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THE CORRELATION OF THE MAIN SEAM IN THE TANTALUS BUTTE COAL MINE AT CARMACKS, YUKON TERRITORY

by

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Abstract

Petrographic profiles of three column samples, taken from areas separated by faulting in the Tantalus Butte Mine, show that they can be correlated and that only one coal seam is present. This seam varies in thickness from 10-14 feet because in the thicker sections additional layers of coal occur in the top and bottom parts. From the correlation it is concluded that a graben structure is present in the mine and that the vertical displacement along the faults is of the order of 40 feet.

Typical of the Main Seam is the presence of 13 "tonstein" horizons, which occur in conjunction with much durite, and which have a good lateral persistence between the column samples. A brief literature review about the occurrence, origin and correlative value of tonstein is included in the report.

Introduction

This study is part of a larger project that is concerned with the determination of the coal reserves in the Carmacks area. Information on this is sought by the Department of Indian Affairs and Northern Development for the purpose of evaluating the feasibility of a coal-fired power plant in the area.

For reserve calculations and structural interpretations the correlation of seams is of great importance. Therefore, the Coal Research Section of the Geological Survey of Canada was given the task of establishing correlations by means of petrographic seam profiles, a method that has been employed successfully in the past in other coalfields of Canada (Hacquebard, 1951, 1952). The present report deals with one correlation problem only, namely the one encountered in the workings of the Tantalus Butte Mine.

The Main Seam of the Tantalus Butte Mine

This mine was opened in 1923 and consists of a horizontal stone tunnel that intersects the Main Seam 220 feet from the entrance (See Fig. 1). The coal dips from 55-60° and a main gangway was driven to the north along the strike of the seam. This gangway is intersected at two places by faults which completely cut off the seam. At both places the gangway was extended by rock tunnels in attempts to relocate the coal. This was successful, but the seam correlation was in doubt because of differences in the heights of coal encountered and unknown structural displacement along the faults. The prevailing view held by the mine operators was that an overlying seam had been brought in juxtaposition with the Main Seam by dislocation along the faults. This could be the seam that is reported to occur about 100 feet stratigraphically higher in the section (Cairnes, 1910; Bostock, 1956).

In order to study this correlation problem the author collected, in June 1969, three column samples from the seam sections that occur in the three parts of the mine, which are separated by the faulting. The columns marked WC-35, 36 and 37 are situated at the high wall on the main gangway at Nos. 2, 11 and 21 raise, which are, respectively, 760 feet and 255 feet apart. At these locations the coal averages 10, 12 and 14 feet in thickness, and includes several thin partings of clay and coaly shale.

Correlation Method and Procedures of Petrographic Study

A petrographic correlation is based on the vertical distribution of the banded ingredients of coal throughout the section of the seam. The types of ingredients are related to the type of vegetation and the mode of preservation that existed in the original peat bogs, from which the coal is derived. During the life of the bog the conditions varied, largely because of changes in the groundwater level. Sections of the same seam, when situated not too far apart, will therefore show similar sequences. The distance between sections should normally not exceed 2 miles, because of the possibility that the horizontal changes might be larger than the vertical changes in composition. For correlations over larger distances intermediate samples are usually considered necessary.

To examine the vertical changes in composition, column samples consisting of a series of solid blocks of coal are preferred, because they permit the exact positioning of the various banded ingredients within the seam section. When the coal is too soft for blocks, then small vertical increments of the friable, powdered coal are collected, but this method is less accurate because characteristic horizons may be overlooked.

From each set of blocks, representing a column sample, a series of polished sections of coal is made. These sections, which are cut at right angles to the bedding plane, are embedded in a plastic bond, and measure 3 x 1 3/4 inches. From the soft parts of the seam, of which no blocks could be obtained, polished grain mounts of crushed coal are prepared.

