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Hg and As Soil Geochemistry

of the

Meager Creek Geothermal Area, British Columbia

(1982?)

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ABSTRACT

A survey of mercury (Hg) and arsenic (As) soil geochemistry involving 696 samples along survey lines and 77 samples in 6 soil profiles was carried out in the Meager Creek Geothermal Area (MCGA), British Columbia. The South Reservoir, currently being confirmed by deep drilling, was delineated by anomalously high Hg and As values and there is remarkable coincidence of the geochemical anomalies with an electrical resistivity anomaly and shallow thermal anomaly. The As results outline three possible geothermally active structures in the South Reservoir. Hg was enriched at depth in soil profiles over the South Reservoir whereas it was enriched in the organic A horizon in soil profiles from outside the South Reservoir. Hg-As results from reconnaissance lines in other parts of MCGA define specific interest areas within broad electrical resistivity anomalies.

INTRODUCTION

The Meager Creek Geothermal Area (Figure 1) is centered around the Meager Creek Volcanic Complex which is of Pliocene to recent age. It is the most northerly major center in the Garibaldi Volcanic Belt, an extension of the High Cascade Volcanos (see Souther, 1970; Read, 1979 and Lewis and Jessop, 1981).

A primary target of about 6 square kilometres, termed herein the South Reservoir, has been identified on the south flank of the complex (Figure 1). Preliminary testing of two deep test wells, MC-1 and MC-2, indicate bottom hole temperatures of over 230 C and 250 C respectively with permeable structures at 1350m and 1600m hole depth in MC-1 and at 2800-3200m hole depth in MC-2.

The thermal regime is illustrated in Figures 2, 3 and 4. The thermal gradients correspond to conductive heat flows of 105 to 620 mWm^{-2} and, in two holes considered to be strongly influenced by convective heat flow, to values of 1100 to 1700 mWm^{-2}. Regional heat flow for the Garibaldi Volcanic Belt is 69-89 mWm^{-2} (Lewis and Jessop, 1981) and average terrstrial heat flow is estimated to be 63 mWm^{-2} (Von Herzen, 1967).

Broad targets in the northern part of the area correspond approximately to the resistivity anomalies in Figure 1. Four shallow gradient wells have been drilled to date and heat flows of the same magnitude as the South Reservoir have been measured.

A detailed case history of the exploration is given in Fairbank, et.al., 1981. The most useful exploration techniques have been found to be water geochemistry, electrical resistivity, shallow thermal gradient drilling, and detailed geologic mapping and fracture analysis.

In this report we are concerned with the results of a survey of mercury (Hg) and arsenic (As) soil geochemistry carried out in the Meager Creek area during the 1981 field season. The study involves 696 soil samples from sample lines and 77 samples from soil profiles. The main focus is the South Reservoir area but reconnaissance lines have been run in other parts of MCGA. New water geochemistry and surface water electrical conductivity results complimentary to the soil geochemistry are discussed.

MERCURY-ARSENIC SOIL GEOCHEMISTRY

Hg in soils has been found to show good correlation with high heat flow areas (Matlick and Shiraki, 1981). In Capuano and Bamford's (1978) work Hg soil geochemistry outlined structures that acted as conduits for the geothermal fluids. As is also commonly associated with geothermal systems and provides significant additional information. The differences in Hg and As soil geochemistries are commonly ascribed to differences in transport mechanisms: As is transported as an aqueous phase whereas Hg is generally considered to be transported as an elemental gaseous species (Jonasson and Boyle, 1972; Juncal and Bell, 1981).

In a preliminary study of the Hg soil geochemistry in the Meager Creek Area (NSBG, 1979) most of the anomalously high values were associated with organic rich soils and the overall usefulness of Hg as an exploration guide was not conclusively demonstrated. The present work shows that Hg-As soil geochemistry can be successfully integrated with the ongoing exploration of the Meager Creek geothermal area at both the reconnaissance level and more advanced stages of development.

SAMPLING AND ANALYTIC TECHNIQUES

The Meager Creek valley is filled with colluvium and slide debris and soil horizons are generally poorly developed. Based on soil profile results 50 to 70cm was established as the optimum sampling depth.

Samples were collected in 150 cc screw-capped plastic jars. Sample drying, preparation, and analyses were done at Chemex Labs Ltd., a commercial laboratory in Vancouver, B.C. Both Hg and As soil contents were determined using atomic absorption techniques.

The sampling interval for the line survey was 100 metres except in areas of particular interest where the interval was reduced to 50m and in one case 20m.

RESULTS

Mean values and standard deviations are listed in Table 1 for three sets of samples. Line S is outside the geothermally active area and is underlain by the same rock types as the South Reservoir. It can thus be used to establish background values for the South Reservoir area. Background values for the entire project area can be represented by the mean for all samples outside the South Reservoir.

The As and Hg results are illustrated in Figures 5 and 6 in which anomalously high As and Hg values are shown by shading. It can be seen that most values for the South Reservoir are anomalous. There is good correspondence between Hg and As on a sample-by-sample basis.

Contoured Hg and As results for the South Reservoir are presented in Figures 7 and 8. For the As results there are three trends: a North-South trend corresponding to No Good Creek, an east-west trend, and a southeast-northwest trend in the Angel Creek area. The Hg results are similar but less discrete. One large anomalously high response is centered roughly around

Angel Creek and a second zone around No Good Creek.

The most significant result from the soil profiles (Figures 9 and 10) is that in geothermally active parts of the area (stations 24 + 00 and 13 + 50E of Line K) Hg is enriched at depth. Profiles outside the South Reservoir area (stations 11 + 60E and 26 + 00E of Line G5 and station 23 + 00 of Line S) show strong Hg enrichment in the organic A horizon and a flat, low response over the rest of the profile. At station 0 + 00 of Line K, situated at the edge of the South Reservoir area, the Hg and As values stay approximately constant with a slight Hg depletion in the organic A horizon.

In Figure 1 areas represented by anomalously high values of Hg and As on the reconnaissance lines are marked by heavy lines. The two areas noted with asterixes in Figure 1 are characterized mainly by strong As responses.

DISCUSSION

The principle result of the study is that the South Reservoir has been clearly delineated by the As-Hg soil geochemistry. The As and Hg responses in Figures 7 and 8 are remarkably coincident with the dipole-dipole resistivity anomaly and shallow thermal anomaly in Figure 1.

Based on past work three structural features in the South Reservoir area have been proposed as controls on fluid movement: the No Good Creek zone, east-west faulting parallel to the Meager Creek fault, and the Ryan River Lineaments (see Figures 3 and 4, and 11). Geothermal activity along these three features is recorded by the three trends of anomalously high As values in Figure 7.

The Ryan River Lineament Zone has been identified in air photos and is correlated with a predominant fracture set in the South Reservoir (Fairbank, et.al., 1981). The idea that these lineaments may be important permeable structures is further supported by the occurrence of saline waters in several swamps and

streams within the Ryan River Lineament Zone in the South Fork Area (Figure 11). The waters are cool and have chemical compositions similar to thermal waters from the South Reservoir. They are considered to represent outflow from the geothermal resource that has been channelled along the Ryan River Lineaments.

The low values of As and Hg in soils around thermal gradient holes M7-79D and M8-80D (Figures 7 and 8) are surprising since these two holes had the highest thermal gradients in the South Reservoir. Refraction seismic work (Fairbank, et.al., 1981) indicates that the area around M7-79D and M10-80D represents a bedrock high that extends into the Meager Creek Valley (Figure 12). Probable geothermal fluid paths are shown in Figure 12. It is seen that although the area itself is impermeable in the near surface environment it is heated from underneath and from the west by fluids in the Meager Creek Fault and the No Good Creek Zone.

The anomalous Hg distribution over the South Reservoir (Figure 8) corresponds to the position of an outflow plume in the colluvium of the Meager Creek Valley. It is suggested therefore that, at least in the

case of MCGA, Hg transport involves not simply the vapor phase but is strongly related to the movement of the liquid phase.

