J.C.S

671397

GEOPHYSICS OF THE COPPER MOUNTAIN AND INGERBELLE ORE BODIES IN BRITISH COLUMBIA

Authors:

W. M. Dolan

E. J. Ballantyne, Jr.

T. N. Macauley

To be presented at the 1973
Annual General Meeting
opening on April 15th

ABSTRACT

Geophysics of the Copper Mountain and Ingerbelle Ore Bodies in British Columbia:

W. M. DOLAN, Amax Exploration Inc., Denver, Colorado,

E. J. BALLANTYNE, JR., Newmont Mining Corporation of Canada Limited, Toronto, Ontario and

T. N. MACAULEY, Newmont Mining Corporation of Canada Limited, Vancouver, B.C.

In 1966 Newmont Mining Corporation of Canada Limited discovered a significant amount of disseminated copper mineralization on the west side of the Similkameen River eleven miles south of Princeton, B.C. This discovery became the Ingerbelle ore body. In 1967 the Copper Mountain ore bodies on the east side of the river were purchased from The Granby Mining Company Limited. Both of these properties are now held by Newmont's wholly-owned subsidary, Similkameen Mining Company Limited. Ore reserves recoverable from open pit mining are estimated to be 76 million tons of 0.53% copper. The ore bodies are disseminated copper deposits occurring in agglomerate, tuff and andesite of the Upper Triassic Nicola Group. Stocks and irregular masses of diorite-monzonite-syenite lie adjacent to the deposits.

The intrusive material is magnetic, while the volcanics and ore zones are not. The ore bodies lie, therefore, in an area of low magnetic relief as seen from the helicopter and ground magnetic data. A pyrite halo is generally present around the ore, which gives IP anomalies of larger areal extent than the ore zones. There are no resistivity anomalies directly associated with the ore.

Geophysics did not contribute to the original discoveries. Notwithstanding, the application of geophysics in support of the drilling program and general exploration, was of significant value.

Ground elimination alone, once the combined relationship of magnetics, IP and resistivity was understood, was a vital contributor. Further to that much of the understanding and insight developed during the geologic mapping was derived from constant awareness of the geophysical data.

INTRODUCTION

This paper will present a summary of the geophysical results of recent exploration efforts on two copper deposits in southern British Columbia, namely Copper Mountain and Ingerbelle.

The Ingerbelle ore body is located ten miles south of Princeton, B.C. The Hope-Princeton highway, which formerly crossed the deposit, has been relocated to the west. The Copper Mountain ore bodies lie one mile to the east on the opposite side of the Similkameen River canyon (Figure 1).

Copper Mountain was first staked for copper in 1892. From 1925 to 1930 and later from 1937 to 1957, The Granby Mining Company produced approximately 35 million tons of ore averaging 1.08% copper largely from underground workings. Included in the 35 million tons were 2.4 million tons of 0.76% copper from several open pits near the main underground mine.

In January, 1966, Newmont optioned a group of claims on the west side of the Similkameen River, opposite Copper Mountain, that became known as the Ingerbelle property. Initial exploration in the vicinity of known copper showings consisted of bulldozer trenching, mapping, sampling and a ground magnetic survey. The encouraging results of early drilling led to various geophysical surveys, a large program of detailed drilling and underground drifting.

Coincident with the activity on Ingerbelle, Granby drilled in the vicinity of its former open pit mines. In December, 1967, Newmont purchased their Copper Mountain property and increased the exploration work during 1968 and 1969. Both of these properties are now held by Newmont's wholly-owned subsidiary, Similkameen Mining Co. Ltd.

Ore reserves recoverable by open pit mining are estimated to be 76 million tons of 0.53% copper. Small, but recoverable quantities of gold and silver are present. Production began in March, 1972. The rate of mill production is in excess of the designed capacity of 15,000 tons per day. The Ingerbelle deposit is being mined first, and will be followed by two Copper Mountain ore bodies.

GENERAL GEOLOGY

For a comprehensive description of the geology of the two deposits, the reader is referred to an article in the April, 1973

C.I.M. Bulletin by T. N. Macauley, or Bulletin 59 of the British Columbia Department of Mines and Petroleum Resources by V. A. Preto.

An appreciation of the general geology of the environment of the two deposits will be gained from Figure 2, particularly as it applies to the subsequent geophysical discussion.

The oldest rocks in the immediate area belong to the Nicola Group of Late Triassic age and it is within these rocks that most of the ore is located. These consist of andesites, tuffs, agglomerates, argillites and siltstones. Due to their lensy nature, locally intense alteration, and the lack of a good marker bed, their stratigraphy and structure are not well understood. Locally, this is particularly exemplified by the fact that geology, geophysics or geochemistry in any combination have not been very successful in categorizing the units within the Nicola over any considerable distance. However, it can be said that at Ingerbelle the Nicola rocks dip about 15° to the north. At Copper Mountain gentle to moderate dips prevail giving an uneven undulating pattern except where they are folded down steeply against the Copper Mountain Stock. Faulting and fracturing are widespread in the belt of volcanics that host the ore bodies although alteration has transformed many of them into hard compact rocks.

Several Late Triassic stocks and numerous small irregular intrusive masses intrude the Nicola group. They are important as they have a structural and genetic relationship to the ore, and are themselves locally mineralized. The two major intrusives that bound the belt of Nicola rocks are the Copper Mountain Stock to the south and the Lost Horse complex to the north. Another intrusive, the Voigt stock, lies to the east.

The Copper Mountain stock is the largest of the three intrusives, being approximately five by two and one-half miles in size. The northeast portion of the contact dips inward 45 to 85°. The western contact is truncated by a fault system, hereinafter referred to as the Boundary Fault, that strikes approximately north-south and dips steeply westward. This stock is composed of three major rock types, exemplifying differentiation. The outer zone is a diorite, the intermediate zone is a monzonite and the core is a syenitic pegmatite.

The Lost Horse complex is in reality a group of intrusions, occurring in a belt two to four thousand feet wide, extending from the Voigt stock on the east to the Boundary Fault on the west. These rocks range from syenite to diorite in composition, and are also quite variable in colour, texture, and mode of occurrence. They contain volcanic inclusions, igneous breccias, and their margins are irregular and sometimes gradational due to alteration. Weak chalcopyrite/pyrite mineralization occurs in many places within this complex and forms a portion of the Pit 2 ore body.

The Voigt stock to the east is composed of medium-grained diorite.

North-south, steeply-dipping felsite dykes cutting the volcanics, intrusions and the mineralization range from a few feet to more than a hundred feet in width.

Tertiary volcanics and minor conglomerates from the Princeton Group are found to the west of the Boundary Fault, north of the Lost Horse intrusions, and in a trough about 300 feet by 2,400 feet and 100 feet deep overlying portions of the Copper Mountain ore bodies.

MINERALIZATION

The suite of minerals occurring in the ore deposits is relatively simple. However, the shape of the deposits and the distribution of the ore minerals within them are irregular.

