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OPEN FILE REPORT SERIES

THE PRE-MINING GEOMORPHOLOGY AND SURFACE GEOLOGY OF THE BEASLEY CREEK GOLD MINE - LAVERTON, WESTERN AUSTRALIA

I.D.M. Robertson and H.M. Churchward

CRC LEME OPEN FILE REPORT 9

October 1998

(CSIRO Division of Exploration Geoscience Report 26R, 1989. Second impression 1998)

CRC LEME is an unincorporated joint venture between The Australian National University, University of Canberra, Australian Geological Survey Organisation and CSIRO Exploration and Mining, established and supported under the Australian Government's Cooperative Research Centres Program.

CRC

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Headquarters: CRC LEME c/o CSIRO Exploration and Mining, Private Bag, PO Wembley, Western Australia, 6014

RESEARCH ARISING FROM CSIRO/AMIRA REGOLITH GEOCHEMISTRY PROJECTS 1987-1993

In 1987, CSIRO commenced a series of multi-client research projects in regolith geology and geochemistry which were sponsored by companies in the Australian mining industry, through the Australian Mineral Industries Research Association Limited (AMIRA). The initial research program, "Exploration for concealed gold deposits, Yilgarn Block, Western Australia" (1987-1993) had the aim of developing improved geological, geochemical and geophysical methods for mineral exploration that would facilitate the location of blind, buried or deeply weathered gold deposits. The program included the following projects:

P240: Laterite geochemistry for detecting concealed mineral deposits (1987-1991). Leader: Dr R.E. Smith.
Its scope was development of methods for sampling and interpretation of multi-element laterite geochemistry data and application of multi-element techniques to gold and polymetallic mineral exploration in weathered terrain. The project emphasised viewing laterite geochemical dispersion patterns in their regolith-landform context at local and district scales. It was supported by 30 companies.

P241: Gold and associated elements in the regolith - dispersion processes and implications for exploration (1987-1991). Leader: Dr C.R.M. Butt.
The project investigated the distribution of ore and indicator elements in the regolith. It included studies of the mineralogical and geochemical characteristics of weathered ore deposits and wall rocks, and the chemical controls on element dispersion and concentration during regolith evolution. This was to increase the effectiveness of geochemical exploration in weathered terrain through improved understanding of weathering processes. It was supported by 26 companies.

These projects represented "an opportunity for the mineral industry to participate in a multi-disciplinary program of geoscience research aimed at developing new geological, geochemical and geophysical methods for exploration in deeply weathered Archaean terrains". This initiative recognised the unique opportunities, created by exploration and open-cut mining, to conduct detailed studies of the weathered zone, with particular emphasis on the near-surface expression of gold mineralisation. The skills of existing and specially recruited research staff from the Floreat Park and North Ryde laboratories (of the then Divisions of Minerals and Geochemistry, and Mineral Physics and Mineralogy, subsequently Exploration Geoscience and later Exploration and Mining) were integrated to form a task force with expertise in geology, mineralogy, geochemistry and geophysics. Several staff participated in more than one project. Following completion of the original projects, two continuation projects were developed.

P240A: Geochemical exploration in complex lateritic environments of the Yilgarn Craton, Western Australia (1991-1993). Leaders: Drs R.E. Smith and R.R. Anand.
The approach of viewing geochemical dispersion within a well-controlled and well-understood regolith-landform and bedrock framework at detailed and district scales continued. In this extension, focus was particularly on areas of transported cover and on more complex lateritic environments typified by the Kalgoorlie regional study. This was supported by 17 companies.

P241A: Gold and associated elements in the regolith - dispersion processes and implications for exploration. Leader: Dr. C.R.M. Butt.
The significance of gold mobilisation under present-day conditions, particularly the important relationship with pedogenic carbonate, was investigated further. In addition, attention was focussed on the recognition of primary lithologies from their weathered equivalents. This project was supported by 14 companies.

Although the confidentiality periods of the research reports have expired, the last in December 1994, they have not been made public until now. Publishing the reports through the CRC LEME Report Series is seen as an appropriate means of doing this. By making available the results of the research and the authors' interpretations, it is hoped that the reports will provide source data for future research and be useful for teaching. CRC LEME acknowledges the Australian Mineral Industries Research Association and CSIRO Division of Exploration and Mining for authorisation to publish these reports. It is intended that publication of the reports will be a substantial additional factor in transferring technology to aid the Australian Mineral Industry.

This report (CRC LEME Open File Report 9) is a Second impression (second printing) of CSIRO, Division of Exploration Geoscience Restricted Report 026R, first issued in 1989, which formed part of the CSIRO/AMIRA Projects P240 and P241.

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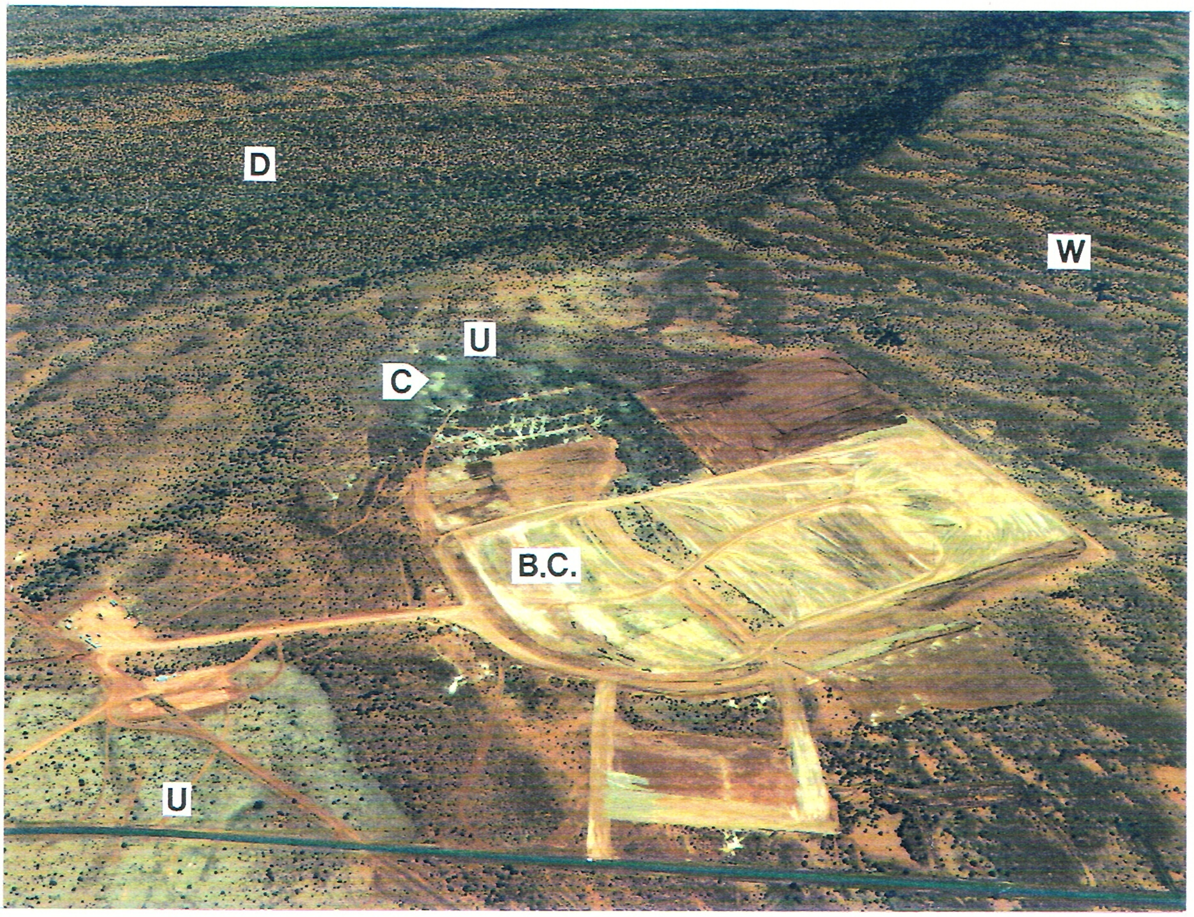

Oblique air photograph of the setting of the Beasley Creek Gold Mine (BC) at an early stage of mine development. This shows the broad active drainage floors (D), the wash plains or Wanderrie Country (W), the subcrop of Archaean Basement (U) with patches of calcrete (C). Photo by Kevron Aerial Surveys.

PREFACE

The CSIRO-AMIRA Research Programme "Exploration for Concealed Gold Deposits, Yilgarn Block, Western Australia" has as its overall aim the development of improved geological, geochemical and geophysical methods for mineral exploration that will facilitate the location of blind, concealed or deeply weathered gold deposits. This report presents results of a study at the Beasley Creek gold mine, a locality which is being actively investigated by both the "Laterite Geochemisty" (P240) and the "Weathering Processes" (P241) modules of the AMIRA Gold programme. Both authors are involved in both projects. It is also a possible study area for the Remote Sensing (P243) module.

The co-operation of Western Mining Corporation Ltd in permitting the early release of this report to the Sponsors of both projects is greatly appreciated.

The authors have mapped the surface units of the regolith at Beasley Creek and have interpreted the inter-relationships of these materials, one with another, to the landscape and to the underly geology. Studies of this type act as a guide to the choice of available sampling media and assist in the interpretation of geochemical data. It is also essential to understand the landscape and its history in order to interpret the history of the regolith and the distribution of elements within it.

R.E. Smith
Project Leader, Laterite Geochemistry Project P240

C.R.M. Butt
Project Leader, Weathering Processes Project P241

July 1989

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I.D.M. Robertson and H.M. Churchward

ABSTRACT

The site of the Beasley Creek Gold mine lies on a small hill 3.5 m high, surrounded by wash plains which form a low tabular divide between broad drainage floors to the north and south. The hill is assymetric, with a very gentle western slope, marked by calcrete and sparse, small, saprolite outcrops, a crest with sporadic ironstone outcrops and a steeper eastern slope protected by lateritic duricrust.

The whole area is mantled by red, friable clay soil and strewn with multi-component lag. The soils on the low-lying areas are deeper than on the hill, are relatively acid and are underlain by Wiluna hardpan but become alkaline and thin on the hill where they are underlain by saprolite and calcrete. Ironstone lag and a duricrust-related khaki lag show only slight dispersion from their sources. Coarse black ferruginous lag has a wider distribution but seems associated with the subcrop of the black shale ore zone. Finer brown ferruginous lags have a wider distribution and their finest fractions seem to have been separated by down slope colluvial sedimentation. Quartz lag is dispersed around small quartz veins unrelated to ore.

INTRODUCTION

An intensive study of the Beasley Creek Gold Deposit, owned by Western Mining Corporation Ltd., is being carried out within the CSIRO/AMIRA Yilgarn Gold Research Programme. This deposit lies about 12 km west north-west of Laverton at 122° 18'E, 28° 34'S. Here, Archaean rocks appear to occupy a small window in the surrounding Permian glacial sediments. The Archaean and Permian rocks have been deeply weathered. Only the saprolite of the Archaean rocks outcrops in a few places.

Proved and probable ore reserves of 2.1 million tonnes at 2 g/t have been outlined by Western Mining Corp. Ltd. The CSIRO research commenced prior to disturbances by mining which began at the end of 1987 and the open pit was well-advanced at the time of writing this report.

CSIRO Work Programme

Research by CSIRO at Beasley Creek comprises studies of the surface geology and geomorphology, the geochemistry of surficial materials and the geochemistry of and dispersions in the saprolite. A report on the geology, geochemistry and mineralogy of the ore zone and footwall rocks is complete (Robertson and Gall, 1988). This report covers the geomorphology and the geology of surficial materials. Two other reports, one on a study of the geochemistry, mineralogy and petrology of the surface lags (Robertson 1989) and another on a study of the surface ironstones, lateritic duricrust, and ore at shallow depth, are in preparation. Geochemical investigations of a profile from surface to about 80 m depth and of the soils and calcrete are in progress and will be the subject of future reports.

In November 1987, when the mine was at an advanced assessment stage and mining was considered imminent, the occurrence of surface materials (soils, lag, vein quartz fragments, calcrete and ironstone) were mapped and samples of both surface lag and soil were collected along two lines, one at 38820 N and another at 38940 N. Percussion drilling along line 38820 N was later sampled to determine dispersion of key elements in the deep saprolite. Samples of ironstone and calcrete were collected over the southern part of the mine site after mining had commenced on the northern part.

GEOMORPHIC SETTING

Regional and Local Geomorphology

The geomorphology was studied by stereo-interpretation of air photographs. Panchromatic air photographs, at a scale of 1:50 000 and dated 15/6/88 were used for this interpretation (Laverton WA 2612; run 8; Nos 5146 - 5148). This interpretive work was substantiated by ground checking.

The Beasley Creek Mine site is on a low hill, flanked by wash plains. The hill is similar to an undulating tract of low relief, extending north-east to the Lancefield and Telegraph mines. The whole area is

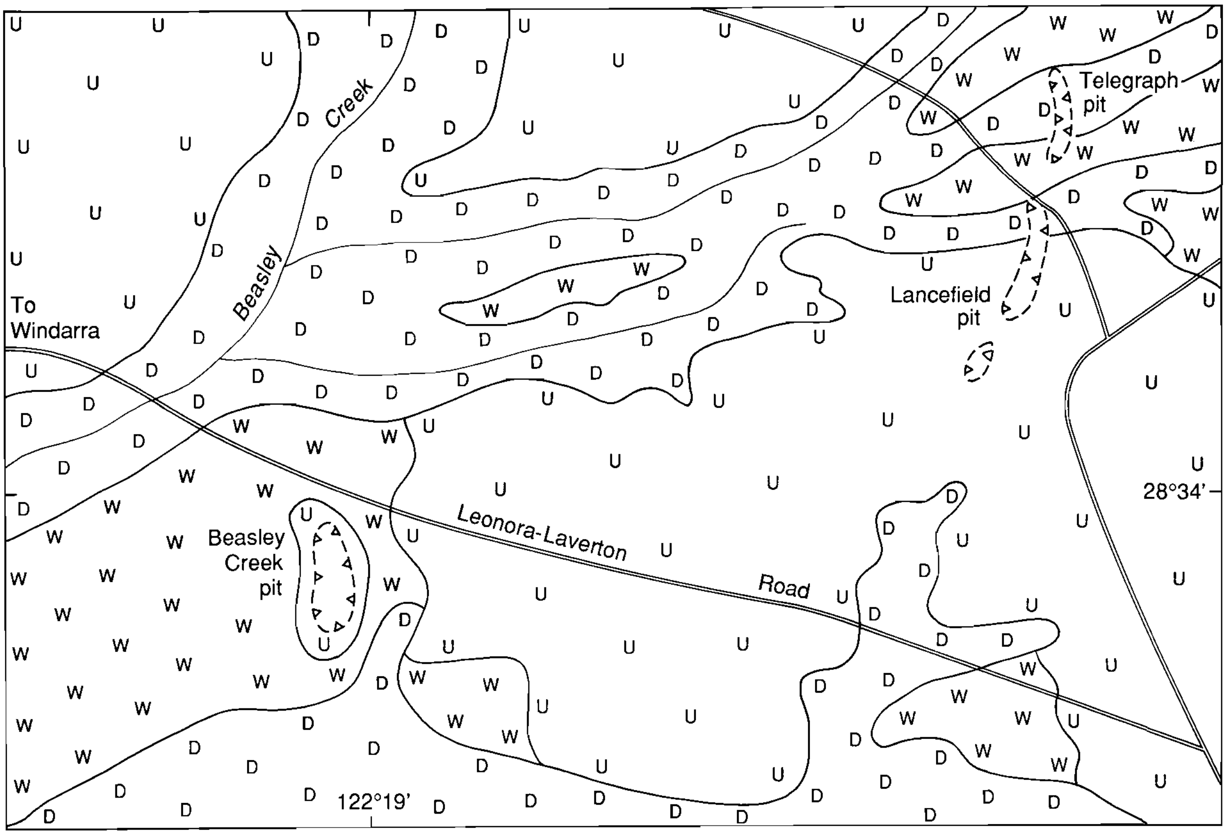


Figure 1.