On the reconnaissance scale electrical conductivity results compliment the anomalous geochemical results in the Job Creek-Affliction Creek area. Job Creek itself has high electrical conductivities as do many small streams coming into Job Creek and Affliction Creek. This area thus is a high priority target for further exploration.

The South Reservoir is characterized by complimentary Hg and As responses. If such geochemical behaviour is a general rule for geothermal areas in the Garibaldi Volcanic Belt then it may be useful in exploration. For instance the two reconnaissance targets defined principally by high As may be due to non-geothermal causes.

Surface depletion of Hg in soil profiles has also been observed by other investigators such as Buseck (1977) and Capuano and Bamford (1978) and thus seems to be characteristic of geothermal systems. It may

represent a diffusion gradient of elemental Hg in the soil degassing into the atmosphere.

CONCLUSIONS

Hg-As soil geochemistry clearly delineates the South Reservoir and combined with other work indicates that the Ryan River Lineaments, a regional feature, may be an important target for permeable structures in the deep reservoir. Production drilling should be oriented to intersect these structures at high angles.

In the northern part of the project area the present work is useful in outlining specific areas within the broader geophysical anomalies.

Soil profiles are an important integral part of any Hg-As soil geochemistry survey. They are essential to determining optimum sampling depths and are potentially useful as a discriminating tool.

ACKNOWLEDGEMENTS

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TABLE 1

Means and Standard Deviations

for Soil Line Samples

Samples	Hg (ppb)	As (ppm)
outside South Reservoir	44 ± 19	5.6 ± 4.7
over South Reservoir	77 ± 67	9.1 ± 6.0
Line S	31 ± 11	5.0 ± 1.9

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FIGURE CAPTIONS

Figure 1 Hg-As Soil Geochemistry survey lines with electrical resistivity and thermal anomalies indicated. Inset shows location of Meager Creek Geothermal Area. (MCGA)

Figure 2 Plan map of thermal regime, South Reservoir, at 600m below ASML. Positions of Sections A-A'-A" and B-B' are indicated.

Figure 3 Section A-A'-A" (Figure 2) through South Reservoir. Meager Creek Fault and Ryan River Lineaments are possible permeable structures. Positions of thermal gradient holes (e.g. M8-89D) and deep test wells (MC-1 and MC-2) are shown.

Figure 4 Section B-B' through South Reservoir showing relation of artesian flows, silicification and lost circulation in MC-1 and MC-2 and H_2S emissions in thermal gradient hole M10-80D to projected Meager Creek Fault.

Figure 5 Line profiles of Hg and As results for South Reservoir area and Line S. Shaded areas represent anomalous values.

Figure 6 Line profiles of Hg and As results for reconnaissance lines in MCGA. Shaded areas represent anomalous values.

Figure 7 Contoured Hg results for South Reservoir area.

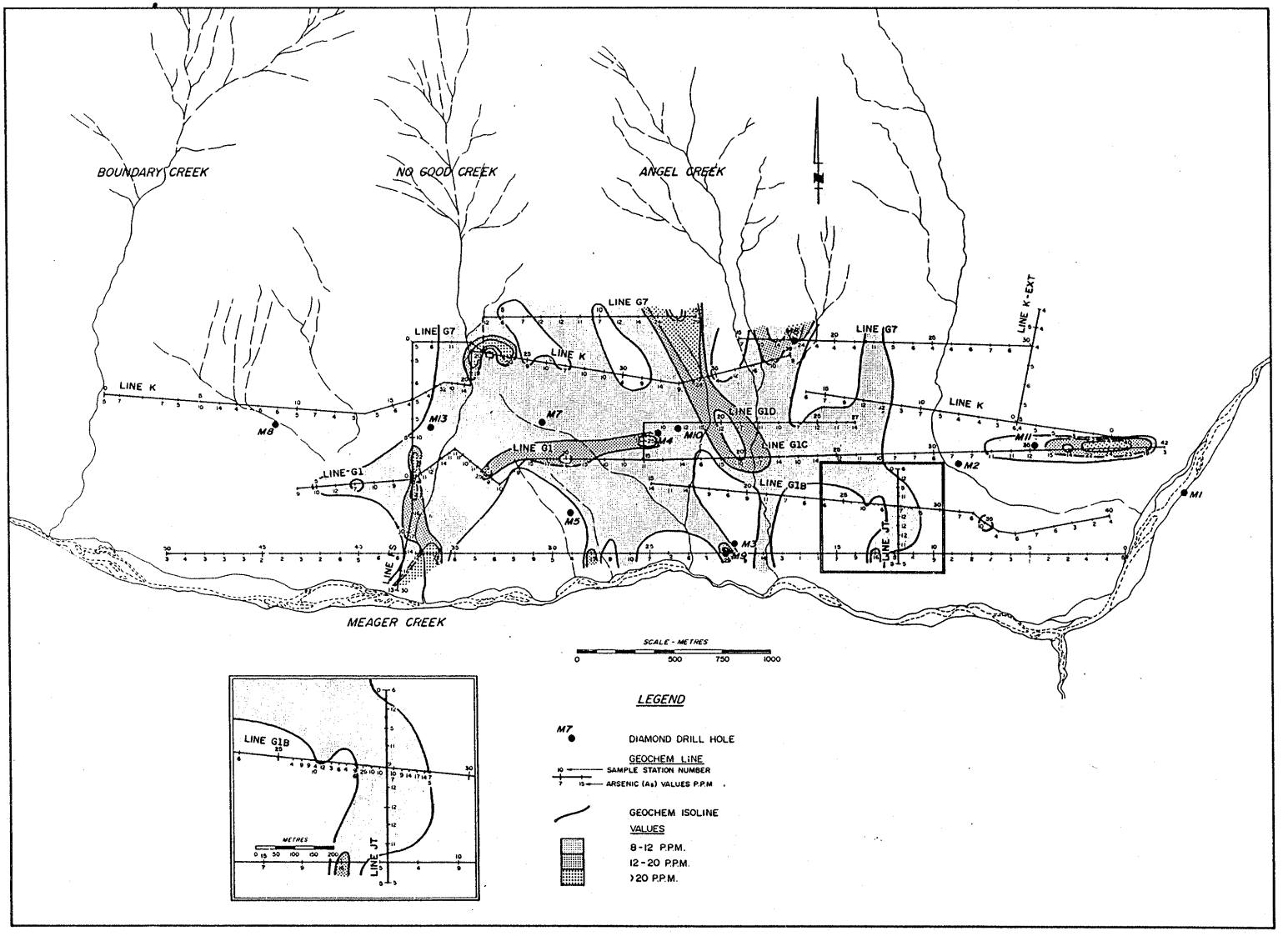
Figure 8 Contoured As results for South Reservoir area.

