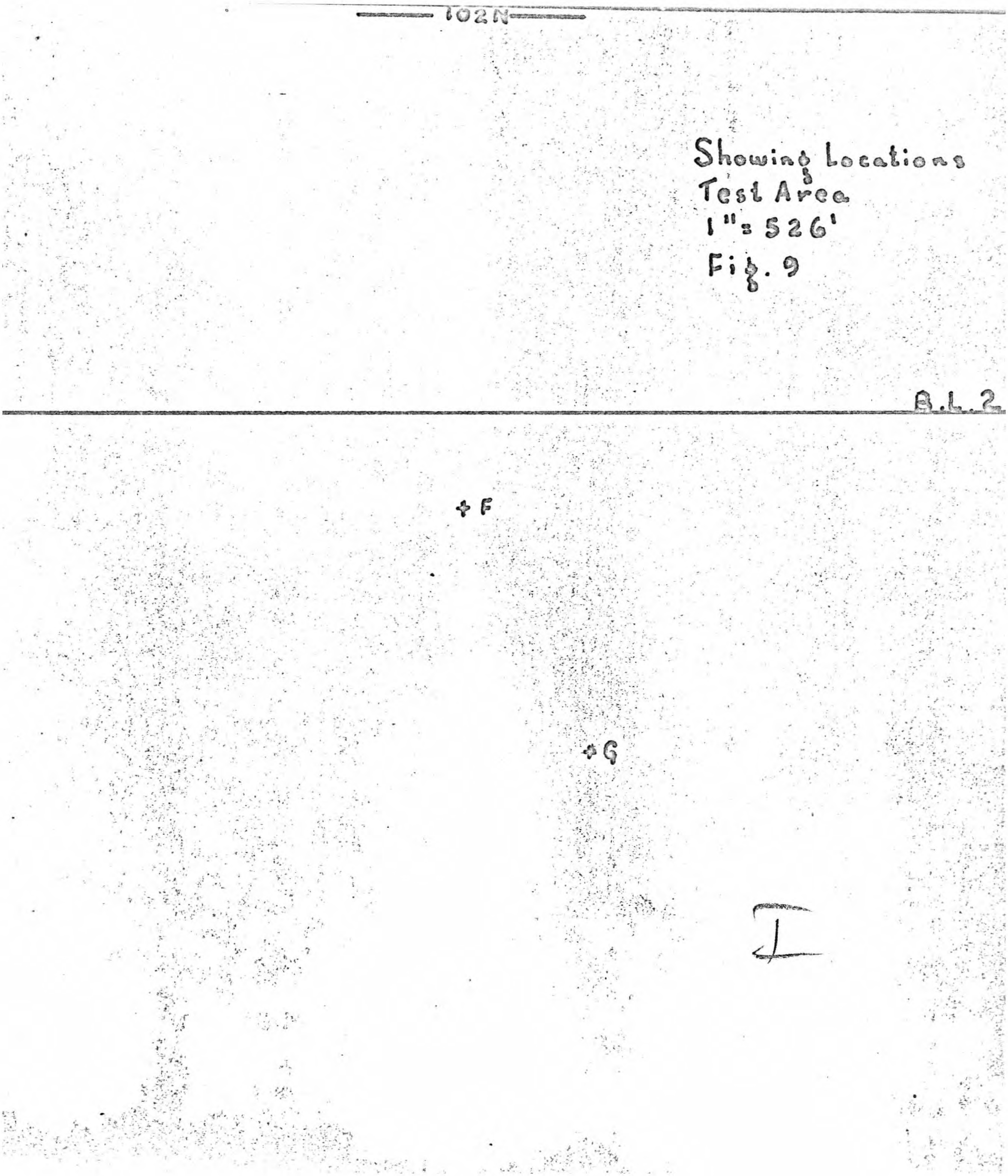
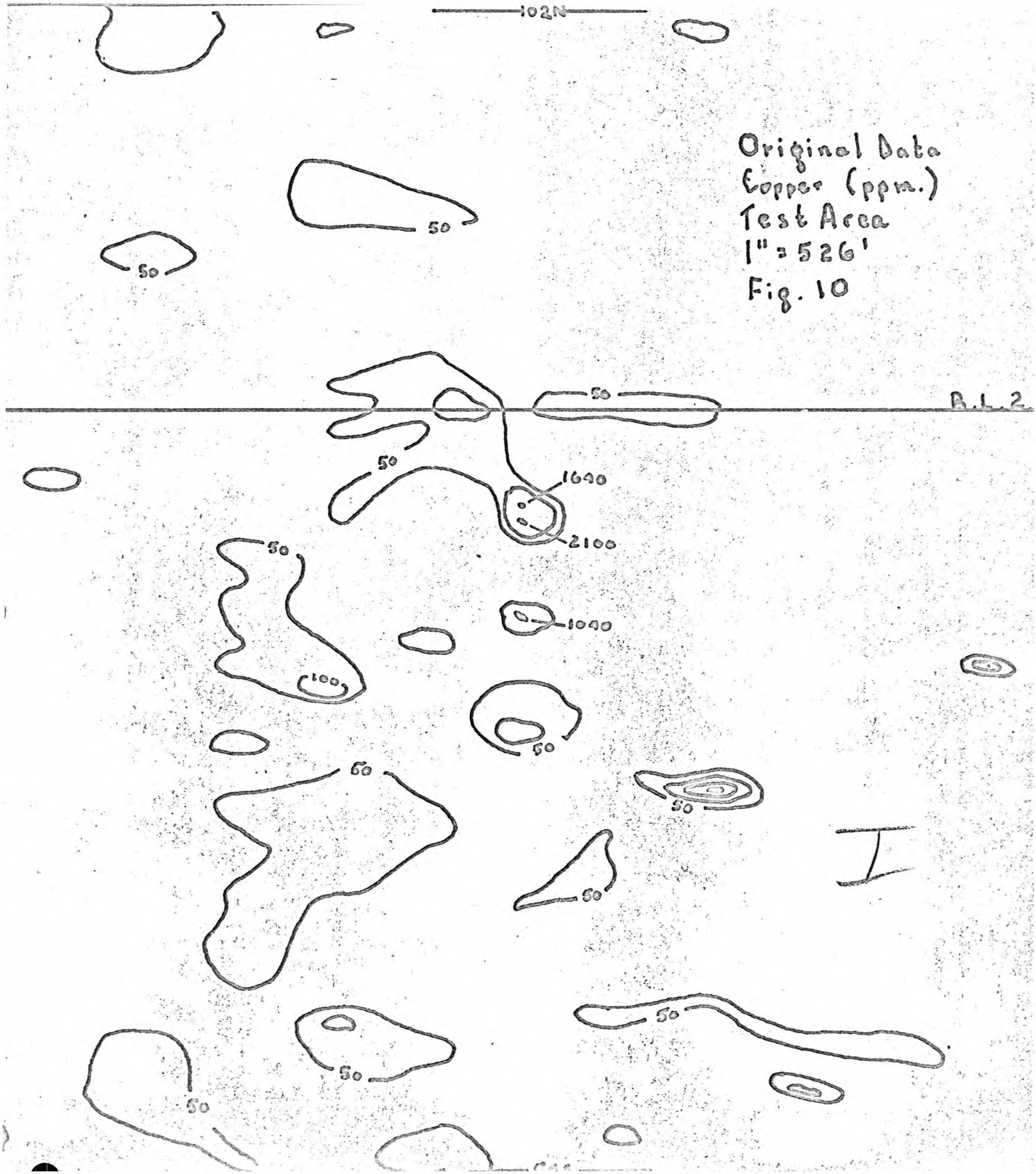
4 Proceeding of a Symposium on Decision Making in Mineral Exploration, Vancouver, B. C. 1968.