Regional geomorphology of the Beasley Creek and Telegraph Mines, Laverton, Western Australia

- D — Broad drainage floors - active fluvial environment
- W — Wanderrie country - wash plains with a complex of low rises and flats
- U — Very gently undulating tracts and very low hills (largely Archaean subcrop and minor outcrop)
- Mine pits

0 1 2km
1:50,000

largely underlain by weathered Archaean rocks. The surrounding wash plains comprise a system of low, broad rises, referred to as Wanderrie banks, and intervening flats. Such banks are oriented along the contour and Mabbutt (1963) has proposed that they are the result of overland flow where the gradient is low and stream channels are ill-defined. Wind transport probably plays a supplementary role. This tract of Wanderrie country forms a low tabular divide to broad drainage floors, that are a few metres below, in which the channels of ephemeral streams are incised. This pattern is shown in Figure 1. The Telegraph pit straddles a broad drainage floor in contrast to the higher physiographic setting of the Beasley Creek mine site.

Physiography

A detailed topographic survey of the natural surface of the "hill" (a relative term) at Beasley Creek had been carried out by Western Mining Corp. Ltd. Data from some 940 survey points were plotted and the contour intercepts were obtained by mathematical interpolation between adjacent data points. Contours were drawn manually at intervals of 0.25 m. This gave an unusually sensitive and accurate picture of the physiography of the hill at Beasley Creek. The resulting 1:1000 plan, which was designed to fit the pit plans, has been reduced to a scale of 1:5000 (Figure 2A) for this report. The purpose of this physiographic study was to provide sufficient information to compare the dispersion of the various lag fractions and to relate the surficial materials and underlying geology to the topography.

The hill has a general north-south orientation and its broad crest is some 3.0 - 3.5 m above the wash plains. Westwards this crest merges with a long gentle slope and, eastwards, through a gentle convexity, to a shorter, steeper slope. This is illustrated by a plot of the R.L. data along lines 38820 N and 38940 N (Figure 3). The gradients are generally gentle to moderate (5 - 45 m/km or 0.3 - 2.6°). The gradient on the east side of the hill, on line 38820 N, is steeper than that on line 38940 N. The orebody subcrops at the crest of the hill on each line and follows the crest as it swings slightly to the north-west at the northern end (Figures 2A, B).

SURFACE GEOLOGY

Local and Regional Geology

The solid geology, as determined by WMC from percussion drilling, is illustrated in Figure 2B. The ore body lies in a black shale zone, some 15 - 40 m thick, which dips at 45° to the east. It strikes generally north but swings to the west at its southern end and flattens. This black shale unit is intensely weathered to considerable depth (>200 m) and gold is associated with ferruginous zones within it. The black shale is enclosed in a narrow, north-striking basaltic, amphibolitic schist which is less intensely weathered, particularly where distant from the black shale. Small porphyry, granitoid and metadolerite lenses intrude the stratigraphy and are associated with north-west striking faults and shears. The amphibolite schist is in turn enclosed in komatiitic lithologies of the Mt. Margaret Anticline.

FIGURE 2

A. Physiography of the hill at Beasley Creek. Scale 1:5000.

B. Solid Geology of the Beasley Creek Gold Mine. Scale 1:5000

C. Distribution of Very Fine Lag over the Beasley Creek Gold Mine. Scale 1:5000.

D. Distribution of Coarse Lag over the Beasley Creek Gold Mine. Scale 1:5000.

E. Distribution of the coarse fraction of the Fine Lag over the Beasley Creek Gold Mine. Scale 1:5000.

F. Distribution of the Khaki Lag over the Beasley Creek Gold Mine. Scale 1:5000.

G. Distribution of small saprolite outcrops over the Beasley Creek Gold Mine. Scale 1:5000.

H. Distribution of Quartz Lag over the Beasley Creek Gold Mine. Scale 1:5000.

I. Distribution of Ironstone outcrop and Ironstone Lag over the Beasley Creek Gold Mine. Scale 1:5000.

J. Distribution of Calcrete outcrop and calcrete exposed by goanna mounds over the Beasley Creek Gold Mine. Scale 1:5000.

K. Location of sampling of surficial materials over the Beasley Creek Gold Mine. Scale 1:5000.

L. Air photograph of Beasley Creek mine site. Scale 1:5000.

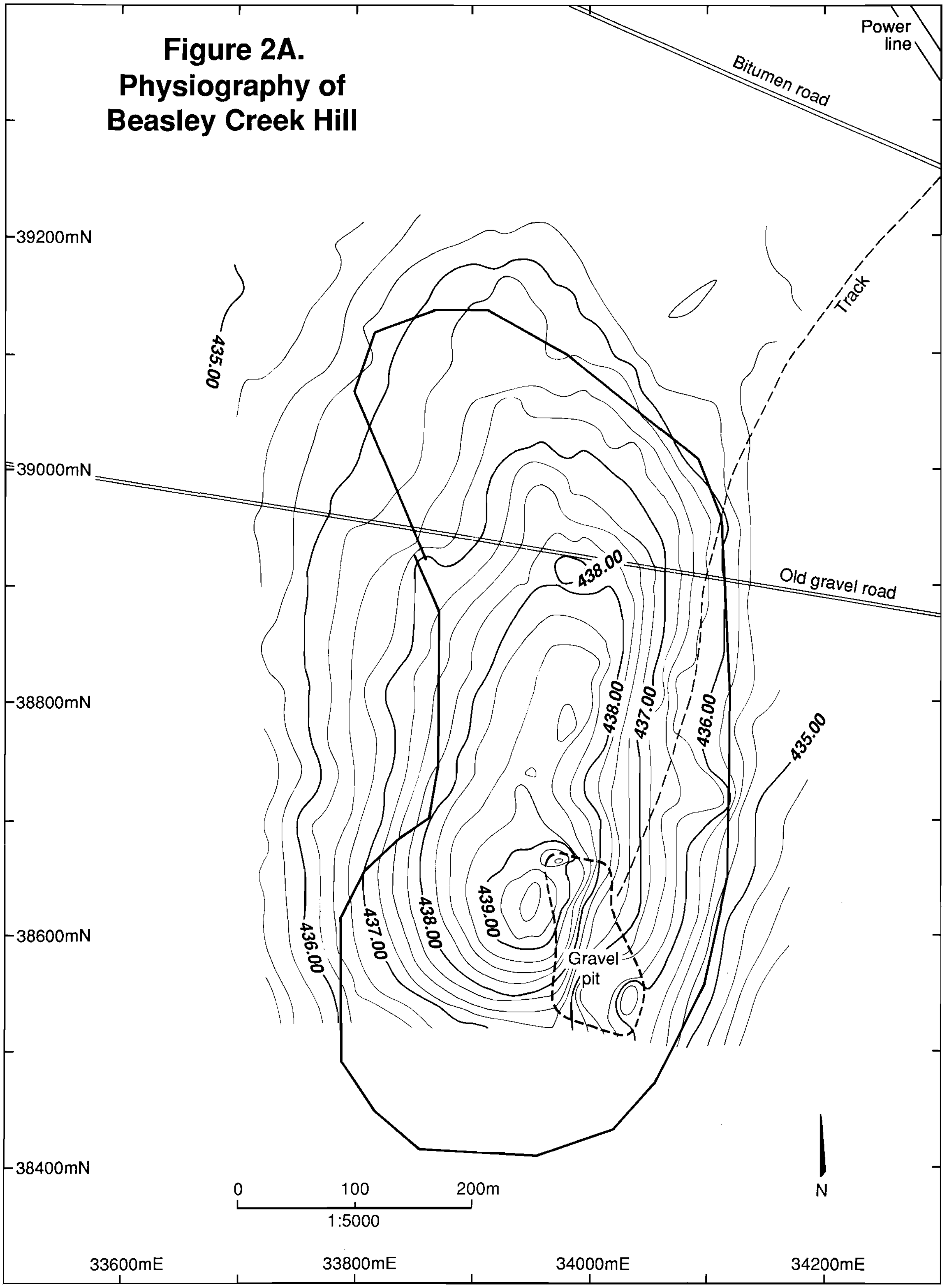


Figure 2A.
Physiography of
Beasley Creek Hill
Power
line
Bitumen road
Track
Old gravel road
Gravel
pit
435.00
436.00
437.00
438.00
439.00
39200mN
39000mN
38800mN
38600mN
38400mN
33600mE
33800mE
34000mE
34200mE
0
100
200m
1:5000
N

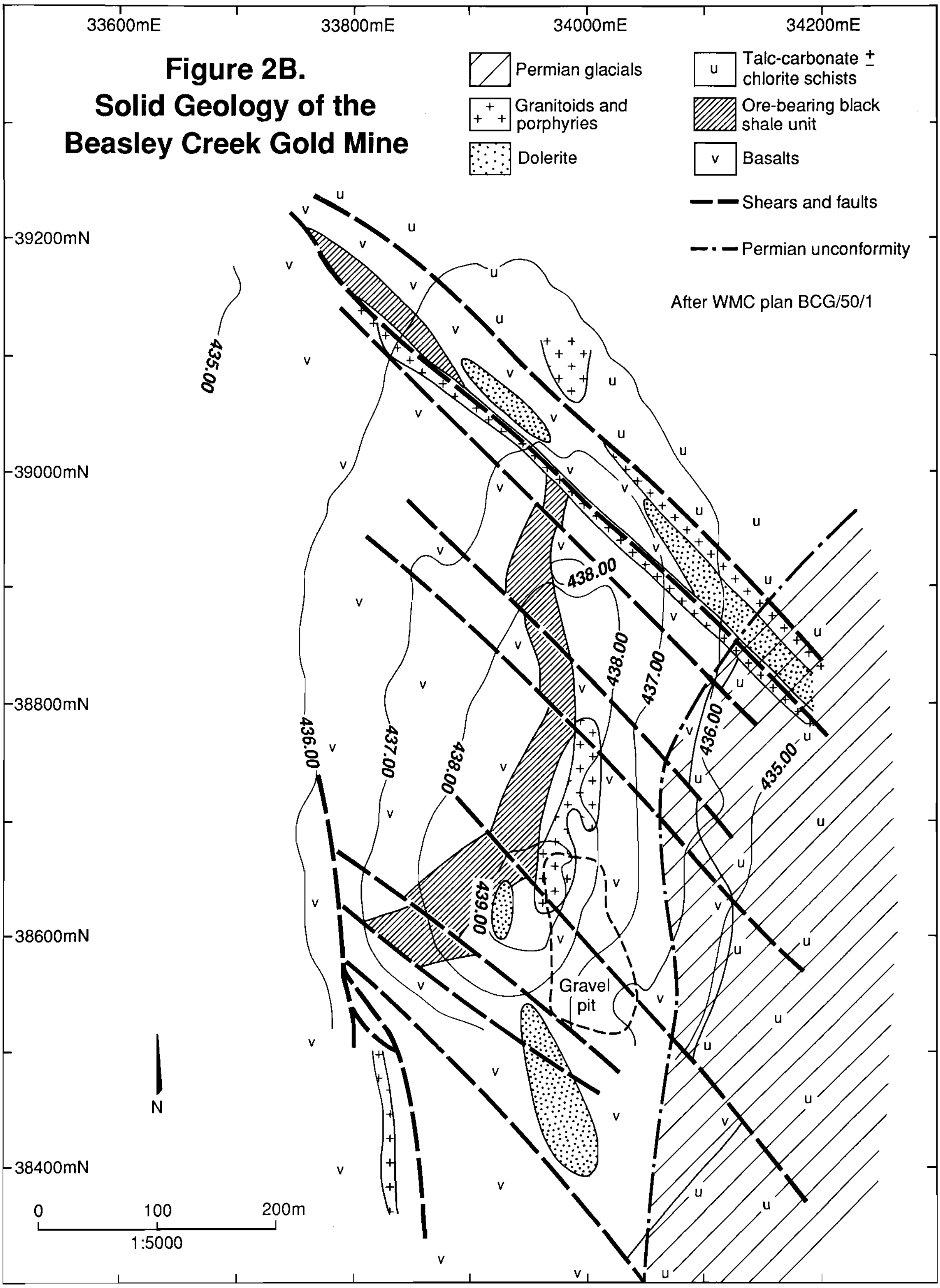


Figure 2B.
Solid Geology of the
Beasley Creek Gold Mine
33600mE
33800mE
34000mE
34200mE
39200mN
39000mN
38800mN
38600mN
38400mN
Permian glacials
Granitoids and porphyries
Dolerite
Talc-carbonate ± chlorite schists
Ore-bearing black shale unit
Basalts
Shears and faults
Permian unconformity
After WMC plan BCG/50/1
435.00
436.00
437.00
438.00
439.00
Gravel pit
N
0
100
200m
1:5000

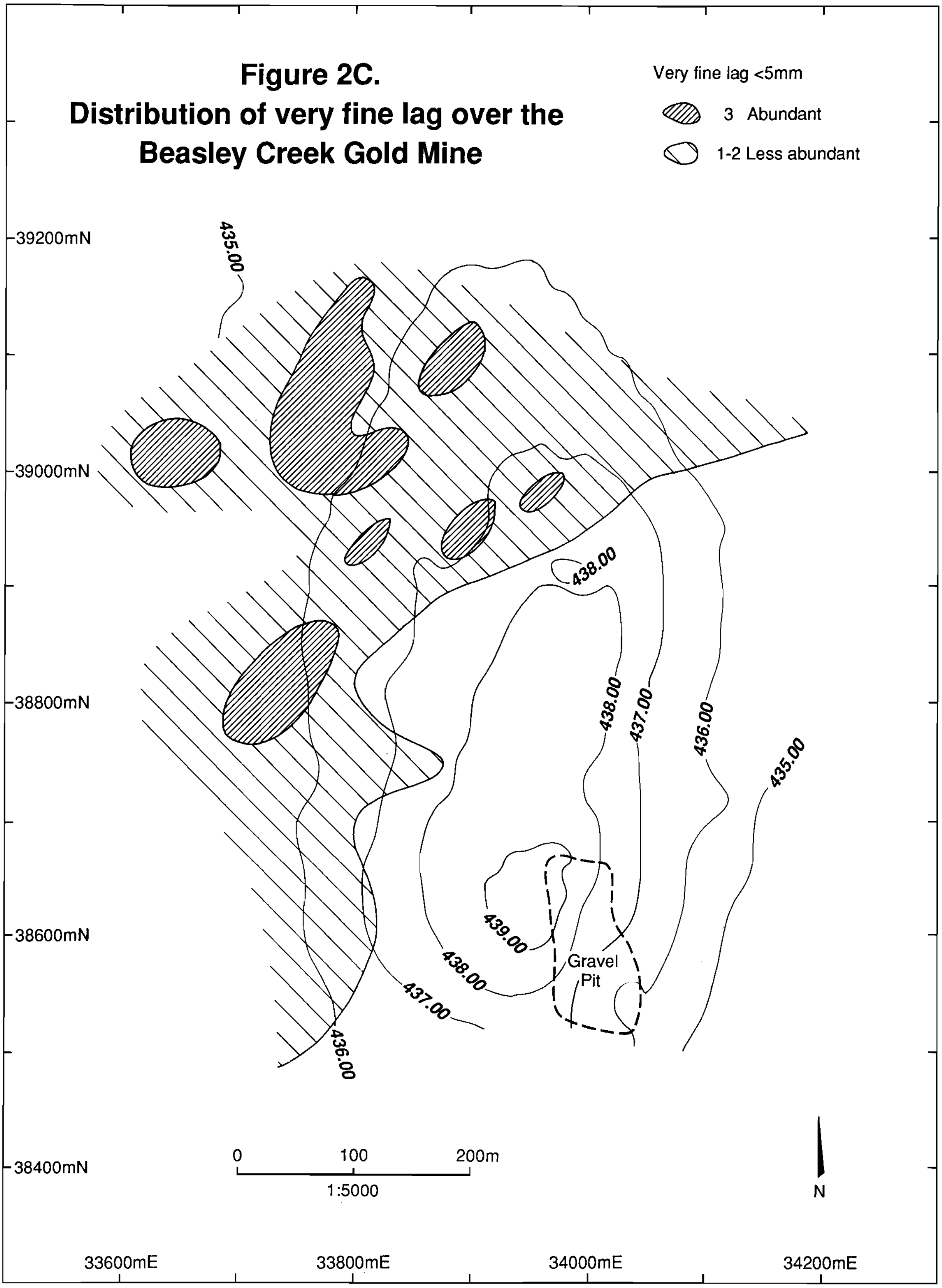


Figure 2C.
Distribution of very fine lag over the
Beasley Creek Gold Mine
Very fine lag <5mm
3 Abundant
1-2 Less abundant
39200mN
39000mN
38800mN
38600mN
38400mN
435.00
438.00
437.00
436.00
439.00
Gravel
Pit
0
100
200m
1:5000
N
33600mE
33800mE
34000mE
34200mE