The copper mineralization at Ingerbelle occurs entirely as chalcopyrite. There is generally a pyrite association and all sulphides are unevenly distributed through the host rocks. They occur mainly as fine disseminations, with some fracture-coatings and a few coarser veins. The total sulphide content varies from 2 to 5% by volume but some of the pyritic material on the fringes of the ore body carries up to 12% sulphides by volume. Locally pyrrhotite has been observed.

At Copper Mountain the ore is slightly different than at Ingerbelle. The Pit 2 deposit carries 2 to 8% sulphidesas chalcopyrite/pyrite mainly in the form of fracture-coatings and veinlets. Much of the Pit 1 deposit consists of very fine chalcopyrite/pyrite disseminations in agglomerates and tuffs. A third type of ore is that found in the fine-grained tuff beds adjacent to the Copper Mountain Stock. It consists of bornite/chalcopyrite fracture fillings with little associated pyrite.

As mentioned before, pyrite occurs with the chalcopyrite mineralization, but is also widely distributed elsewhere. At Ingerbelle it is found at the margins on all but the north side of the deposit, and also in the argillite to the west of the Boundary Fault. At Copper Mountain, there is no clear tendency for a pyrite zone to be present around the ore deposits, though it is widely distributed through the Nicola and Lost Horse rocks in many areas.

Magnetite occurs as an accessory mineral in the stocks and in the less altered portions of the Nicola volcanics, while magnetite of a later origin occurs in a variety of forms. It is normally absent from the more altered albitized volcanics that comprise the principal host rock for copper mineralization. It is totally absent in the most intensely altered rocks, which carry only occasional traces of mineralization. This inverse relationship of magnetite to copper is illustrated in the geophysical section.

HELICOPTER MAGNETIC SURVEY

In 1967 a helicopter magnetic survey was executed using a Newmont-built proton precision magnetometer. Neither an altimeter nor a path-recovery camera were employed. Navigation was controlled visually with the aid of air photographs. Because of the foregoing, herringbone is noted on the magnetic map (Figure 3), particularly where tie lines did not provide an adequate basis for adjustment.

The zoning of the Copper Mountain Stock to the south of the map area is immediately evident. The dioritic outer portion of the stock exhibits a magnetic high. The monzonitic section, as one moves inward towards the core, is somewhat intermediate and not clearly defined. The pagmatitic core occurs as a distinct low. The magnetic expression observed over the Copper Mountain Stock is regarded as classical for well differentiated intermediate intrusives.

On the eastern margin of the map the diorite of the Voigt stock is expressed as a magnetic high. The Lost Horse intrusions to the north in part express themselves as a moderate magnetic ridge. From the air, the Nicola Group between the intrusives and the Princeton Group to the west of the Boundary Fault and north of the intrusives are expressed as relative magnetic lows. To the southwest a magnetic high coincides with an area of known Tertiary basalts.

GROUND MAGNETIC SURVEY

In 1968, having accumulated data from nine different magnetic surveys covering both Ingerbelle and the Copper Mountain area, the computer facilities of Newmont Exploration were utilized to compile a single ground magnetic map (Figure 4).

There are several singularly well-defined features on the ground magnetics; the most striking one and the most easily seen is the contact of the Copper Mountain Stock south of Pit 1 and the old mine.

West of the Boundary Fault, the magnetics are flat, reflecting the absence of intrusions. The fault north of Ingerbelle does not appear to be straight. The irregularities indicated on the geological map are deducted from the magnetics, because of the absence of outcrop.

In a crude sense there is a chain of higher magnetic features extending northward from the Copper Mountain Stock margin, just to the west of the old highway. These are interrupted by two sectors of intermediate to low magnetic features. The southern most of these two sectors essentially coincides with the Ingerbelle ore body; the northern most, 2,400 feet north of the Ingerbelle zone, coincides with a zone of copper mineralization known as the Red Buck zone. The Red Buck zone, while not commercial, saw minor copper mining in earlier days.

At Copper Mountain, magnetics exhibit less correlation with mineralization. Nonetheless, there are several features worth noting. Extending northward from the intrusive contact west of Pit 1 is a series of dykes and intrusive outlyers that are exceedingly well expressed on the magnetics, and indeed also on the resisitivity, which will be discussed later. At the Pit 2 ore body, a zone of magnetic highs trends east-west. It is reasonable to suggest that these magnetic features are related to the southern contact of the Lost Horse complex reflecting contact metasomatism. On the northern portion of the magnetic map, there are a series of highs that are related to concentrations of magnetite in breccias and other phases of the Lost Horse complex.

In general, the low magnetics between the Lost Horse complex and Copper Mountain Stock reflect the Nicola Volcanics as on the helicopter magnetics.

Despite considerable efforts to categorize rock types magnetically, only limited geological confirmation was forthcoming.

INDUCED POLARIZATION SURVEY

The results of eight different IP surveys have been combined and are shown on this slide. Different arrays, spacings, equipment and contractors were used on the various surveys, making a meaningful presentation difficult. Therefore, for illustration purposes, this simplified presentation shows areas above background and above twice background. While somewhat simplified, the absence of masking by the overburden of sulphide distributions makes this illustration reasonably valid.

The majority of the data were taken using a gradient array in a series of 2, 000 by 2, 000-foot contiguous blocks, with a current electrode spread of 6, 000 feet and a 200-foot receiving dipole. Lines were 200 feet apart and a station spacing of 100 feet was used. Two receiver parties were employed simultaneously for efficiency.

Starting in the western section, the Boundary Fault is well expressed due to the presence of the pyritic argillites immediately west of the fault.

The intrusives have, in general, low chargeabilities. The chargeability data, coupled with the magnetics, make an excellent mapping tool for the concealed intrusive contacts.

As might be expected at Ingerbelle, the areal extent of the IP response in the vicinity of the ore bodies is larger, approximately three times, than the ore zone, due to the pyritic halo. Although larger, the IP in conjunction with the magnetic and resistivity data served to confine the drilling pattern. Furthermore, the IP effectively aided in eliminating ground away from the ore zone. This has operating connotations, as well as its use for exploration, in that the IP assisted in eliminating ground from the prospecting interest that was suitable for waste dump sites.

On the Copper Mountain side, it should be noted that the total area of above background effect is perhaps five times the area of the ore bodies. Thus the ground elimination advantage was less than on the Ingerbelle side.

The ore zone at Pit 1 is well delineated by the twice background contour line. The mineralization responds well to IP being a true disseminated sulphide body without a pyrite halo.

The data in the vicinity of the Pit 2 ore body are more erratic, attributable in part to coarser mineralization and, in part, to incomplete coverage in the pit. Nevertheless, in large measure the anomaly to the east of the pit does occur over that portion of the ore zone.

The twice background chargeability occurring over the underground mine is partially interpolated from the data taken on opposing sides. Ground subsidence precluded effective coverage. There is adequate evidence supporting the interpolation.