Both the polished sections and the grain mounts (also referred to as pellets) are examined microscopically under incident light. In the present study this examination has been carried out at a magnification of X 75, with a dry objective. The latter can be used for the Carmacks coal because of its relatively low rank, namely high volatile "B" bituminous coal. For coals of higher rank it is essential to use a low power oil immersion objective, otherwise the various coal components cannot be properly identified.

The banded ingredients recognized under the microscope are vitrite, clarite, durite, fusite and intermediate forms, such as clarodurite, duroclarite and semifusite. These constituents occur in coal in distinct bands or lenses and their widths are measured from the polished sections and plotted at true scale in the so-called coal-logs. Other features, related to recognizable plant entities, such as cuticles of leaves, micro- and megaspores, pollen grains, resin globules and mineral matter (quartz, calcite, kaolinite) are also indicated. The coal-logs, therefore, are a graphical expression of the change in petrographic composition of a coal seam between roof and pavement.

The petrographic sequence in the soft parts of the column sample, which is not revealed in the friable coal, is deduced from the quantitative analyses made of the grain mounts. From these analyses it is only possible to obtain the total aggregate thickness of the individual constituents for each increment. Their distribution and individual band thickness as plotted in the coal-logs is assumed. It is based in part on comparisons with the corresponding intervals in the other columns and in part on overlying or underlying portions of the seam from which solid blocks could be collected.

Seam Sections and Preparation Data on Column Samples
Taken in Tantalus Butte Coal Mine

Sample KC-35. Type column of Main Seam, taken from high wall on main gangway at No. 2 raise.

Seam section:

Roof: Sandstone, light grey, fine-grained, with plant remains. 0'2" cap rock, consisting of dark grey shale.

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Seam Sections and Preparation Data on Column Samples Taken in Tantalus Butte Coal Mine

Sample WC-35. Type column of Main Seam, taken from high wall on main gangway at No. 2 raise.

Seam section:

Roof: Sandstone, light grey, fine-grained, with plant remains. 0'2" cap rock, consisting of dark grey shale.

A.	1'8"	coal, hard		11 sections (bracketed with the mudstone)
	0'1/2"		mudstone	
B.	0'10 1/2"	coal, hard		5 sections
	0'2"		coaly shale	1 pellet
C.	2'3"	coal, hard		18 sections
	0'9"	coal, soft		1 pellet
	0'2"		brown clay	1 pellet
D.	1'2"	coal, soft		3 pellets
	1'1/2"	coal, hard		17 sections (bracketed: 1'1/2" coal, hard; 0'1/2" coaly shale; 1'3" coal, hard)
	0'1/2"		coaly shale	
	1'3"	coal, hard		
E.	0'6"	bench coal, hard		4 sections

Pavement: Sandy shale, black.

Total thickness of seam: 9'11"

Total number of polished sections: 55; total pellets: 6

Sample WC-36. Column from unidentified seam encountered in fault block; taken from high wall on main gangway at No. 11 raise.

Seam section:

Roof: Sandstone, light grey, fine grained, with plant remains

0'2" siltstone, dark grey } cap rock
0'1" soft grey shale } cap rock

A.	1'7"	coal, soft		3 pellets
	0'2"		clay and coal, mixed	1 pellet
B.	0'10"	coal, soft		3 pellets
	0'1"		coaly siltstone, dense	2 sections (bracketed with the coaly shale)
	0'2 1/2"		coaly shale	
C.	3'7"	coal, hard		20 sections
	0'1"		brown clay	

[illegible]'2" coal, hard
0'1/2" coaly shale — 24 sections
1'1[illegible] 1/2" coal, hard
0'7" coal, soft
0'1" coaly shale — 1 pellet
0'5" shaley coal — 5 sections
0'8 1/2" bench coal, hard

[illegible] [illegible] shale, black

[illegible] thickness of seam: 12'0"

[illegible] number of polished sections: 51; total pellets: 13

[illegible]. Column from unidentified seam encountered north of fault block; taken from high wall on main gangway at No. 21 raise.