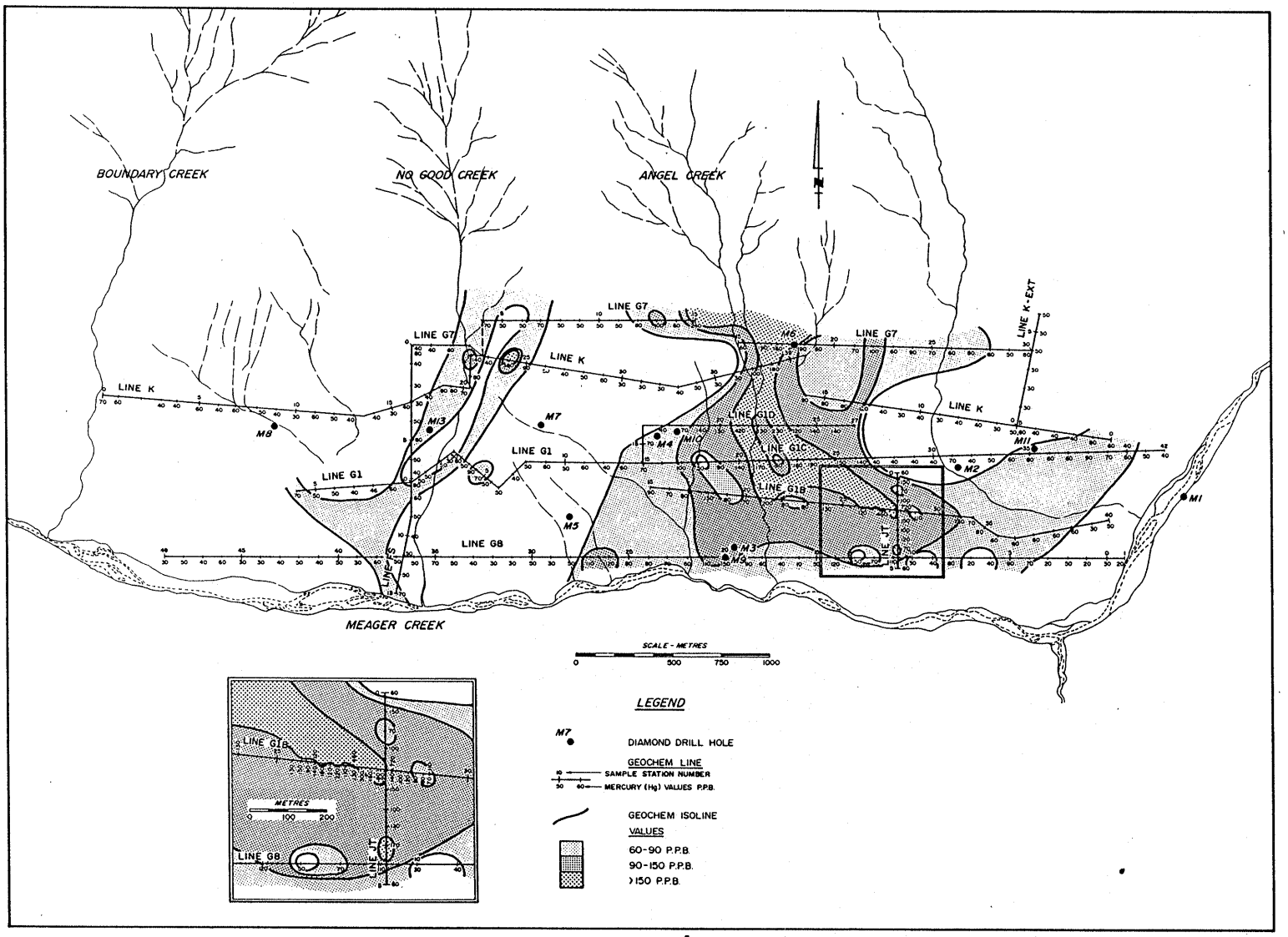
Figure 9 Soil profile results for South Reservoir.

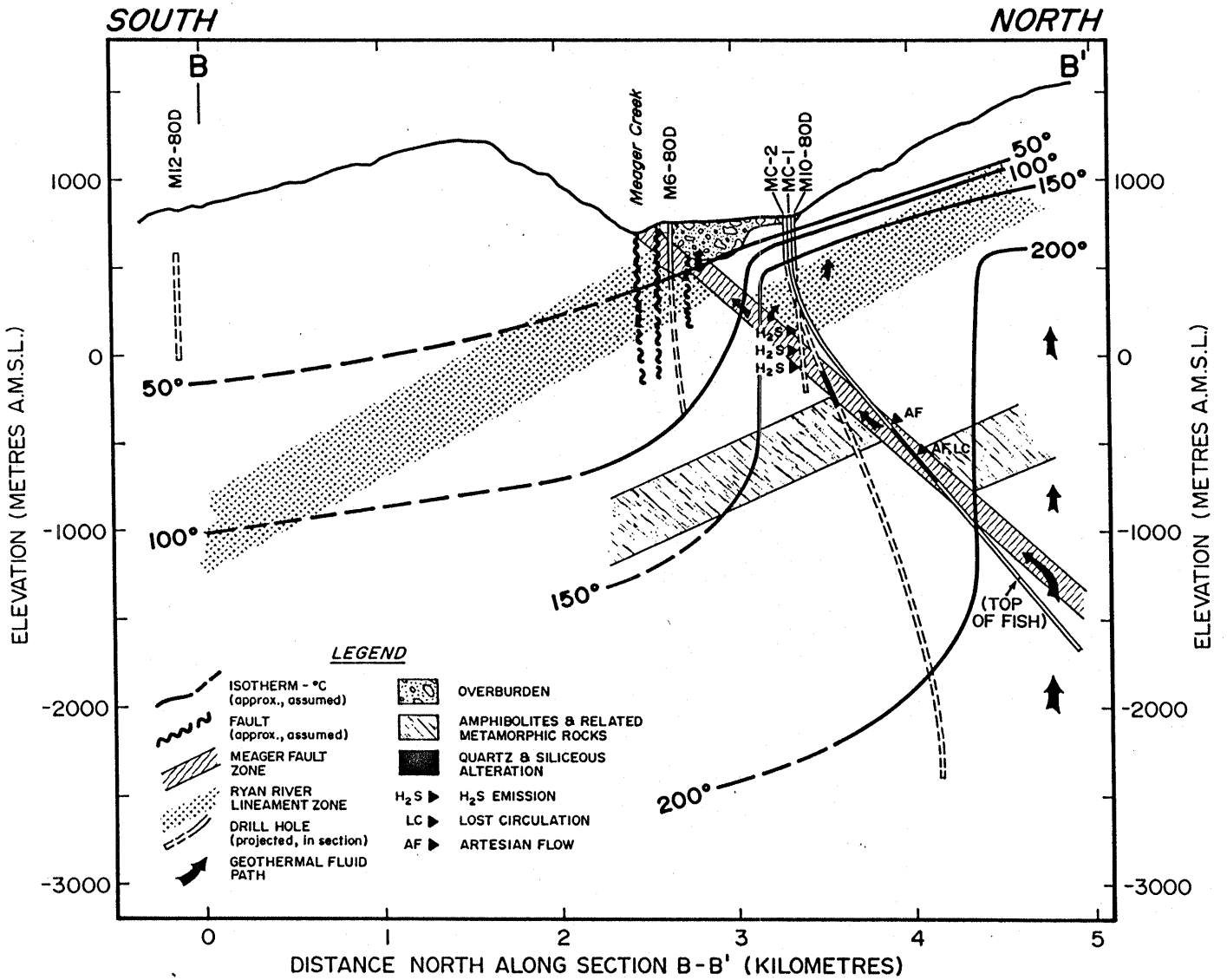
Figure 10 Soil profile results outside South Reservoir.