Some of the practical considerations in using the gradient array deserve discussion. The gradient work, as previously mentioned, was conducted in contiguous blocks. This, coupled with the absence of overburden masking effects, means that the contour presentation of the chargeability is representative of the sulphide distribution, much as a magnetic contour map is representative of magnetite distribution. An important advantage was thus derived from the geologist being able to immediately re-assess the IP data in the light of new drill hole information.

RESISTIVITY

The resistivity data (Figure 6) is now compared to the chargeability data.

It will be noted that the Ingerbelle ore zone lies in a relatively broad zone of moderate resistivities, generally of the order of 200 to 500 ohm meters. To the south of the ore zone, the diorite portion of the Copper Mountain Stock exhibits resistivities that are appreciably higher, ranging from 500 to 1,000 ohm meters. To the west in the argillites resistivities drop to values less than 100 ohm meters.

On the Copper Mountain side, the Lost Horse complex is largely expressed by moderate to high resistivities, i.e. 200 to 1,000 ohm meters, with the highest occurring over the intrusive outlyer immediately to the west of Pit 1.

Generally speaking, the ore zones exhibit resistivities very similar to the rest of the volcanics.

The resistivity-chargeability patterns exhibited here are not surprising. Disseminated copper occurrences rarely appreciably alter the resistivities of the containing rocks. The IP data therefore must usually be analyzed as though each rock unit were part of a separate survey.

FURTHER GEOPHYSICAL WORK

An airborne electromagnetic survey failed to reveal any significant conductors on the property and a limited program of ground EM in the vicinity of the Pit 2 ore body produced similar results. It was concluded that EM is an ineffective tool in the search for this type mineralization.

Figure 7 is a north-south geological section through Ingerbelle. The profiles show that the highest chargeabilities and magnetics occur to the south (left side) of the ore zones, where considerable pyrite and lesser pyrrhotite and magnetite are present. To the north of the ore body sulphides are nearly absent and magnetite is concentrated in certain phases of the Lost Horse intrusive rocks.

Figure 8 portrays the magnetic susceptibility versus copper assays on a section 200 feet west of the geological section. The plots to the left of the drill holes are the assayed copper values. The magnetic susceptibility is on the right hand side of the holes. The susceptibility information was obtained with a continuously-recording magnetic susceptibility meter, responding to the traversing of a sensing head along the core, without removal from the core boxes. The instrument was developed by Newmont Exploration Limited.

The combined copper-susceptibility section illustrates the inverse relationship existing between the copper and magnetite. An early recognition of this inverse relationship is what prompted the development of the instrument. Unfortunately, this work was somewhat after the fact and of an experimental nature, but it points up an application of magnetic physical properties that has contributed to a better understanding of the geology. Had the equipment been available sooner, assistance in examination of the core might have been routinely provided.

CONCLUSION

It is concluded that:

The Ingerbelle and Copper Mountain ore bodies are not readily distinguishable on magnetic surveys.

They are located within an area of IP anomalies that are several times the size of the ore bodies.

The volume and/or degree of interconnection of sulphides in these deposits are insufficient to detect with electromagnetic or resistivity methods.

While geophysics did not contribute to the original discoveries, the application of geophysics in support of the drilling program and general exploration was unquestionably of significant value. Certainly ground elimination alone, once the combined relationship of magnetics, IP and resistivity were understood, was a vital contributor. Further to that, much of the understanding and insight developed during the geologic mapping program was derived from constant awareness of the geophysical portrayals.

We would like to thank the officers of Similkameen Mining Co. and Newmont Mining Corporation of Canada for permission to publish this paper.

REFERENCES:

Macauley, T. N., Geology of the Ingerbelle and Copper Mountain Deposits in Princeton, B.C., CIM Bulletin, Vol. 66, No. 732, pp. 105, 1973.

Preto, V. A. G., Geology of Copper Mountain, B.C. Dept. of Mines and Petroleum Resources, Bulletin 59, 1972.

W. M. DOLAN

William M. Dolan received his B.S. and M.S. degrees in geophysics from the University of Utah in 1956 and 1957 respectively. Prior to that he had served four years in the U.S. Navy Air Corps.

Dolan was a geophysicist engaged in both electromagnetic research and prospecting operations with Newmont Exploration, first in 1955, then from 1957 to 1966. From 1966 to 1970 he was Chief Geophysicist for Newmont Mining Corporation of Canada Ltd. Since the beginning of 1970 he has held the position of Chief Geophysicist for Amax.

Dolan is a member of the CIMM, Society of Exploration Geophysicists, past President of the Canadian Exploration Geophysics Society (KEGS), Sigma Xi and the Associations of Professional Engineers of both B. C. and Ontario.

****

T. N. MACAULEY

Terrence N. Macauley was born in Sudbury, Ontario, and studied geological engineering at Queen's University (B.Sc., 1958), and Michigan Technological University (M.Sc., 1962). Following positions with Sherritt Gordon Mines in Lynn Lake, Manitoba, and with Franc R. Joubin and Algoma Central Railway in the Algoma district of Ontario, he joined Newmont Mining Corporation of Canada in 1965. In the period 1966 to 1970 he was employed in the exploration and development of Newmont's copper deposits near Princeton, B.C.