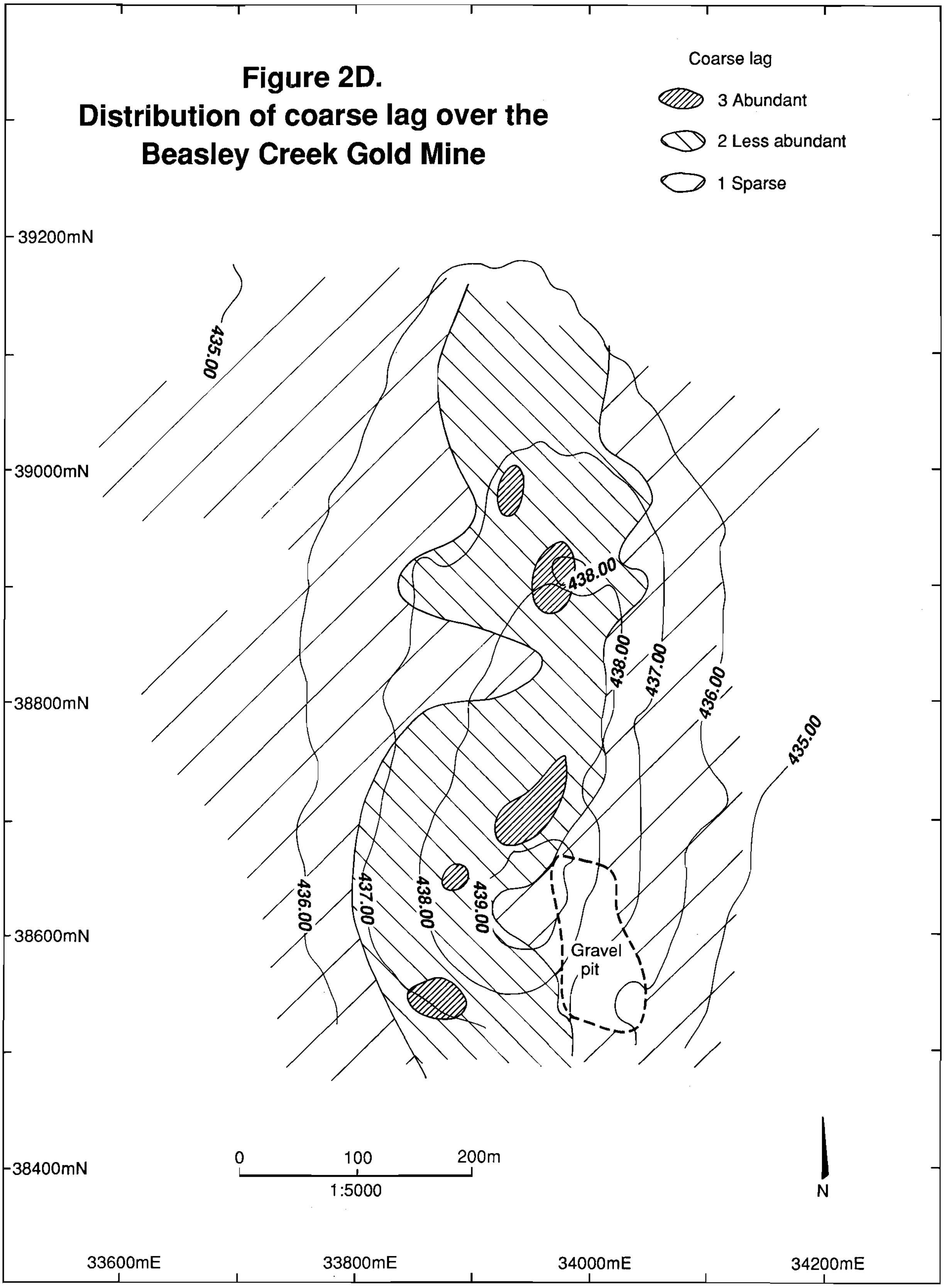


Figure 2D.
Distribution of coarse lag over the
Beasley Creek Gold Mine
Coarse lag
3 Abundant
2 Less abundant
1 Sparse
39200mN
39000mN
38800mN
38600mN
38400mN
33600mE
33800mE
34000mE
34200mE
435.00
436.00
437.00
438.00
439.00
Gravel pit
0
100
200m
1:5000
N

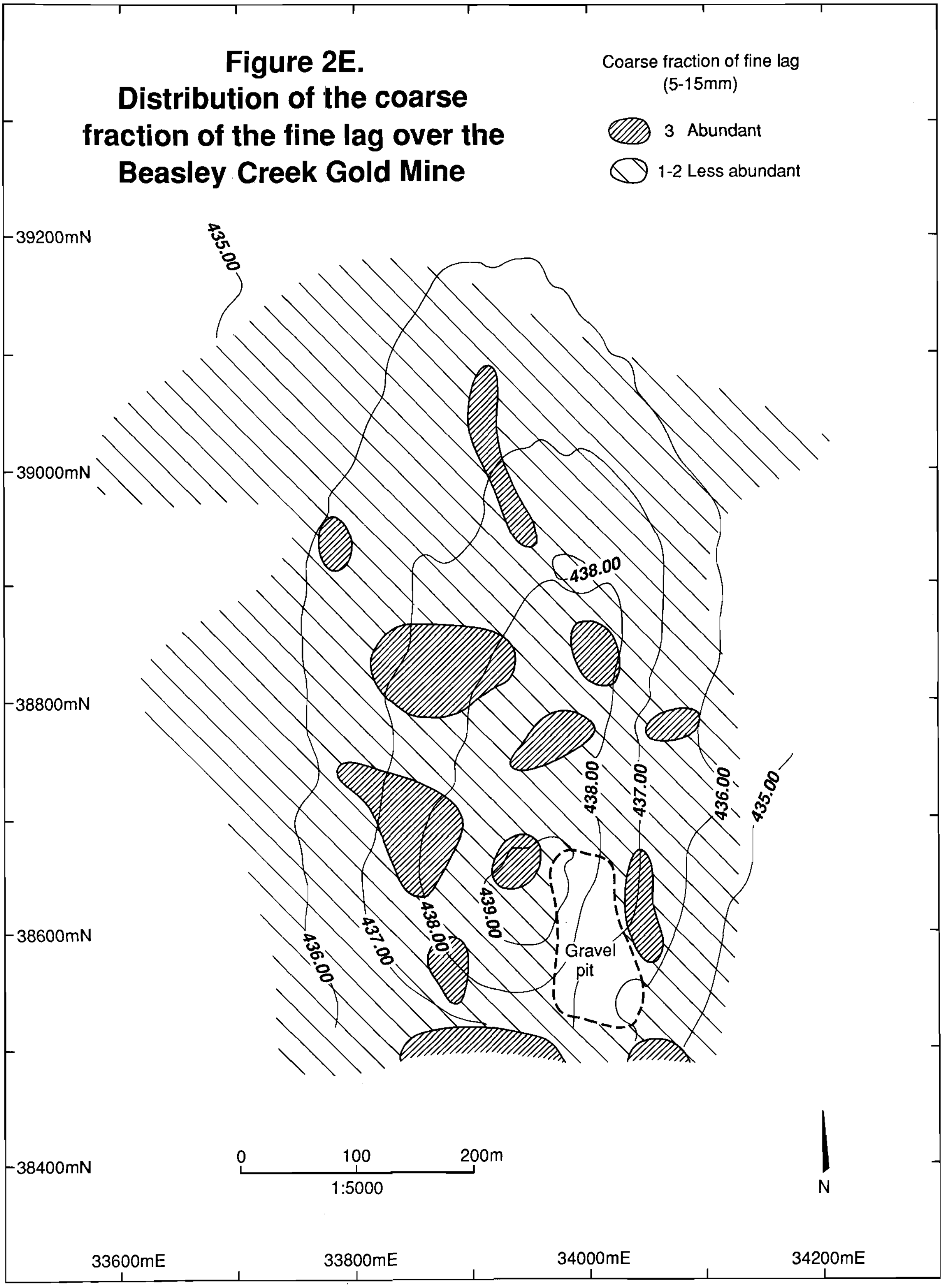


Figure 2E.
Distribution of the coarse fraction of the fine lag over the Beasley Creek Gold Mine
Coarse fraction of fine lag
(5-15mm)
3 Abundant
1-2 Less abundant
39200mN
39000mN
38800mN
38600mN
38400mN
435.00
438.00
438.00
437.00
436.00
435.00
439.00
438.00
437.00
436.00
Gravel pit
0
100
200m
1:5000
N
33600mE
33800mE
34000mE
34200mE

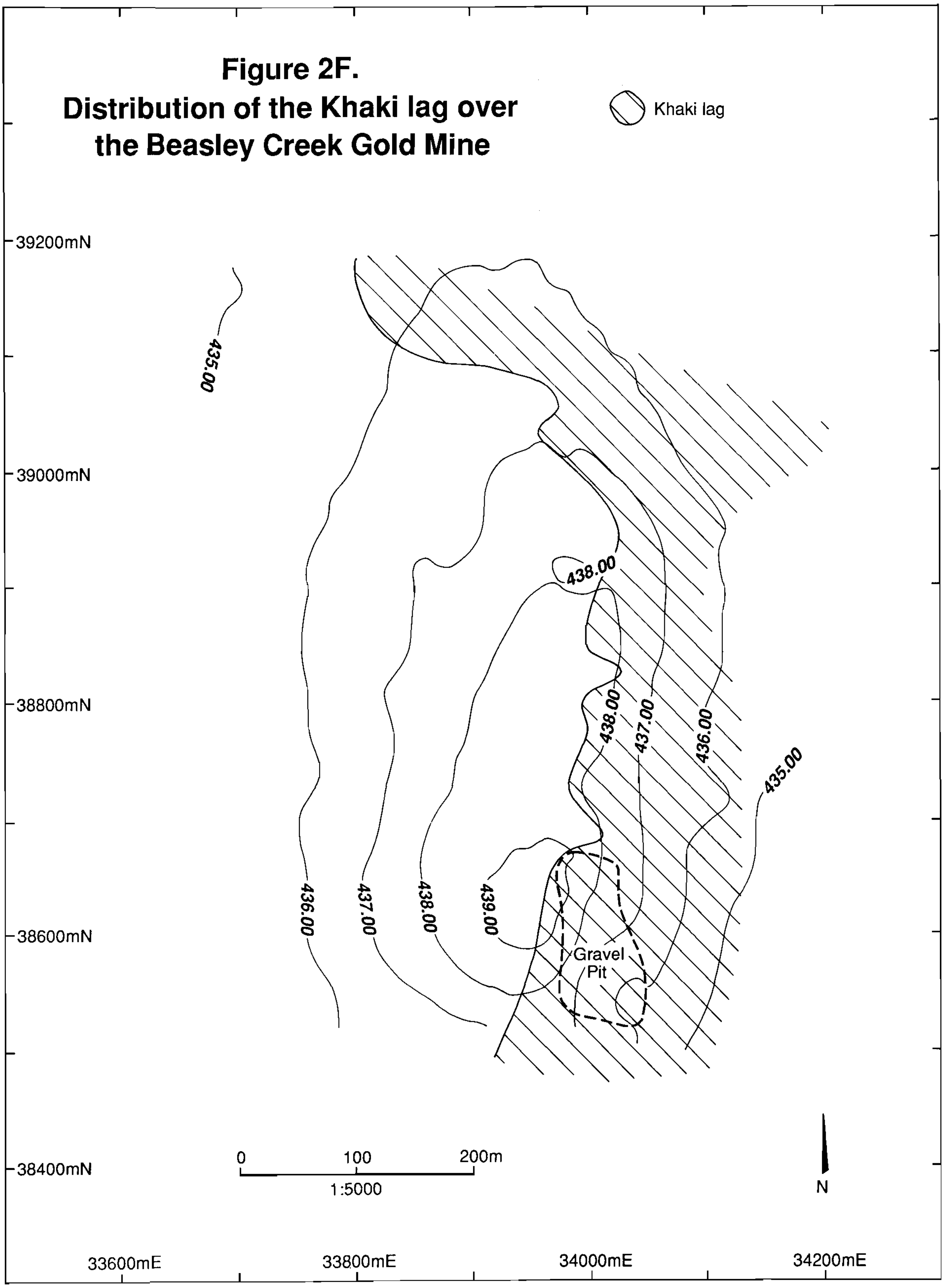
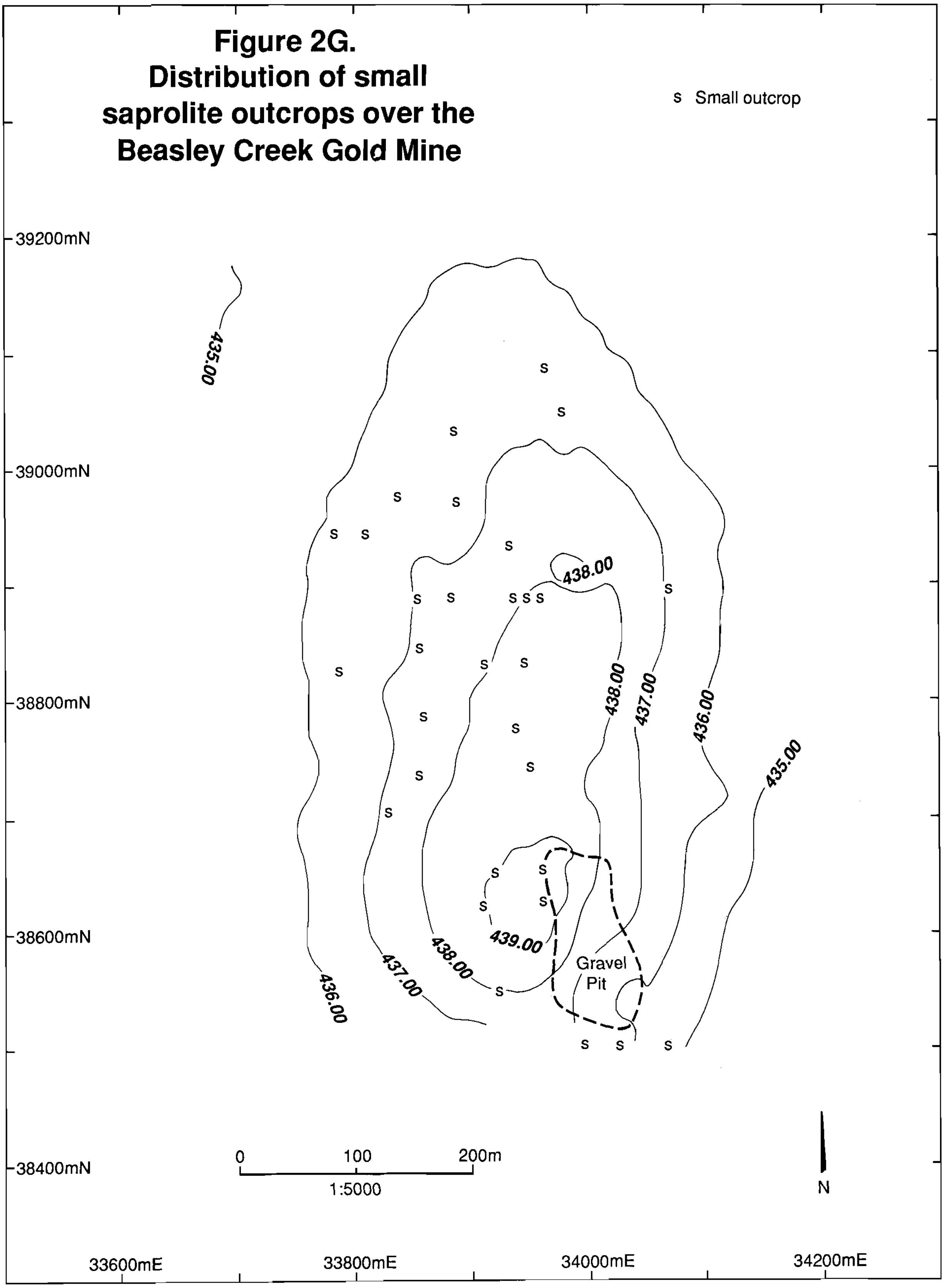