Appendix I - Lod Geology
II - Location map

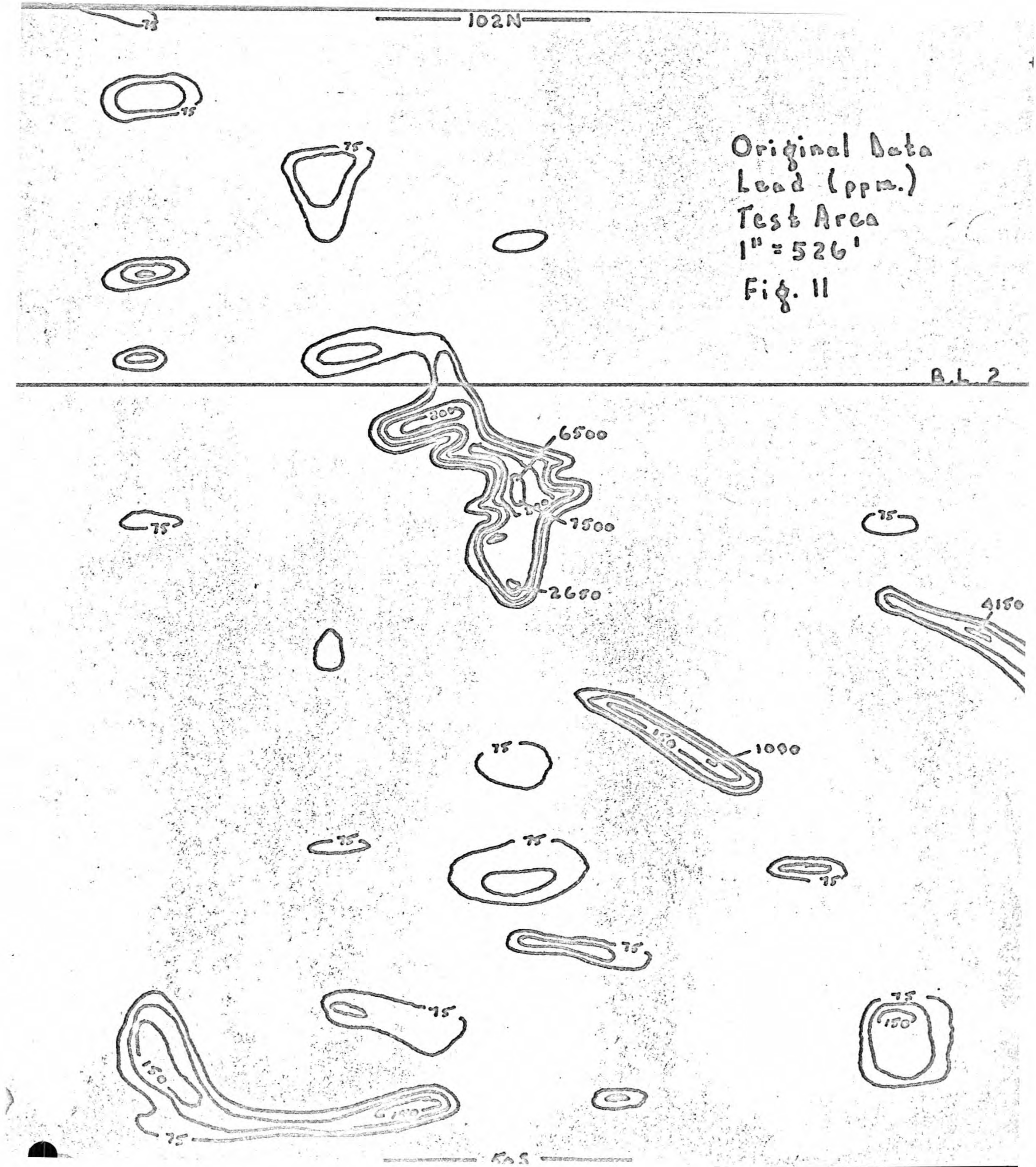
Appendix III



Showing Locations
Test Area
1" = 526'
Fig. 9

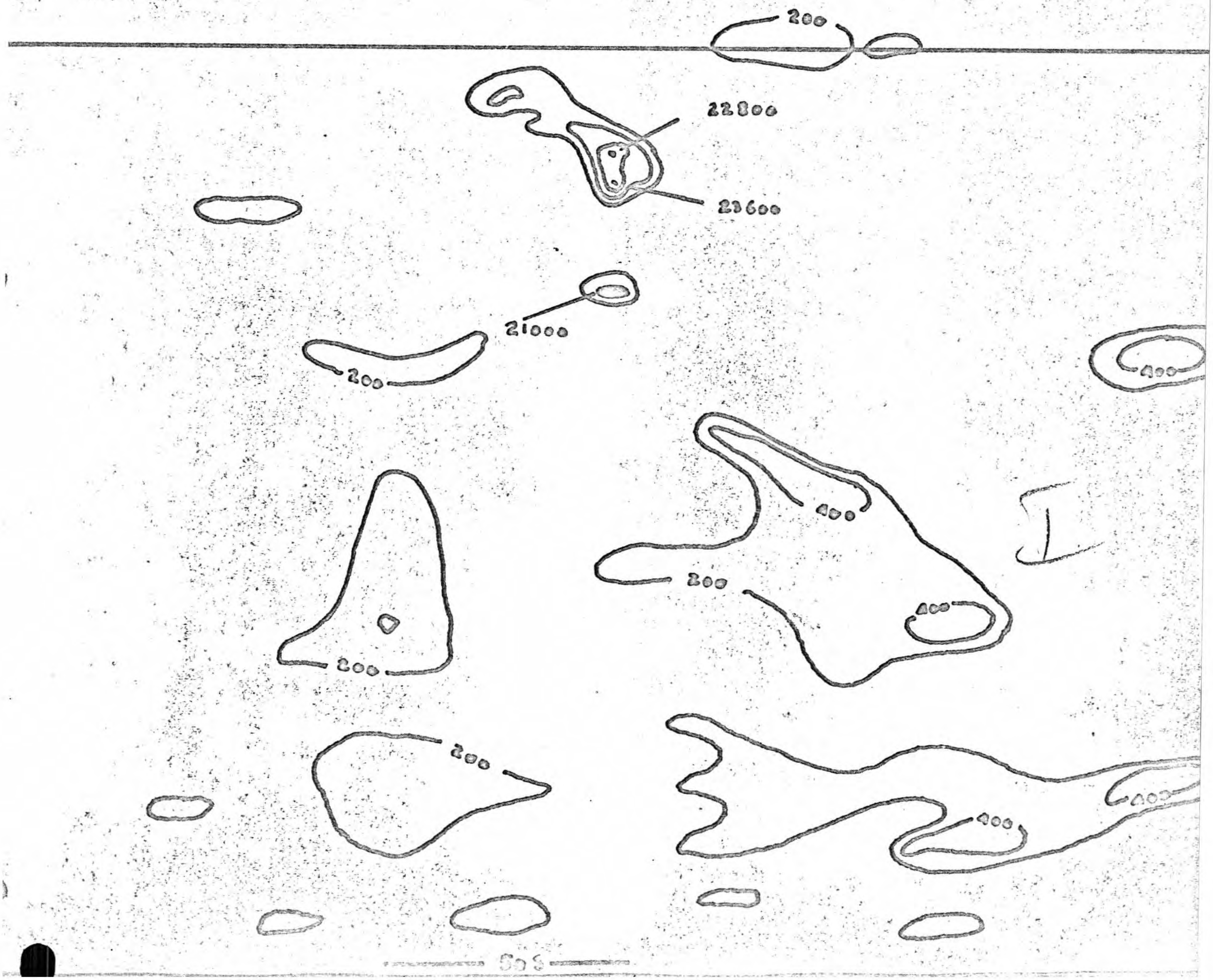


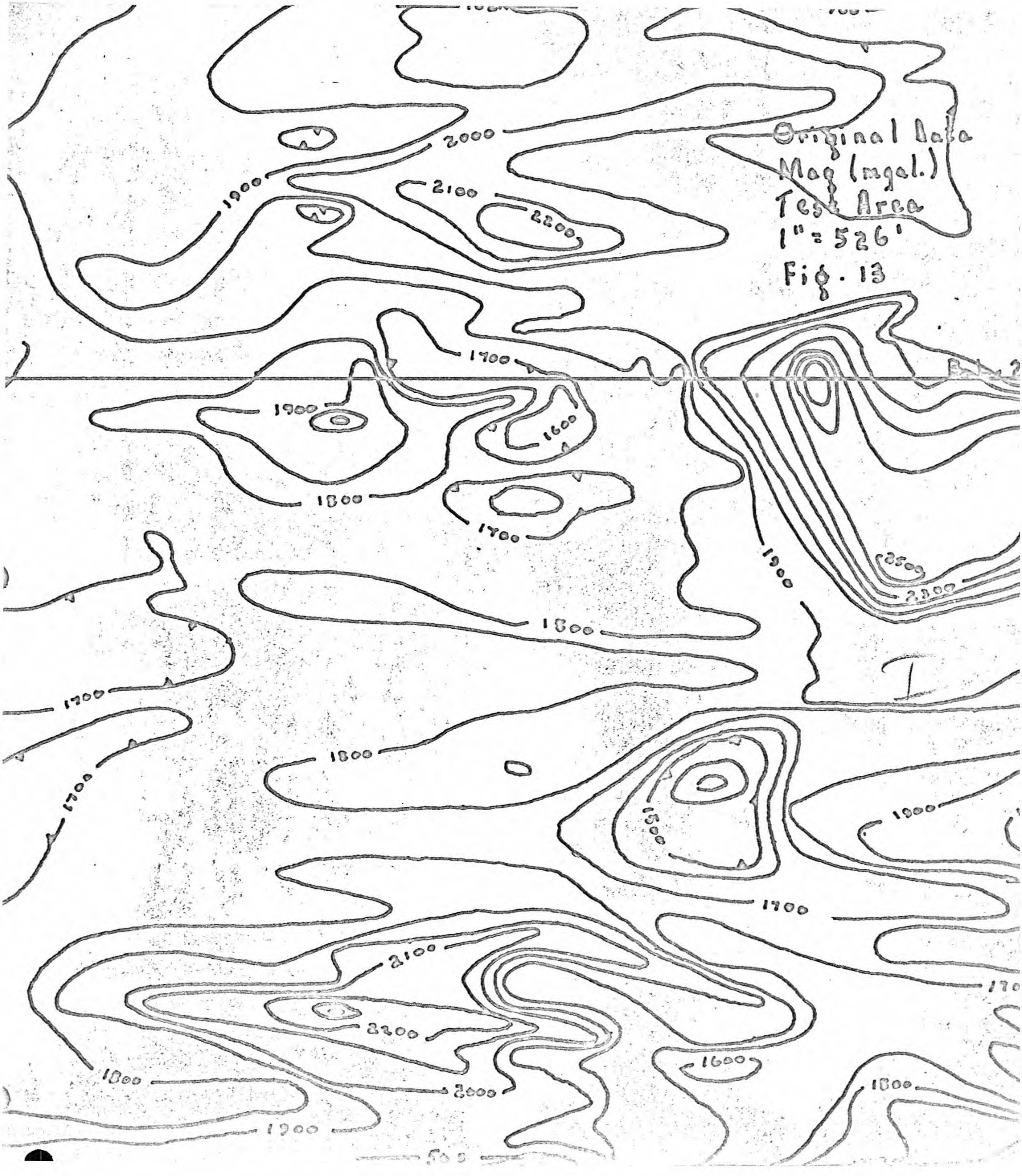
Original Data
Copper (ppm.)
Test Area
1" = 526'
Fig. 10