****

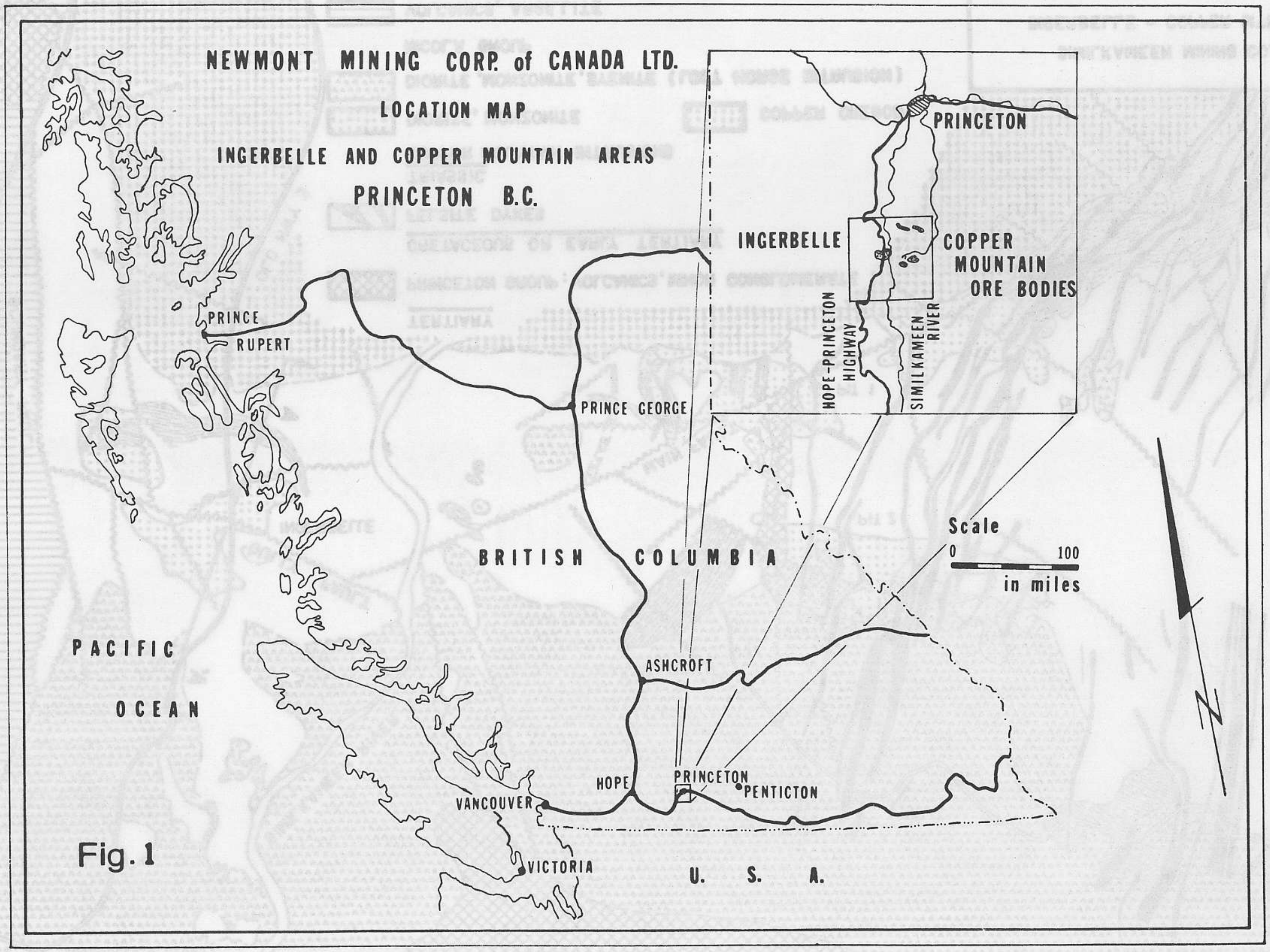
E. J. BALLANTYNE, JR.

Edwin J. Ballantyne, Jr. received his B.S. and M.S. degrees in Mining Engineering - graduate work being done in geophysics - from Missouri School of Mines in 1960 and 1961 respectively. Prior to that he had served four years in the military service, the last two and one-half years as a Naval Aviator with the U.S. Marine Corps.

Ballantyne worked for the New Jersey Zinc Company as a research and exploration geophysicist from 1961 to 1967. He conducted geophysical exploration programs in the United States and Canada. In addition, in 1963 he justified one of the first in-house digital computers to be used for geophysics in the mining industry.

In 1967 he joined Newmont and served as Chief Geophysicist for Newmont Pty. Ltd. in Australia for over two years. Since the beginning of 1970 he has held the position of Chief Geophysicist of Newmont Mining Corporation of Canada Ltd.

Ballantyne is a member of the Society of Exploration Geophysicists, European Association of Exploration Geophysicists, Canadian Exploration Geophysical Society (KEGS), CIMM and the Association of Professional Engineers of Ontario.



NEWMONT MINING CORP. of CANADA LTD.
LOCATION MAP
INGERBELLE AND COPPER MOUNTAIN AREAS
PRINCETON B.C.
PRINCETON
INGERBELLE
COPPER MOUNTAIN ORE BODIES
HOPE-PRINCETON HIGHWAY
SIMILKAMEEN RIVER
PRINCE RUPERT
PRINCE GEORGE
Scale
0
100
in miles
BRITISH COLUMBIA
PACIFIC OCEAN
ASHCROFT
HOPE
PRINCETON
PENTICTON
VANCOUVER
VICTORIA
U. S. A.