Figure 2F.
Distribution of the Khaki lag over
the Beasley Creek Gold Mine
Khaki lag
39200mN
39000mN
38800mN
38600mN
38400mN
435.00
436.00
437.00
438.00
439.00
Gravel
Pit
0
100
200m
1:5000
N
33600mE
33800mE
34000mE
34200mE

Figure 2G. Distribution of small saprolite outcrops over the Beasley Creek Gold Mine



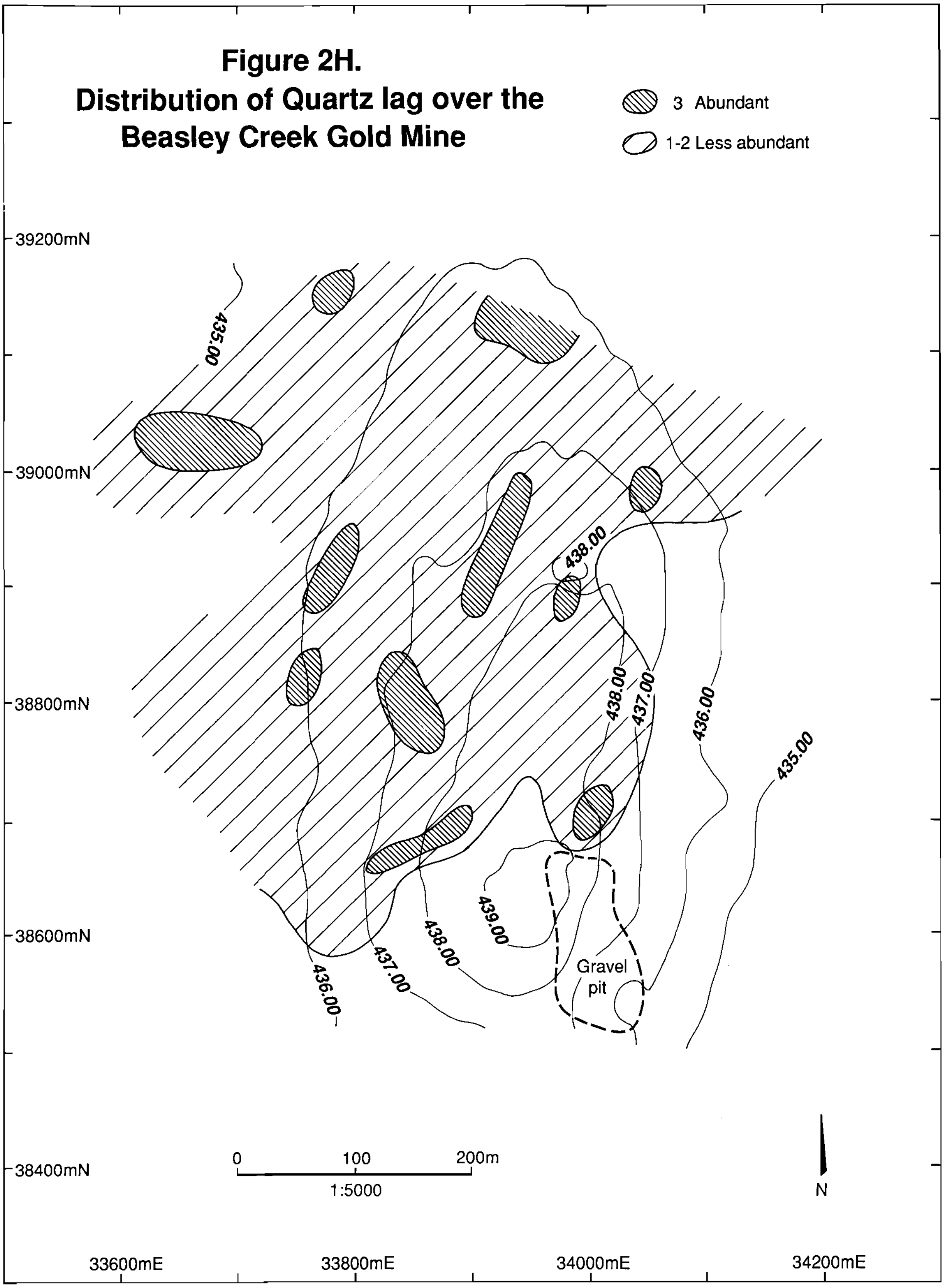


Figure 2H.
Distribution of Quartz lag over the Beasley Creek Gold Mine
3 Abundant
1-2 Less abundant
39200mN
39000mN
38800mN
38600mN
38400mN
33600mE
33800mE
34000mE
34200mE
435.00
438.00
438.00
437.00
436.00
435.00
439.00
438.00
437.00
436.00
Gravel pit
0
100
200m
1:5000
N

Figure 2I. Distribution of Ironstone outcrop and Ironstone lag over the Beasley Creek Gold Mine

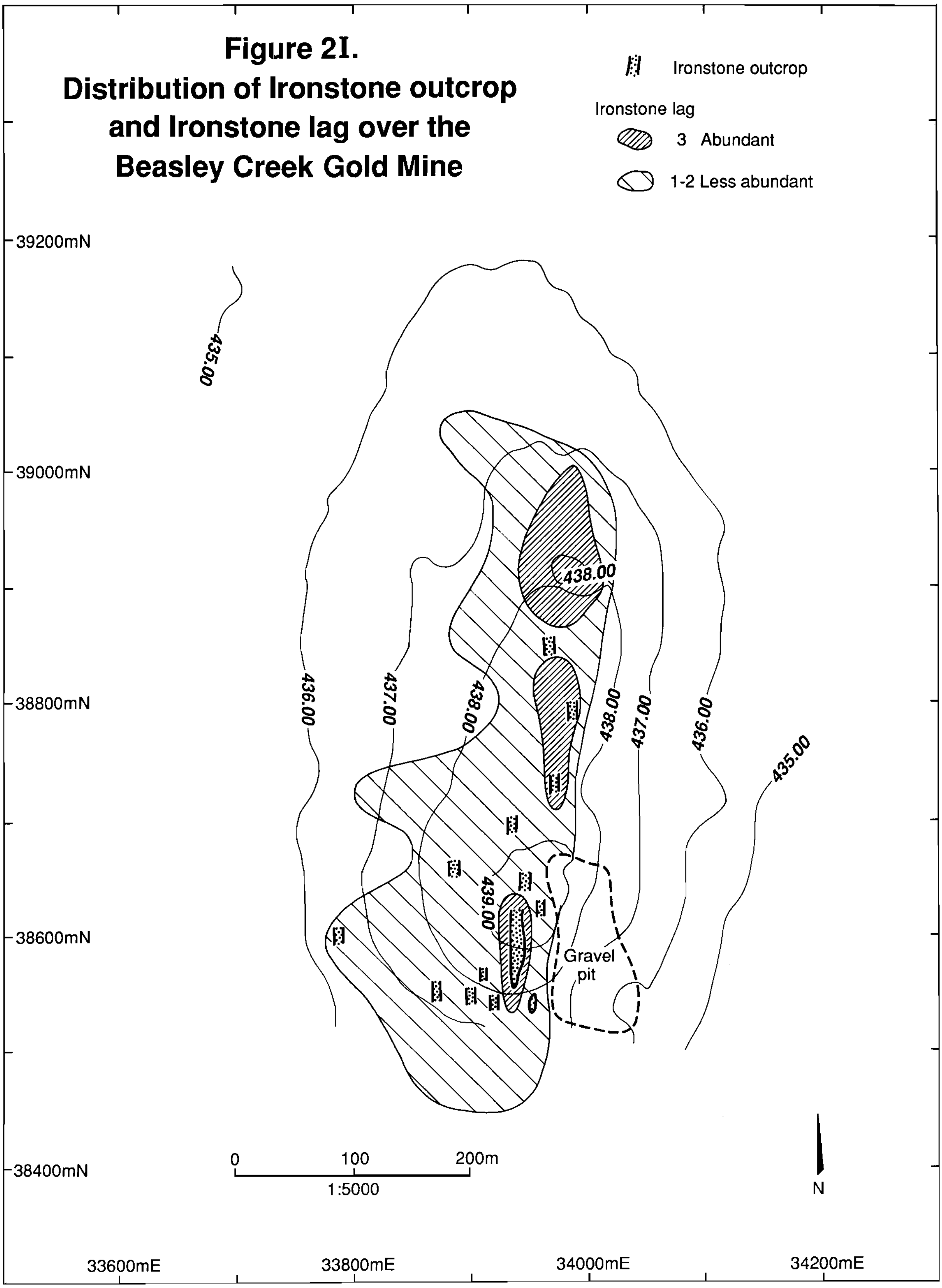
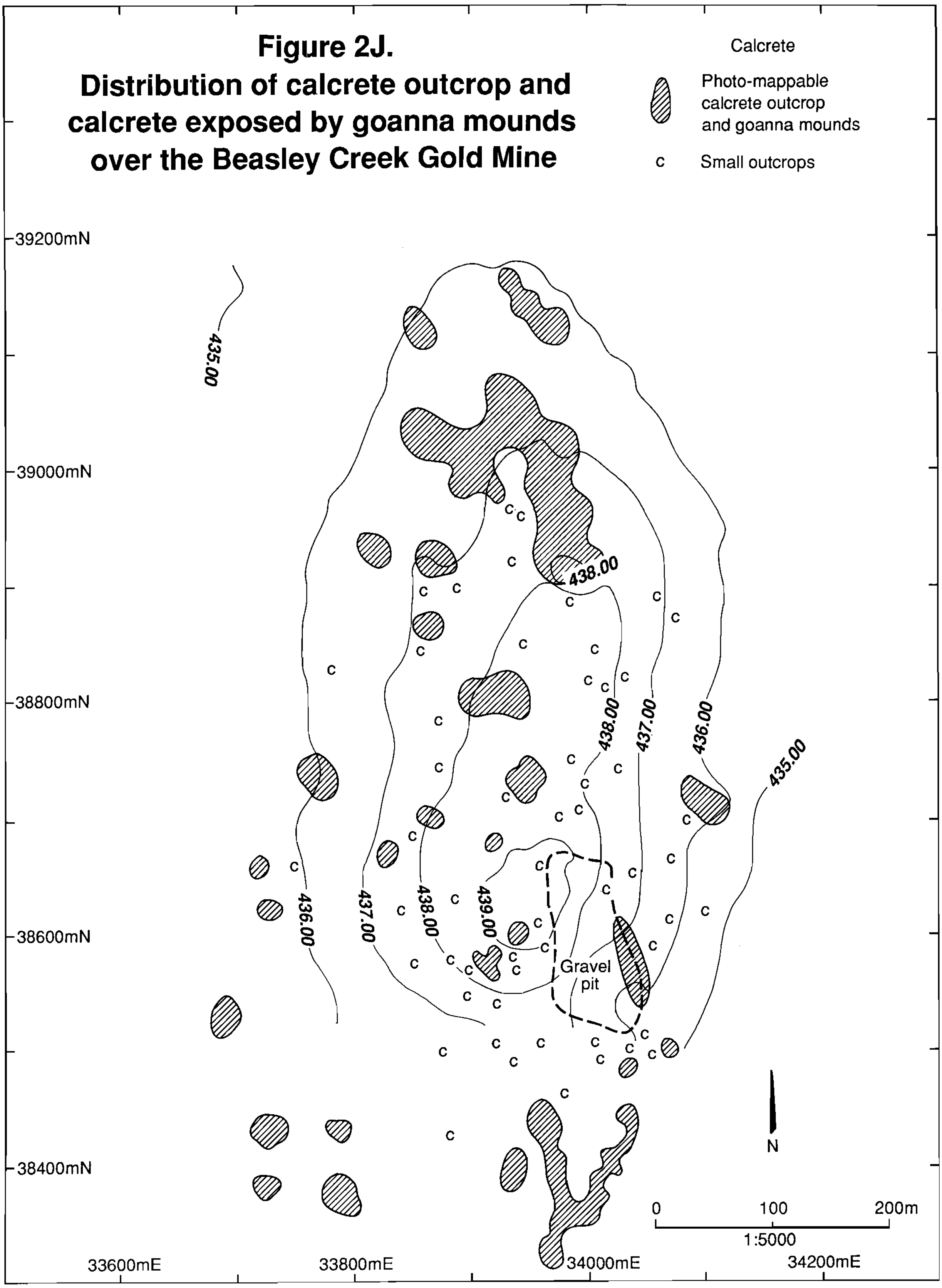


Figure 2J.
Distribution of calcrete outcrop and calcrete exposed by goanna mounds over the Beasley Creek Gold Mine