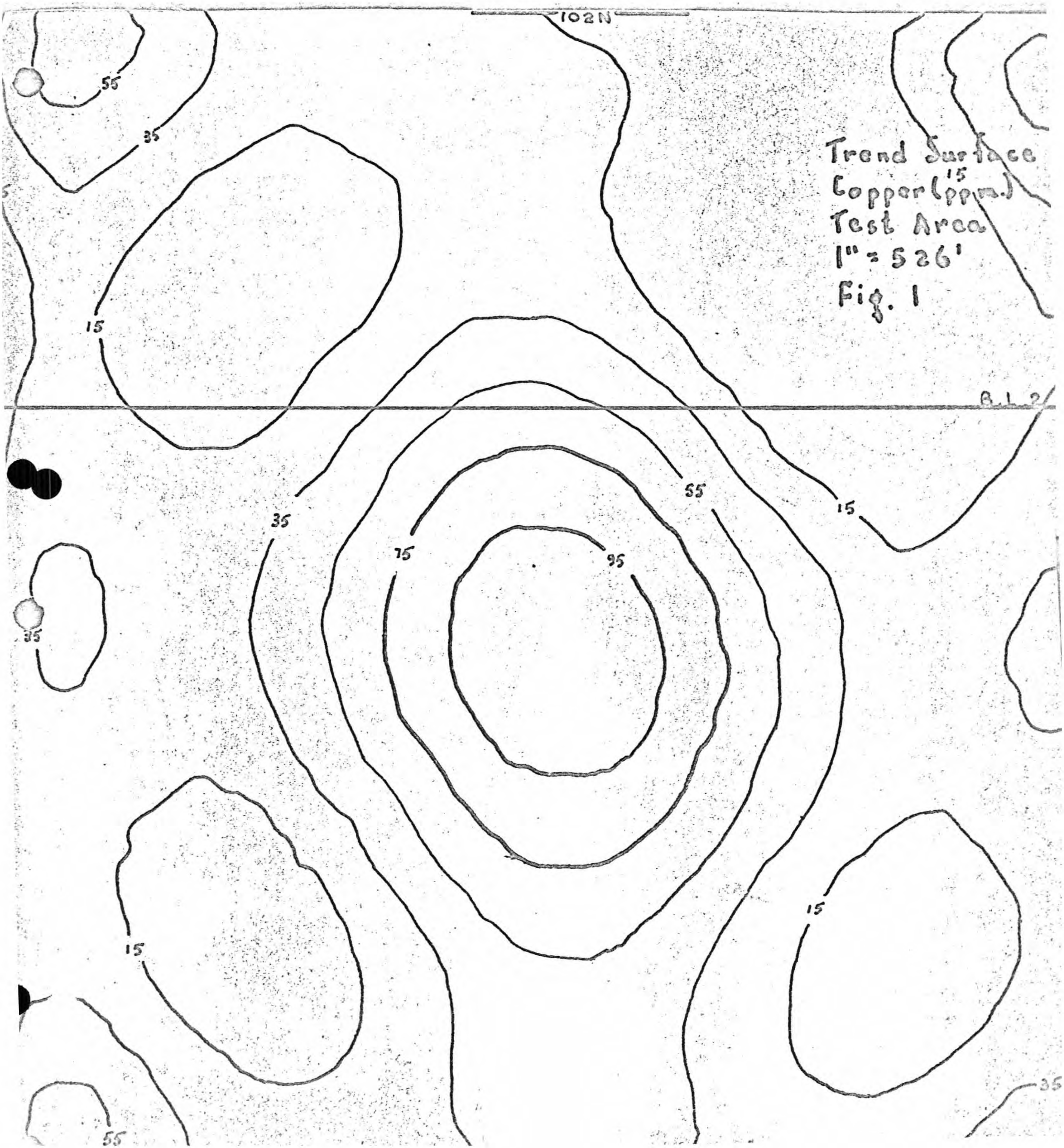
Original Data
Lead (ppm.)
Test Area
1" = 526'
Fig. 11

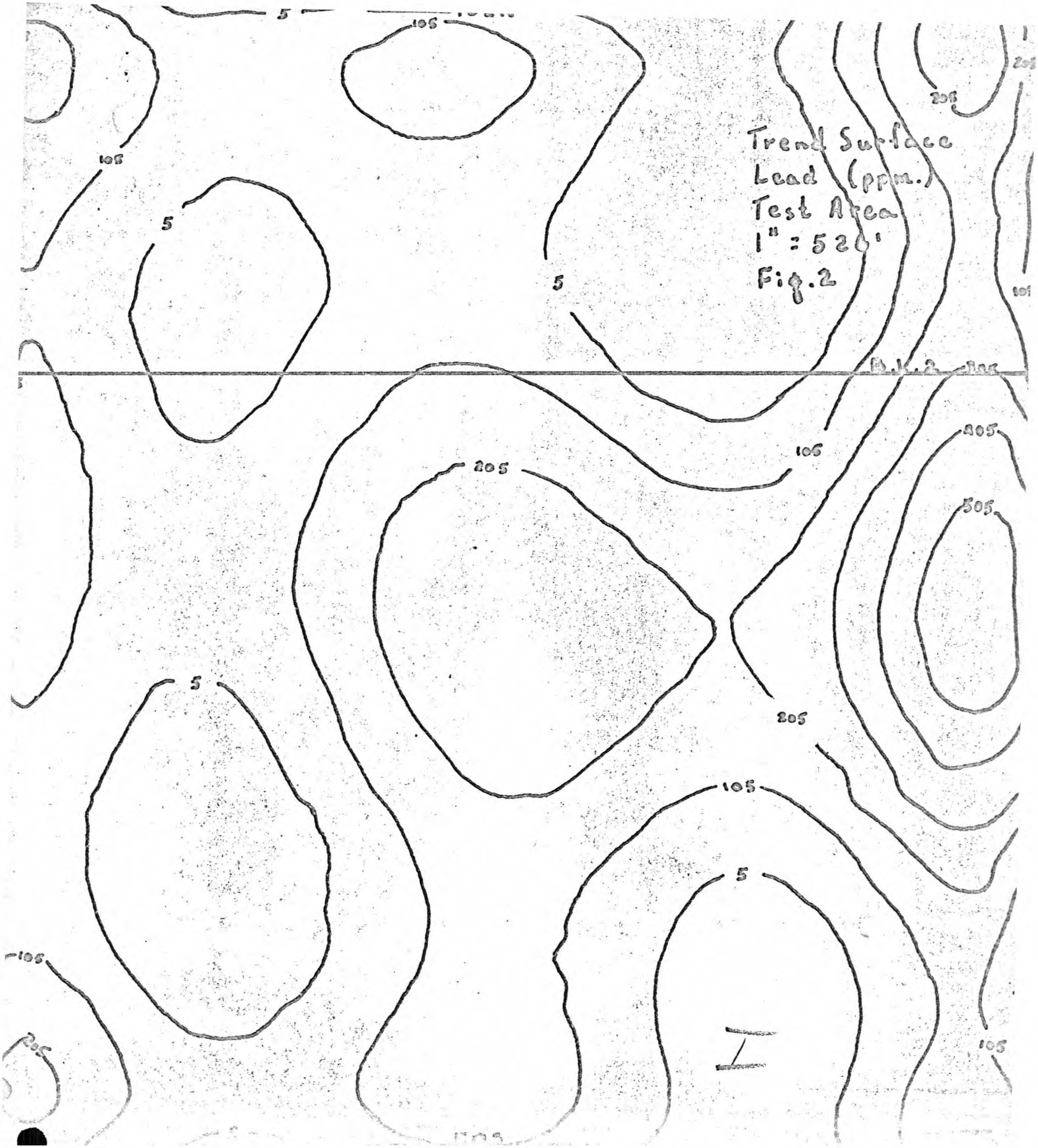
Original Data
Zinc (ppm)
Test Area
1" = 526'
Fig. 12