[illegible] section:

[illegible] dark grey shale, slicken-sided.

A. 1'10" coal, soft
0'1/2" stone nodule — 4 pellets

B. 0'6" coal, soft
0'1" brown clay
0'4" coal, soft
0'1" stone nodule — 4 pellets
0'3 1/2" coal, soft
0'2 1/2" coaly shale

C. 2'6 1/2" coal, hard — 15 sections
1'6" coal, soft — 3 pellets
0'2" brown clay

D. 0'11 1/2" coal, soft — 2 pellets
1'1" coal, hard
0'1" coaly shale
0'2" coal, hard — 12 sections
0'1/2" coaly shale
0'1" coal, soft — 1 pellet

[illegible]. 3'1 1/2" coal, hard — 6 sections

0'1 1/2" coal, soft — 1 pellet

F. 0'3" shaley coal

1'7 1/2" coal, hard — 8 sections (bracketed)

0'1/2" shaley coal — 1 pellet

G. 1'2" bench coal, hard — 7 sections

Pavement: Sandy shale, dark grey

Total thickness of seam: 13'11"

Total number of polished sections: 48; total pellets: 12

Petrographic Composition and Correlation

Coal-logs have been prepared of the three column samples and a condensed and much simplified version is plotted in Figure 1. The logs show that the petrographic composition changes considerably between pavement and roof, and also that it is possible to divide the seam section into a number of intervals in which certain banded ingredients predominate, or show a specific succession or alternation. These divisions, or petrographic intervals, are indicated with roman numerals to the left of column WC-37.

In the type column of the Main Seam (WC-35) ten petrographic intervals are present. Of these, intervals III, V, VII and XI consist entirely of bright coal constituents (vitrite, clarite and fusite), and the last two mentioned contain in addition distinct clay partings. In IV and VI, the dull coal constituents (durite) represent the entire interval or greatly predominate. In the four remaining intervals (VIII, IX, X and XII) distinct durite bands of varying thicknesses alternate with bands and lenses of clarite, vitrite, fusite and semifusite.[1] Besides the petrographic intervals, column WC-35 also has two distinct partings of coaly shale, which occur between V-VI, and X-XI. Furthermore, there are eight

[1] In Figure 1 vitrite is included with clarite and semifusite with durite.

kaolinite or tonstein horizons present, of which two developed as actual clay partings, as previously mentioned.

The ten intervals and partings of the type column are also represented in columns WC-36 and 37. Some variations are apparent, but these are within the limits of lateral changes that normally occur within one seam. The eight tonstein horizons are also present at the corresponding positions in each seam section. On the basis of these similarities it is concluded that the three column samples can be correlated and that only one seam is present.

This correlation is further supported by the distribution of so-called squat-bulky spores(?) (or possibly resin globules), which were found only in the upper half of all three samples. These entities are shown in Figure 1 with a solid black dot to the right of each column.

Other characteristics that are typical of the Main Seam in the Tantalus Butte Mine are: 1) the exceptionally high inertinite (mostly semi-fusinite) content of the durite bands; 2) the occurrence of relatively large number of spores as compared to pollen grains in this Cretaceous coal; 3) the high concentration of calcite in the lower part of the seam (in the form of carbankarite and as cell-filling of fusite).

The Variations in Seam Thickness

Figure 1 shows that the variations in thickness are caused by the differences in thickness of the individual petrographic intervals and by the fact that the total number of intervals increases in the thicker seam sections. In the latter the coal formation started earlier and continued longer than in the section where the thickness is the least. WC-37 is 4 feet thicker than WC-35, mainly because of the presence of intervals I, II, XIII and the coaly shale between II and III, which together measure 3'4". However, at WC-35, there exists the possibility that interval II may be present in the floor of the seam below the present pavement, as is the case in WC-36. At the time of sampling, this possibility was not realized and therefore no attempt to locate II was made. Nevertheless, there is a definite increase in thickness when proceeding north from sample WC-35 to WC-37 and this may indicate a deepening of the original basin of coal deposition in this direction. From this it would appear that the present workings are advancing towards an area of better coal, as compared to the old workings near WC-35.