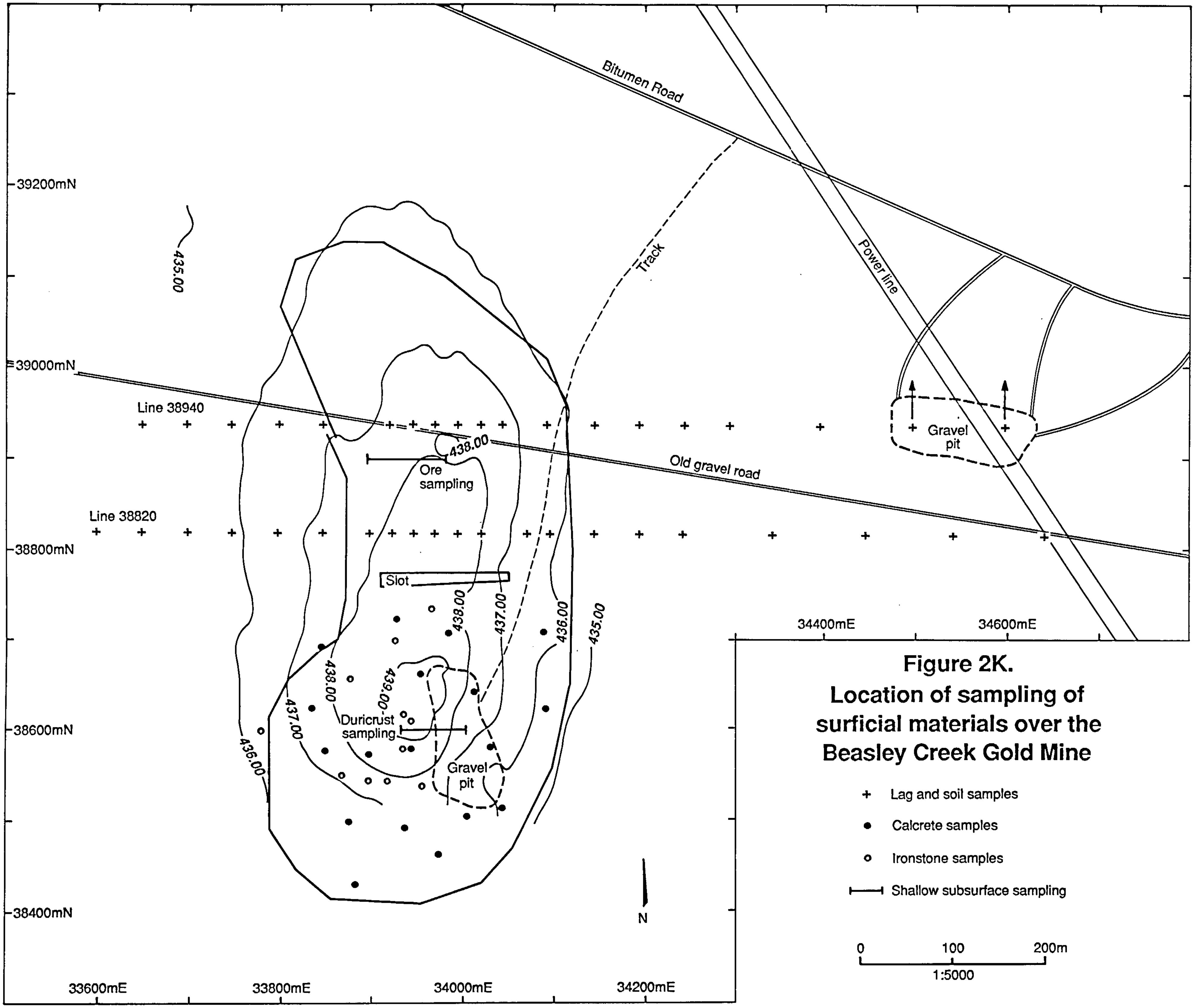


Figure 2K.
Location of sampling of surficial materials over the Beasley Creek Gold Mine

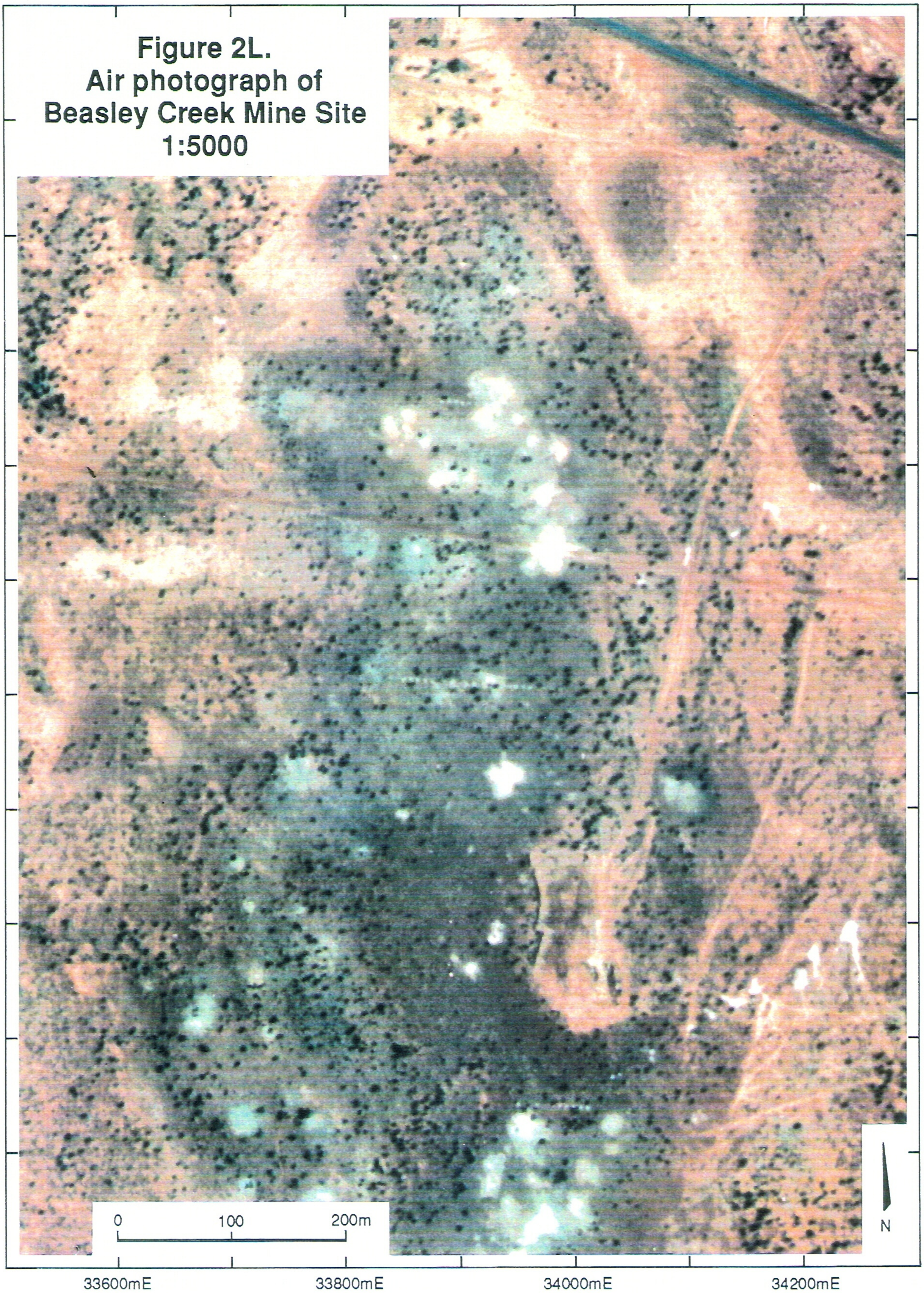
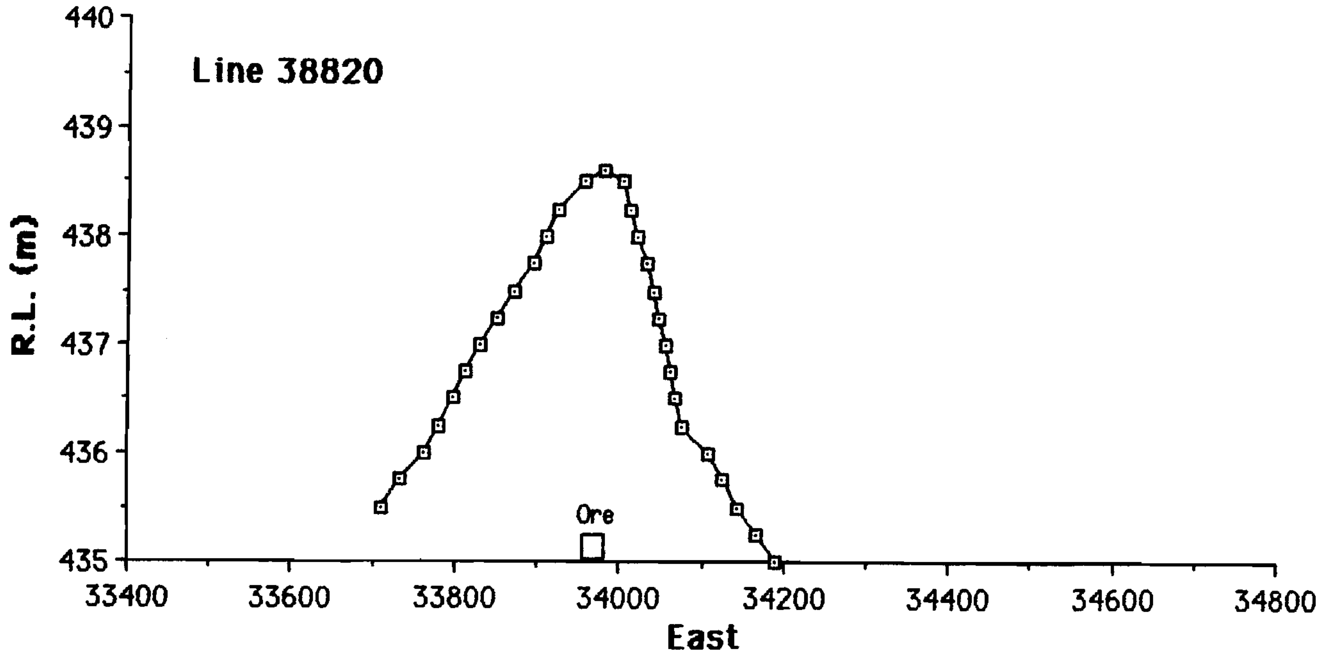
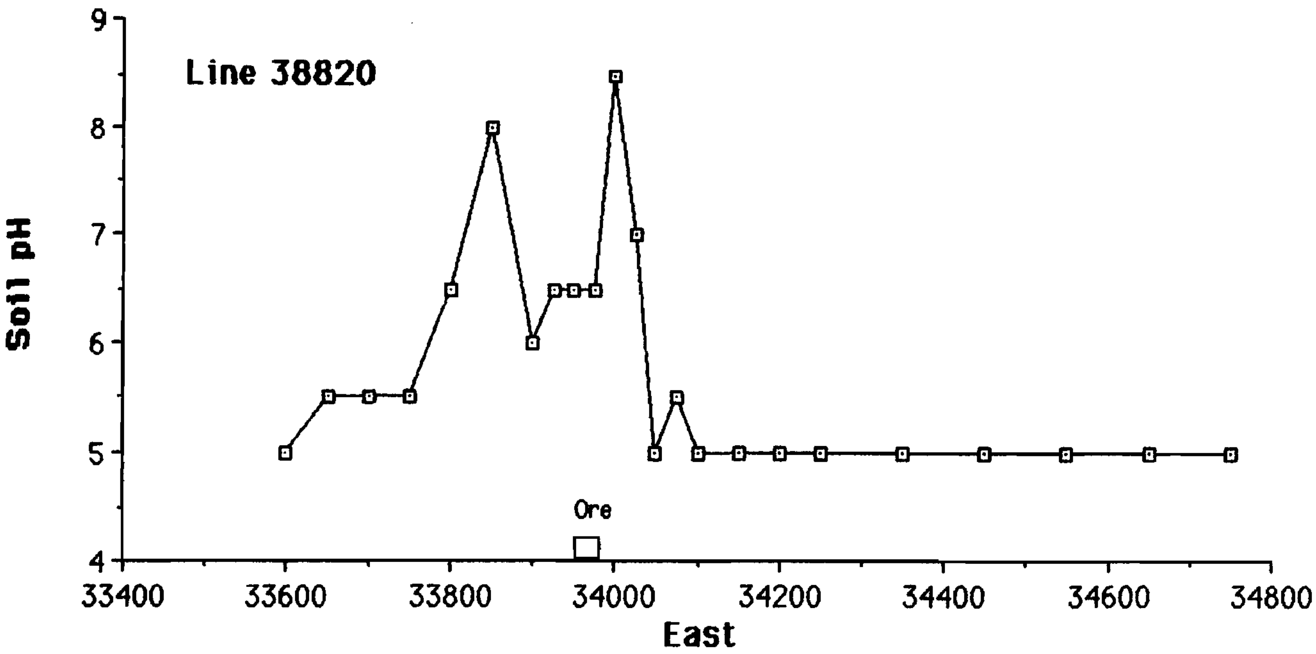


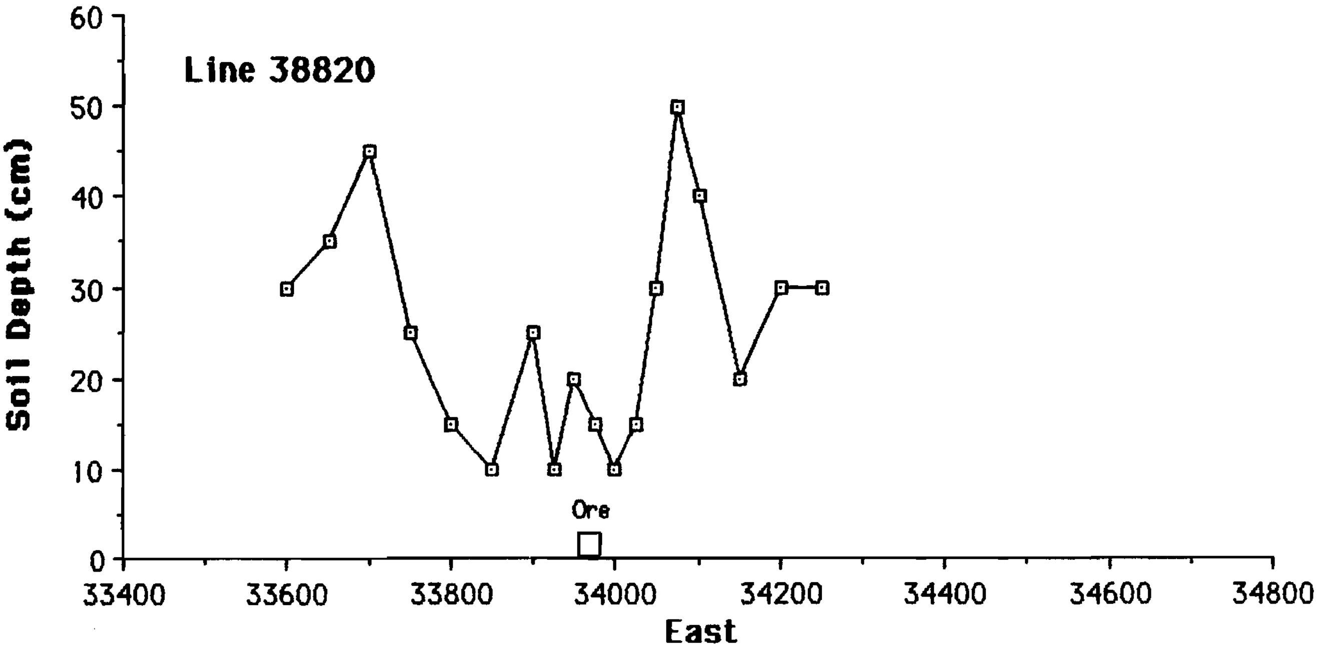
Figure 2L.
Air photograph of
Beasley Creek Mine Site
1:5000
39200mN
39000mN
38800mN
38600mN
38400mN
33600mE
33800mE
34000mE
34200mE
0
100
200m
N

