92P-14

(Coal Division, Annual Meeting CIM District 6)

DEPOSITIONAL ENVIRONMENT AND STRATIGRAPHIC SUBDIVISION HAT CREEK NO. 1 DEPOSIT, B. C.

October 1979

H. Kim, Geologist
B. C. Hydro & Power Authority
Vancouver, B. C.

805

CONTENTS

		Page
	LIST OF TABLES	i
	LIST OF ILLUSTRATIONS	ii
1.	INTRODUCTION	1
2.	PHYSIOGRAPHY & GEOLOGICAL OUTLINE	
	2.1 Physiography	2
	2.2 Regional Stratigraphy	2
	2.3 Regional Structure	4
3.	GEOLOGY OF NO. 1 DEPOSIT	
	3.1 Local Stratigraphy	5
	3.2 Local Structure	6
4.	DETRITAL SEDIMENTATION	6
5.	DEPOSITION OF THE HAT CREEK COAL MEASURES IN A LIMNIC ENVIRONMENT	7
6.	CORRELATION	
	6.1 General	9
	6.2 Geophysical Correlation Methodology	9
	6.3 Correlation of Coal Measures	11
	D-Zone	11
	C-Zone	12
	B-Zone	14
	A-Zone	14
7.	SOME ASPECTS OF THE HAT CREEK COAL BASIN	
	7.1 Burn Zone	16
	7.2 Limnic Marls	16

CONTENTS (Cont'd)

Page

8. QUALITY AND RESERVE DETERMINATION BASED ON STRATIGRAPHIC CORRELATIONS USING DOWNHOLE GEOPHYSICAL DATA ---------- 18

9. CONCLUSION ---------- 19

ACKNOWLEDGEMENTS ---------- 19

REFERENCES ---------- 20

LIST OF TABLES

Table	1	Stratigraphy of Hat Creek Coal Basin
	2	Generalized stratigraphic Division, Hat Creek Coal Formation
	3	Summary of Palynomorph Assemblages, hole 74-44 by G. Rouse UBC (1976)
	4	Geophysical Breakdowns For Stratigraphic Correlation
	5	Thickness Variation of C1 Zone
	6	Thickness Variation of A6 Zone
	7	Chemical Data From The Organic Mat In The Spike-Rash Environment, After Speckman (1969)

Note: For discussion purposes the following listed figures are attached.

LIST OF ILLUSTRATIONS:

Figure	
1	Location Map
3	Bedrock Geology of No. 1 Deposit
4	Structural Contour Map, Base of D-Coal Zone
8	Isopach Map, C1 waste zone
9	Isopach Map, A6 waste zone
15-1 15-2	Regression Curves, Gamma Ray Value Versus Thermal Value
19	Palynological Correlation

A complete set of figures will be supplied on written request.

LIST OF ILLUSTRATIONS:

Figure	
1	Location Map
2	Regional Geology of Hat Creek Coal Basin
3	Bedrock Geology of No. 1 Deposit
4	Structural Contour Map, Base of D-Coal zone
5	Lithofacies Map, Base of the Hat Creek Coal Formation
6	Idealized Paleographic Profile, Hat Creek No. 1 Deposit
7	Lithofacies Map, C1 - zone Sedimentation
8	Isopach Map, C1 waste zone
9	" , A6 "
10	NS Section 18E
11	EW " S
12	Stratigraphic Correlation, Section 18E
13	" , " S
14	Sample Method - 1979 Drilling Program
15	Regression Curves, Gamma Ray Value Versus Thermal Value
16	Regression Curves, Bulk Density Versus Ash Content
17	Statistical Analysis of Proximate Data, DDH 135, 136 and combined zones A,B and C
18	Statistical Analysis of Proximate Data, DDH 135, 136 and 274 combined zone D
19	Palynological Correlation
20	Computer-digitized Section P, showing 16 stratigraphic subzones
21	" Q
22	" S
23	" T
24	Computer-digitized Sect. W
25	" Z

1. INTRODUCTION

The Hat Creek coalfield contains low-grade coal deposits which are the thickest in the world. The diamond drilling and geophysical surveys conducted by B. C. Hydro over the last six years have indicated in excess of 2 billion tonnes of subbituminous to lignitic coal.

The coalfield is in the Interior Plateau Dry Belt, about 240 km NE of Vancouver and contains two, explored, near-surface coal deposits amenable to surface mining (Figure 1). The No. 1 Deposit contains approximately 740 million tonnes of coal at 17.71 MJ/kg or 7,600 Btu/lb at 34.82% Ash and 24% Moisture. The No. 2 Deposit to the south contains appreciably more coal resources at somewhat lower grade, but it has not been explored so extensively because of its higher stripping ratio. Therefore, most of the exploration activities to date have been directed towards the development of the No. 1 Deposit.

The No. 1 Coal Deposit has been selected as the source of fuel for a proposed 2,000 MW thermal powerplant to be built about 5 km east of the deposit.

The purpose of this paper is to summarize the data obtained from the diamond drilling and the geophysical logging in the No. 1 Deposit between 1974 and 1979. An attempt is made to explain the depositional environment of the Hat Creek coal measures. Since the understanding of the depositional environment in a particular basin is essentially an evaluation of all the geologic properties of the area, the available geological information in the No. 1 Deposit has been compiled on the basis of consistent criteria. This includes data on the lithology of the coal measures, thickness and areal distribution of the clastic sediments, and on the changes in the megascopic stratigraphic profile based on geophysical correlation. The palyno-petrographic relationship and detailed sedimentological aspects are not examined in this paper. Such studies should provide important information relating the causal vegetal and chemical responses of the coals to environmental changes.

Extensive deposition of surficial materials during de-glaciation left most of the area of the Upper Hat Creek Valley devoid of bedrock exposures. Structural and stratigraphic features are hidden beneath glacial deposits and/or post-Eocene volcanics. As a result, the geological interpretation of the Hat Creek coal basin has been based primarily on drilling and geophysical data. Because of this, any explanation of the depositional environment details is tentative until the deposits are stripped for development.

2. PHYSIOGRAPHY AND GEOLOGICAL OUTLINE

2.1 Physiography

When measured in a north-south direction, the upper Hat Creek Valley is 24 km long and 3.6 km wide. The valley ranges in elevation from 820 m to 1,280 m. The mountains bordering the valley on the east and west are elevated to 2,050 m and 2,300 m, respectively. Hat Creek with a width of 5 to 10 m flows northward and turns north-easterly to merge with the Bonaparte River north of Cache Creek. The Thompson and Fraser Rivers, both flowing to the south, are 19 and 22 km respectively from the Hat Creek Valley.

As an introduction to the depositional environment of the Tertiary coal basin in the No. 1 Deposit, it may be necessary to examine briefly the geology of the Hat Creek Valley (Figure 2).

2.2 Regional Stratigraphy

The stratigraphic sequence shown in Table 1 covers a span of over 200 million years of sedimentation processes and igneous activities in the vicinity of the Upper Hat Creek Valley.

The lowest stratigraphic unit is the Paleozoic Cache Creek Group, which has been divided into limestone of the Marble Canyon Formation and Greenstone. The limestone was intruded by the Mount Martley stock of Jurassic or Cretaceous age which is composed of granodiorite and tonalite, coeval with the Lytton Batholith. The stock is overlain unconformably by Lower Cretaceous andesite and basalt of the Spences Bridge Group. The Kamloops Group is of Eocene Age. Deposition of this unit began with volcanic eruptions of lavas and pyroclastics composed of rhyolite, dacite and basalt. The volcanic pile is overlain by clastic rocks composed mainly of conglomerate, sandstone and siltstone of the Coldwater Formation. Lying conformably over the Coldwater

Table 1

REGIONAL STRATIGRAPHY - HAT CREEK COAL BASIN

Period	Epoch	Million Years	Formation or Group	Thickness (m)	Rock Types
Quaternary	Recent			Not Determined	Alluvium, Colluvium, fluvial sands and gravels, slide debris, lacustrine sediments.
	Pleistocene	1.5 - 2			Glacial till, glacio-lacustrine silt, glacio-fluvial sands and gravels, land slides.
Unconformity					
Tertiary	Miocene	7 - 26	Plateau Basalts	Not Determined	Basalt, olivine basalt (13.2 m.y.), andesite, vesicular basalt.
	Unconformity (?)				
	Miocene or Middle Eocene ?		Kamloops Group: Finney Lake Formation	Not Determined	Lahar, sandstone, conglomerate.
			Unconformity		
	Late Eocene		Kamloops Group: Medicine Creek Formation	600+	Bentonitic claystone and siltstone.
			Paraconformity		
	Late Eocene to Middle Eocene	* 36 - 42	Kamloops Group: Hat Creek Coal Formation	550	Mainly coal with intercalated siltstone, claystone, sandstone and conglomerate.
			Kamloops Group: Coldwater Formation	375	Siltstone, claystone, sandstone, conglomerate, minor coal.
			Fault Contact or Nonconformity		
	Middle Eocene	43.6-49.9	Kamloops Group	Not Determined	Rhyolite, dacite, andesite, basalt and equivalent pyroclastics.
Unconformity (McKay 1925; Duffell & McTaggart 1952)					
Cretaceous or Later	Coniacian to Aptian **	88.3±3 m.y.	Spences Bridge Group	Not Determined	Andesite, dacite, basalt, rhyolite; tuff breccias, agglomerate.
	Erosional Unconformity (Duffell & McTaggart 1952)				
		98	Mount Martley Stock	Not Determined	Granodiorite, tonallite.
Intrusive Contact (Duffell & McTaggart 1952)					
Pennsylvanian to Permian or earlier		250-330	Cache Creek Group: Marble Canyon Formation	Not Determined	Marble, limestone, argillite
			Cache Creek Group: Greenstone	Not Determined	Greenstone, chert, argillite; minor limestone and quartzite, chlorite schist, quartz-mica, schist.