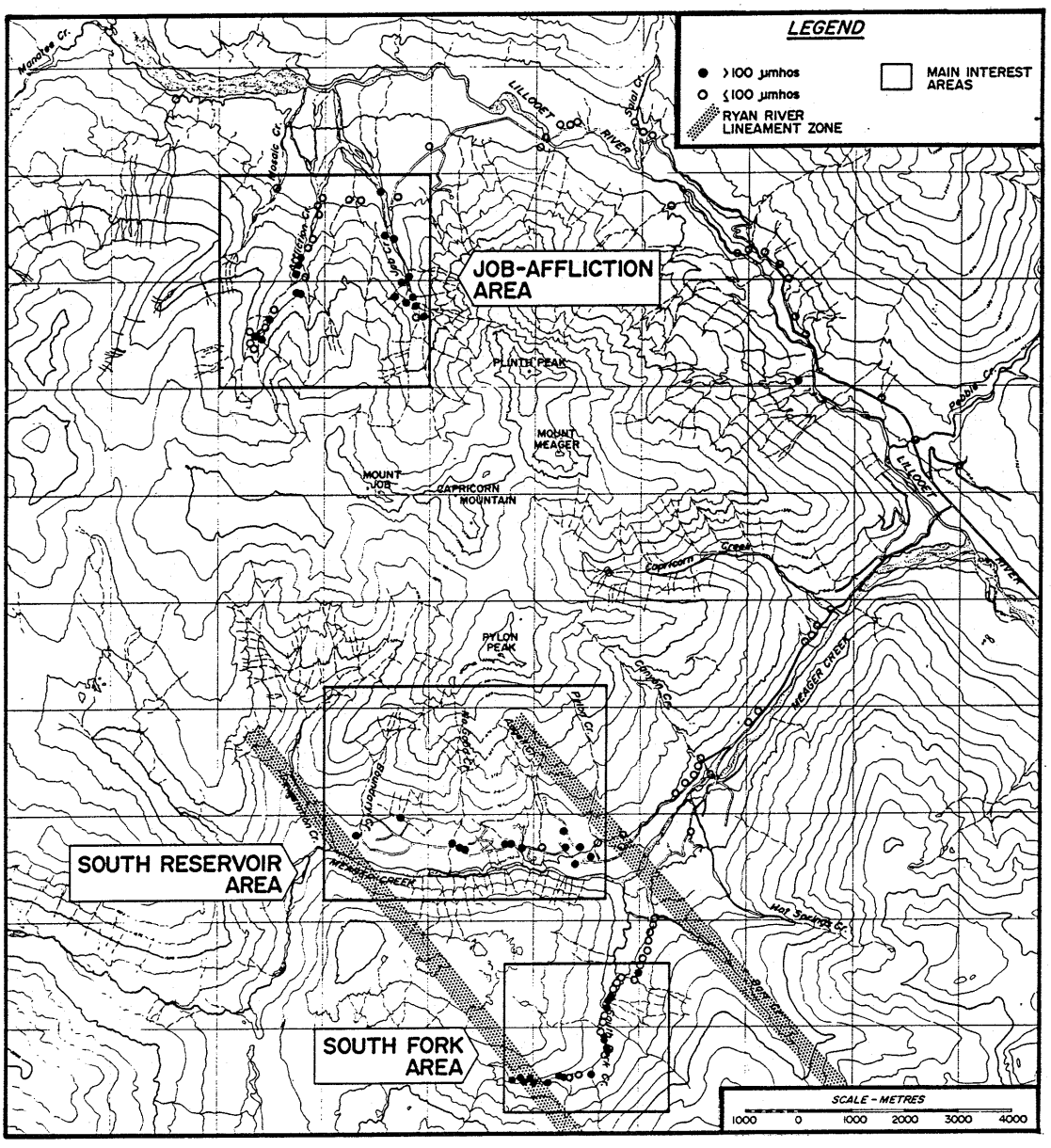
Figure 11 Map of surface water electrical conductivities showing areas of anomalous conductivities (>100 µmhos). Ryan River Lineament Zone also outlined.

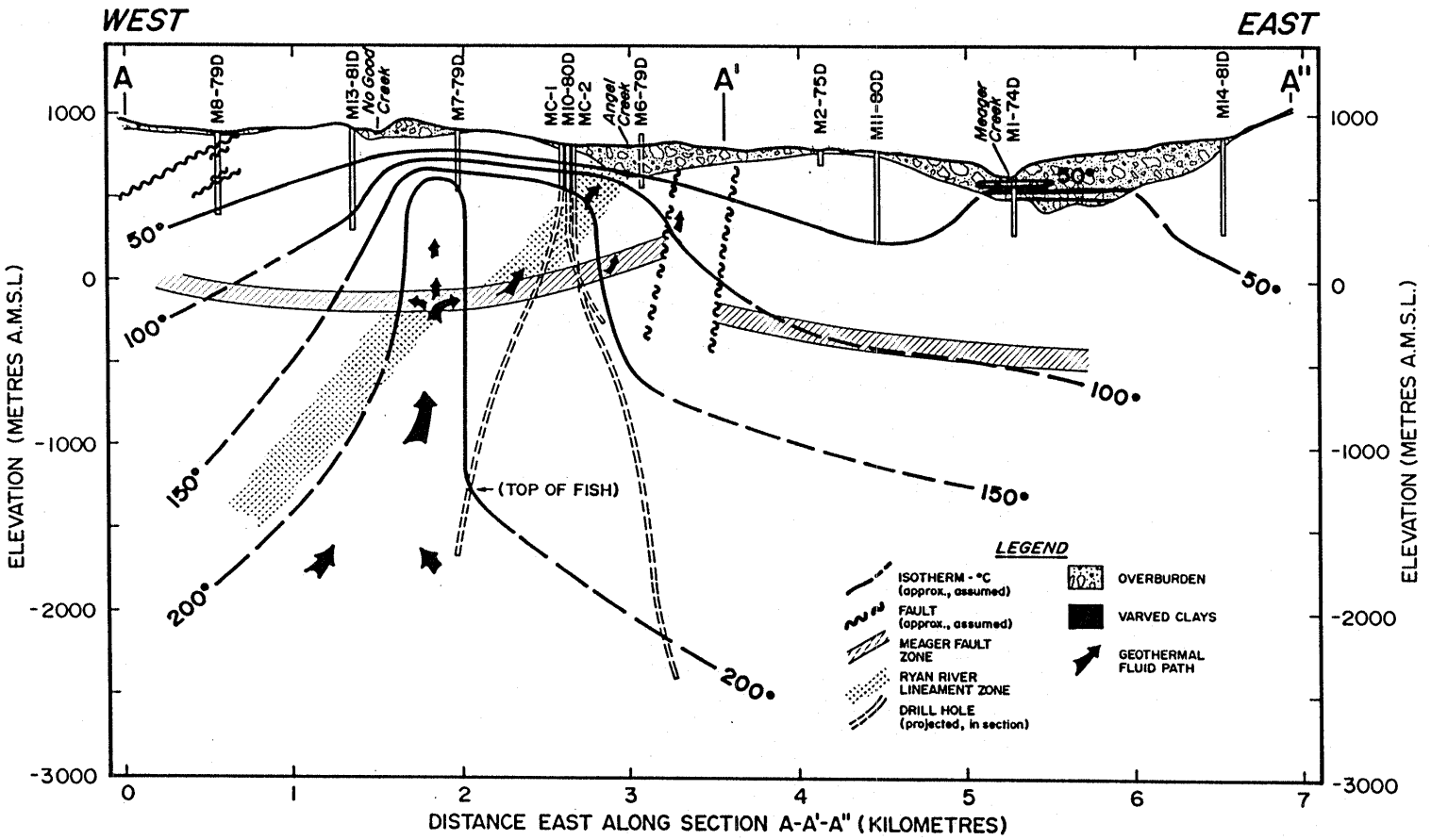
Figure 12 Diagram showing bedrock topography to 800m elevation and possible geothermal fluid paths (arrows). Note bedrock high around thermal gradient holes M7 and M10. Geothermal fluids upwelling in the No Good Creek zone are diverted along Meager Creek Fault.