Fig. 1

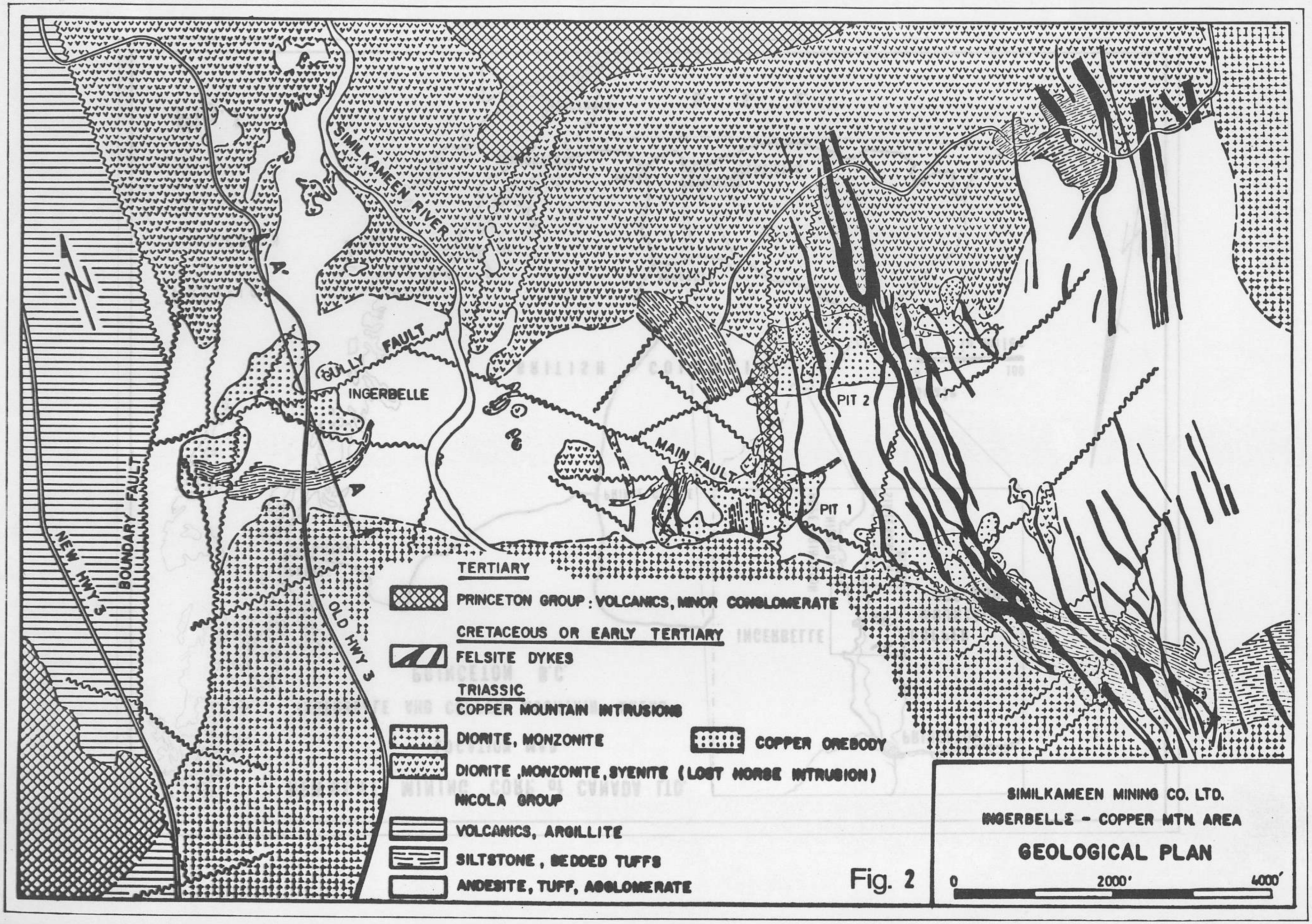

SIMILKAMEEN RIVER
GULLY FAULT
INGERBELLE
MAIN FAULT
PIT 1
PIT 2
A'
A
BOUNDARY FAULT
NEW HWY 3
OLD HWY 3
TERTIARY
PRINCETON GROUP : VOLCANICS, MINOR CONGLOMERATE
CRETACEOUS OR EARLY TERTIARY
FELSITE DYKES
TRIASSIC
COPPER MOUNTAIN INTRUSIONS
DIORITE, MONZONITE
COPPER OREBODY
DIORITE, MONZONITE, SYENITE (LOST HORSE INTRUSION)
NICOLA GROUP
VOLCANICS, ARGILLITE
SILTSTONE, BEDDED TUFFS
ANDESITE, TUFF, AGGLOMERATE
SIMILKAMEEN MINING CO. LTD.
INGERBELLE - COPPER MTN. AREA
GEOLOGICAL PLAN
0
2000'
4000'

Fig. 2

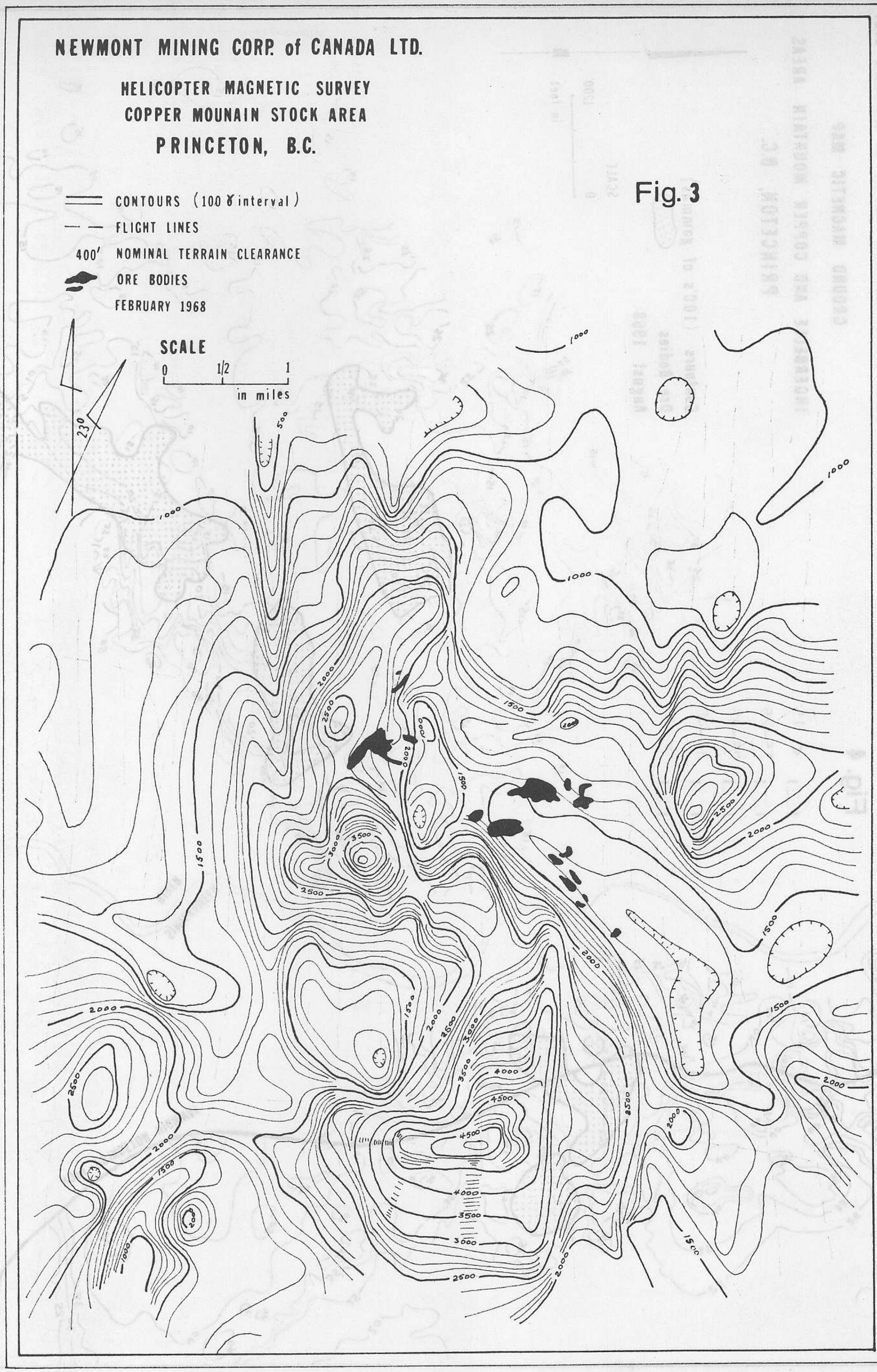
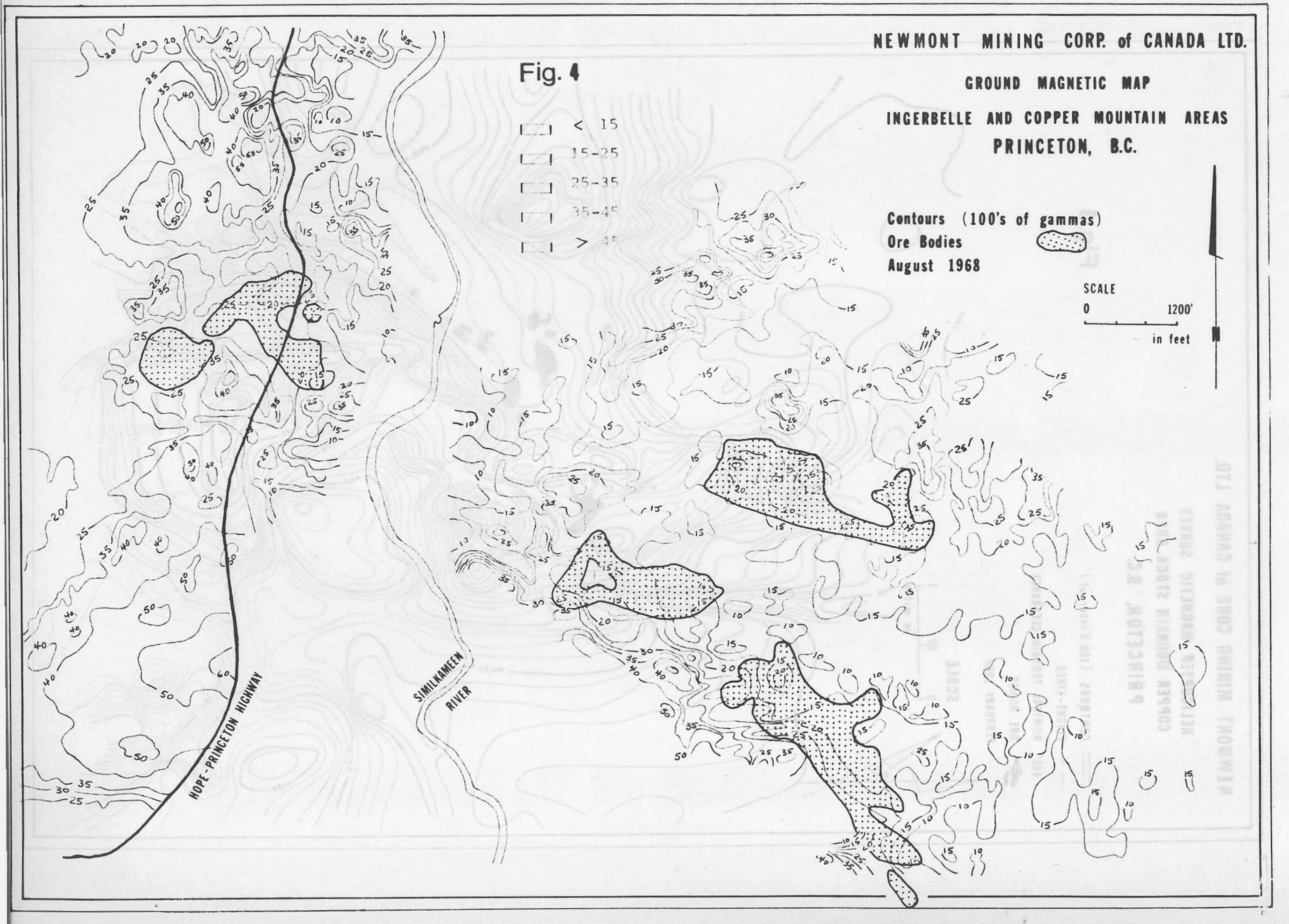