* Based on palynology by Rouse 1977

** Based on *plant fossils* by Duffell & McTaggart 1952.

Formation is the coal-bearing, over 550 m thick, Hat Creek Coal Formation. The coal-bearing strata are overlain in apparent paraconformity by the Medicine Creek Formation, which is made up of monotonous lacustrine sediments, with over 550 m in true thickness. The Finney Lake Formation represents the uppermost stratigraphic unit of the Kamloops Group in the Hat Creek coal basin. It overlies unconformably the Medicine Creek and/or Hat Creek Formations and consists of lahar beds above and sandstone and conglomerate beds below. Generally, the above-mentioned sedimentary rocks are semi-indurated and derived from the underlying igneous, sedimentary and metamorphic assemblages.

The youngest volcanic rocks in the area are olivine basalt, basalt, vesicular basalt, andesite (locally) and the equivalent pyroclastics, all of the Miocene Epoch. A flow or dyke of these rocks occurs in the headwall of the active slide northwest of the No. 1 Deposit.

During the Pleistocene Epoch the entire Hat Creek area, along with much of the Interior Plains, underwent extensive glaciation. This resulted in the deposition of a variety of glacial and glacio-fluvial sediments, ranging in thickness from a few metres to 200 m.

2.3 Regional Structure

The Hat Creek coal basin lies in a north-trending topographic depression within the south-west part of the Intermontane basin of the Canadian Cordillera. The Fraser River separates the Intermontane Belt from the Coast Plutonic Complex. During the Eocene Epoch, non-marine, synorogenic and syntectonic clastic sediments were deposited, preceded and possibly succeeded by the accumulation of sub-aerial volcanics. Mid-Tertiary erosional activities resulted in widespread surfaces of low relief. The main physiographic features of the Fraser and Thompson river drainage systems were well established at this time.

The general structure of the Tertiary Coal Basin in the Hat Creek Valley is a graben, flanked on either side by gravity faults. This interpretation of the structure is based on the regional tectonic trend and the available geological records.

This graben is formed principally by downward movement on a series of north-southerly trending tensional faults. Transverse faults trending north-west have locally offset the graben.

3. GEOLOGY OF NO. 1 DEPOSIT

Figure 3 reflects an interpretation of the subsurface geology of the No. 1 Deposit based on data obtained from the 152 m grid pattern of diamond drilling for 496 holes totalling 78,236 m in the vicinity of the No. 1 Deposit.

3.1 Local Stratigraphy

The sediments in the area of the proposed open pit have been divided, in ascending stratigraphic order, into three formations: The Coldwater Formation (river deposits), the Hat Creek Coal Formation (swamp deposits), and the Medicine Creek Formation (lacustrine deposits). Individual rock types within these three formations have been adequately described by Campbell, Jory and Saunders (CIM Vol. 70, No. 782, 1977).

Based on lithological and geophysical logs and core quality, four zones, A, B, C and D, were recognized within the Hat Creek Coal Formation. Further work identified two distinct waste zones between A and B, and between B and D, which have been correlated over most of the deposit. The general characteristics of these zones, in descending stratigraphic order, are tabulated below.

Table 2

Generalized Stratigraphic Division

Hat Creek Coal Formation

Zone	Thickness (m)	Remarks
A	110 - 225	62% coal (15.46 MJ/kg) 38% waste
A6	0 - 90	Mostly waste
B	50 - 70	Mostly coal(16.60 MJ/kg)
C1	0 - 170	Mostly waste
C	15 - 60	Mixed coal and carb. clst. 13.72 MJ/kg
D	60 - 100	Clean coal (21.12 MJ/kg)

Detailed stratigraphic correlation of the Hat Creek Coal Formation is described in the succeeding chapter.

3.2 Local Structure

As may be substantiated further by the structural contour map of the base of the lowermost coal layer, D-Zone (Figure 4), the main structure of No. 1 Deposit is characterized by a broad synclinal feature, the Hat Creek Syncline. It strikes north-south and plunges southerly at 15° to 25°. The trough of the syncline is relatively open in the north and rapidly closes in the south. The west limb is fairly continuous and dips 20° to 40° to the east. The east limb, which parallels the synclinal axis, is modified to a broken anticline with dips steepening to 70° to 90°, and partially truncated by the north-westerly trending "Creek Fault" (Figure 13). The Hat Creek synclinal structure is truncated in the south by the north-easterly trending "Finney Fault".

The Harry syncline immediately east of the Creek Fault strikes N 20° W and plunges gently to the southeast. It is also truncated by the Finney Fault.

The Finney Fault is one of the major tectonic elements modifying the structure and coal reserves of No. 1 Deposit. Movement occurred after formation of the Hat Creek syncline and preceded the Creek Fault. The Finney Fault is offset in places by secondary oblique transcurrent faults, i.e. Creek Fault, Harry Faults No. 1-6.

The Aleece Lake fault system in the southwest part of the deposit is also a significant tectonic feature resulting in numerous internal thrust faulting and local overturning of portions of the "A" coal horizon (Figs.12 & 23).

4. DETRITAL SEDIMENTATION IN HAT CREEK BASIN

Deposition of the basal clastic sediments (Coldwater Formation) below the coal measures is interpreted as occurring in a narrow, intermontane lake basin. The nature of the detrital sedimentation is illustrated in the lithofacies map (Figure 5) and the schematic paleographic profile (Figure 6). It is composed of conglomerate, sandstone, siltstone and claystone and minor coal lenses or pods.

Figure 5 indicates that fine clastics, with gyttja materials, such as carbonaceous claystone, occupy the central position of the basin. They are flanked by areas of siltstone, which in turn are bordered by sandstone and pebbly conglomerates. Macroscopically, the conglomerate exhibits poor sorting. The coarse clastic sediments are more pronounced in the west. These features indicate that the latter were carried into the basin by surrounding streams. The flow velocity and capacity of the streams was higher in the west than in the east and can be related to the regional uplift to the west.

It is noted that the central area with fine clastics and carbonaceous materials coincides, more or less, with the main area of coal deposition in the No. 1 Deposit.

5. DEPOSITION OF THE HAT CREEK COAL MEASURES IN A LIMNIC ENVIRONMENT

The Hat Creek coals were formed in a limnic environment; no marine fossils have been found to date. At the inception of peat deposition, following coarse detrital sedimentation, the area now known as the Hat Creek Region was generally a broad north-trending marsh with little or no circulating water. The climate at that time was sub-tropical in which plants flourished, growing near the water table. The favourable climatic condition aided by the slowly sinking basin throughout the period of D-Zone deposition accounts for the immense thickness of the virtually uninterrupted coal mass. During this period, the accumulation of the vegetal matter was balanced by subsidence (Figure 6).

When equilibrium was disturbed by rapid sinking, the area was cyclically flooded by fresh water, leading to the deposition of numerous rock interbeds in the coal measures, following the deposition of "D" coal zone.

Along with intermittent but slow and progressive subsidence, there formed a region of lower relief on the west and southwest of the present coal basin, which encouraged the development of the drainage pattern northwards. The peat that accumulated along the southwest margin was not of the normal banded variety, but of hypautochthonous (semi-drifted) origin due to a mixing of the plant debris by the intermittent action of running water. This is substantiated by the fact that carbonaceous shale or the coals in C-Zone generally grade to claystone both horizontally and vertically rather than forming discrete seams. Most of the detritus carried by the stream was deposited near the margin, but very finely suspended quartz grains were carried into the centre of the basin (Figure 7). Therefore, the west and southwest of the "Hat Creek No. 1" peat basin was for the most part, innundated by this system during the post D-Zone depositional period. This resulted in a rapid facies change from "main coal" to "main gyttja and rock" towards the southwest particularly in rock member units Cl and A6 (Figures 10 & 11). This further indicates that the CI and A6 rock members might have been deposited at the same time as those of the peat sequence in the main Hat Creek marsh towards the north. It may also be that a stagnant morass, or the initial peat, that deposited on the edges of the basin, was partially or totally eroded by the stream and that the depression was filled by sediment. The resulting "cut and fill sedimentation" is exemplified by the Cl and A6 rock units which might have varied with location and time during the period of peat deposition and was dependent on the environmental changes caused by various factors such as climate, the rate of subsidence, quantity and grain size of the sediment load, runoff, etc. (Figures 23-25). The isopach maps for the A6 and Cl waste zones indicate clearly the southerly thickening of the sediment influx affected by the stream having meandered northwards (Figures 8 & 9).