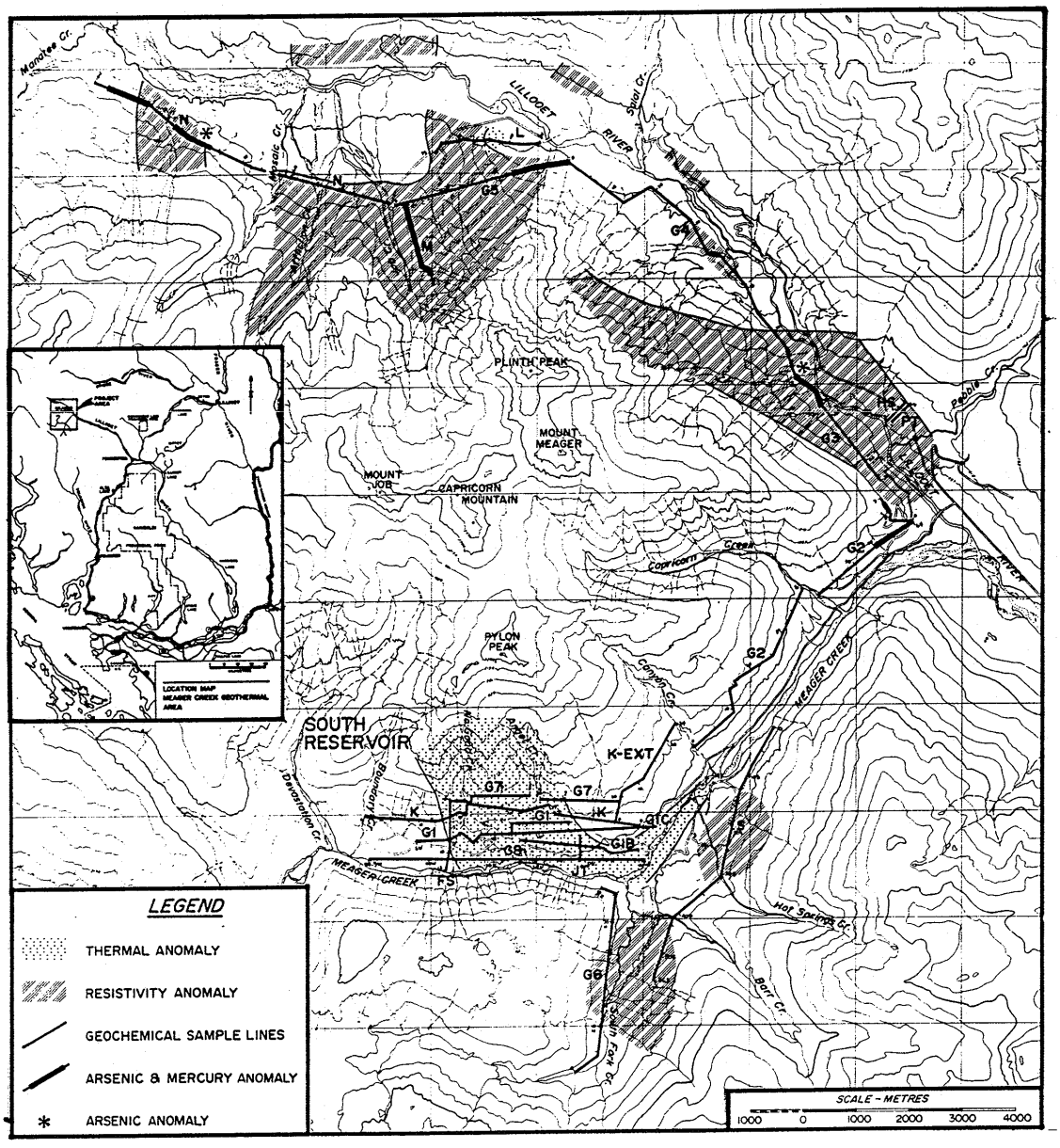

BOUNDARY CREEK
NO GOOD CREEK
ANGEL CREEK
MEAGER CREEK
LINE K
LINE G7
LINE G1
LINE G1B
LINE G1C
LINE G1D
LINE K-EXT
LINE JT
M1
M2
M3
M4
M5
M6
M7
M8
M9
M10
M11
M13
SCALE - METRES
0
500
750
1000
LEGEND
M7
DIAMOND DRILL HOLE
GEOCHEM LINE
SAMPLE STATION NUMBER
ARSENIC (As) VALUES P.P.M
GEOCHEM ISOLINE
VALUES
8-12 P.P.M.
12-20 P.P.M.
>20 P.P.M.
METRES


BOUNDARY CREEK
NO GOOD CREEK
ANGEL CREEK
MEAGER CREEK
LINE K
LINE G7
LINE G1
LINE G8
LINE G10
LINE G1C
LINE G1B
LINE K-EXT
LINE J-T
M1
M2
M3
M4
M5
M6
M7
M8
M9
M10
M11
M13
SCALE - METRES
0
500
750
1000
LEGEND
DIAMOND DRILL HOLE
GEOCHEM LINE
SAMPLE STATION NUMBER
MERCURY (Hg) VALUES P.P.B.
GEOCHEM ISOLINE
VALUES
60-90 P.P.B.
90-150 P.P.B.
>150 P.P.B.
METRES
0
100
200

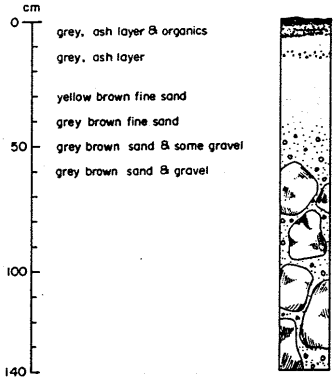

SOUTH
NORTH
B
B'
M12-80D
Meager Creek
M6-80D
MC-2
MC-1
M10-80D
50°
100°
150°
200°
H2S
AF
AF,LC
(TOP OF FISH)
ELEVATION (METRES A.M.S.L.)
1000
0
-1000
-2000
-3000
0
1
2
3
4
5
DISTANCE NORTH ALONG SECTION B-B' (KILOMETRES)
LEGEND
ISOTHERM - °C (approx., assumed)
FAULT (approx., assumed)
MEAGER FAULT ZONE
RYAN RIVER LINEAMENT ZONE
DRILL HOLE (projected, in section)
GEOTHERMAL FLUID PATH
OVERBURDEN
AMPHIBOLITES & RELATED METAMORPHIC ROCKS
QUARTZ & SILICEOUS ALTERATION
H2S ▶ H2S EMISSION
LC ▶ LOST CIRCULATION
AF ▶ ARTESIAN FLOW

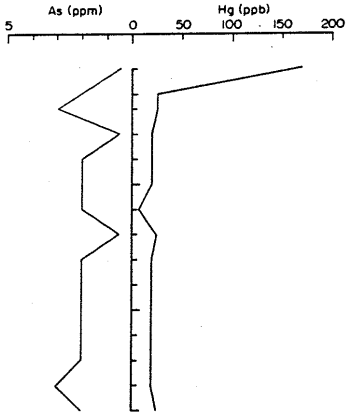

LEGEND
> 100 µmhos
< 100 µmhos
RYAN RIVER LINEAMENT ZONE
MAIN INTEREST AREAS
JOB-AFFLICTION AREA
SOUTH RESERVOIR AREA
SOUTH FORK AREA
PLINTH PEAK
MOUNT MEAGER
MOUNT JOB
CAPRICORN MOUNTAIN
PYLON PEAK
LILLOOET RIVER
MEAGER CREEK
Capricorn Creek
Pebble Cr.
Hot Springs Cr.
SCALE - METRES
1000 0 1000 2000 3000 4000


WEST
EAST
A
A'
A''
M8-79D
M13-81D
No Good Creek
M7-79D
MC-1
M10-80D
MC-2
Angel Creek
M6-79D
M2-75D
M11-80D
Meager Creek
M1-74D
M14-81D
50°
100°
150°
200°
(TOP OF FISH)
LEGEND
ISOTHERM - °C (approx., assumed)
FAULT (approx., assumed)
MEAGER FAULT ZONE
RYAN RIVER LINEAMENT ZONE
DRILL HOLE (projected, in section)
OVERBURDEN
VARVED CLAYS
GEOTHERMAL FLUID PATH
ELEVATION (METRES A.M.S.L.)
1000
0
-1000
-2000
-3000
0
1
2
3
4
5
6
7
DISTANCE EAST ALONG SECTION A-A'-A" (KILOMETRES)


LILLOOET RIVER
Manatee Cr.
Mosaic Cr.
Spud Cr.
PLINTH PEAK
MOUNT MEAGER
MOUNT JOB
CAPRICORN MOUNTAIN
Capricorn Creek
PYLON PEAK
Cariboo Cr.
MEAGER CREEK
SOUTH RESERVOIR
Devastation Cr.
Lucerne Cr.
Hot Springs Cr.
Barr Cr.
Fox Cr.
Pebble Cr.
RIVER
G1
G2
G3
G4
G5
G6
G7
G1B
G1C
K
K-EXT
JK
JT
FS
N
L
LOCATION MAP
MEAGER CREEK GEOTHERMAL AREA
LEGEND
THERMAL ANOMALY
RESISTIVITY ANOMALY
GEOCHEMICAL SAMPLE LINES
ARSENIC & MERCURY ANOMALY
ARSENIC ANOMALY
SCALE - METRES
1000 0 1000 2000 3000 4000