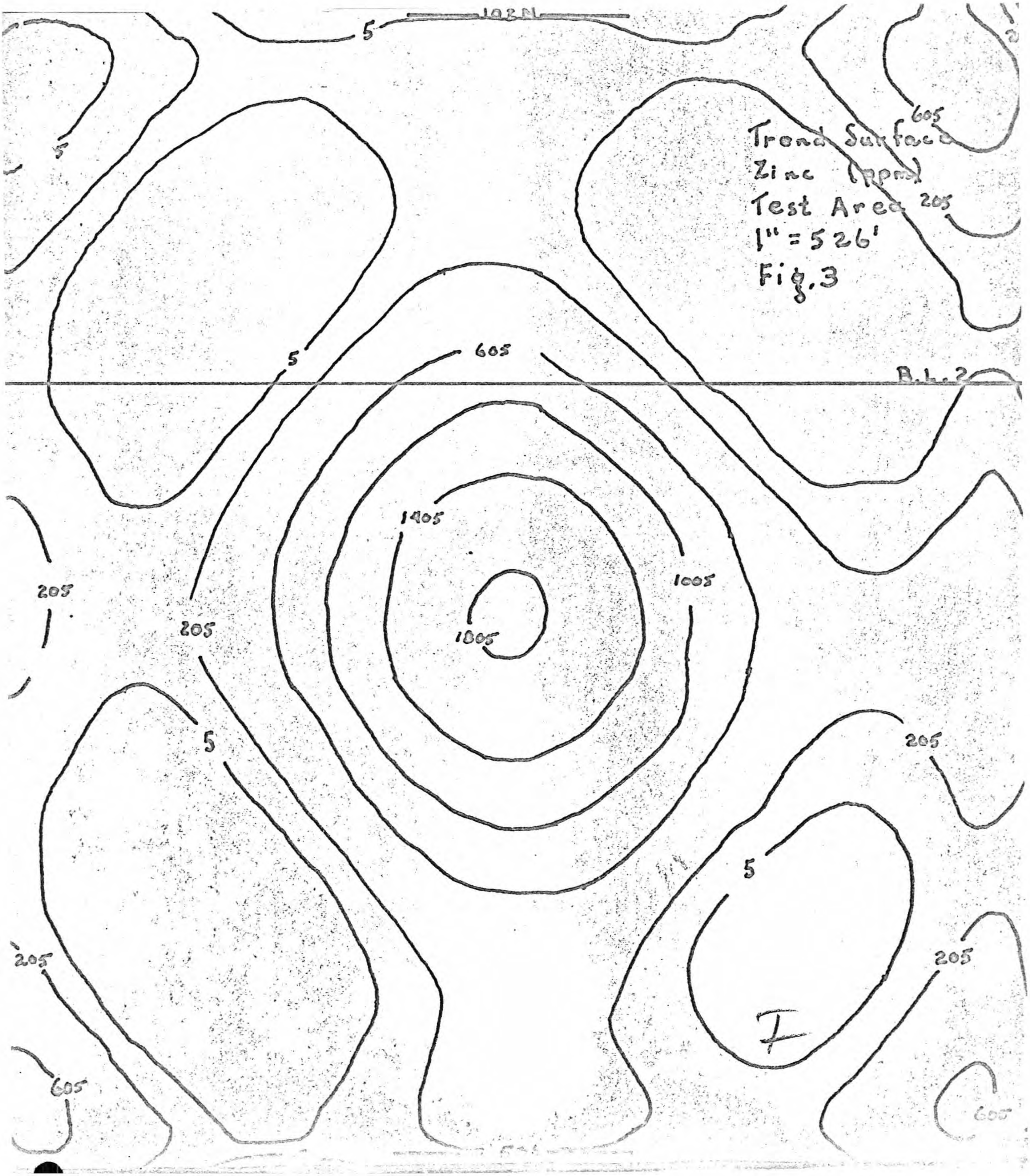


Original Data Map (mgal.) Test Area 1" = 526' Fig. 13

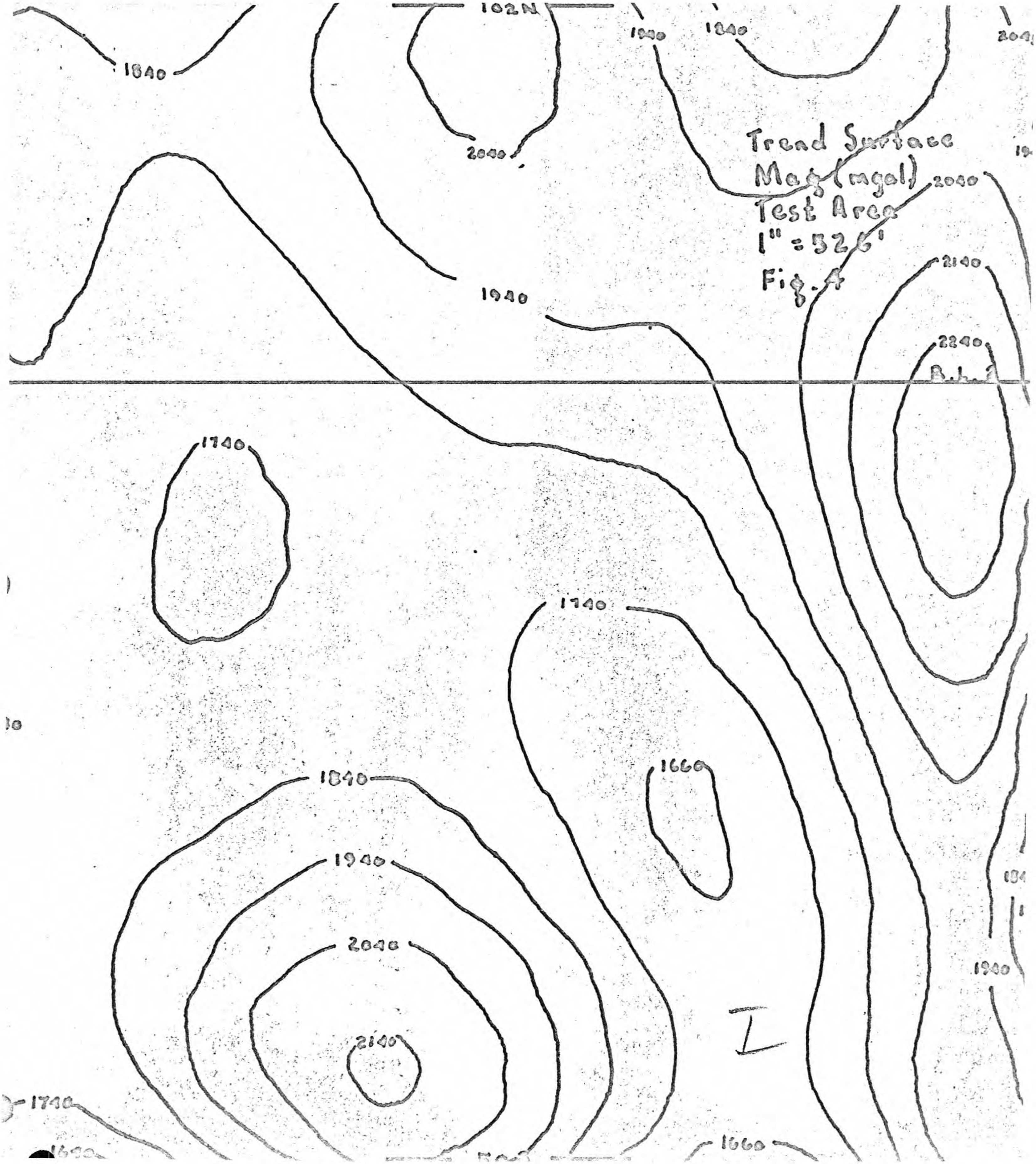

102N
Trend Surface
Copper (ppm.)
Test Area
1" = 526'
Fig. 1
B.L. 2
15
35
55
75
95



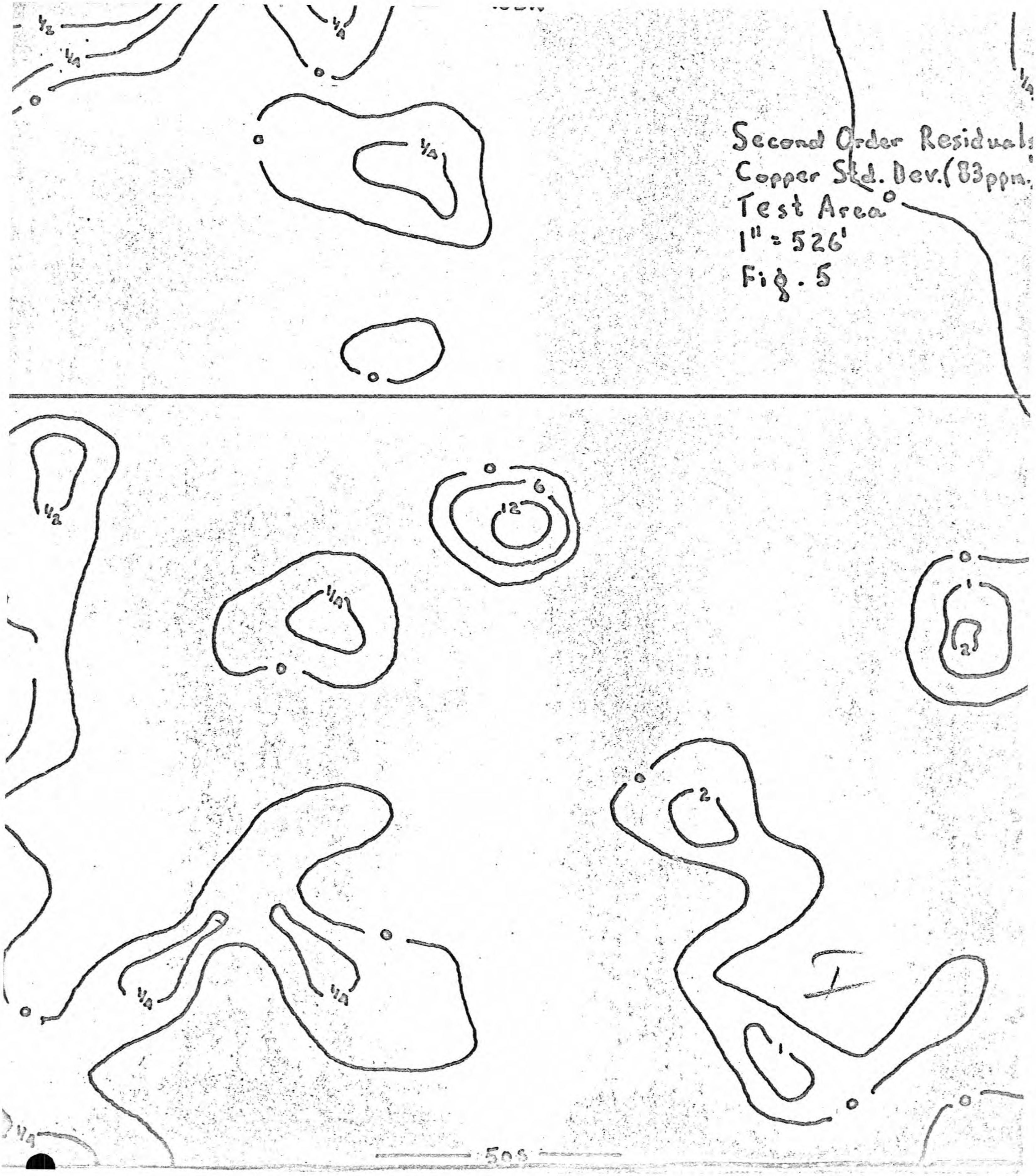
Trend Surface
Lead (ppm.)
Test Area
1" = 520'
Fig. 2