The Structure Encountered in the Mine Workings

From the measurements made on the faults by Mr. R.A. Latour of the Geological Survey of Canada at the time of sampling in June 1969, and the present correlation of the seams the following can be reported on the structure.

Sample WC-36 lies in a down-faulted block (or graben) as compared to WC-35 and WC-37. The vertical displacement of this block, as indicated in the cross-section plotted on Figure 1, is of the order of 40 feet. This is considerably less than was originally thought, when instead of only one seam, at least two different seams were believed to be present. In that case a vertical displacement of 200-240 feet would be required, when the unidentified seam is correlated with the first known coal above the Main Seam. This coal, according to Cairnes (1910) lies 100 feet stratigraphically higher in the section.

The Mode of Occurrence and Significance of Kaolin-Coal Tonstein

The term kaolin-coal tonstein was accepted by the International Committee for Coal Petrology in 1963 as the English equivalent of the

German term Kaolin-Kohlentonstein introduced by Burger, Eckhard and Stadler (1962). Although the word tonstein simply means argillaceous shale, when used with reference to coal it has obtained a very specific connotation.

Kaolin-coal tonstein, or simply tonstein, refers to kaolinite-rich bands in coal seams that have a wide areal distribution, and vary in thickness from a few millimetres to a few centimetres only. The thicker bands range in colour from a yellowish-white to black; they have a dense, fine-grained texture, and are not generally stratified. Tonstein is difficult to distinguish with the unaided eye from ordinary stone partings, and definite identification requires the use of the microscope and X-ray diffraction.

The characteristic and predominant mineral is kaolinite or a mineral belonging to the kaolinite group. Secondary minerals are: illite, muscovite-illite ("leverriete") and chlorite of the clay minerals; quartz (in abundance), apatite, siderite, pyrite, feldspar, mica and zircon. In tonsteins containing components of volcanic origin the following further minerals may be recognized: montmorillonite-illite, halloysite and potassium feldspar (sanidine) (I.C.C.P. glossary, 1963).

Kaolinite occurs in tonstein in different forms, namely: 1) as prismatic or tabular crystals (so-called kaolinite worms) in a finely-crystalline or cryptocrystalline kaolinite groundmass; 2) as pseudomorphs of feldspar and mica; 3) as granules or "Graupen"; 4) almost entirely as a fine-grained groundmass. On the basis of the mode of kaolinite occurrence, Schuler et al. (1956) has distinguished four different types, namely crystalline-, pseudomorphous-, "Graupen-" and dense, non-crystalline tonstein.

Kaolin-coal tonstein bands were first recognized in the Carboniferous coals of Germany. They were found to have a wide lateral persistence and extensive vertical range, and for this reason are valuable in seam correlation and regional stratigraphy. Once this was realized, an intensive search for tonsteins was undertaken in all the major coalfields of continental Europe and Great Britain. This work has been in progress during the past twenty years and has resulted in many publications on this subject. From these studies it is apparent that a coal seam may sometimes be traced over an entire field by means of a tonstein band only a few millimetres thick. The position of this band within the seam section is always approximately the same, and may be considered a characteristic feature. It permits the identification of different seams, even though both may have the same number of tonstein bands. The mineralogical composition also varies between different tonsteins, and according to studies made by Burger (1962) can be used to separate one band from another.