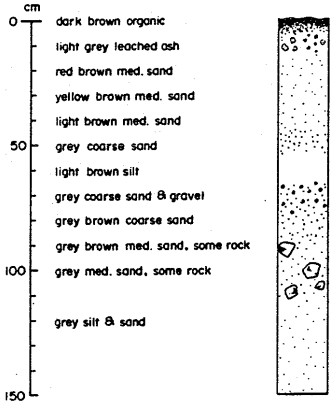
LINE S - STN 23+00

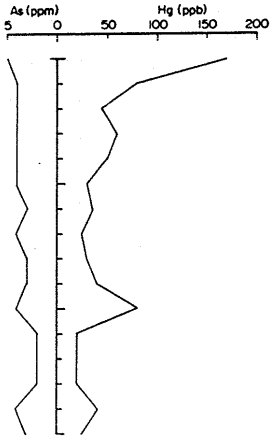




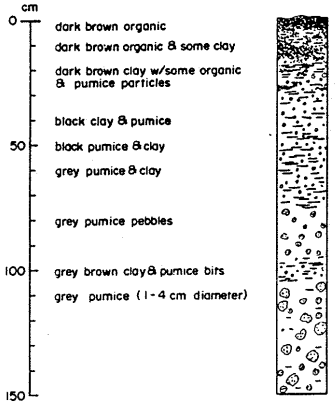
NOTE: sand & gravel was between tightly packed large rocks. The sand was found in layers of alternating grey brown & black.