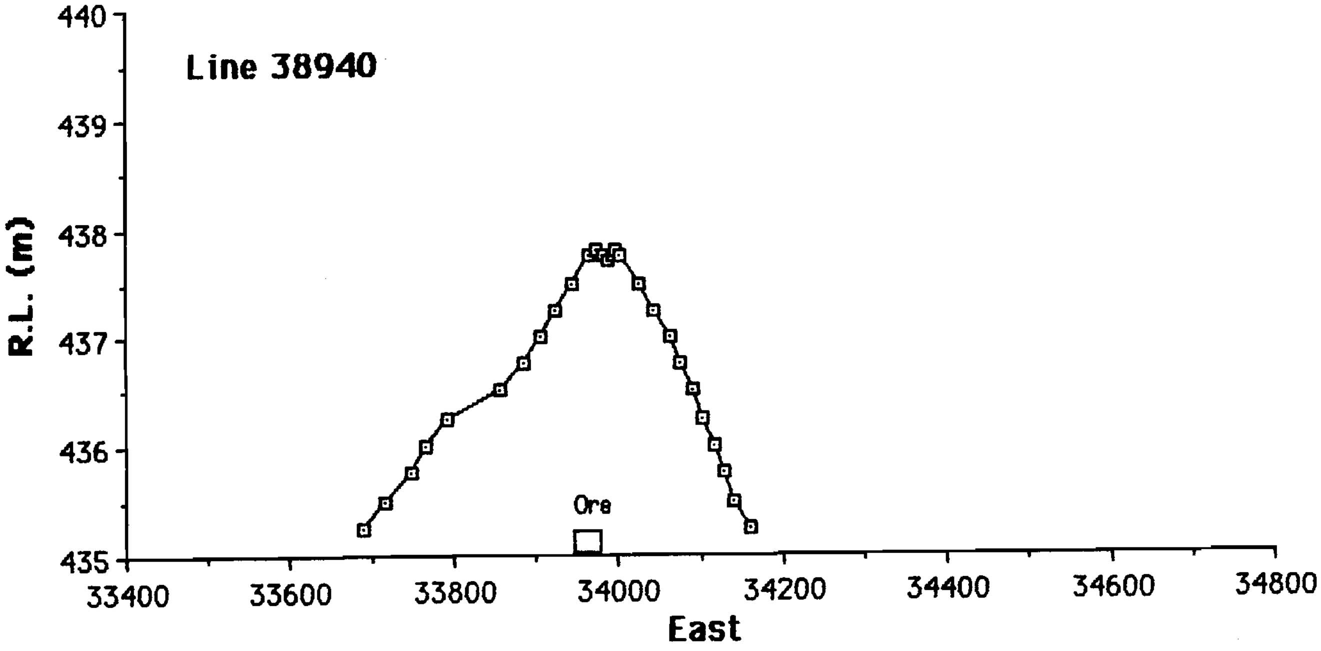
FIGURE 3

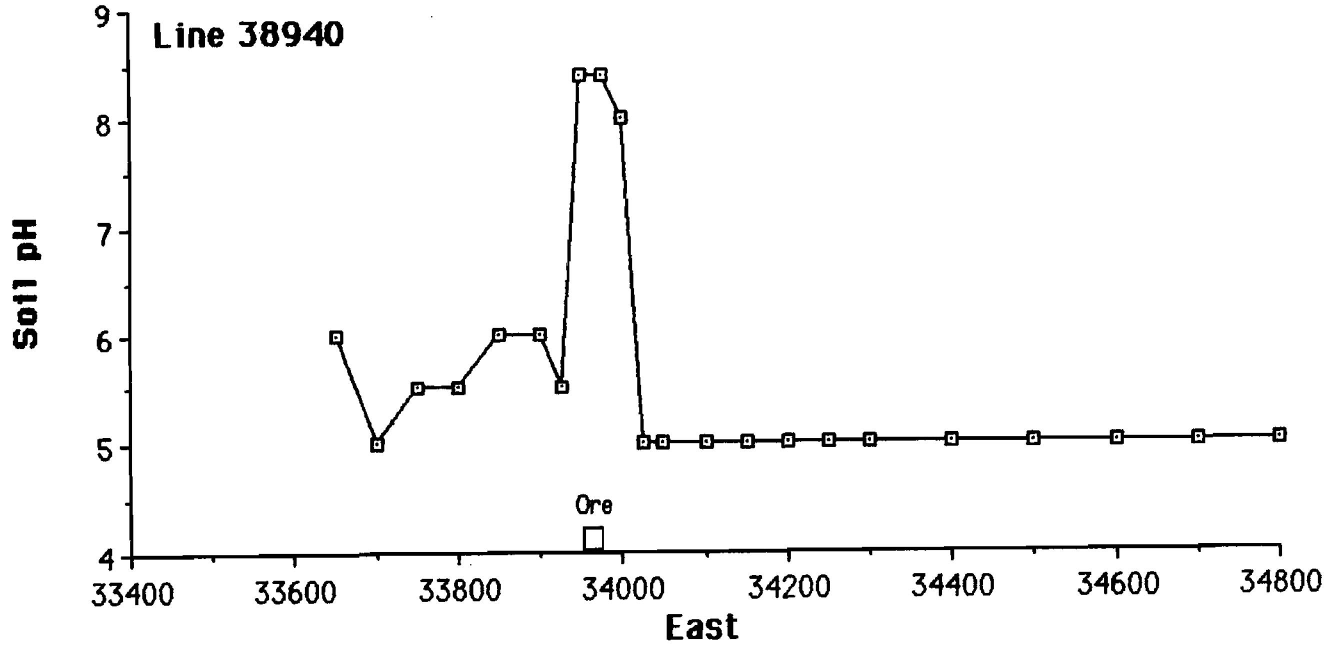
Physiographic sections, gradients, soil depths and soil pH data along lines 38820 and 38940. Note severe vertical exaggeration in physiographic sections.

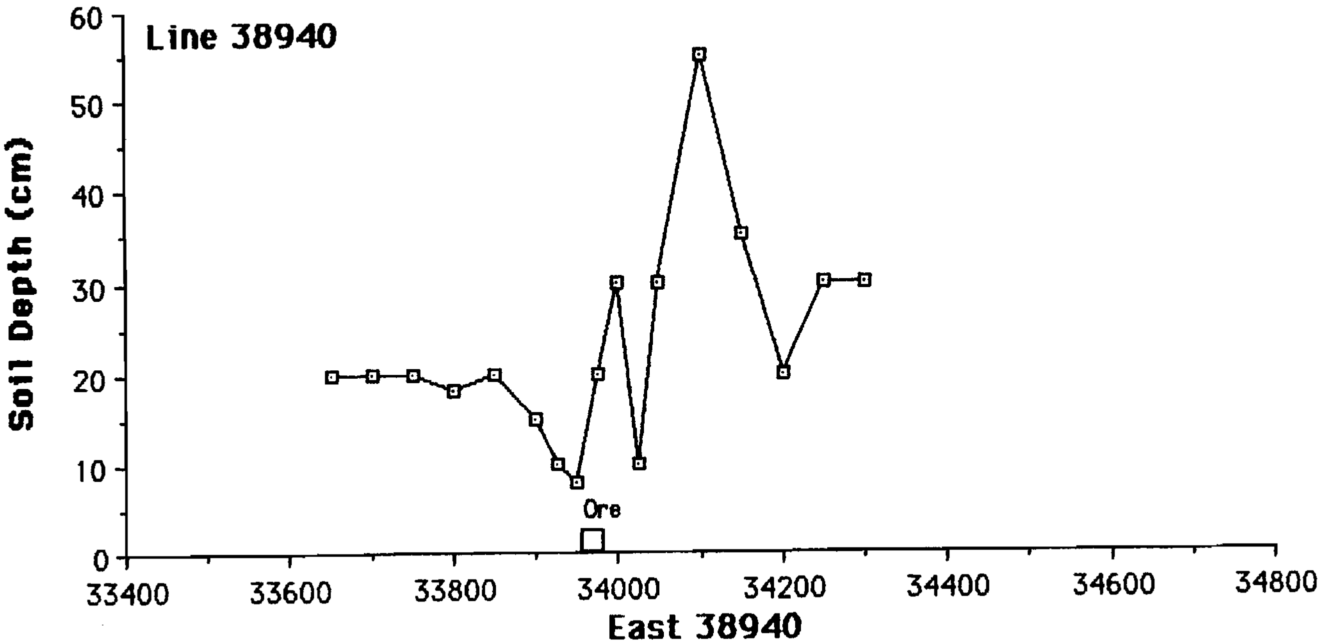

Line 38820
R.L. (m)
Ore
East

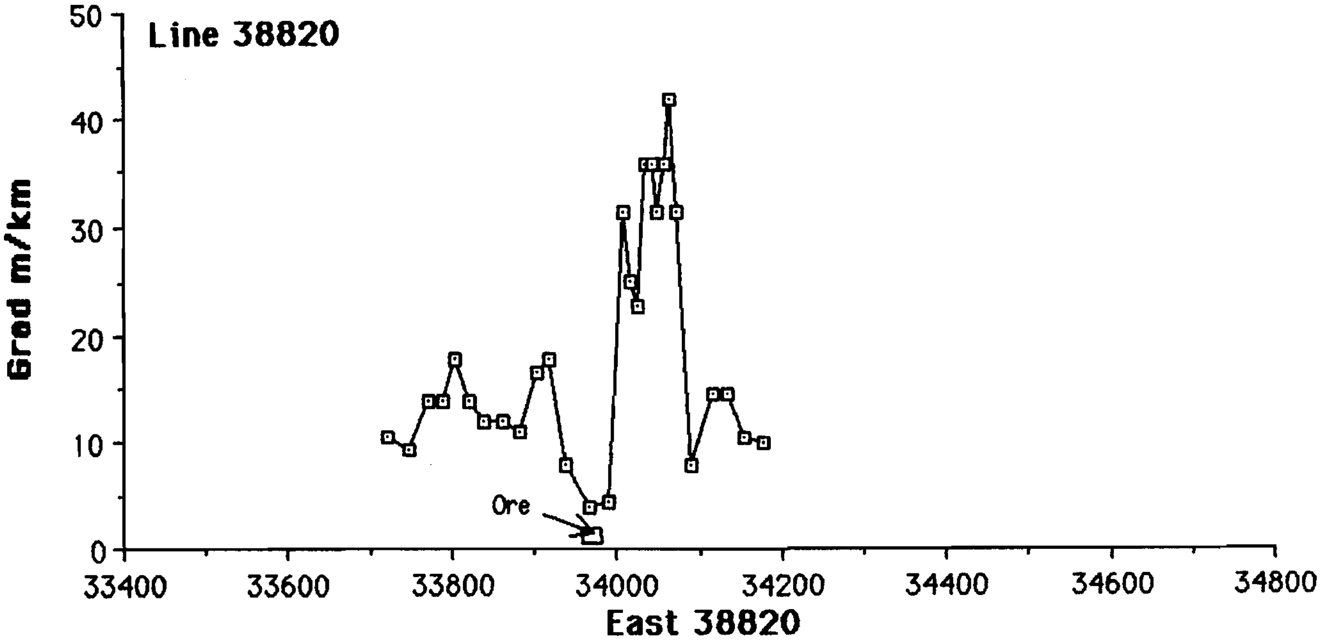

Line 38820
Soil pH
Ore
East

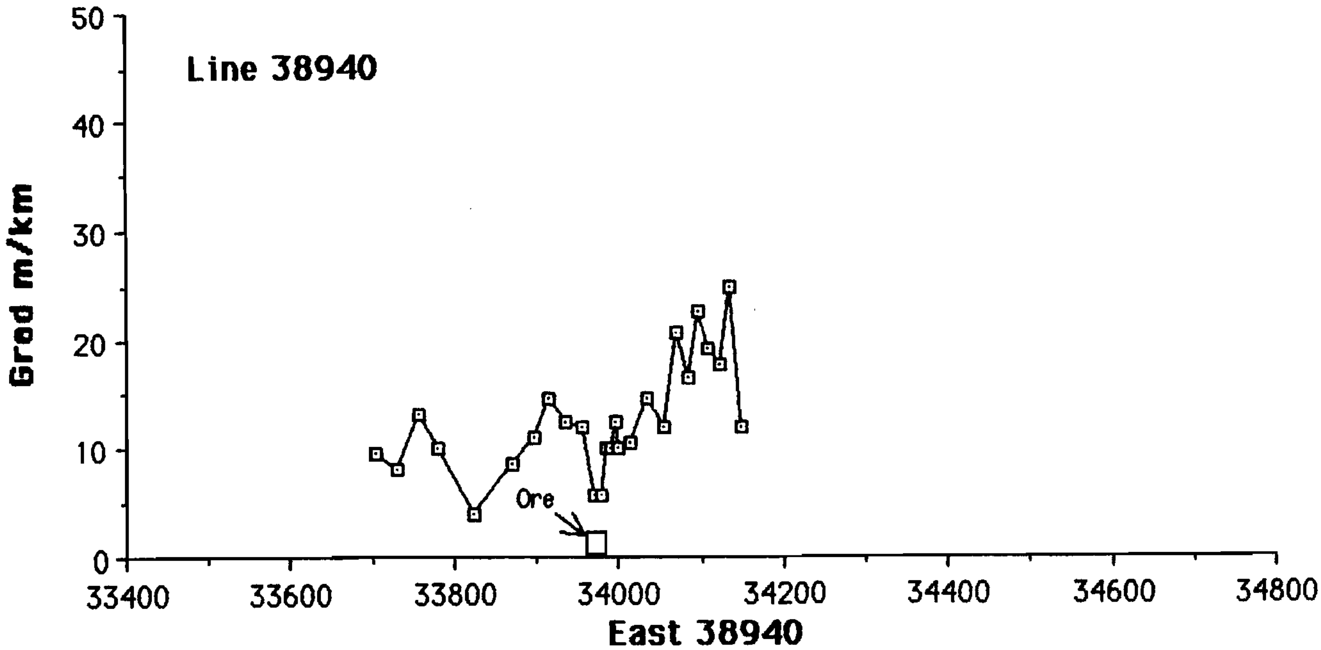

Line 38820
Soil Depth (cm)
Ore
East


Line 38940
R.L. (m)
440
439
438
437
436
435
Ore
33400
33600
33800
34000
34200
34400
34600
34800
East


Line 38940
Soil pH
9
8
7
6
5
4
Ore
33400
33600
33800
34000
34200
34400
34600
34800
East


Line 38940
Soil Depth (cm)
60
50
40
30
20
10
0
Ore
33400
33600
33800
34000
34200
34400
34600
34800
East 38940


Line 38820
Ore
Grad m/km
0
10
20
30
40
50
33400
33600
33800
34000
34200
34400
34600
34800
East 38820


Line 38940
Ore
Grad m/km
0
10
20
30
40
50
33400
33600
33800
34000
34200
34400
34600
34800
East 38940

Mapping of Surficial Materials

The distribution of surficial materials was mapped before mining commenced. The larger outcrops of ironstone and calcrete, several tens of metres in size, were mapped by conventional means at a scale of 1:1000 but these are comparatively scarse. The distribution of very small outcrops of calcrete, saprolite and ironstone, generally metres or centimetres in size, and the surface strews of various lag types are inextricably mixed and could not be mapped conventionally but their distribution is nevertheless important. A visual impression of the relative abundance of these materials and small outcrops, on a scale of 1 to 3, was recorded at locatable points on the mine grid. These data were later compiled and rough contoured. Though the method is only semi-quantitative, the results show these distributions in a better than qualitative way and are presented in Figures 2C - J. These maps, prepared by CSIRO, were completed before the solid geology map, prepared by WMC, was received. It is interesting to see the close fit between the solid geology and some of the lag distributions, illustrating the validity of this mapping method.