The amazing lateral extent (up to 200 miles in NW Europe) of thin layers of uniformly fine-grained material, such as the tonstein bands, is a rare geological feature. It is comparable to certain marine shales and limestones, coals, varved clays and volcanic ash beds. The mode of formation of kaolin-coal tonstein is still much debated and over the years conflicting views have been expressed. These fall into three main categories, which have been summarized by Williamson (1961) as follows:

(i) Sedimentary origin by deposition of fine kaolinite particles in the coal swamps and subsequent recrystallization. The kaolin-rich sediment was originally derived from the erosion of neighbouring granites. This view was first proposed by Pruvost (1934).

(ii) Volcanic origin from kaolinitized ash by atmospheric fall-out. Stach (1950) first suggested this theory for the tonstein occurrences in the Ruhr coalfield of Germany. His main supporturs are Bouroz (1962, 1966) in France, and Price and Duff (1969) in Great Britain. The considerable lateral extension of most tonsteins and their mineralogical composition are regarded as arguments in favour of a volcanic origin. Price and Duff point to the presence of montmorillonite-illite, halloysite, sanidine and minerals of the goyazite series, which have been found in several tonsteins (though certainly not in all) as characteristic volcanic constituents.

(iii) Diagenetic origin, through the formation of kaolinite by recrystallization <u>in situ</u> from illite-rich clay in a markedly acid environment. The reputed association of tonstein with durite, both indicative of a sub-aquatic environment, is mentioned in support of this view. Most German coal geologists and coal petrographers appear to favour the diagenetic mode of formation, as i.e. M. & R. Teichmüller (1952); Eckhardt and von Gaertner (1962); Stadler (1962); Hoehne (1964). The views expressed by Moore (1964) that biochemical soil-forming processes controlled the formation of tonstein, can be included in this category.

<u>Kaolin Tonstein in Main Seam of Tantalus Butte Mine</u>

Kaolin tonstein, although of widespread distribution in the European coal measures, has not been widely recognized in North America. The only published reference to tonstein that the author was able to find is contained in the 1959 and 1964 papers of Hoehne. He mentions the presence of kaolinite graupen and crystals in pieces of coal that came from the Bellevue Mine of Blairmore, Alberta, and also refers to a report [illegible] (1916) on a parting (probably tonstein) in a coal bed of the [illegible] Creek coalfield of Montana. At both occurrences, as well as at Carmacks, the coals are Cretaceous in age.

The finding of kaolin tonstein in the Main Seam is therefore an important discovery. Its reputed significance for seam correlation is supported by the present investigation, although it should be born in mind that the samples are only 1500 feet apart. Nevertheless, the presence of tonstein is most encouraging when considering future correlations over greater distances.

In the three samples examined kaolinite is abundantly present and it occurs in the following manner.

a) As isolated kaolinite crystals or sometimes granules in different parts of the seam. These do not constitute marker horizons.

b) Kaolinite is often seen as cell-filling of fusite and semifusite, sometimes in isolated particles and sometimes in bands in association with kaolinite granules (Graupen). The latter vary in size from 70-630 microns in diameter.

c) There are many thin bands with kaolinite Graupen and stringers, which lie in a groundmass of coal, and occur in association with kaolinite crystals and rounded quartz grains. These bands are 1-5 mm thick (averaging 2 mm) and are found in specific horizons of the seam, although their number is not always the same. Bands like these, though very thin, are known also from the Ruhr coalfield in Germany and are considered as tonstein (Burger, 1962, re. Zollverein No. 6 seam).

d) Zones with scattered black kaolinite Graupen, stringers and lenticles (up to 6 mm in longest diameter) are present at specific levels of the seam section. Although these zones, which are 5-11 cm thick, constitute marker horizons, they cannot be referred to as tonstein bands, but simply are isolated kaolin inclusions in the coal.

e) Clay and stone partings, 1-5 cm thick, occur which contain densely packed Graupen and lenticles that lie in a groundmass of fine grained kaolinite in the centre of the band and are surrounded by a coaly matrix at top and bottom. Also present are angular and subangular quartz grains, kaolinite crystals and pseudomorphs of mica. Other minerals, not positively identified, have also been observed. These bands are entirely comparable to the classical tonsteins that have been so widely reported from Europe.