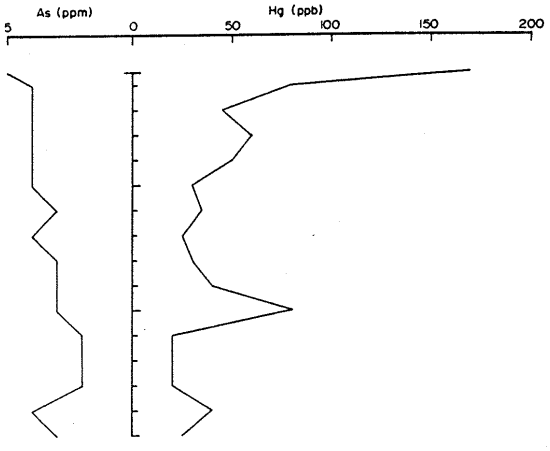
LINE G5 - STN 11+60



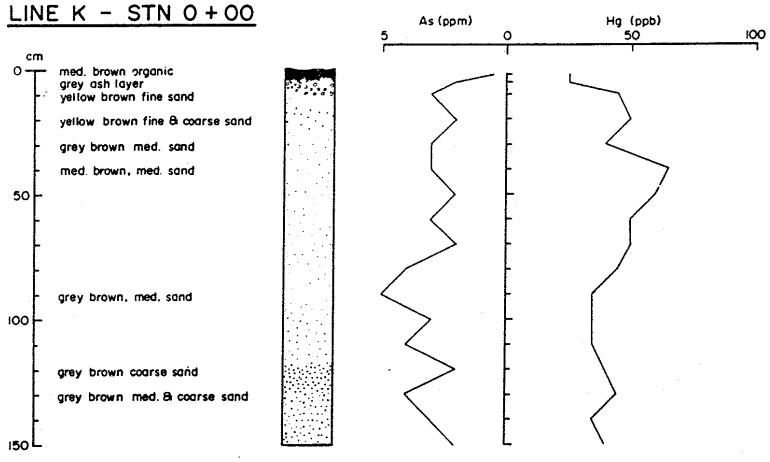


LINE G5 - STN 26+00

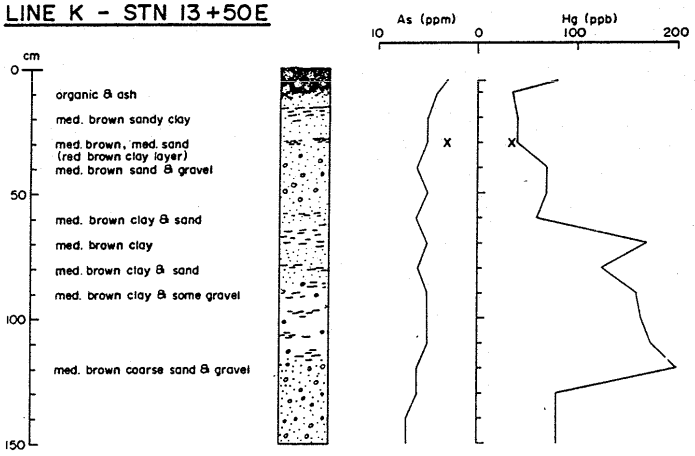




LINE K - STN 0+00

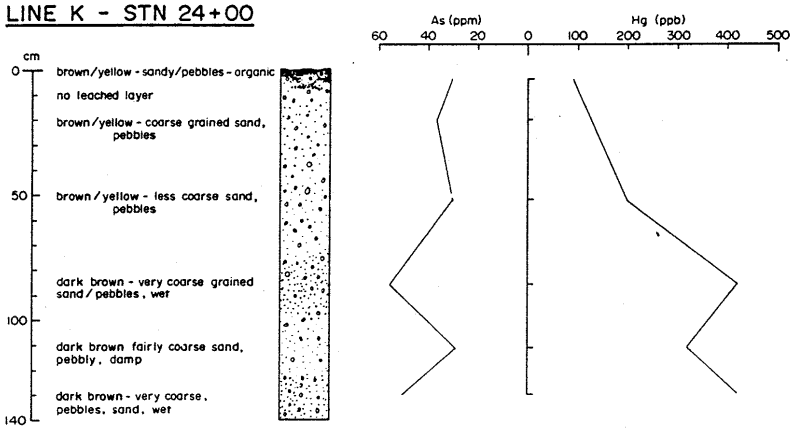


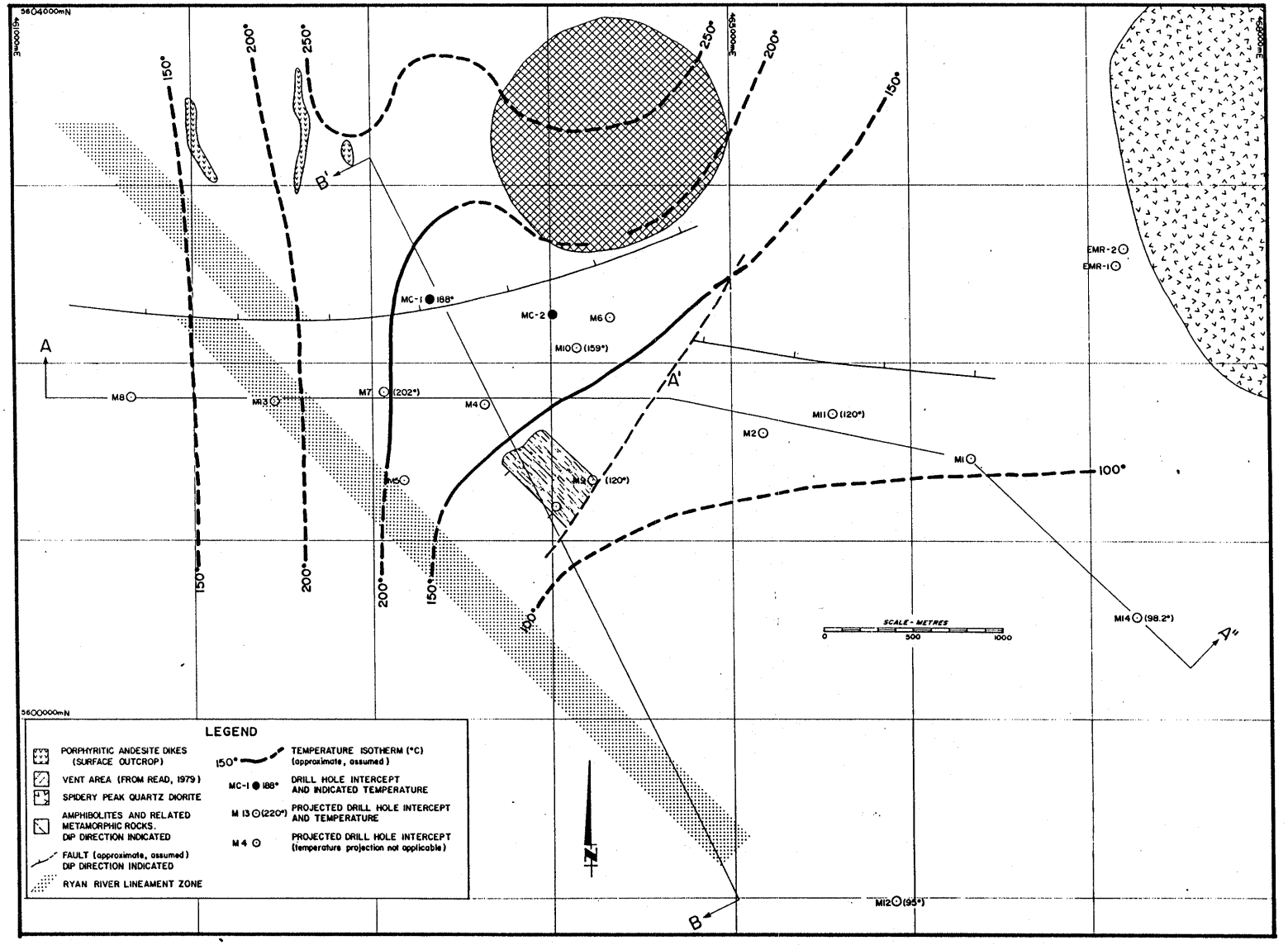
LINE K - STN 13+50E

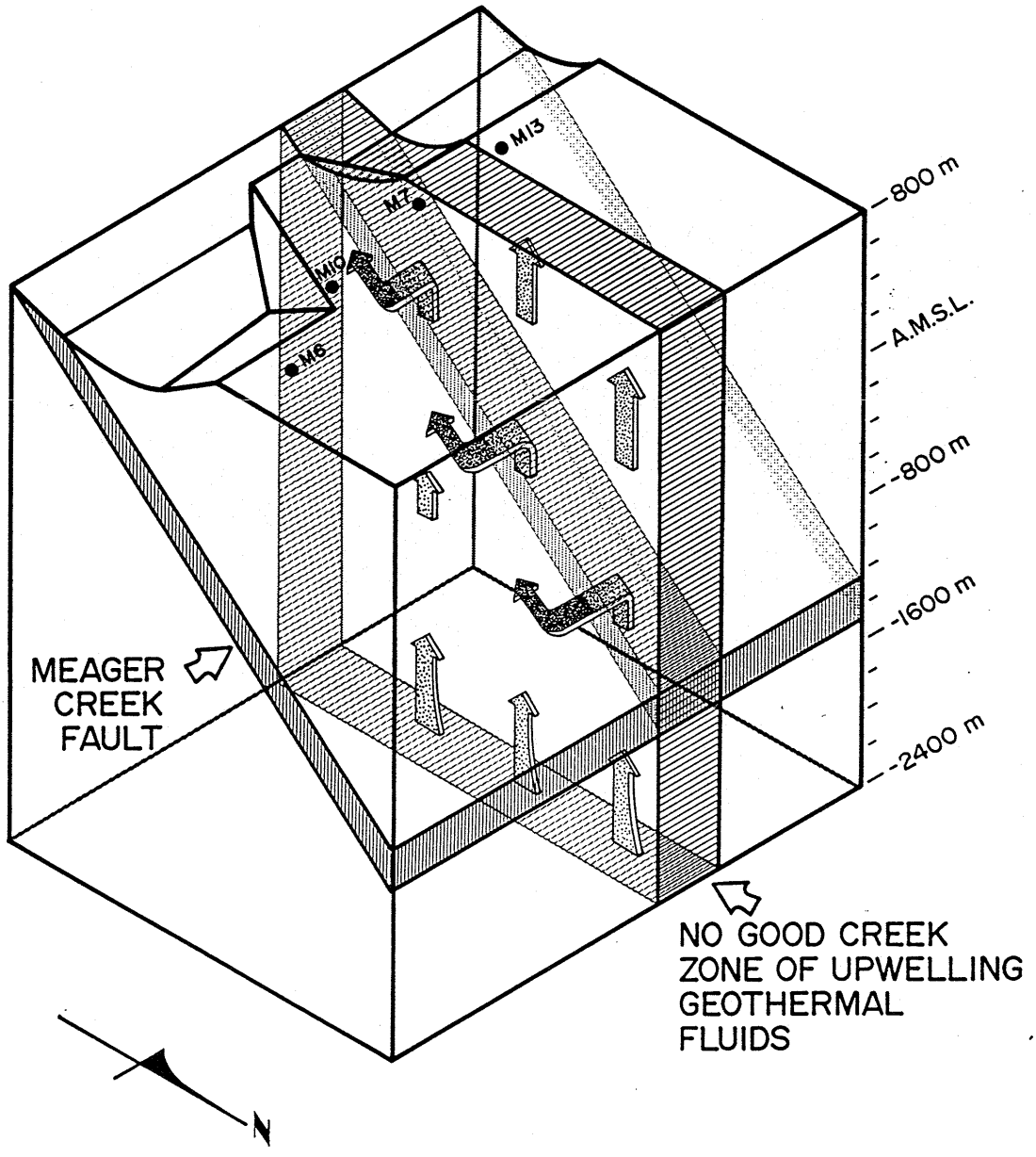


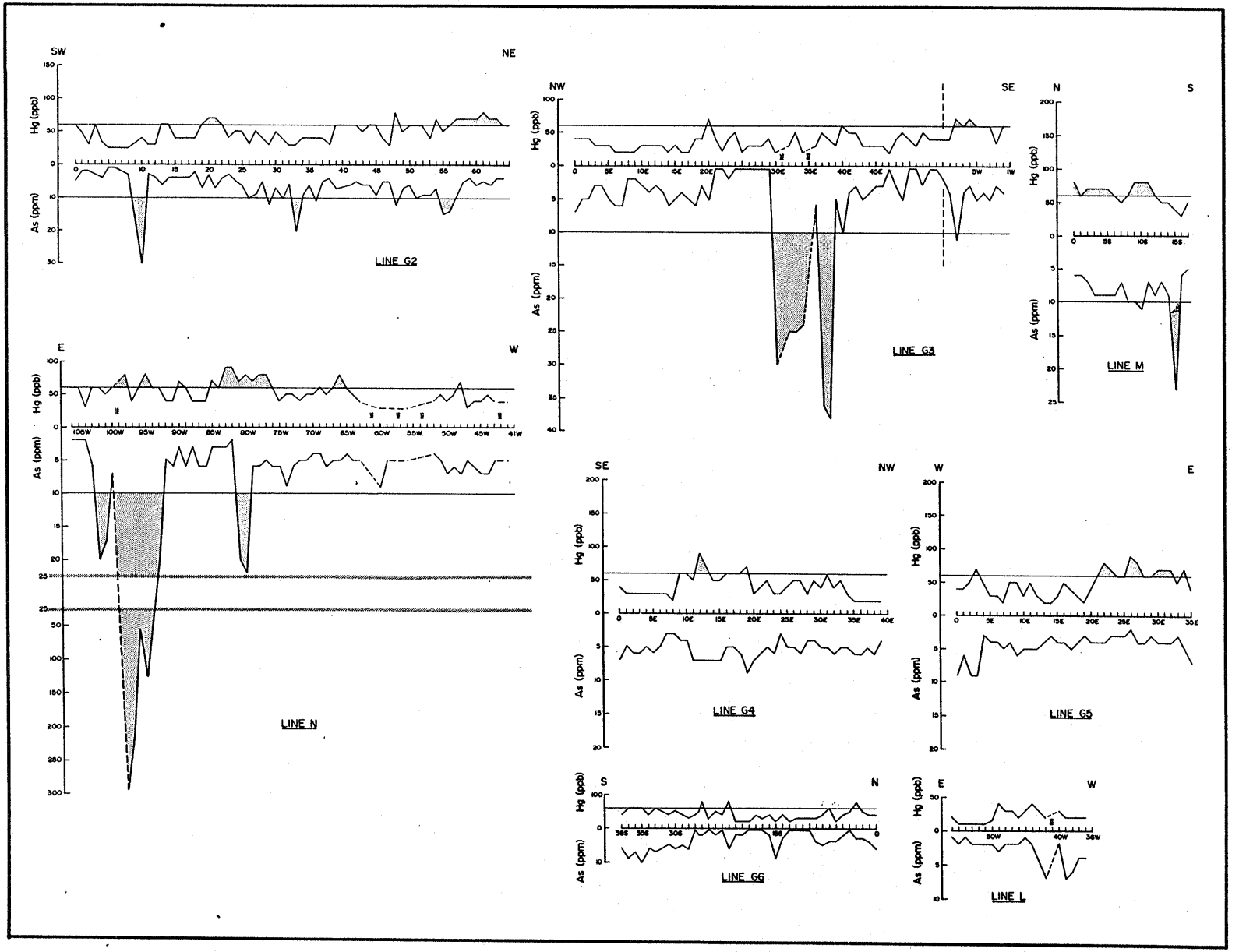
NOTE: The clay, sand & gravel formed layers of different grain size and gradient.
(X) A reddish layer 1 cm thick was found at about 30 cm. Clay was very cohesive.