In the centre and northeast parts of the peat basin, the rates of subsidence and deposition were about equal and the effect of the silty sediment from the western stream was minimal. This situation allowed for the continued, uninterrupted accumulation of plant debris. The peat deposit in the northeast was virtually free of extraneous mineral matter, i.e. clay or silt. The Interior Plateau region was affected by volcanic activity, contemporaneous with the Hat Creek peat deposition. Dust and ash composed primarily of very fine pyroclastics were ejected from volcanic vents and blown intermittently over large portions of the Hat Creek peat basin. The volcanic ash was accumulated over the plant debris or peat body and later decomposed to bentonite and other clays. The widespread occurrence of ash beds in the coal measures reflects these episodic volcanic eruptions.

Palynological analysis of 65 samples from the No. 1 Deposit indicates that the coal-forming plants, at the inception of the peat basin, were subtropical types of alnus, walnut and fungus, growing under moist or waterlogged conditions (D coal horizon). As the Eocene Epoch (or possibly Early Miocene) drew to a close the climate cooled, so that the character of the plant life gradually changed from moisture-loving vegetation to massive tree types such as alder, cypress, pine and oak, growing under relatively dry conditions ("A" coal horizon). Table 3 summarizes the palynomorph assemblages from Hole 74-44 determined by Dr. G. Rouse, U.B.C. (1976). A palynological correlation between holes 74-44 and 76-136 is shown on Figure 19.

The close of the coal-depositional phase was followed by a pronounced regional sinking of the basin resulting in the deposition of a thick layer of lake sediments. Accumulation of this uniform sequence of lake silts up to 550 m thick continued for an undetermined time (Figures 6 & 10).

6. CORRELATION

6.1 General

The Hat Creek Coal Formation was initially divided into six main zones: A, the rock member between A and B, B, C and D by Dolmage Campbell & Associates (1976). These zones were further classified into 14 subzones in the recent report by Cominco-Monenco Joint Venture (1979). Our current geological study of the No. 1 Deposit based on geophysical logs has recognized a total of 16 stratigraphically correlatable horizons: A1, A2, A3, A4, A5, A6, B1, B2, C1, C2, C3, C4, D1, D2, D3, and D4 (Figures 12 & 13).

6.2 Geophysical Correlation Methodology

The contrast in physical properties between coals and waste rocks offers an accurate and convenient method of obtaining sub-surface information on the coal measures, especially depth to the top of bedrock, lithologic identification, depth and thickness of individual coal beds, general heating value and ash contents of coals.

The types of geophysical logs tested in the Hat Creek Coal Deposit were Gamma Ray, Bulk Density, Resistance, Caliper, Focused Beam, Self Potential and Acoustical. The two most useful logs were the natural Gamma Ray and Bulk Density, which could be applied through the drill stem. The other logs were of limited application because they could only be run in open holes.

A marked contrast between coals and waste materials on the Gamma Ray and Bulk Density logs leads to an accurate (depthwise), unbiased, graphic presentation of the coal measures.

Table 3

HAT CREEK PALYNOMORPH ASSEMBLAGES--Hole 74-44

ZONE	INDEX PALYNOMORPHS	DOMINANTS	SUB-DOMINANTS	OTHERS
H.C.-1 pine-oak 44-193; 44-323	Eleagnus-type Gothanipollis-1	Pinus contorta Quercus-1 Quercus-2	Tsuga spp. Glyptostrobus Picea-small	Pterocarya Juglans Engelhardtia
H.C.-2 -cypress zone-	Tricolpites-1 Tilia	Glyptostrobus Taxodium	Alnus Pinus cont. spruce, Tsuga	Carya Sciadopitys Rhoiipites cryptocorpus
H.C.-3 -alder-ash-	Retitricolpites -1; Retitricolpites -2	Fraxinus, Alnus, fungal spores & hyphae	Quercus	Castanea, Liliacidites, Acanthaceae, Caprifoliipites scabratus, Tilia, Liquidambar
H.C.-4 -fungal-	Striopollenites, Monocolpites-1 Fagus	Pleurocellae-Granatisporites, Multicellae-Ovoidites, Taxodium-2(18u)	Caprifolii-scabratus	Tilia, Platycarya
H.C.-5 -ash-walnut	Engelhardtia, Liliacidites, Tricolporites (17u,oculate) Retitriporites -1	Ovoidites, Fraxinus, Juglans, Carya	--------	Rhoiipites cryptocorpus
H.C.-6 -Alnus -	Tetracolporo-Cupaneidites, Rhoiipites latus, Carya-2 Gothanipollis -2	Alnus-2	Triporates (Corylus, Carpinus, Carya-1&2)	Ilex, Castanea, Tilia Engelhardtia, Liquidambar

Based on the various API (American Petroleum Institute unit) ranges from the Gamma Ray log, the rocks and coal within the formation were classified into the five different categories for stratigraphic correlation and structural interpretation (Figure 14). The formations were cross checked against Bulk Density values.

Table 4

The five API ranges tentatively correspond to the following ash-thermal values;

API	Colour	Description
0 - 15	Black	Coal: (22% Ash, 22.0 kJ/kg db)
15 - 25	Orange	Coal: (22.0-40.0% Ash, 22.0-16.0 kJ/kg db)
25 - 35	Blue	Coal: (40.0-60.0% Ash, 16.0-9.5 kJ/kg db)
35 - 45	Green	Coaly shale and/or carbonaceous shale
+45	Yellow	Claystone, siltstone, conglomerate, shale, sandstone, marl, petrified wood, volcanic ash.

6.3 Correlation of Coal Measures

The lithofacies change from coal to rock as mentioned in the preceding chapter is pronounced to the south of Section T and to the east of 17E. This lithofacies change in the southern sector occurs in all stratigraphic subzones. Reliable stratigraphic correlation can be made based on the geophysical criteria (Table 4), except the area of the extreme lithofacies change which is compounded by structural deformation due to faulting.

D-Zone

D-Zone represents the initial peat deposition which continued uninterrupted in the slowly sinking basin. It varies in thickness from 60 m to 100 m and contains the best quality of coal in the entire Hat Creek coal measures. The D-Zone coal is commonly black, hard, bright, breaks with conchoidal-fracture, and contains prominent bands of vitrinite. At its base there is a pronounced transition from green-coloured claystone/siltstone, to dark-coloured mudstone or coal. Such coaly mudstone at the base of D-Zone indicates that the Hat Creek peat was deposited in a eutrophic lake environment. The contact between D and C-Zones is characterized by petrified wood and ironstone. This marker-horizon is pronounced in Gamma-Density logs because of their different densities.

The geophysical logs for D-Zone are in sharp contrast with the overlying C-Zone. The D-Zone coal generally contains very few rock partings except for some siderite or petrified wood, so that the visual (macroscopic) differentiation of D into further subzones is not well defined. However, geophysical correlation discerns four subzones as follows:

D1: This horizon is readily distinguished on the geophysical log throughout the deposit. A series of higher gamma-density values to the right of the chart shifts to the left in the good D-Zone coal. Near the D1 horizon, there is generally petrified wood or ironstone serving as a marker horizon.

D2: Not prominent, but may be marked by a higher gamma value (15 - 20 API range) below D1.

D3: Generally identified by a relatively high gamma value, 20 API below the D2.

D4: Distinguished throughout the property, commonly identified by the highest gamma value, 25-30 API immediately above the base of D.

C-Zone

C-Zone indicates a hypautochthonous peat accumulation, which followed the deposition of D-Zone. Its lower members represent transitional periods due to the influx of fluctuating amounts of sediments, as reflected by numerous interbeds of claystone, siltstone and sandstone.

C1: This unit consists essentially of claystone/siltstone, sandstone, conglomerate, and occasionally minor carbonaceous shale. Table 5 shows the varying thickness of this sub-unit in different sections.

C2: This horizon represents the base of the C1 stream bed as mentioned above, marked by a band of petrified wood.