NEWMONT MINING CORP. of CANADA LTD.
HELICOPTER MAGNETIC SURVEY
COPPER MOUNAIN STOCK AREA
PRINCETON, B.C.
CONTOURS (100 γ interval)
FLIGHT LINES
400' NOMINAL TERRAIN CLEARANCE
ORE BODIES
FEBRUARY 1968
SCALE
0 1/2 1
in miles
23°

Fig. 3


NEWMONT MINING CORP. of CANADA LTD.
GROUND MAGNETIC MAP
INGERBELLE AND COPPER MOUNTAIN AREAS
PRINCETON, B.C.
Fig. 4
< 15
15-25
25-35
35-45
> 45
Contours (100's of gammas)
Ore Bodies
August 1968
SCALE
0
1200'
in feet
HOPE-PRINCETON HIGHWAY
SIMILKAMEEN RIVER

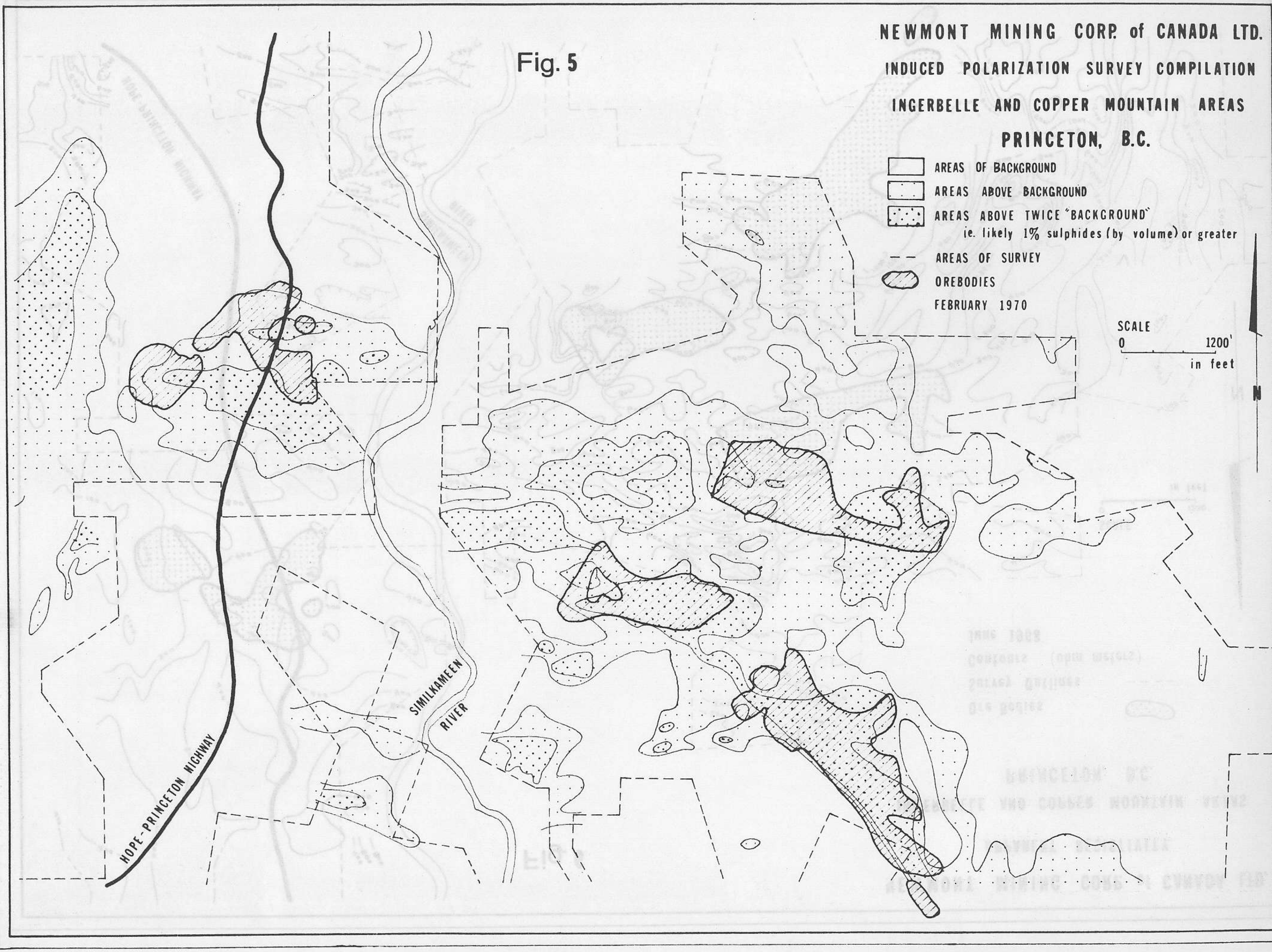


Fig. 5
NEWMONT MINING CORP. of CANADA LTD.
INDUCED POLARIZATION SURVEY COMPILATION
INGERBELLE AND COPPER MOUNTAIN AREAS
PRINCETON, B.C.
AREAS OF BACKGROUND
AREAS ABOVE BACKGROUND
AREAS ABOVE TWICE "BACKGROUND"
ie. likely 1% sulphides (by volume) or greater
AREAS OF SURVEY
OREBODIES
FEBRUARY 1970
SCALE
0
1200'
in feet
N
SIMILKAMEEN
RIVER
HOPE-PRINCETON HIGHWAY