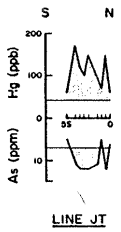
LINE K - STN 24+00

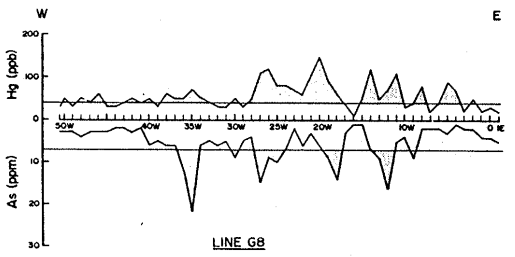


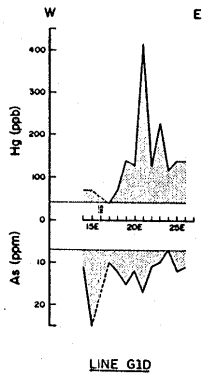

5604000mN
5600000mN
460000mE
150°
200°
250°
100°
A
A'
A''
B
B'
MC-1 188°
MC-2
M6
M10 (159°)
M8
M13
M7 (202°)
M4
M11 (120°)
M2
M1
M5
M9 (120°)
M14 (98.2°)
M12 (95°)
EMR-2
EMR-1
SCALE - METRES
0
500
1000
N
LEGEND
PORPHYRITIC ANDESITE DIKES (SURFACE OUTCROP)
VENT AREA (FROM READ, 1979)
SPIDERY PEAK QUARTZ DIORITE
AMPHIBOLITES AND RELATED METAMORPHIC ROCKS. DIP DIRECTION INDICATED
FAULT (approximate, assumed) DIP DIRECTION INDICATED
RYAN RIVER LINEAMENT ZONE
150° TEMPERATURE ISOTHERM (°C) (approximate, assumed)
MC-1 188° DRILL HOLE INTERCEPT AND INDICATED TEMPERATURE
M 13 (220°) PROJECTED DRILL HOLE INTERCEPT AND TEMPERATURE
M 4 PROJECTED DRILL HOLE INTERCEPT (temperature projection not applicable)

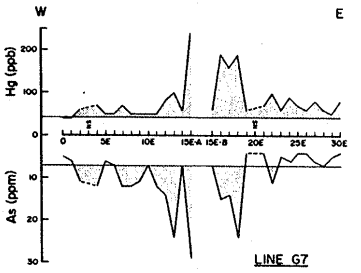

M13
M7
M10
M6
800 m
A.M.S.L.
-800 m
-1600 m
-2400 m
MEAGER
CREEK
FAULT
NO GOOD CREEK
ZONE OF UPWELLING
GEOTHERMAL
FLUIDS
N

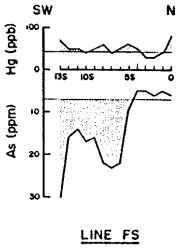

SW
NE
Hg (ppb)
As (ppm)
LINE G2
NW
SE
LINE G3
N
S
LINE M
E
W
LINE N
SE
NW
LINE G4
W
E
LINE G5
S
N
LINE G6
E
W
LINE L

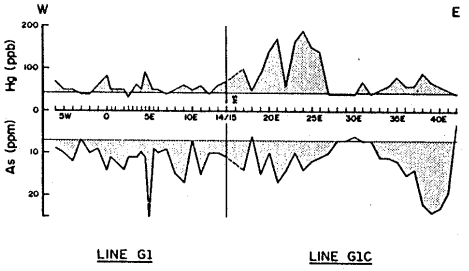

S
N
Hg (ppb)
As (ppm)
LINE JT

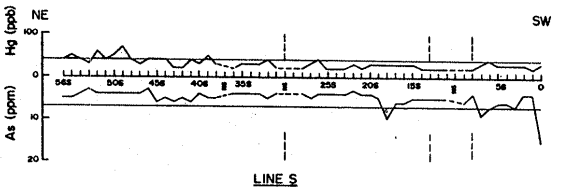

W
E
Hg (ppb)
As (ppm)
LINE G8

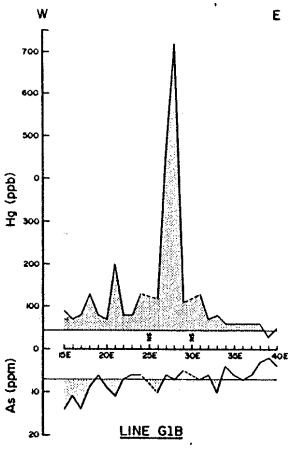

W
E
Hg (ppb)
As (ppm)
LINE G1D

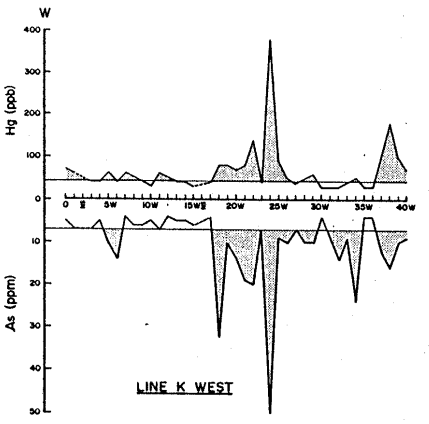

W
E
Hg (ppb)
As (ppm)
LINE G7

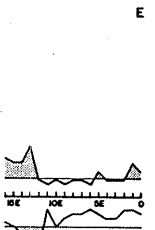

SW
N
Hg (ppb)
As (ppm)
LINE FS

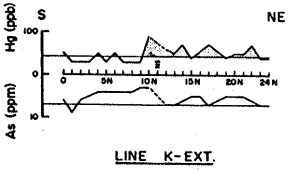

W
E
Hg (ppb)
As (ppm)
LINE G1
LINE G1C


NE
SW
Hg (ppb)
As (ppm)
LINE S


W
E
Hg (ppb)
As (ppm)
LINE G1B


W
Hg (ppb)
As (ppm)
LINE K WEST


E
LINE K EAST


S
NE
Hg (ppb)
As (ppm)
LINE K-EXT.