Table 5

THICKNESS VARIATION OF C1 ZONE

Hole No.	Section	True Thickness of C1(m)	Composition
127	S	+80	S.S., cgl., slst.
240	T	+160	Slst., S.S. cgl, carb.sh.
248	T	+90	Clst.
171	T	+70	S.S., slst.
44	U	75	S.S.
259	U	75	Clst, s.s. some carb. sh.
51	U	130	Slst., S.S. some carb.sh.
137	U	+100	Clst., slst., cgl.
132	U	+100	Clst., slst., cgl.
249	V	+170	Slst., s.s. cgl., some carb.
176	V	+170	Slst., s.s. cgl., some carb.
236	W	120	Clst., s.s. cgl.
179	W	+120	Clst., slst., some carb.sh.
173	W	+120	Slst., s.s.
237	X	+140	Slst., s.s. minor clst.
241	Y	+170	S.S., cgl.

C3: A band of claystone/siltstone or locally sandstone/conglomerate marks this horizon.

C4: The highest gamma ray value of 55 API is obtained immediately above the good D coal zone and marks this claystone or siltstone horizon.

B-Zone

B-Zone consists mainly of coal with minor interbeds of carbonaceous claystone. It ranges in thickness from 50 m to 70 m and tends to thin to the south. Sub-division of B was based on the following geophysical criteria:

B1: This horizon is the bottom of the A6 claystone/siltstone bed, which shows conspicuously high gamma and density values in contrast to the underlying coal zone. The mixture of low-grade coal and carbonaceous shale in this horizon represents the transitional phase, where the ratio of the coal interbeds to waste partings increases, in general, towards the top, denoting an end of the peat depositional phase.

B2: The division of B2 is made on the midpoint of the B coal zone, presenting a high gamma ray shift (45-50 API range).

A-Zone

Deposition of A-Zone was interrupted by periodic flooding or sediment influx from the south. This is reflected in the numerous lithologic interbeds in the coal measures and their increasing thickness in the south. There are about 20 rock partings ranging in thickness from 1-10 m in the A coal zone. For this study, six correlatable horizons are presented.

A1: This horizon represents the base of the thick lacustrine strata (Medicine Creek Formation), denoting the termination of the Tertiary coal deposition in the Hat Creek area.

A2: This horizon represents the base of the third claystone bed including carbonaceous claystone, viewing from the top to the bottom. API units range from 45-50. The sharp contact with the underlying good coal sequence indicates an abrupt flooding condition which caused a temporary pause in peat deposition.

A3: This horizon represents the upper limit of the third major clastic sediments in descending stratigraphic order from A1. The claystone or sandy bed thickens to more than 20 m. The sharp contact of this waste bed with the lower coal sequence indicates an abrupt flooding condition which discontinued the peat deposition.

A4: This horizon is the base of a significant claystone or siltstone bed (55 API) below the A3 horizon.

A5: The A5 horizon is sharply defined by claystone or sandstone below the A4 horizon; Gamma, 50 API and Density, minimum 1.8 grams/cc.

A6: A6 marks the second major sediment influx in the Hat Creek coal deposit - the first one being C1 which indicates a break in peat deposition between B2 and C2 coal horizons. The thickness variation for the A6 clastic sediments which inundated the existing peat deposit is shown on Table 6.

Table 6

THICKNESS VARIATION OF A6 ZONE

Hole No.	Section	True Thickness of A6(m)	Composition
120	S	50	Claystone, Siltstone, Minor Carbonaceous Shale.
195	T	75	Sandstone, Siltstone, Claystone, Minor Carbonaceous Shale.
52	Z	115	Siltstone, Conglomerate
254	X	+70	Siltstone, Sandstone

7. SOME ASPECTS OF THE HAT CREEK COAL BASIN

7.1 Burn Zone

The burned zone in the Hat Creek Valley resulted from combustion of near-surface coal and baking of inherent clay and the associated claystone partings in the coal seam. It is exposed in the eastern part of Trench A. Its presence has also been noted in the drill cores and outcrops adjacent to Dry Lake. A geophysical (magnetic) survey carried out by B. C. Hydro in 1977-78 delineated the sub-surface distribution of the burn zone (Figure 3).

The most striking effect from burning the coal seam is the reddening of the adjoining rock. The claystone in the burned zone has a bright yellow colour. A total of eight coal samples in Trench A were taken to B. C. Hydro's Hat Creek site lab and burned at 1100°C. The resulting colour and textural characteristics were identical to the "Burn Zone" material now seen in Trench A and drill cores.

The ignition of coal could have been caused by spontaneous combustion, lightning, volcanic flows or forest fires. Burning extended through the whole sequence of coal, continuing down to a depth of 50 m.

The burned zone in Trench A is believed to be the burned B coal zone of the Hat Creek Coal Formation. It shows a contorted structure resembling somewhat that of a crumpled schist. Part of this structural feature may have been caused by slumping of the baked clay partings as the burning progressed.

The sharp contact between the burned zone and the overlying till indicates that the burning preceded Pleistocene glaciation. However, the lack of glacial till above the burned zone in most of the area and a deep collapse at Dry Lake would indicate that most of the burned zone in the Hat Creek is post-glacial origin.

7.2 Limnic Marls

Limey beds which are primarily "marls" occur irregularly within the coal measures. The marl in the basin appears to have originated in a fresh water environment. The author suggests that the origin of fresh water marls in Southern Florida (Speckman and others 1969) is similar to that in the Hat

Creek basin. The marl was probably derived from an algal mat, which "develops on the ground surface between the herbaceous plants and actually clothes subaqueous portions of the rush leaves. The mat is composed of a complex mixture of filamentous and colonial algae, diatoms and bacteria and entrapped organic and inorganic debris. The calcium contained in the surficial water could be readily precipated either by lime-secreting algae or by the combined effect of all plants present in the mat on the carbon dioxide content of the flowing surface water." (Geological Society of America, special paper 114, Environments of Coal Deposit, Boulder, Colorado 1969, pp 22-23).

The chemical data on the organic mat used by Speckman and others (1969) is adopted in this paper:

Table 7

CHEMICAL ANALYSIS OF AN ORGANIC MAT IN THE SPIKE-RUSH ENVIRONMENT

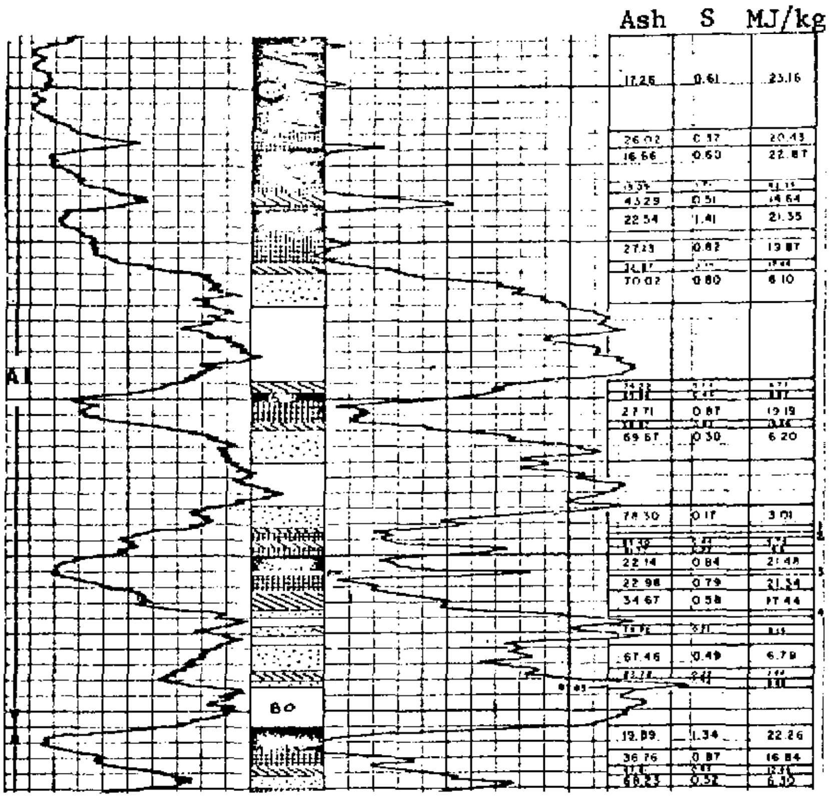
	Percent of "dry" sample
Moisture and Ash	
H_2O	1.35
Ash	49.87
C	16.46
H	1.07
S (total)	0.19
Fe	0.11
Ca	35.2
Si	0.37
Al	0.17
Mg	0.42
Ti	0.01
Mn	0.0140
U	0.0002

8. QUALITY AND RESERVE DETERMINATION BASED ON STRATIGRAPHICAL CORRELATIONS USING DOWNHOLE GEOPHYSICAL DATA

The coal sampling method used during the 1979 drilling program was geophysically oriented, where each sample interval corresponds to one of the five categories seen in Table 4. As mentioned, these same five categories were used for the stratigraphic correlation. The sampling method in the 1979 drilling program is shown:

Figure 14

Sample Method
1979 Drilling Program



A total of 1555 samples from the 1978 drilling program were analyzed to provide a base for correlating the gamma ray and bulk density values to the heat value and the ash content. The recent detailed statistical study of the analytical data versus geophysical log values indicated that the ash and thermal values could be predicted approximately and directly from the geophysics (Figure 15 and 16).