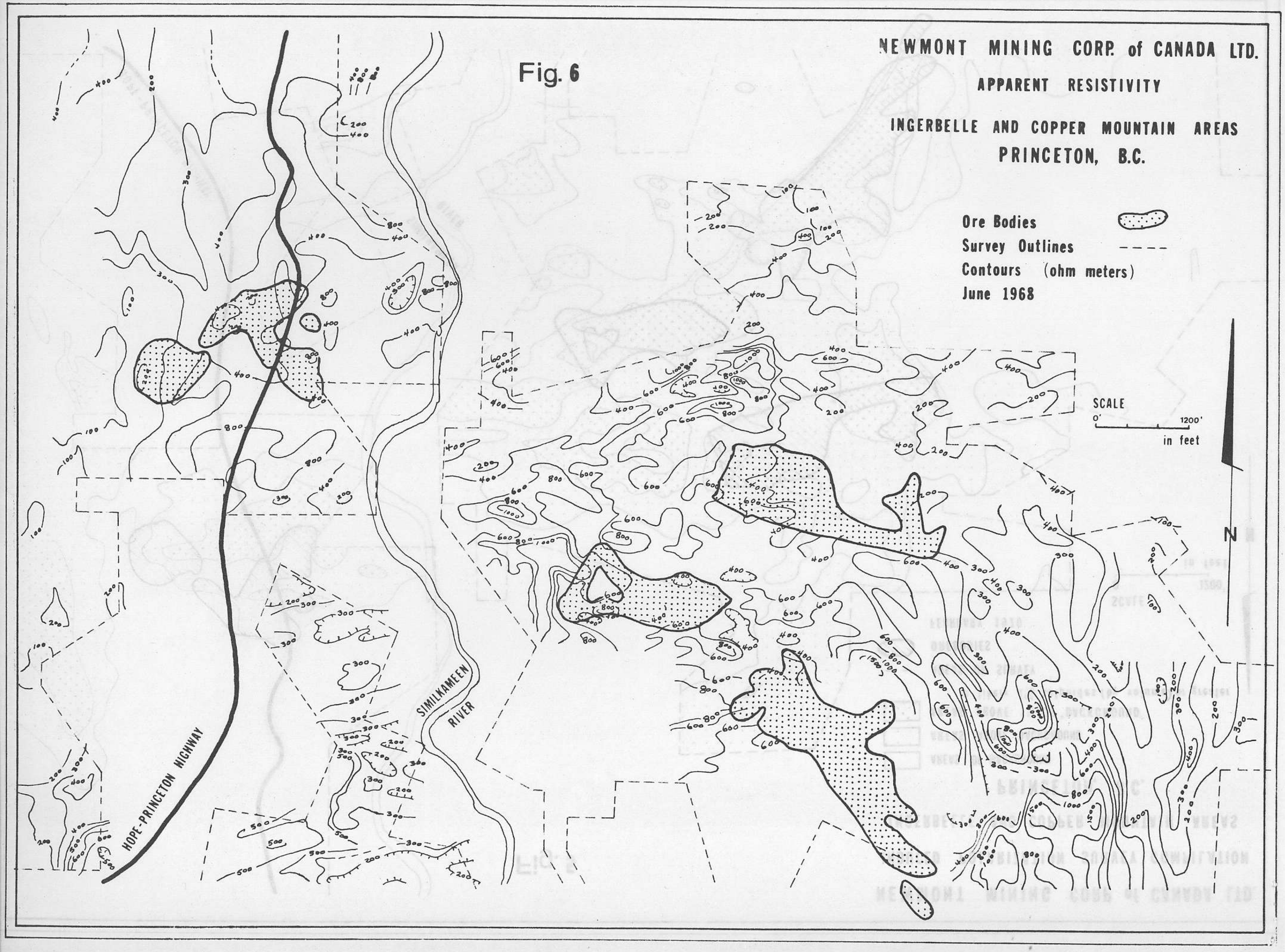
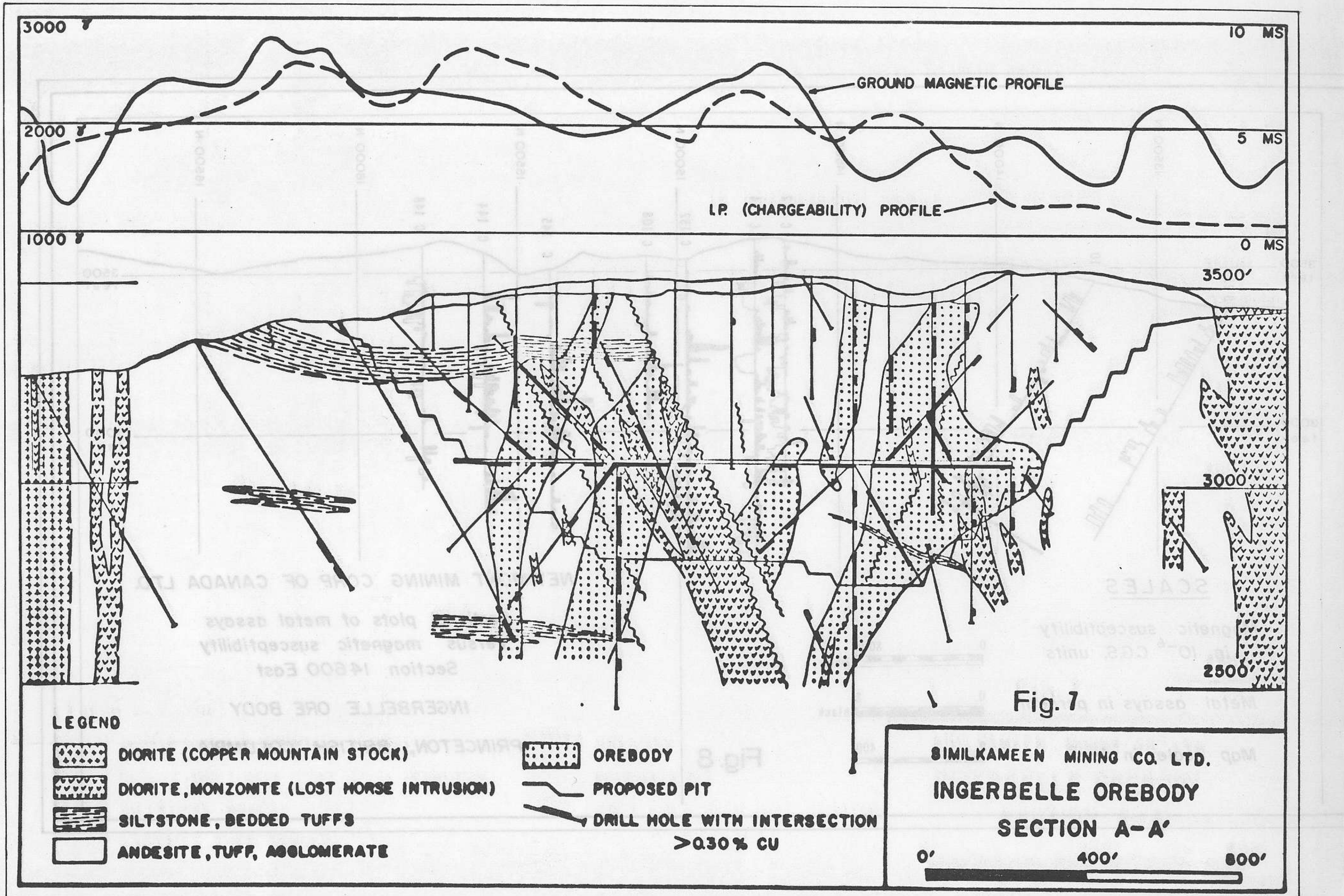