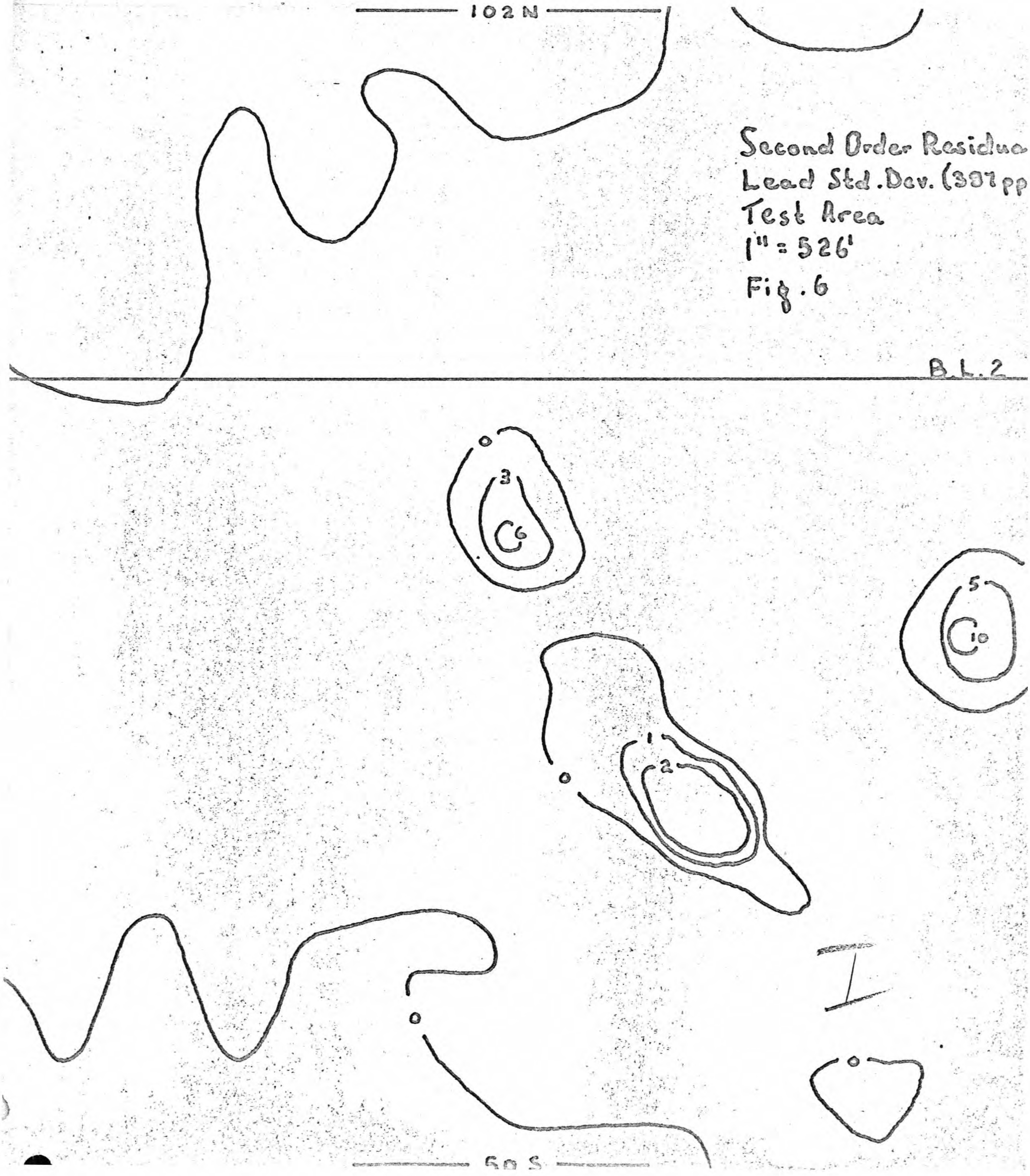
Trend Surface
Zinc (ppm)
Test Area
1" = 526'
Fig. 3

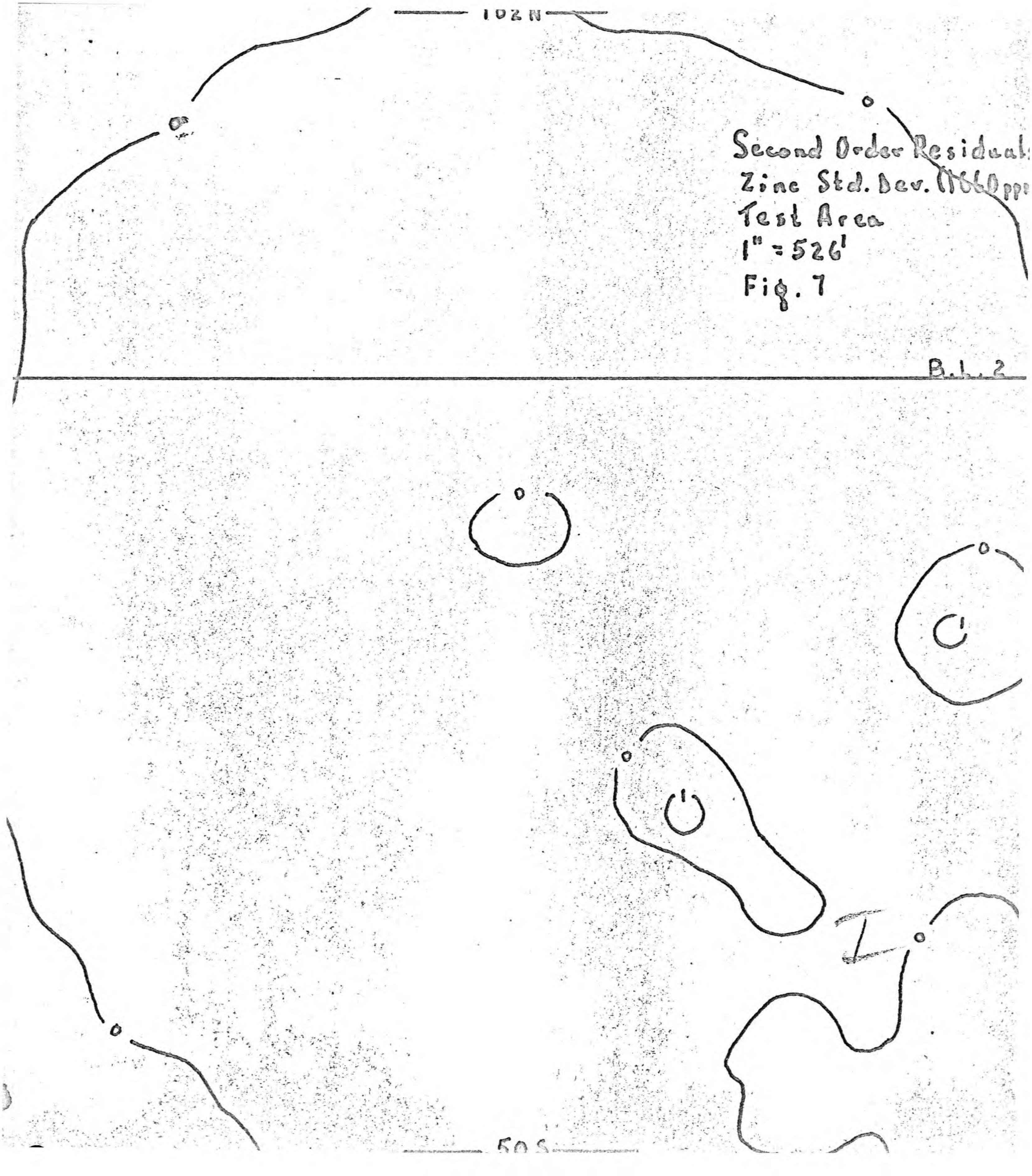


102N
Trend Surface
Mag (mgal)
Test Area
1" = 526'
Fig. 4
B.L. 1
1840
1940
2040
2140
2240
1740
1660
1840
1940
2040
2140
1740
1660