The ability to predict the ash and thermal values from the geophysics has immediate application in reevaluating the earlier geophysical logs, and identifying in more detail than is possible with lithological logs, all the intervals that are below the cutoff grade for selective mining.

9. CONCLUSION

The peat deposits of the Hat Creek Coal Formation were derived from vegetation which grew in fresh water marshes and swamps in a northerly trending intermontane basin. The origin of the coals may be the combination of autochthony and hypautochthony.

During the overall period of coal deposition, the rate of areal subsidence and peat deposition maintained an equilibrium for a long period of time so that an immense, probably the thickest low-grade coal deposit in the world formed in the upper Hat Creek Valley. However, the equilibrium was periodically disturbed by a variation in the rate of subsidence which lead to the alternation of coal layers and country rock. The western and the southwestern margins of the peat basin received fluctuating amounts of coarse clastic sediments from a drainage system which meandered northwards following the deposition of "D" coal zone.

The stratigraphic correlation presented here has been established with a high degree of confidence. Based on this correlation, the coal deposits are reasonably divisible into detailed subzones containing no waste partings which can be separated by selective mining. The stratigraphic correlation using the geophysical parameters will enhance the geological evaluation of the coal deposit. A preliminary statistical study indicates that this correlation based on detailed reevaluation of the geophysics would upgrade the quality more than 8% and reduce the tonnage more than 12%.

ACKNOWLEDGEMENT

The author wishes to acknowledge the management of B. C. Hydro and Power Authority for allowing this presentation. Special mention is made of S. D. Handelsman, Chairman of Coal Division - District 6, 1979, who arranged this presentation. The author also extends his appreciation to J. J. Fitzpatrick, B. Dutt, P. T. McCullough and A. W. Penner for useful comments.

REFERENCES

Campbell, D.D., Jory, L.T. and Saunders, C. R., 1977, "Geology of the Hat Creek Coal Deposits.", CIMM Bulletin Vol. 70, No. 782, pp. 99-108.

Church, B. N., 1975, "Geology of the Hat Creek Basin." Summary of Field Activities B. C. Dept. of Mines, pp. 104-108.

Church, B. N., 1977, "Geology of the Hat Creek Coal Basin." In "Geology in British Columbia.", B. C. Ministry of Mines Publication.

Cominco-Monenco Joint Venture, July 1978, "Hat Creek Project, Mining Feasibility Report." Vol. II Geology and Coal Quality.

Dawson, G. M., 1895, Kamloops Map - Sheet, B. C. Report, Geol. Surv. of Canada

Dickenson, W., 1976, "Sedimentary Basins Developed During Evolution of Mesozoic-Cenozoic Arc-trench System in Western North America."

Dolmage Campbell & Associates Ltd., 1976, "Hat Creek Coal Exploration Project-Assessment Report." B. C. Hydro File.

Dolmage Campbell & Associates Ltd., 1976, "Exploration Report, No. 1 Deposit Hat Creek Coal Development."

Duffell, S. and K. C. McTaggart. 1951, "Ashcroft Map - Area, B. C." Memoir 262, 122 p., Geological Survey of Canada (including Map No. 1010A).

Höy, T., 1975, "Geology of a Tertiary Sedimentary Basin NE of Hat Creek." Summary of Field Activities, B. C. Dept. of Mines, pp. 109-115.

McCullough, P. T., 1975, "Hat Creek Magnetometer Survey." B. C. Hydro File.

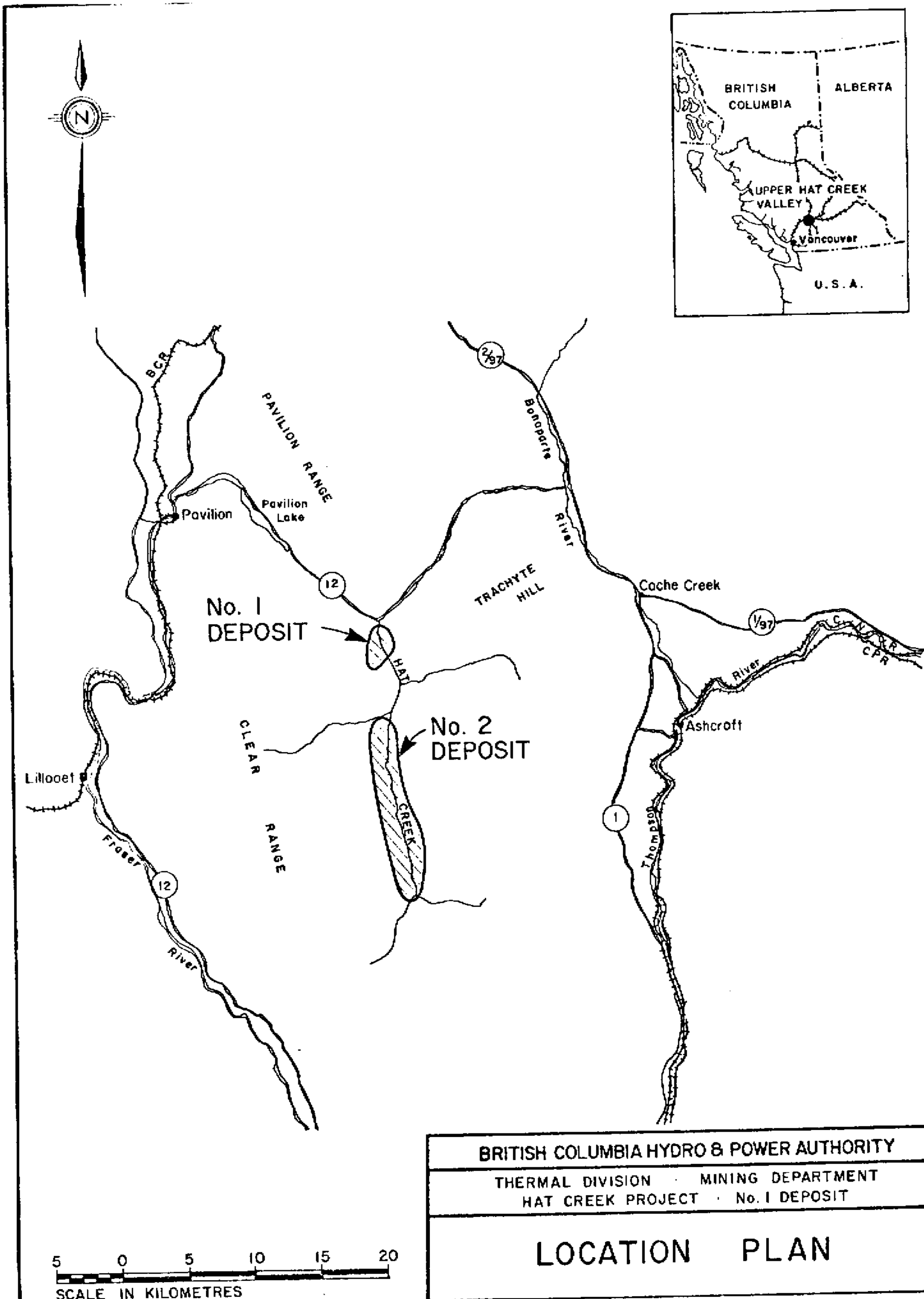
MacKay, B. R., 1926, "Hat Creek Coal Deposit, Kamloops District, B. C." Summary Report, Geol. Surv. of Canada, pt. A, pp. 164-181.

Marchioni, D. L., 1979, "Reflectance Studies in Brown Coals - An Example From the Hat Creek Deposit of B. C.", Inst. of Sedimentary & Petroleum Geology. IX Carboniferous Congress, Illinois May '79.

Quigley, R. M., 1975, "Preliminary Mineralogical Analyses - Hat Creek Coal Measures, B. C."

Rouse, G. E., 1976, "Palynological Zonation and Correlation of Hat Creek Core Samples."

Wilkinson and Galloway, 1924, "Hat Creek Coalfield" B. C. Dept. of Mines Report.