Much of the area is mantled by soil. These soils were examined by surface observation enhanced by the excavation of small pits, limited by any hard horizon (hardpan or calcrete), to determine the stratigraphy. Soil reaction was measured in the field using the Universal Indicator from a CSIRO soil pH kit. Soil textures were determined by the standard method of manipulating a handful of soil when moist (McDonald *et al*, 1984).

Lag-Gravels

The lag, or more specifically lag-gravel, forms a poorly developed and uncemented desert armour over much of the surface underlain by mafic rocks near Laverton. It contains a variety of rock fragments, including several types of ironstone, less abundant pieces of saprolite and lateritic duricrust and varying proportions of white vein quartz. The black ironstone fragments are generally dominant and are mostly sub-rounded, though some are angular. A few adjacent fragments were found that could be fitted together and are thought to be the result of splitting by differential thermal expansion in the contrasting temperatures of day and night or summer sun and rain. Surface textures vary from glazed by desert varnish to mat or desert polished. Some show the classic driekanter form.

The lag forms a partial cover of residual stony fragments, from which the finer material is thought to have been removed by wind and water. Compacted or silica-indurated soil (dominant, Figure 4A) and patches of saprolite(more rarely, Figure 4D), calcrete (Figure 4F, G), ironstone and lateritic duricrust (Figure 5F - H) show through this partial cover. The lag, together with the cover of mulga-eremophila scrub (Figure 5A), perform a vital function in retarding soil erosion in this arid area.

In general, the gold at Beasley Creek is related to zones of intense ferruginisation in the basement rocks rather than to the occurrence of vein quartz. Ferruginous lag was considered to be a potentially useful geochemical sampling medium as it is almost ubiquitous at Beasley Creek. Key indicator

FIGURE 4

A. A strew of abundant very fine ferruginous lag (3), scarse coarse lag (1) and moderately abundant quartz lag (3) over compacted soil (north-east flank of hill).

B. A strew of abundant coarse fraction of fine lag, some coarse ferruginous lag, quartz lag and ironstone lag masking soil (overlying the ore body).

C. A strew of khaki lag, partly set in soil, overlying the lateritic duricrust to the east of the orebody (approx 34050E, 38750N).

D. A typical small outcrop of saprolite partly masked by soil and khaki lag (west of the orebody).

E. A goanna burrow at the north end of the hill. Note the slight mound of loose calcareous soil around the burrow with calcrete lumps (33950E, 39030N).

F. A small calcrete outcrop containing pisoliths of lateritic duricrust, partly masked by pisolithic khaki lag, some fragments of which show remnants of a calcareous skin (north-east of gravel pit).

G. A calcrete outcrop containing numerous small pisoliths of lateritic duricrust, which have been fragmented and some even veined by calcareous material (gravel pit).

H. A calcrete outcrop containing non-ferruginous saprolite fragments, partly masked by soil and lag. Note the micro-karstic surface texture. (33880E, 38420N)

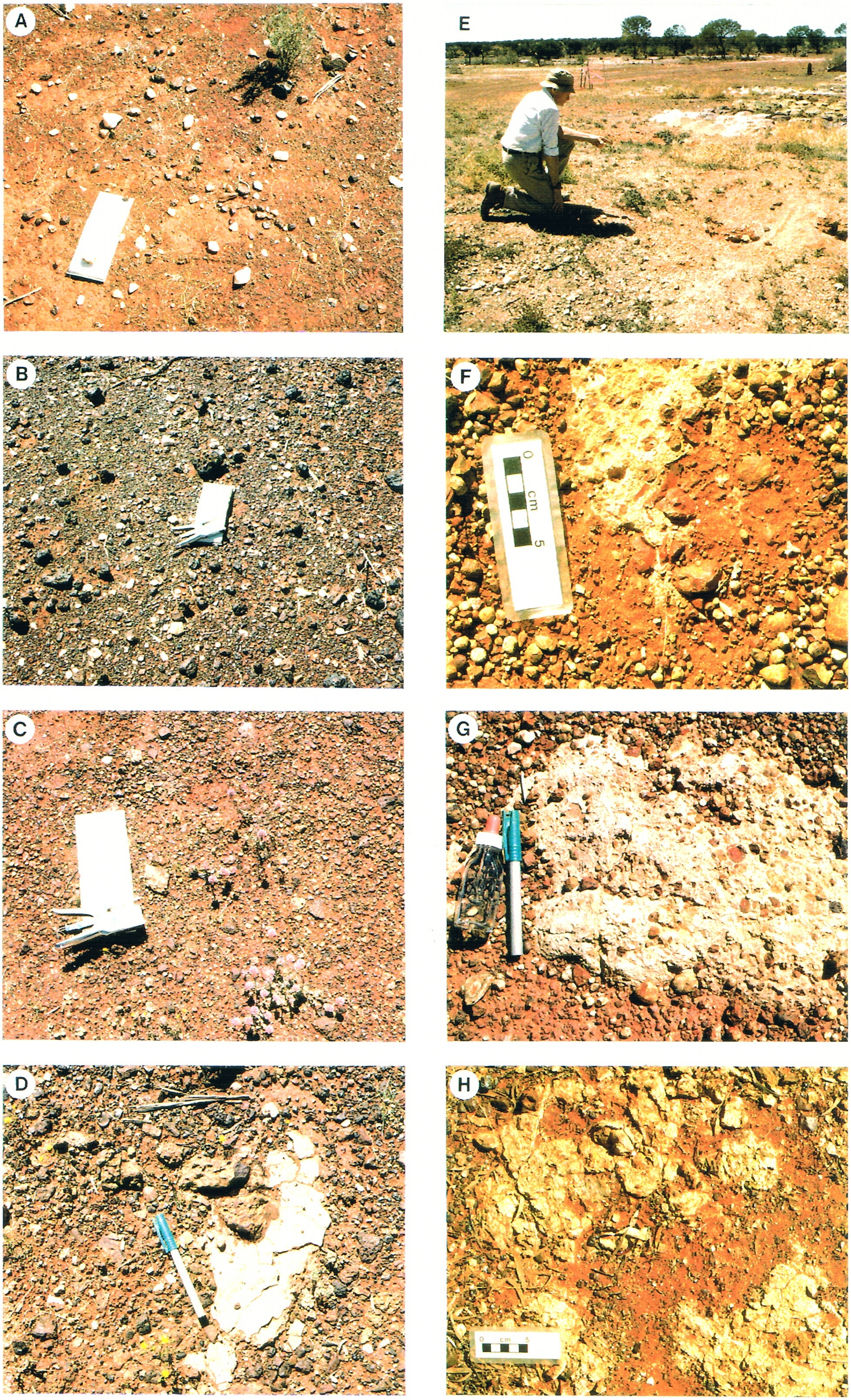

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FIGURE 5

A. Typical scene on lower flanks and onto flats, north-west of hill, showing Wanderrie Country, a sparse strew of lag, bare soil, grass tufts and mulga eremophila scrub.

B. An outcrop of ironstone at crest of hill, showing hackly surface and numerous boulders (33990E, 38780N).

C. A collection of ironstone boulder types to emphasise abundance of secondary iron and botryoidal goethite surfaces (south-east flank of hill).

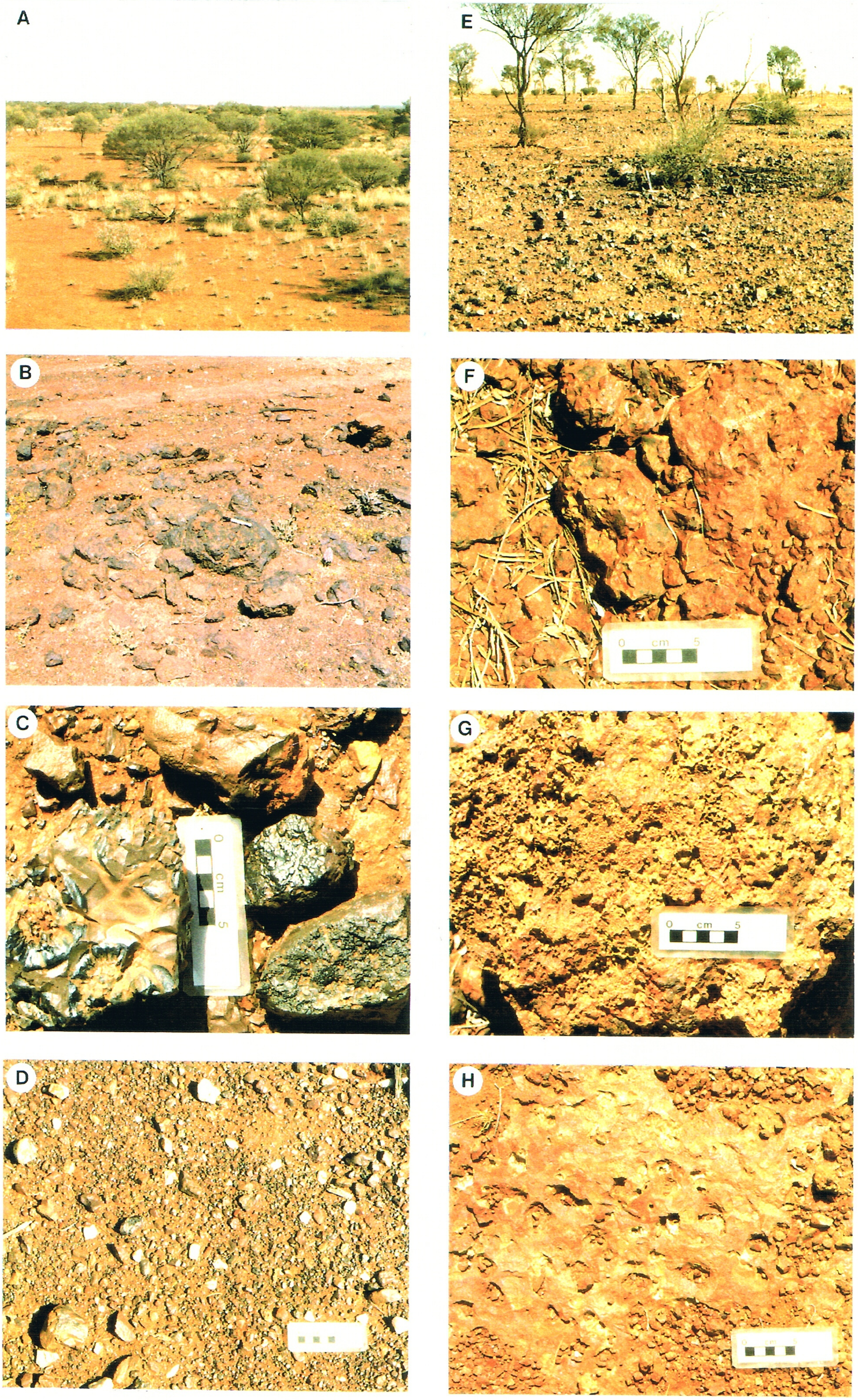
D. Abundant ironstone lag, together with strew of quartz, on SW flank of hill (33800E, 38500N).

E. Typical scene near crest of hill showing abundant ironstone lag and bouldery outcrop, sparse grass and slightly taller trees than on flats (33860E, 38560N) - compare with Fig 5A.

F. Outcrop of lateritic duricrust, surrounded by related khaki lag (north of gravel pit).

G. Top surface of lateritic duricrust with solution cavities and from which the khaki lag is shed (gravel pit).

H. Dense lateritic duricrust, from deeper in profile (gravel pit).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elements are readily adsorbed by goethite which is its major component. It is also likely to have been derived from the underlying saprolite and lateritic duricrust and its high density would tend to retard dispersion by wind or water. Lag geochemical surveys have been used extensively by WMC (Carver *et al*, 1987) and this technique was used at Beasley Creek.

The size distribution of the lag is variable. In places the distribution is bimodal, distinct fine and coarse fractions (Figure 4A), with one size fraction tending to dominate. Very fine lag is defined as having a size of generally <5 mm, the coarser fraction of the fine lag ranges from 5 - 15 mm and coarse lag is >15 mm in size. In other places, the lag has a more continuous size distribution and these size fractions have a lesser use and validity. Both fine lags tend to be rounded to subrounded and the coarse lag subrounded to subangular. While, at first sight, these lag types seem to be quite distinct, they are generally intimately mixed.

Fine Lag (<5 - 15 mm)

The finer fraction of this granular lag (<5 mm) occurs largely on the flats to the north-west and blankets the lower slopes of the north-west and west of the hill (Figure 2C), where its abundance appears to be largely random. Elsewhere the fine lag grades into its coarser pebbly fraction (5 - 15 mm) and the coarser fraction is dominant (Figure 4B). This lag is almost ubiquitous and its abundance does not seem to be linked to any underlying geological feature. The areas of its higher abundance seem to be centred on the hill in a general way and it seems to give way to the very fine lag in the north-west (Figure 2E). Both fine lag fractions are brown.

Coarse Lag (>15 mm)

The coarse pebbly fraction is relatively ubiquitous (Figure 2D) but it is best developed and is comparatively coarse near the crest of the hill. This lag is generally darker, often black to blue-black. Fragments exceeding 50 mm (cobbles) are not uncommon and fragments of ironstone may abound.

Khaki Lag

The slope to the east of the orebody, underlain by a lateritic duricrust, is partly covered by a lag containing two and in places three components. The ubiquitous black to dark brown nodular material is generally dominant but this is accompanied by a lesser amount of yellow-brown to khaki coloured lag and in places by small amounts of a red-brown lag (Figure 4C). The last two lag types may be found attached in the same fragment. They appear to be derived from the underlying lateritic duricrust. Both the coarse and the fine lag fractions here show these varieties.

Quartz Lag

White, opaque vein quartz (Figures 4A, B, D, 5D) varies considerably in its contribution to the lag as it appears to be related to limited mechanical dispersion around small quartz veins, some of which outcrop. It is a significant contributor to the lag on the flats to the north and north-west of the hill

(Figure 4A, 5A), where there appear to be some subcropping quartz veins. It make little contribution to the lag on the eastern flank, where lateritic duricrust subcrops (Figures 2H, 4C).

Soil and Wiluna Hardpan

The hill at Beasley Creek mine is mantled by red, very friable, clay soils - red earths (Stace *et al*, 1968) but Wiluna hardpan is usually encountered at a depth of less than 0.5 m. On the plain to the west, the soils are very friable sandy loams to fine sandy clay loams, underlain by Wiluna hardpan at 0.3 - 0.4 m and the pH is 5.0 - 5.5. Up the long, gentle western slope to the broad crest, the soil distribution is much more complex. Sporadic pockets of very friable, light brown, calcareous clays are associated with goanna mounds (Figure 4E). These are surrounded by more extensive red, very friable fine sandy clay loams. Wiluna hardpan, or sometimes saprolite (as a pale brown hard mass) occurs at 0.15 - 0.20 m. Where carbonate coats the surface of these substrates, the pH of the soil is from 6.0 - 7.0. Where there is no carbonate, the pH is 5.0 - 5.5. On the mid to lower eastern slopes, much lateritic gravel is present in the red friable fine sandy clay loams. The presence of these gravels makes it difficult to dig and to determine whether Wiluna hardpan is present. The soil on the mid-eastern slope has a pH of 5 - 5.5. The soils associated with goanna mounds are calcareous earths (Stace *et al*, 1968). These are light-brown, very friable, sandy clay loams to light clays that react vigorously with dilute HCl. Their pH is from 8.0 - 9.0. The soils on the eastern plain are similar to those to the west of the hill but small amounts of the khaki gravels are present and the soils are slightly more clayey, with a pH of 5.0 - 5.5. Details of soil depth, pH, texture and the hard layers encountered in the small pits that were used for soil sampling are given in Table 1 and summarised as plots in Figure 3. The generally shallow soils with a high pH on the hill are well illustrated.