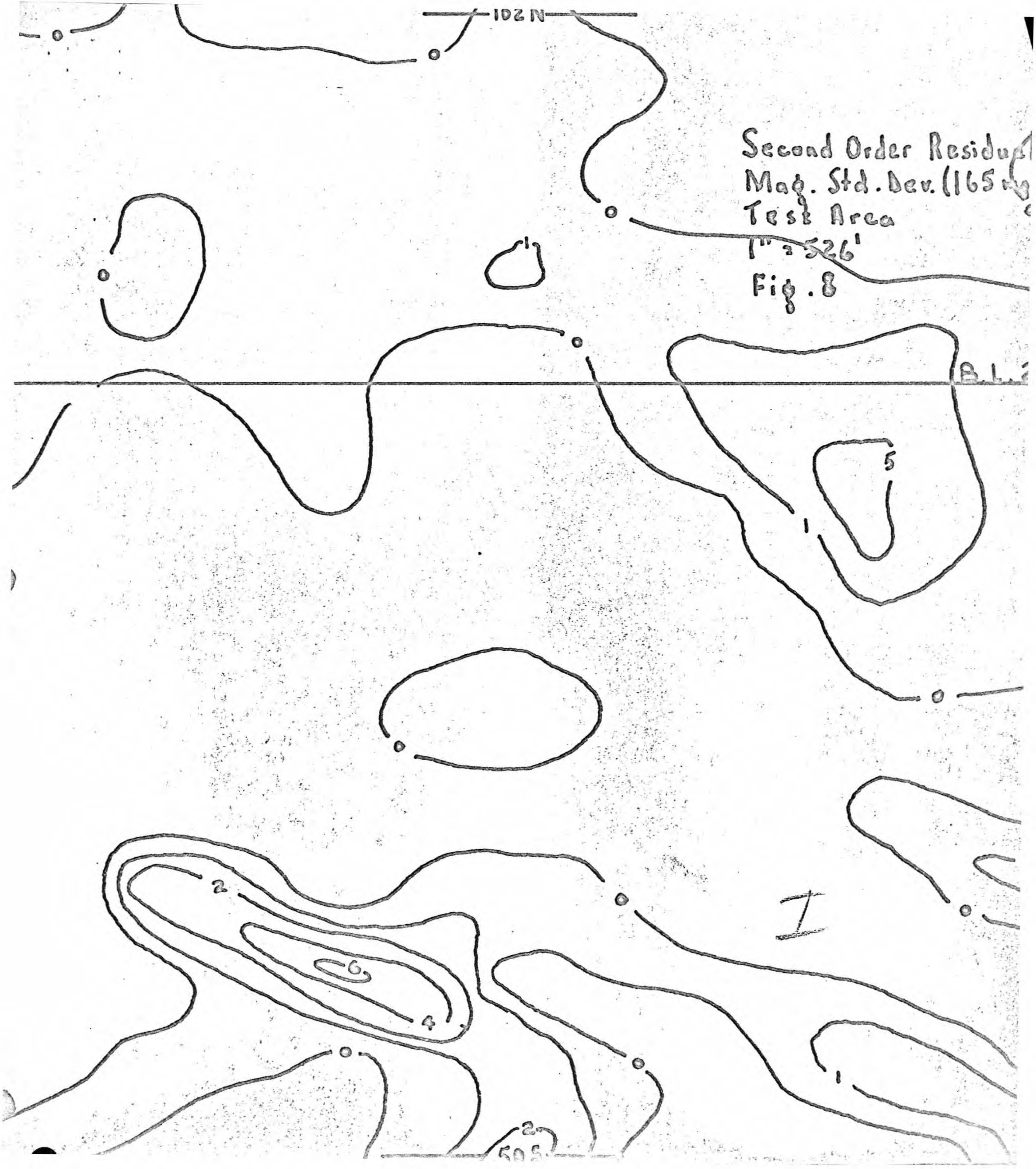


Second Order Residuals
Copper Std. Dev. (83ppm.)
Test Area
1" = 526'
Fig. 5

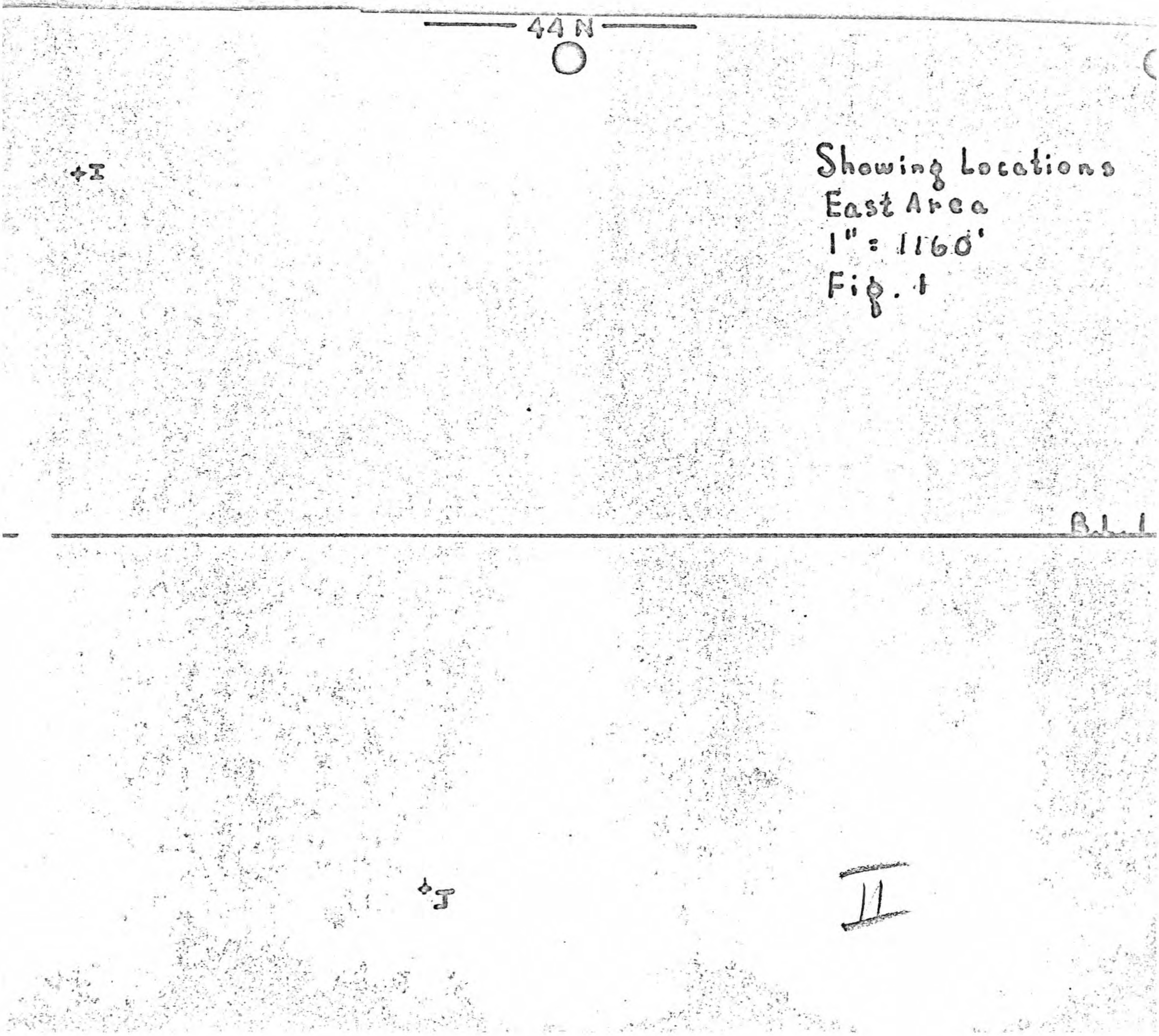

102 N
Second Order Residua
Lead Std. Dev. (337 pp
Test Area
1" = 526'
Fig. 6
B.L. 2
0
3
6
5
10
1
2
0
0
0
50 S



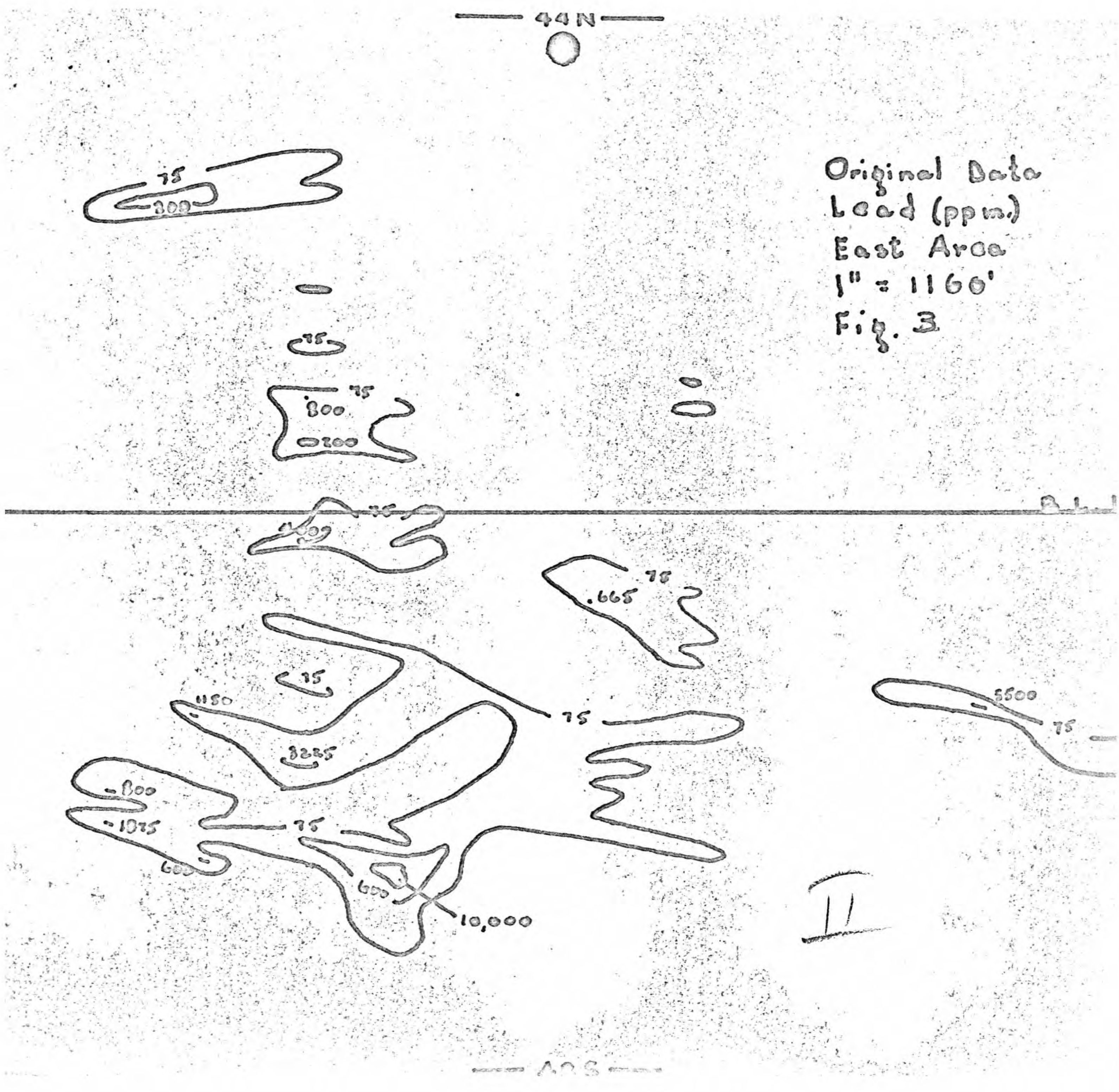
Second Order Residuals
Zinc Std. Dev. (1660 ppm
Test Area
1" = 526'
Fig. 7