BRITISH COLUMBIA HYDRO & POWER AUTHORITY

THERMAL DIVISION · MINING DEPARTMENT
HAT CREEK PROJECT · No. 1 DEPOSIT

LOCATION PLAN

SEPTEMBER 1979

FIG. 1

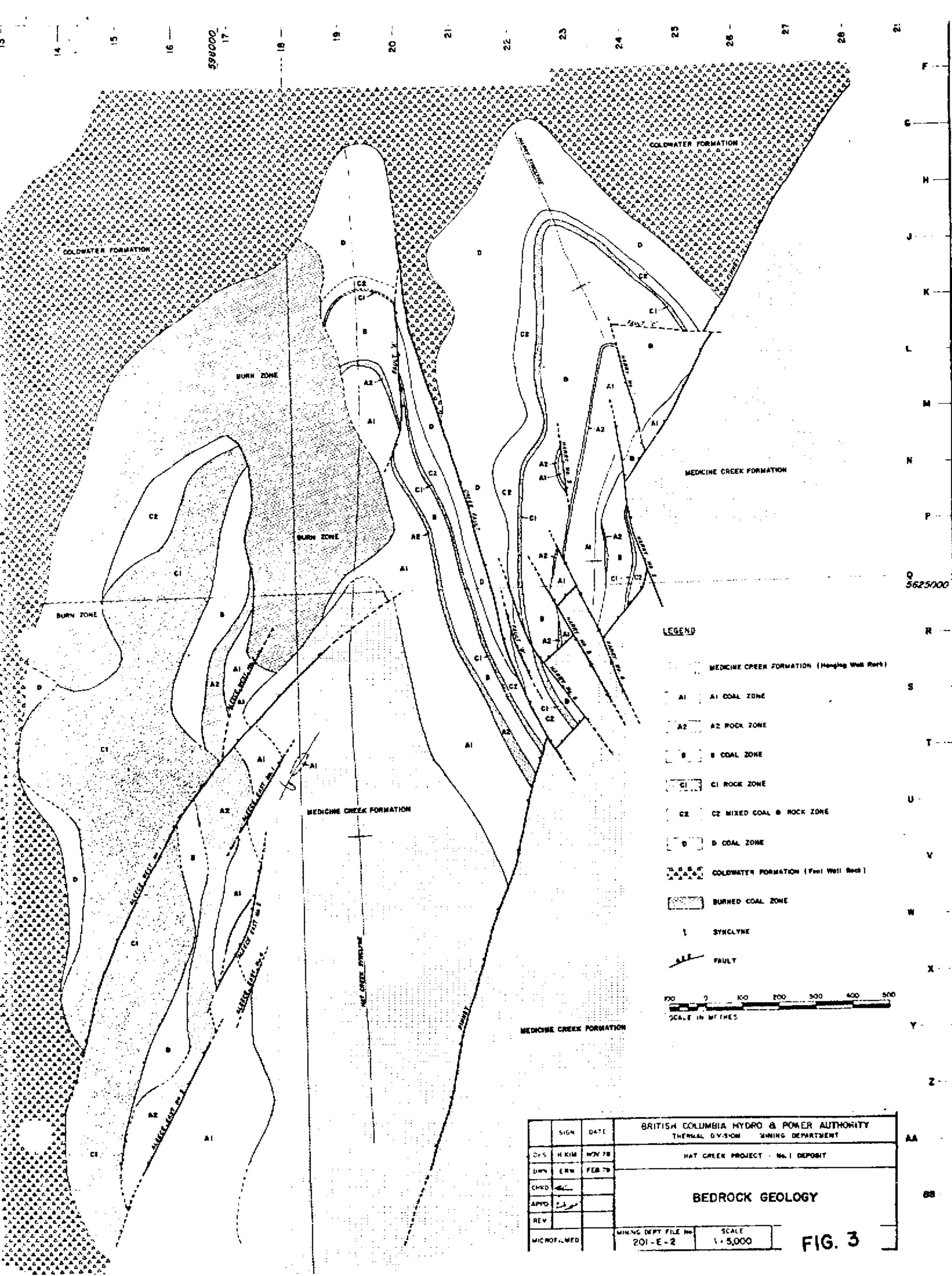

COLDWATER FORMATION
COLDWATER FORMATION
BURN ZONE
BURN ZONE
BURN ZONE
MEDICINE CREEK FORMATION
MEDICINE CREEK FORMATION
MEDICINE CREEK FORMATION
HAT CREEK SYNCLINE
598000
5625000
A1
A2
B
C1
C2
D
LEGEND
MEDICINE CREEK FORMATION (Hanging Wall Rock)
A1 COAL ZONE
A2 ROCK ZONE
B COAL ZONE
C1 ROCK ZONE
C2 MIXED COAL & ROCK ZONE
D COAL ZONE
COLDWATER FORMATION (Foot Wall Rock)
BURNED COAL ZONE
SYNCLYNE
FAULT
100 0 100 200 300 400 500
SCALE IN METRES
BRITISH COLUMBIA HYDRO & POWER AUTHORITY
THERMAL DIVISION MINING DEPARTMENT
HAT CREEK PROJECT - No. 1 DEPOSIT
BEDROCK GEOLOGY
SIGN
DATE
DRS H KIM NOV 78
DWN ERW FEB 79
CHKD
APPD
REV
MICROFILMED
MINING DEPT FILE No. 201-E-2
SCALE 1:5,000