Fig. 6
NEWMONT MINING CORP. of CANADA LTD.
APPARENT RESISTIVITY
INGERBELLE AND COPPER MOUNTAIN AREAS
PRINCETON, B.C.
Ore Bodies
Survey Outlines
Contours (ohm meters)
June 1968
SCALE
0'
1200'
in feet
N
HOPE-PRINCETON HIGHWAY
SIMILKAMEEN RIVER



3000 γ
2000 γ
1000 γ
10 MS
5 MS
0 MS
GROUND MAGNETIC PROFILE
I.P. (CHARGEABILITY) PROFILE
3500′
3000′
2500′
LEGEND
DIORITE (COPPER MOUNTAIN STOCK)
DIORITE, MONZONITE (LOST HORSE INTRUSION)
SILTSTONE, BEDDED TUFFS
ANDESITE, TUFF, AGGLOMERATE
OREBODY
PROPOSED PIT
DRILL HOLE WITH INTERSECTION >0.30 % CU
SIMILKAMEEN MINING CO. LTD.
INGERBELLE OREBODY
SECTION A–A′
0′
400′
800′

Fig. 7

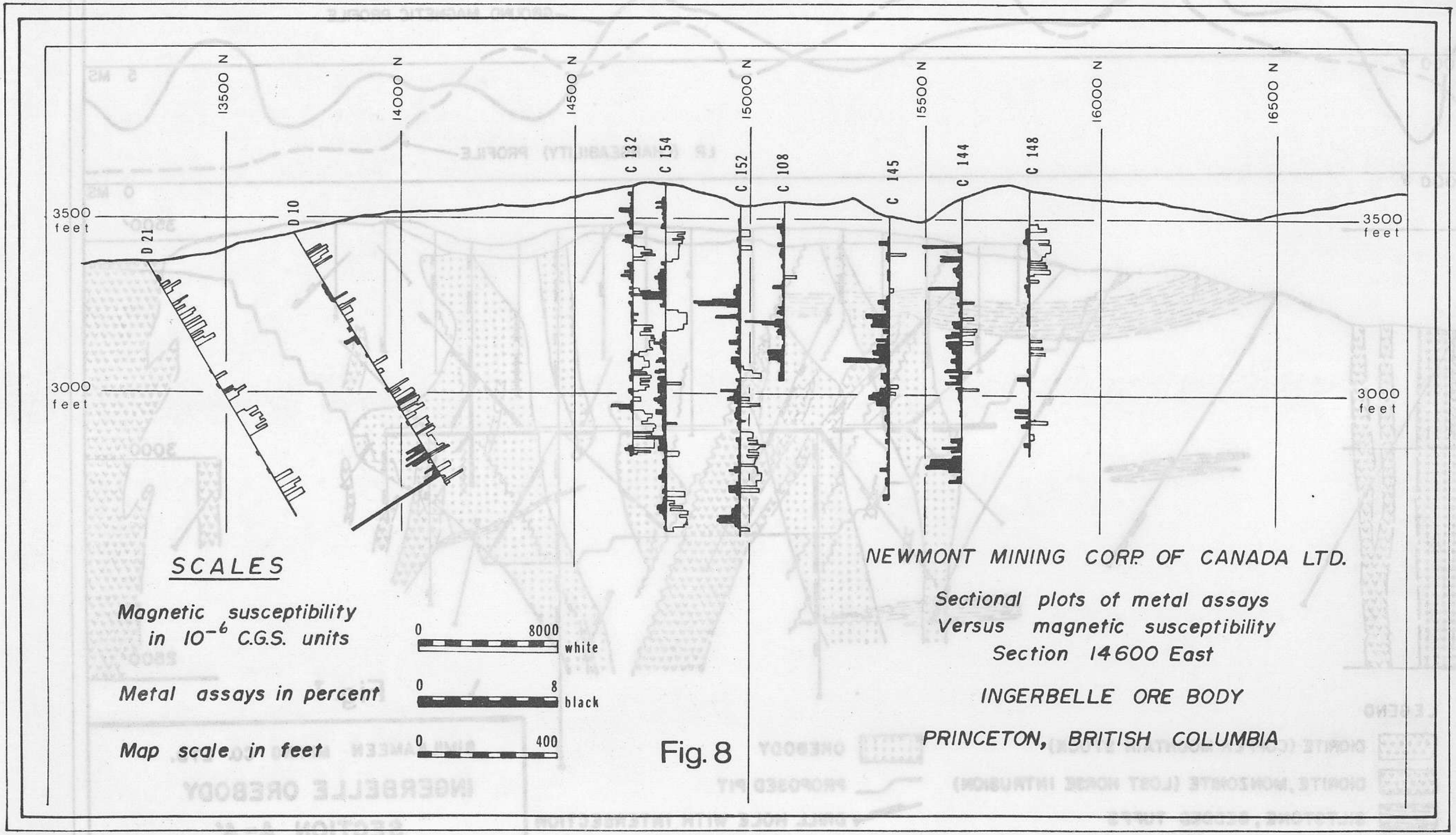

13500 N
14000 N
14500 N
15000 N
15500 N
16000 N
16500 N
3500 feet
3000 feet
D 21
D 10
C 132
C 154
C 152
C 108
C 145
C 144
C 148
SCALES
Magnetic susceptibility in 10^{-6} C.G.S. units
0
8000
white
Metal assays in percent
0
8
black
Map scale in feet
0
400
NEWMONT MINING CORP. OF CANADA LTD.
Sectional plots of metal assays Versus magnetic susceptibility Section 14600 East
INGERBELLE ORE BODY
PRINCETON, BRITISH COLUMBIA

Fig. 8