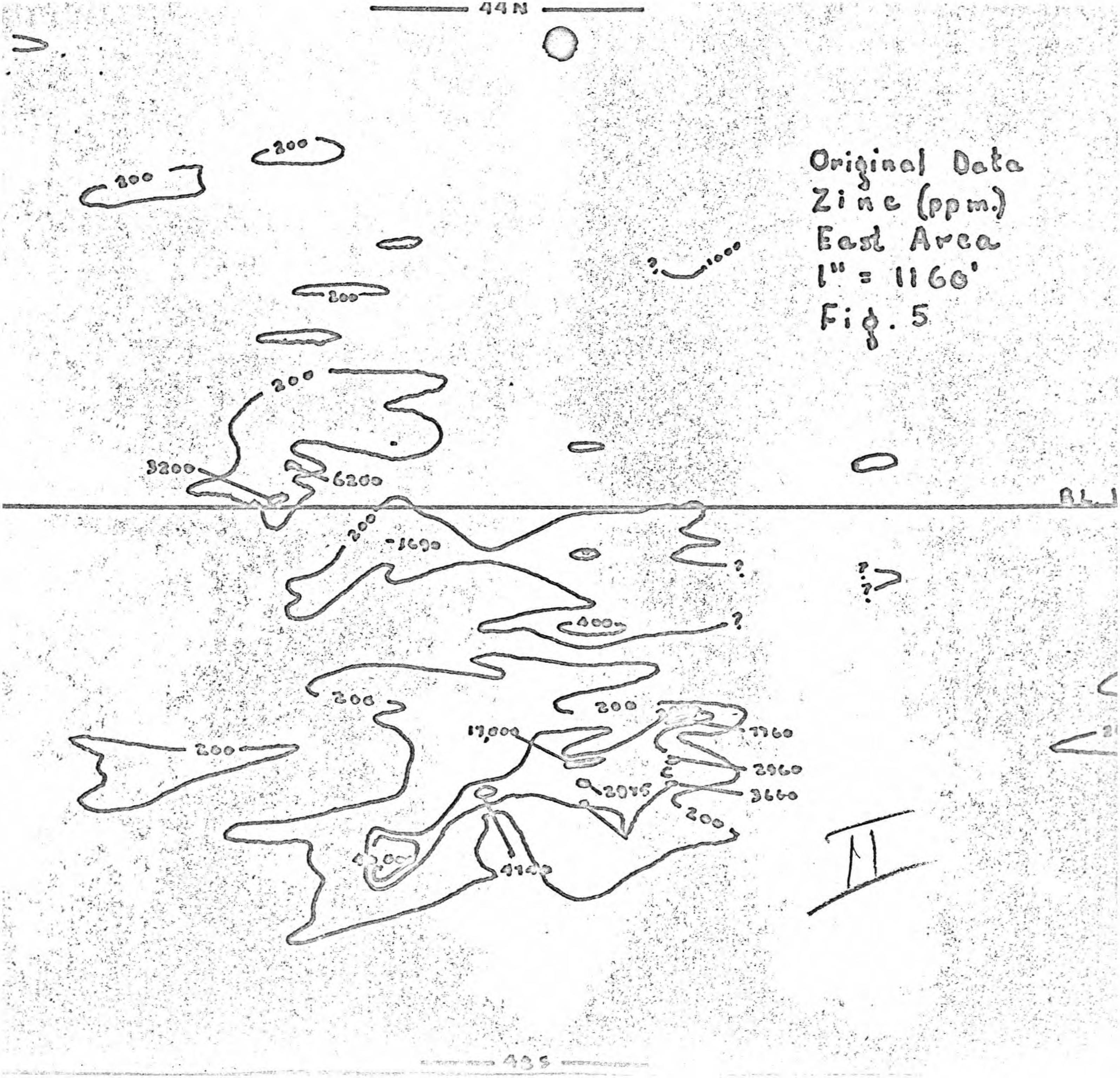


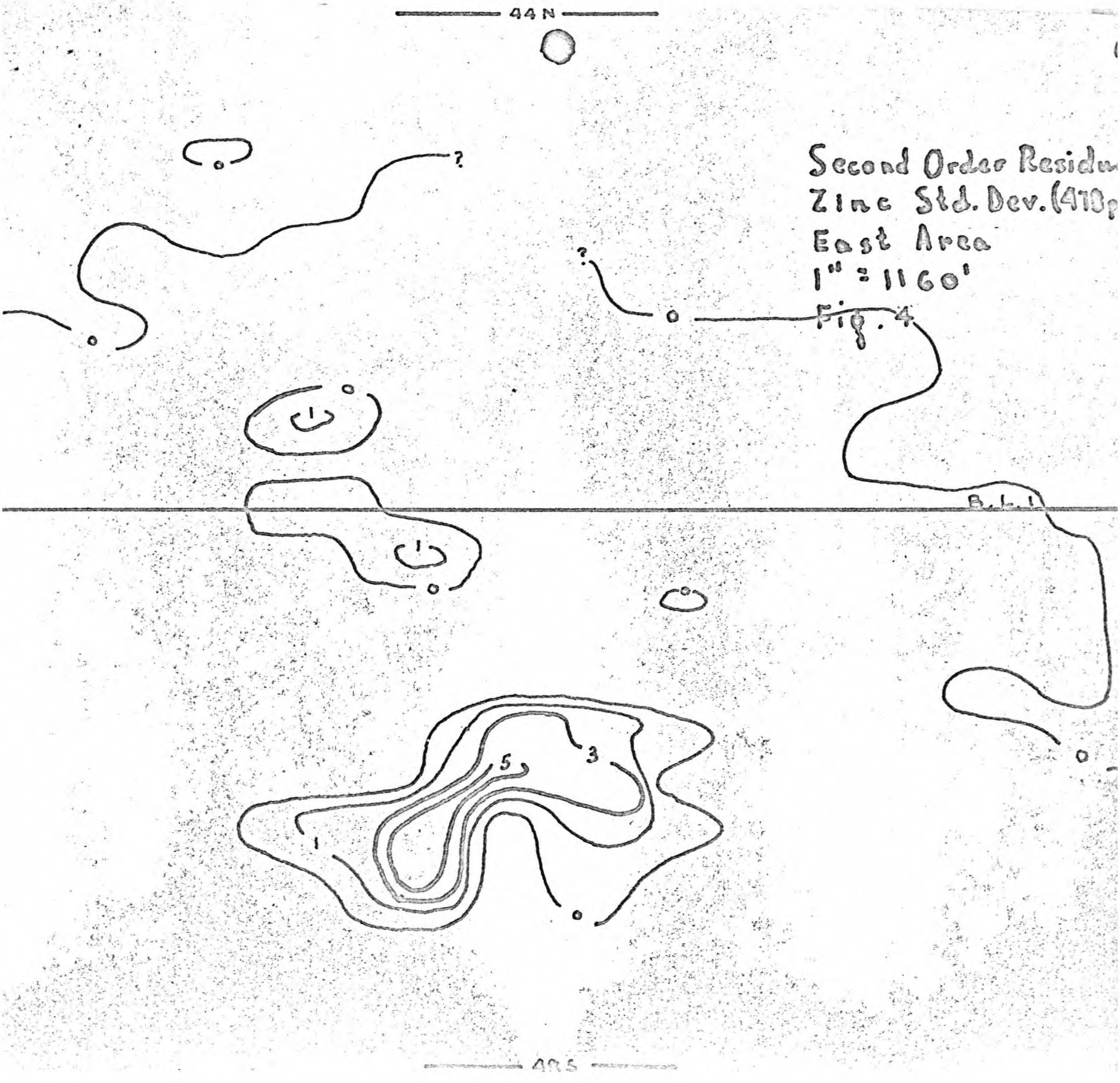
102 N
Second Order Residu
Mag. Std. Dev. (165
Test Area
1" = 526'
Fig. 8
B. L.
I
505