FIG. 3

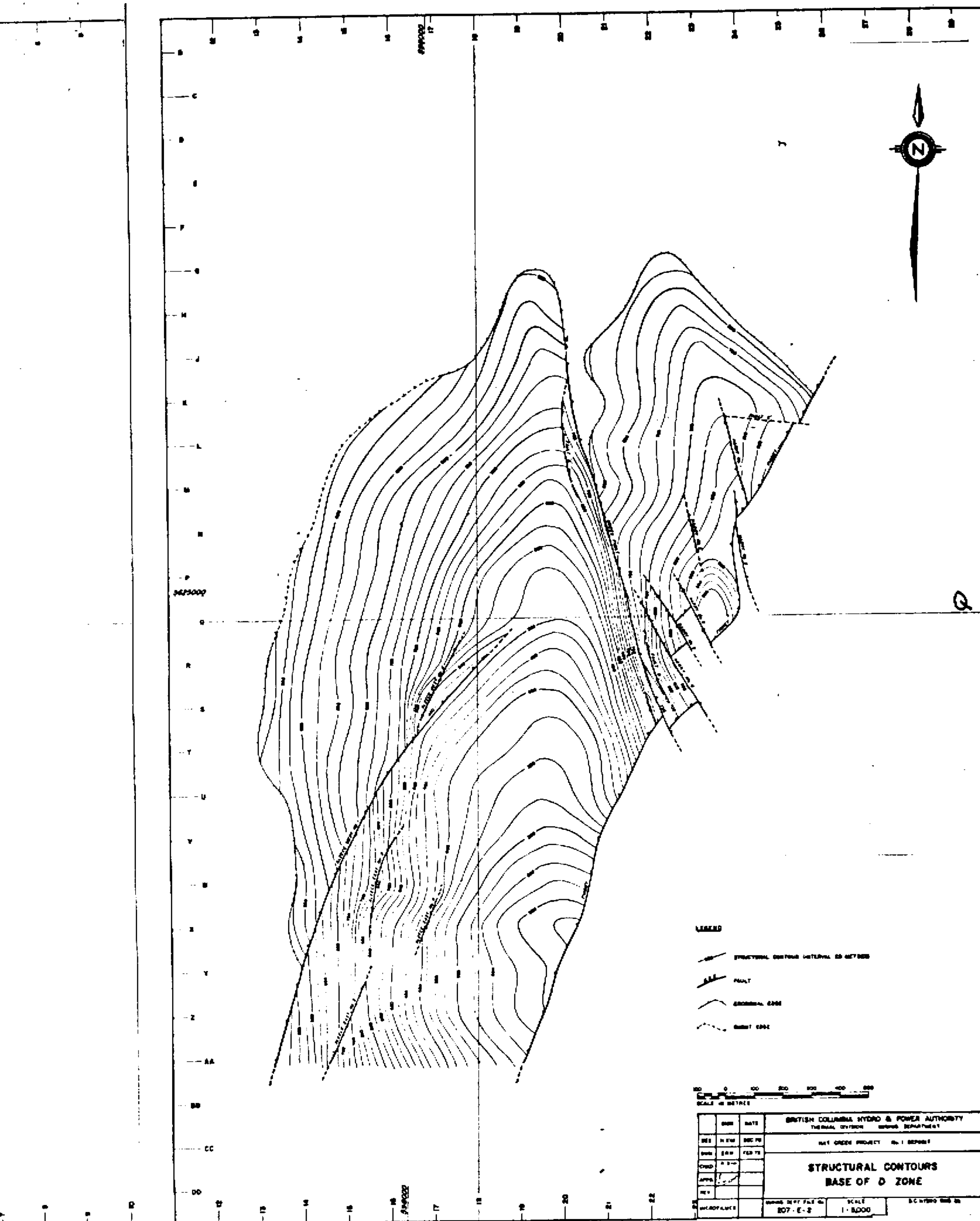

BRITISH COLUMBIA HYDRO & POWER AUTHORITY
STRUCTURAL CONTOURS
BASE OF D ZONE
SCALE
1 : 5000
207 - E - 2
Q

FIG. 4

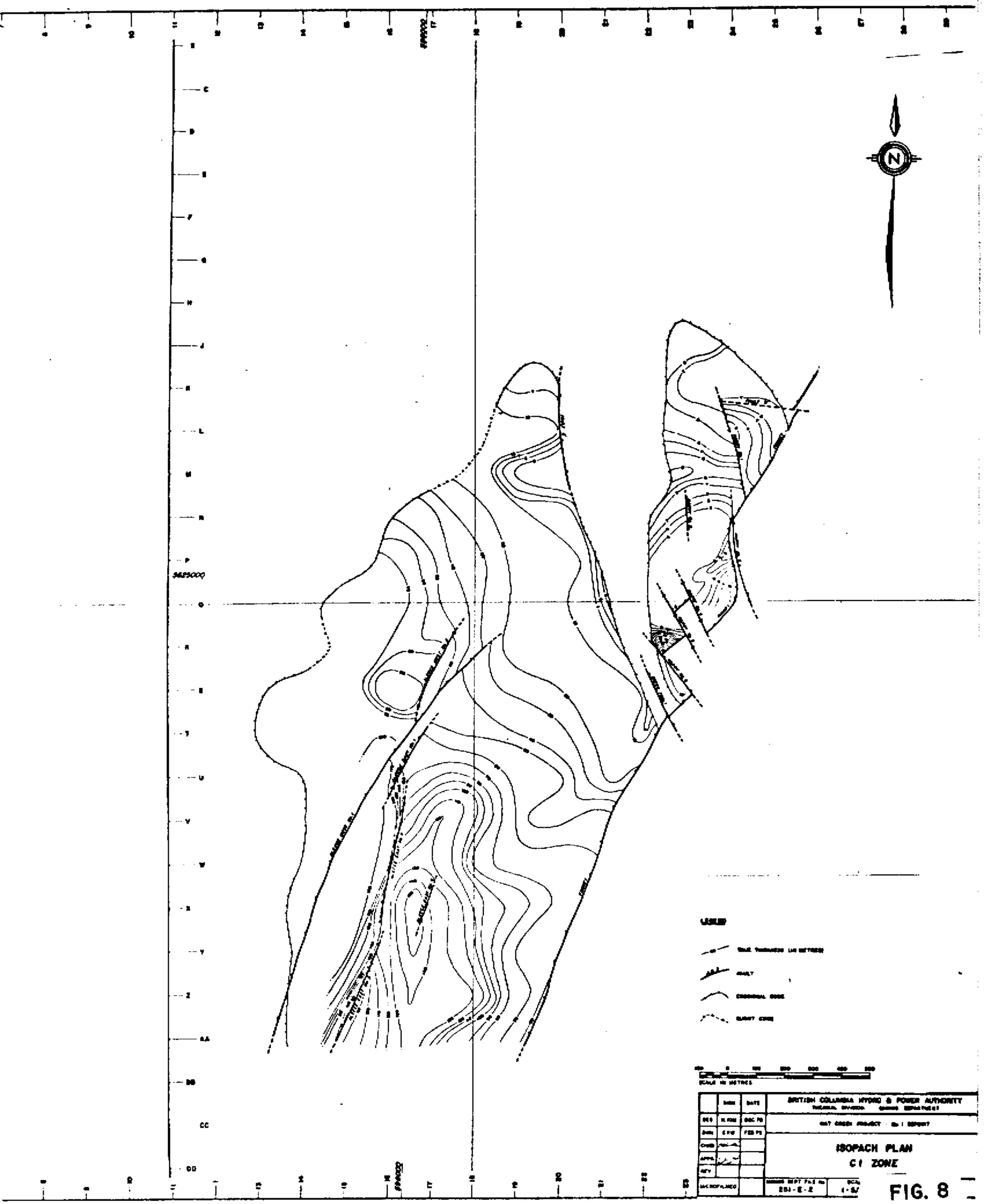
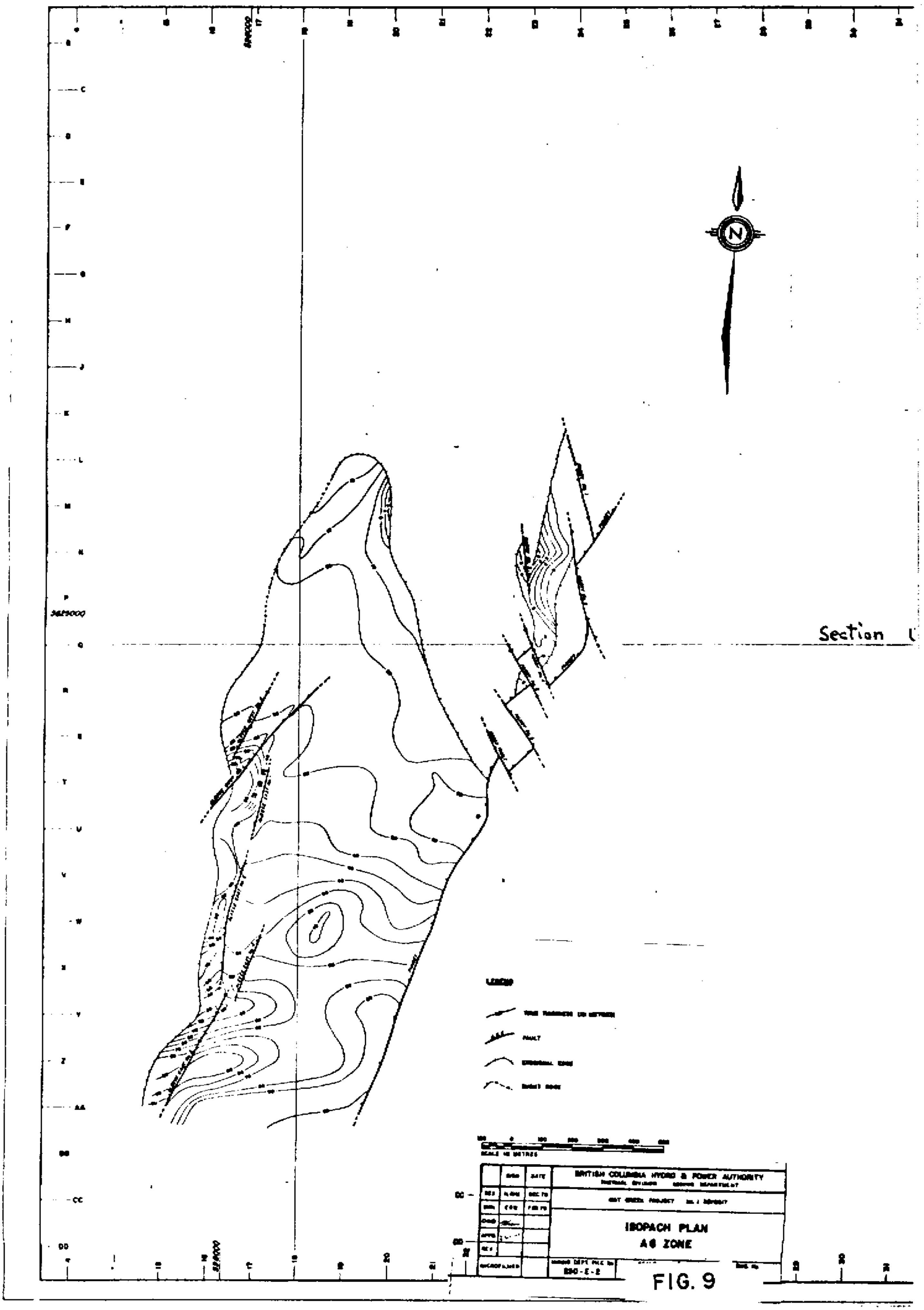