Calcrete

Much of the crest of the hill is sporadically underlain by calcrete. It is a pale brown to pale reddish-brown material with creamy white, dull fractures. Pale brown to pale creamy-white zones of late-stage carbonate, 1 - 10 mm thick, are present close to the surface of some outcrops and these have a sub-conchoidal porcellaneous fracture. Very small voids are common. The whole mass is cemented to a varying degree with carbonate and/or silica. Local stringers of glassy secondary quartz are present.

Whereas some calcretes consist of relatively pure carbonate, others consist of a matrix-supported conglomerate of red ferruginous pisoliths in a granular calcrete matrix. This is particularly prevalent in calcretes to the south and south-east of the hill and were well exposed in the gravel pit (Figures 4F, G). Here the red pisoliths have yellow to khaki coloured rims (cutans). Some pisoliths are fractured and veined by the carbonate cement. In other places saprolite is veined with calcrete and saprolitic fragments occur in a calcrete matrix (Figure 4H).

TABLE 1 - BEASLEY CREEK SOILS

Field No	Easting	Northing	pH	Texture	Depth (cm)	Hard Layer
BC 00401	33600	38820	5.0	SL	30	RB Hardpan
BC 00402	33650	38820	5.5	CL	35	RB Hardpan
BC 00403	33700	38820	5.5	CL	45	RB Hardpan
BC 00404	33750	38820	5.5	CL	25	RB Hardpan
BC 00405	33800	38820	6.5	SL	15	RB Hardpan + CO3
BC 00406	33850	38820	8.0	LC	10	RB Hardpan + CO3
BC 00407	33900	38820	6.0	CL	25	Saprolite
BC 00408	33925	38820	6.5	SL	10	Saprolite
BC 00409	33950	38820	6.5	CL	20	Saprolite
BC 00410	33975	38820	6.5	LC	15	Saprolite
BC 00411	34000	38820	8.5	CL	10	Saprolite + CO3
BC 00412	34025	38820	7.0	CL	15	RB Hardpan + CO3
BC 00413	34050	38820	5.0	CL	30	Laterite
BC 00414	34075	38820	5.5	LC	50	RB Hardpan
BC 00415	34100	38820	5.0	CL	40	RB Hardpan
BC 00416	34150	38820	5.0	CL	20	RB Hardpan
BC 00417	34200	38820	5.0	CL	30	RB Hardpan
BC 00418	34250	38820	5.0	LC	30	RB Hardpan
BC 00606	34350	38820	5.0	LC	-	-
BC 00607	34450	38820	5.0	SCL	-	-
BC 00608	34550	38820	5.0	SLC	-	-
BC 00609	34650	38820	5.0	SLC	-	-
BC 00610	34750	38820	5.0	SLC	-	-
BC 00421	33650	38940	6.0	LC	20	RB Hardpan
BC 00422	33700	38940	5.0	LC	20	RB Hardpan
BC 00423	33750	38940	5.5	CL	20	RB Hardpan
BC 00424	33800	38940	5.5	SL	18	Saprolite + CO3
BC 00425	33850	38940	6.0	CL	20	RB Hardpan + CO3
BC 00426	33900	38940	6.0	SL	15	RB Hardpan + CO3
BC 00427	33925	38940	5.5	SL	10	RB Hardpan
BC 00428	33950	38940	8.4	CL	8	Saprolite + CO3
BC 00429	33975	38940	8.4	CL	20	CO3
BC 00430	34000	38940	8.0	CL	30	CO3
BC 00431	34025	38940	5.0	SL	10	Saprolite
BC 00432	34050	38940	5.0	LC	30	Laterite
BC 00433	34100	38940	5.0	SCL	55	Laterite
BC 00434	34150	38940	5.0	S	35	RB Hardpan
BC 00435	34200	38940	5.0	LC	20	RB Hardpan
BC 00436	34250	38940	5.0	LC	30	RB Hardpan
BC 00437	34300	38940	5.0	CL	30	RB Hardpan
BC 00601	34400	38940	5.0	SCL	-	-
BC 00602	34500	38940	5.0	SCL	-	-
BC 00603	34600	38940	5.0	CL	-	-
BC 00604	34700	38940	5.0	LC	-	-
BC 00605	34800	38940	5.0	LC	-	-

Background Samples

BC 00441	33747	39311	5.0	SCL	-	-
BC 00442	34172	39314	5.0	SCL	-	-
BC 00443	33545	38146	5.0	SLC	-	-
BC 00444	34290	38110	5.0	SLC	-	-

SL= Sandy Loam: CL=Clay Loam: LC=Light Clay: SCL=Sandy Clay Loam: SLC=Sandy Light Clay:

Where calcrete is most strongly developed, goannas and rabbits have excavated the friable calcareous soils around sub-horizontal slabs of calcrete and built their well-protected burrows beneath (Figure 4E). These excavations and their surrounding pale calcareous soils are slightly raised above the surrounding ground by 0.1 - 0.2 m and coincide with slight flexures in the contours (Figures 2A, J). They also show as pale bluish-white patches on the colour air photographs and so they can be readily mapped (Figure 2J). In addition, the occurrence of very small outcrops of calcrete has been identified on this map as "c". This does not imply that the calcrete is a continuous underlying sheet but shows the very broad distribution of this material.

Ironstone

The ironstones are a very variable material but most are hard, dark and dense. Colours vary from glistening black to red, yellow-brown and dull-brown. The surface of the ironstone can be vitreous, cavernous or vesicular. Dark brown, ferruginous, botryoidal coatings with a conchoidal fracture are common (Figure 5C). Detailed examination by hand lens shows a yellow-brown material which has a varied fabric from very fine-, even-grained to cellular and is thought to be of saprolitic origin. This is cut by veins and broader fractures of dark, metallic goethite, which forms colloform structures in places.

Outcrops of the ironstones are generally restricted to the crest of the hill where they form discontinuous patches and lenses of large dark brown irregular boulders with a hackly surface (Figure 5B). They are surrounded by a strew of coarse lag, derived from them (Figure 5D). These ironstone lags are most strongly developed along the axis of the hill and, to a lesser extent, on the upper south-western flank (Figure 2I). There seems to be a good correlation of outcropping ironstone with the ore zone, though some ironstone outcrops overlie meta-dolerite.

Lateritic Duricrust

Lateritic duricrust is exposed in a gravel pit on the eastern flanks of the hill but the occurrence of khaki-coloured lateritic duricrust-related lags (Figures 2F, 4C) suggest that much of the eastern flank of the hill is underlain by this material. This has been borne out by subsequent mining. The lateritic duricrust exposed in the gravel pit has a lower part which is reddish yellow and is rich in vermiform voids (vesicular lateritic duricrust). These have yellow-brown linings. The voids occupy more of the upper part of the duricrust and the remaining material has a darker, nodular appearance (nodular lateritic duricrust). The voids are so dominant in the top of the lateritic duricrust that nodular fragments become detached and shed into the overlying lag. The lateritic duricrust can be divided into the four types described below. The area underlain by lateritic duricrust has been shown by WMC to be an area of very intense short-wavelength magnetic noise.

(a) Lateritic duricrust with a mottled appearance. This has a red fine-grained matrix having well defined dark red mottles (<10 mm dia.) and a few fine (2 - 4 mm) vermiform voids. The voids are lined with fine, granular, light-reddish yellow to pale yellowish white coatings. This material, in places, fills the voids as a finely porous mass. Fracture faces of this lateritic duricrust are irregular and have a dull lustre.

(b) Lateritic duricrust penetrated by coarse (10 - 15 mm dia.) irregular vermiform voids. The matrix ranges from red to dark red with a few clearly-defined reddish black mottles. Pisoliths, with thick concentric coatings, are rare. In places the matrix forms an open framework, enclosing many coarse vermiform voids with reddish-yellow and yellowish-white dull, granular linings. At the other extreme, most of the voids are filled with this material in a range of porosities.

(c) Concretionary types of lateritic duricrust. These are dominated by a range of concretions, well defined from the matrix in places by a thin skin (<1.0 mm thick). The concretions are reddish-black to black pisolithic or nodular with diameters in the range of 4 - 15 mm.

(d) Reddish black, dark reddish-grey and dark red lateritic duricrusts. These materials are dominated by fine vesicular and vermiform voids (<5 mm). Void linings and fillings range in colour from red to light reddish-yellow. Some linings are finely granular and porous, others have a dull fracture and some are non-porous. This type of duricrust is noticeably more dense than the other types and is similar to the goethitic pods found at Mt. Gibson (Anand *et al*, 1989).

Saprolite

Exposures of saprolite are very small, relatively uncommon and are found along the axis of the hill and along its western flank (Figure 2G). They consist of brown to cream coloured, soft remnants with little to no recognisable fabric. Some calcretes contain numerous saprolite fragments. Saprolite fragments make a significant contribution to the fine fraction of the lag in places. Preservation of small outcrops of saprolite on the surface (Figure 4D) is probably due to slight silicification or protection by calcrete.

SUMMARY AND CONCLUSIONS

The results of this work are presented diagramatically in Figure 6. The hill at Beasley Creek is asymetric, with a steeper slope to the east. This steeper slope is preserved by hard lateritic duricrust and appears to be maintained by more active erosion at the foot of the hill due to runoff from the gently undulating terrain to the east. The crest of the hill is protected by the lateritic duricrust, calcrete and surficial ironstone.

The soils on the plains on either side of the hill are relatively deep (0.3 - 0.45 m), have a low pH (5.0 - 5.5) and are underlain by Wiluna hardpan. On the hill, the soil is thin (0.1 - 0.2 m), has a high pH and hardpan gives way to calcrete, saprolite and in places to ironstone.

The occurrence of calcrete seems related to the shallow depth to saprolite at the top of the hill and to a mafic lithology. The Beasley Creek site is in keeping with regoliths elsewhere in the north-east Goldfields in which hardpan is abundant. The Eastern Goldfields contrast in having calcareous soils which overlie plastic, non-calcareous red clay substrates and hardpan is rarely present.

The regolith at Beasley Creek has been partly stripped. This is indicated by the absence of a lateritic duricrust over all but the eastern flank of the hill. The extent of stripping is probably more severe at Telegraph, where there is no true lateritic duricrust and only a mottled zone is preserved. Much of the saprolite at Telegraph is overlain by several metres of recent fluvial sediments (and in places by intermittent Permian glacial tills, now saprolite). This contrasts with Beasley Creek, which is overlain by a few tens of millimetres of colluvial material. Saprolitic Permian sediments only overlap the eastern margin of the orebody (Figure 2B).

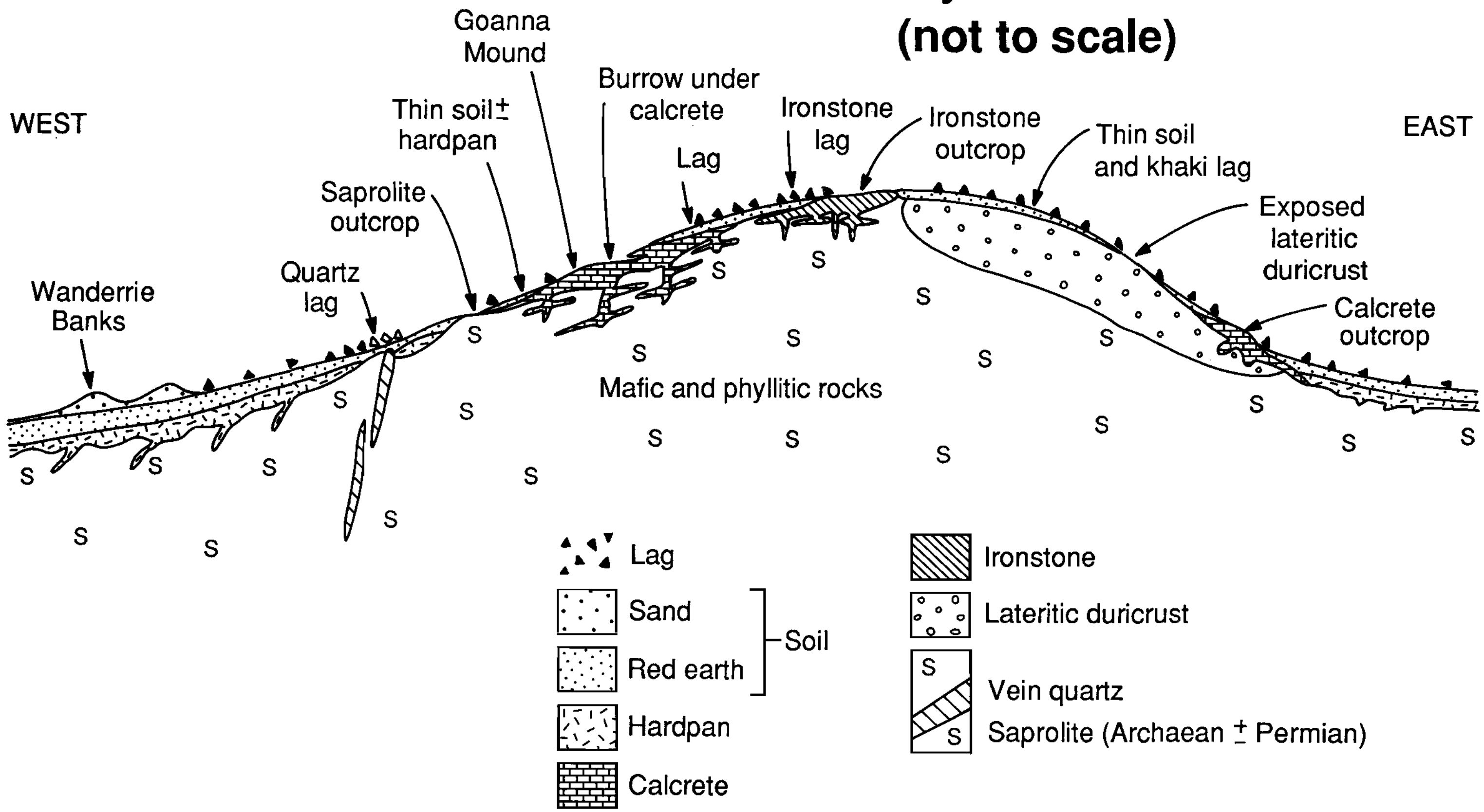
The ferruginous lateritic duricrust closely follows the upper surface of the ore-bearing black shale unit and it seems likely that iron in this unit, probably originally as sulphides, was the source of iron for the lateritic duricrust. Ironstones overlie both the ore-bearing black shale unit and metadolorites.

The coarse lag, the ironstone lag and the khaki lag show relatively little dispersion from their sources. The distribution of the khaki lag closely follows the lateritic duricrust and the hangingwall of the black shale orebody. The ironstone lag is dispersed around its small outcrops and closely follows the subcrop of the ore body and some dolerites. It appears to be spread no more than 200 m from source. The coarse lag is more widely dispersed but it is strongly concentrated within 200 m of source.

The fine lag is widely distributed. The increase in abundance of the fine fraction of the fine lag to the north-east of the hill is probably related to colluvial sedimentation and fractionation of the lag as it passes down slope and away from source. The quartz lag appears to have been mechanically dispersed around small quartz veins which are particularly abundant to the north-west and have no apparent correlation with ore.

The landscape around the Beasley Creek Gold Mine leaves a first impression of simplicity. This study, summarised in Figure 6, emphasises its actual complexity. The geochemical media available to the explorationist are elements of this complex landscape. This type of study is essential to aid the choice of sample medium and to provide background for later interpretation.

Figure 6.
Sketch cross section of the hill at Beasley Creek showing relationships between major surficial materials (not to scale)



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