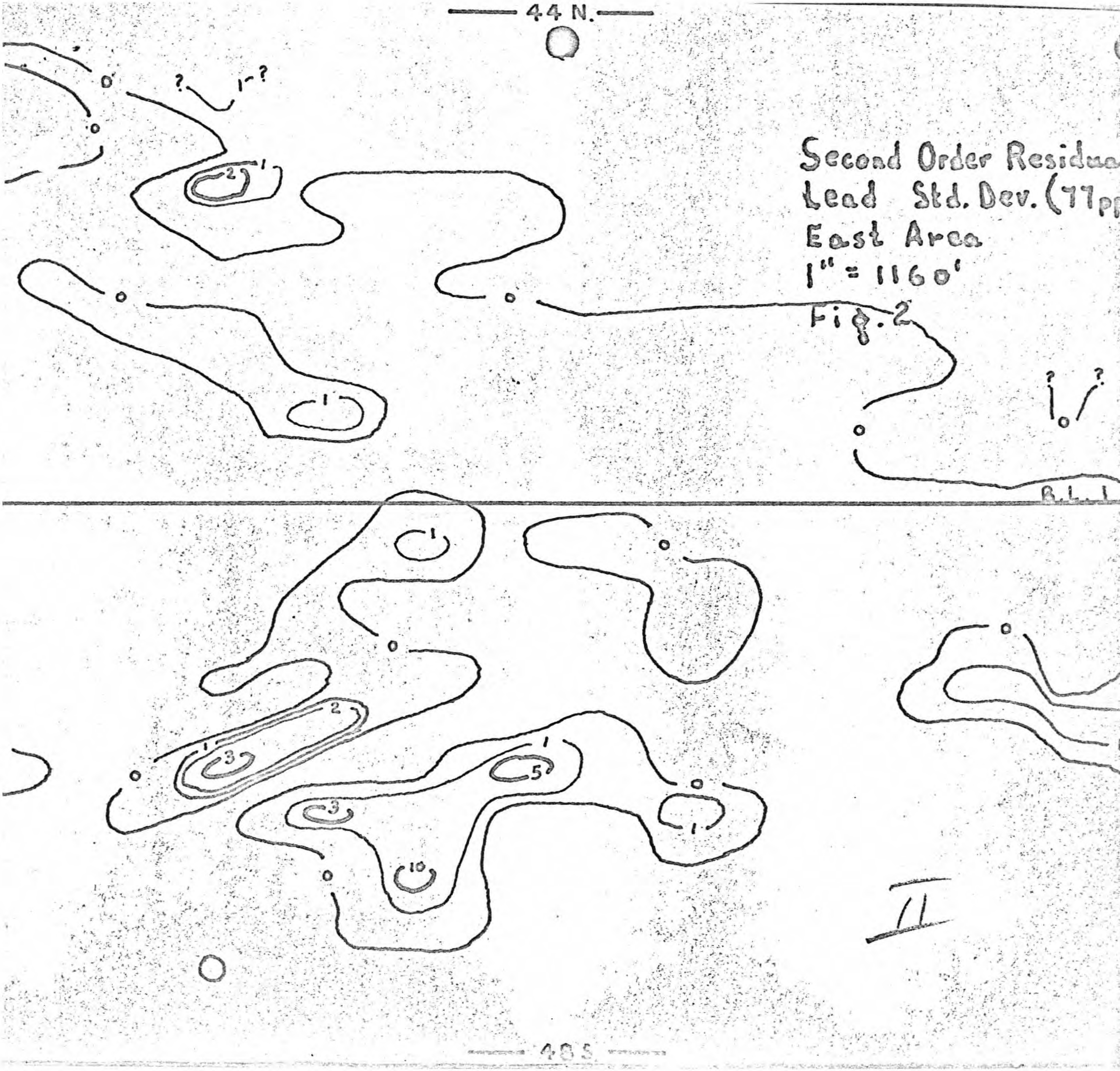


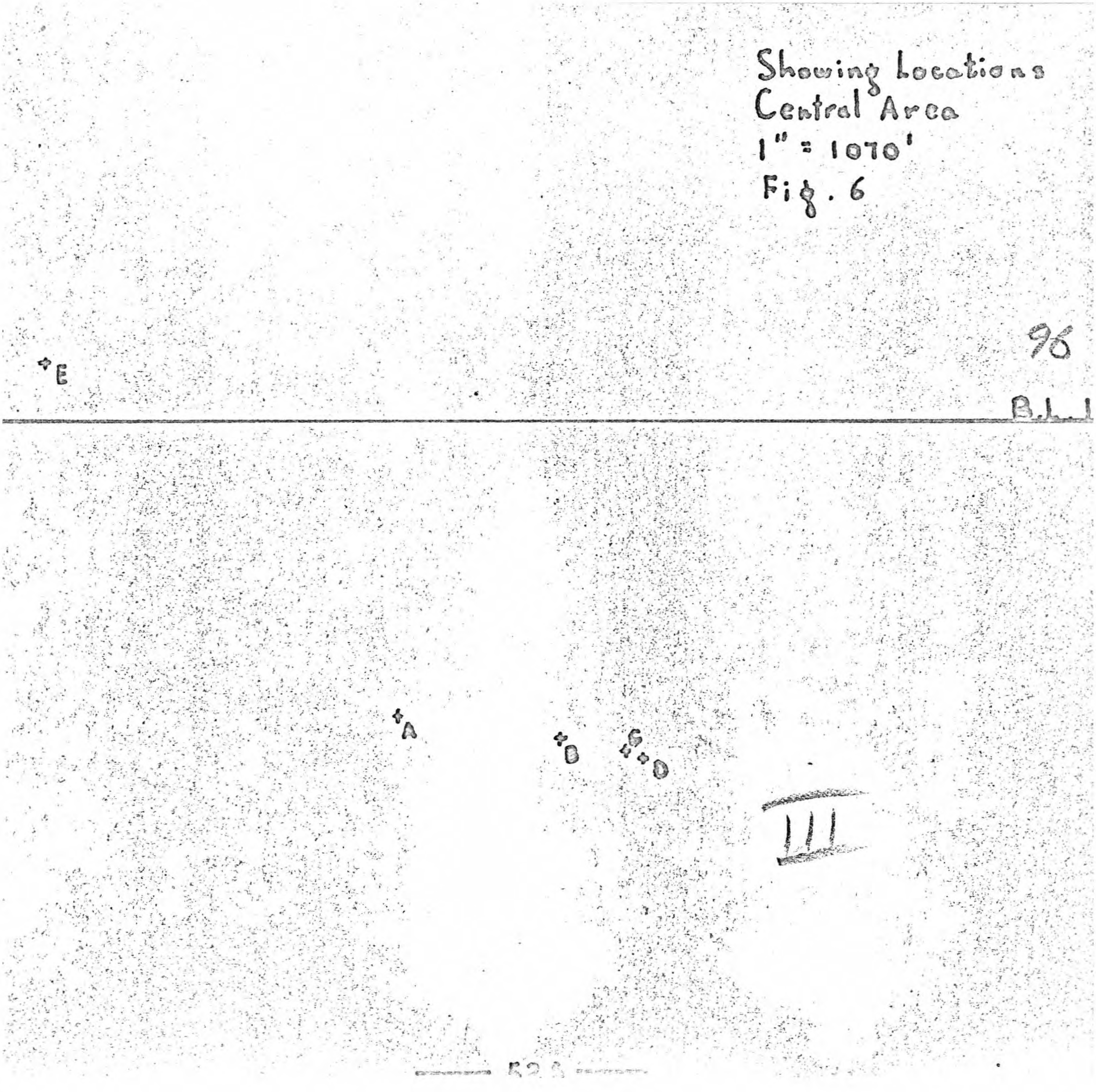
Showing Locations
East Area
1" = 1160'
Fig. 1


44N
Original Data
Lead (ppm.)
East Area
1" = 1160'
Fig. 3
75
300
75
75
800
200
75
75
.665
75
1150
3225
5500
75
75
800
1075
75
600
600
10,000
II

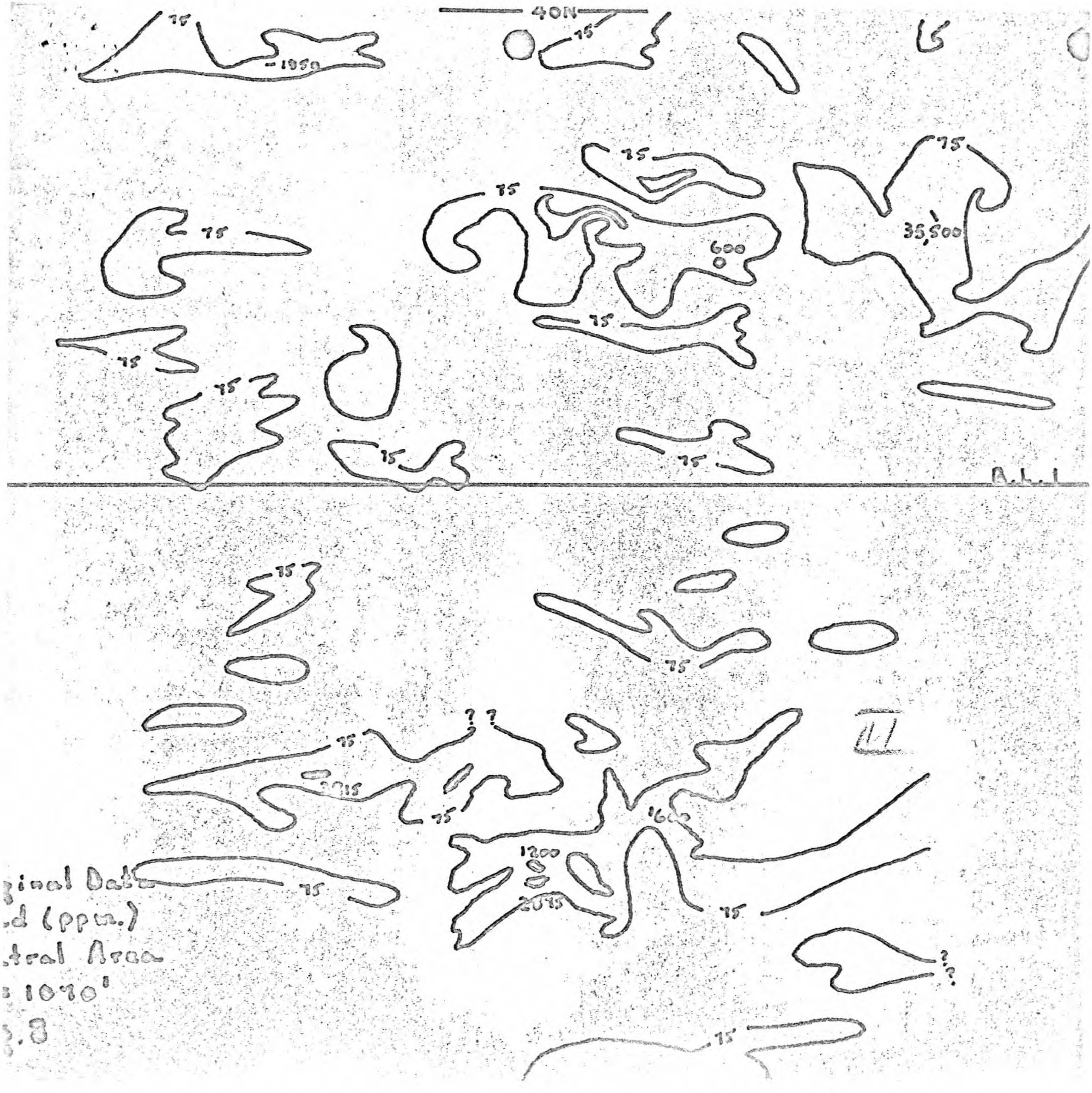

44N
Original Data
Zinc (ppm.)
East Area
1" = 1160'
Fig. 5
200
200
200
200
3200
6200
BL
1690
400
200
200
200
17,000
7760
2960
3660
2075
200
4100
43S


44 N
Second Order Residu
Zinc Std. Dev. (470p
East Area
1" = 1160'
Fig. 4
B.L. 1
?
0
1
3
5
48 S


44 N.
Second Order Residual
Lead Std. Dev. (77pp
East Area
1" = 1160'
Fig. 2
B.L. 1
48 S.



Showing Locations
Central Area
1" = 1070'
Fig. 6



40N
75
1950
35,500
600
1600
1200
ginal Data
d (ppm.)
tral Area
s 1070'