BRITISH COLUMBIA HYDRO & POWER AUTHORITY
ISOPACH PLAN
C1 ZONE
SCALE IN METRES
3625000

FIG. 8



Section
FAULT
SCALE IN METRES
BRITISH COLUMBIA HYDRO & POWER AUTHORITY
ISOPACH PLAN
A6 ZONE

FIG. 9

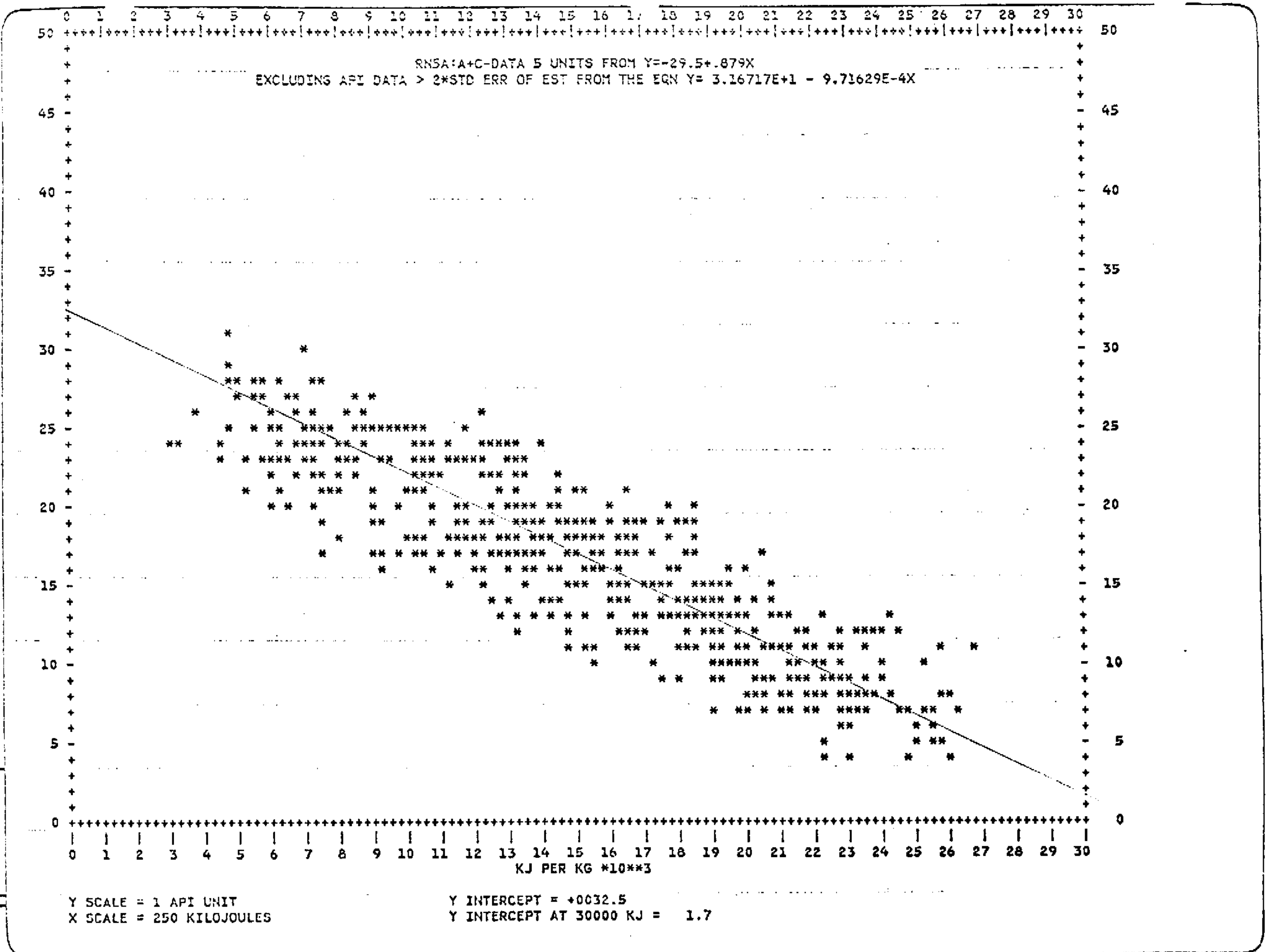

RNSA:A+C-DATA 5 UNITS FROM Y=-29.5+.879X
EXCLUDING API DATA > 2*STD ERR OF EST FROM THE EQN Y= 3.16717E+1 - 9.71629E-4X
KJ PER KG *10**3
Y SCALE = 1 API UNIT
X SCALE = 250 KILOJOULES
Y INTERCEPT = +0032.5
Y INTERCEPT AT 30000 KJ = 1.7

FIG. 15-1

RN5A:A+C-DATA 5 UNITS FROM Y=-29.5+.879X
EXCLUDING API DATA > 2*STD ERR OF EST FROM THE EQN Y= 3.16717E+1 - 9.71629E-4X

SAMPLE TYPE	TOTAL LENGTH	COUNT	DRY BASIS API VALUE	DRY BASIS GROSS KJ PER KG
SERIES 1- 899	834.2	564		
SERIES 901- 999	0.0	0		
SERIES 2001-2999	0.0	0		
MAXIMUM			31.15	26828
MINIMUM			4.29	3008
RANGE			26.86	23820
WEIGHTED MEAN			15.98	16143
SAMPLE COUNTS		564		
WGTD STANDARD DEVIATION			6.06	5325
WGTD COEFF. OF VARIATION %			37.97	32.98

WGTD REGRESSION EQUATIONS (DRY BASIS): Y = 3.25886E+01 + -1.02901E-03 X WHERE Y = API,
X = 3.16700E+04 + -9.71812E+02 Y X = GROSS KILOJOULES PER KILOGRAM.

WGTD LINEAR CORRELATION COEFFICIENT = -0.9032

STANDARD ERROR OF ESTIMATION = 2.6024 SE**2 = 6.7725

FIG. 15 - 2

CORRELATION OF PALYNOZONES - 19E
(NOT TO SCALE)

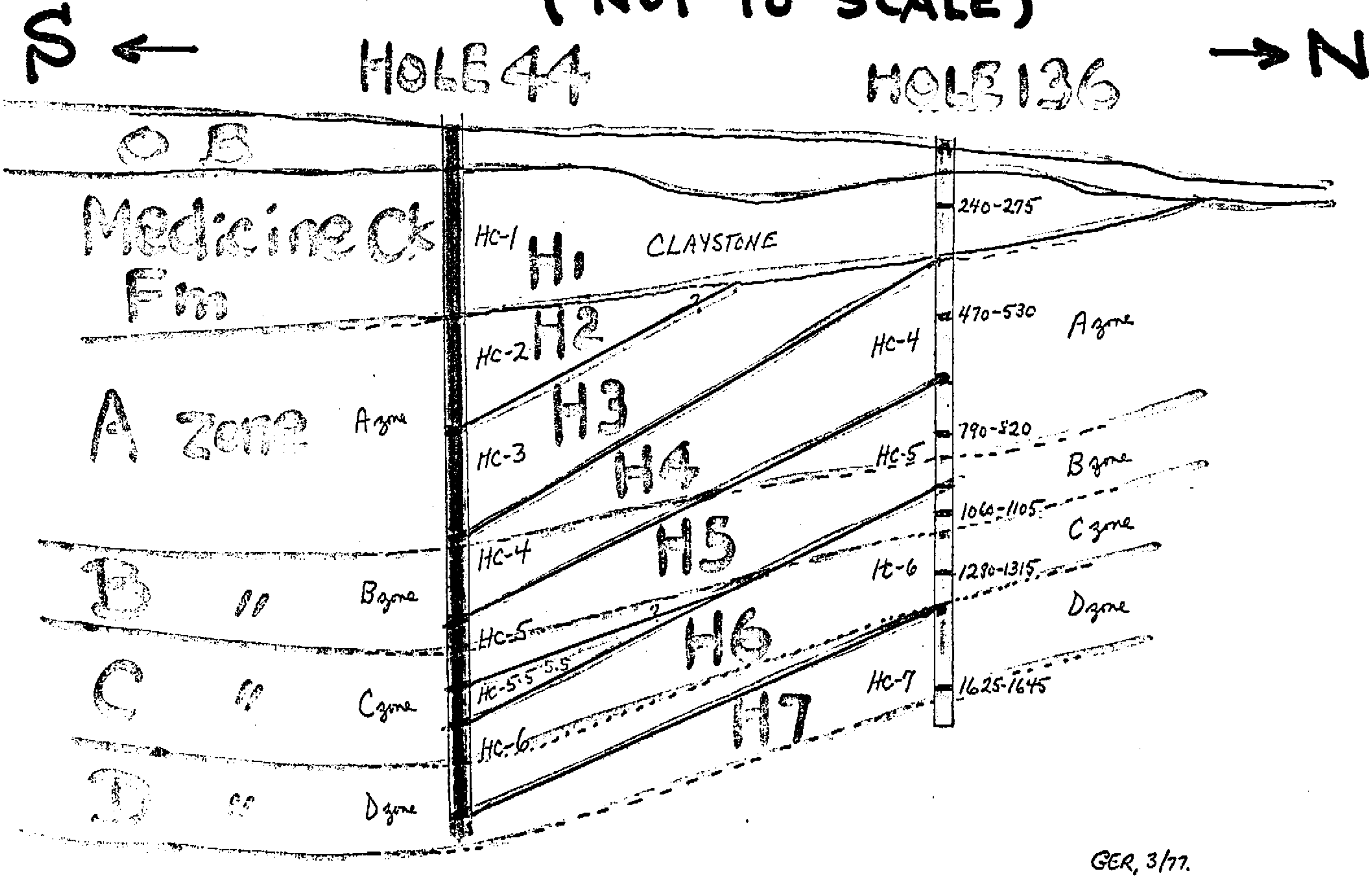


FIG. 19

AFTER G.E.ROUSE (1977)