In Figure 1 the horizons at which the kaolinite granules (Graupen) occur have been marked and numerically indicated. The distribution and nature of the kaolinite occurrence at each horizon is given in Table I. A total of 13 horizons has been recognised, of which all but 4 and 6 can be classed as tonstein bands. The latter cannot be so regarded because they represent zones with scattered Graupen, rather than well defined bands. The presence of more than eleven tonstein bands in one seam (at one horizon there is often more than one band, as is shown in Table I) is probably unique. The highest number found in the European literature is eight tonsteins, which occur in the Schwalbach Seam of the Saar Basin, and which vary in thickness from 0.5-4 cm (Guthörl, 1955). In the Main Seam this variation is from 0.1-5 cm.

Figure 1 shows that the lateral persistance of the "tonstein" horizons in the three columns is good. All 8 horizons present in WC-35 were found at the corresponding positions in WC-36 and 37, notwithstanding the fact that many of these are only a few millimetres thick. In WC-37 an additional 5 horizons were observed, but these occur in intervals which are not present in WC-35.

The mode of occurrence of tonstein in the Main Seam, its relative abundance throughout the seam section and its presence in conjunction with much durite would seem to favour a diagenetic origin, at least for the thin bands and for zones 4 and 6 (compare p. 13 d of this report). The genesis of the two tonstein partings (9 and 11), however, may be different. A volcanic origin of these bands cannot be ruled out, but to express a definite opinion on this, detailed mineralogical determinations with X-ray diffraction are required. These have not yet been made and more discussion on this will be incorporated in a following report on the Carmacks investigation.

Table 1. Distribution of Kaolinite in Samples WC-35, 36 and 37

Horizon in Figure 1	Mode of occurrence and characteristics
13	Six bands with kaolinite Graupen and stringers, 1-3 mm thick, occur within 9 cm of section in WC-35. Kaolinite is also present in grainmounts of WC-36 and 37.
12	One band with kaolinite Graupen, 1 mm thick, occurs in WC-35; particles with Graupen are present in grainmounts of WC-36 and 37.
11	Stone and clay parting, 1.3 to 2.5 cm thick, with numerous kaolinite Graupen in WC-35 and 36, together with a few kaolinite crystals, pseudomorphs of mica and angular quartz grains.
10	Two or three bands with kaolinite Graupen and stringers, 1-4 mm thick, occur within 1-3 cm of section. Many well-rounded quartz grains are also present.
9	Clay and stone parting, 2-5 cm thick, with kaolinite Graupen and stringers, which in WC-36 pass into a dense tonstein composed of a massive, fine-grained groundmass with occasional crystals and granules of kaolinite.
8	Two bands with kaolinite Graupen and stringers, 2 and 5 mm thick and 1 cm apart, are present in WC-36 in association with rounded quartz grains. Particles with Graupen occur in grainmounts of WC-35 and 37.
7	One band with small black Graupen, 1-3 mm thick, occurs in association with many sub-angular and rounded quartz grains.
6	A zone with scattered black Graupen, stringers and lenticles of up to 6 mm in diameter in WC-36, occurs within 5-11 cm of section.
5	Three to five bands with brown and black kaolinite Graupen and stringers, 2-4 mm thick, occur within 4-8 cm of section in WC-36 and 37.
4	A zone with scattered black Graupen and kaolinite lenses occurs within 5 cm of section in WC-36 and 37.
3	Two bands with kaolinite crystals and Graupen, both 2 mm thick, occur within 1 cm of section in WC-37.
2	One band with kaolinite stringers and crystals, 2 mm thick, occurs with numerous sub-angular and rounded quartz grains in WC-37.
1	Two bands with kaolinite stringers and Graupen, 2 and 3 mm thick, occur within 6 cm of section in WC-37.

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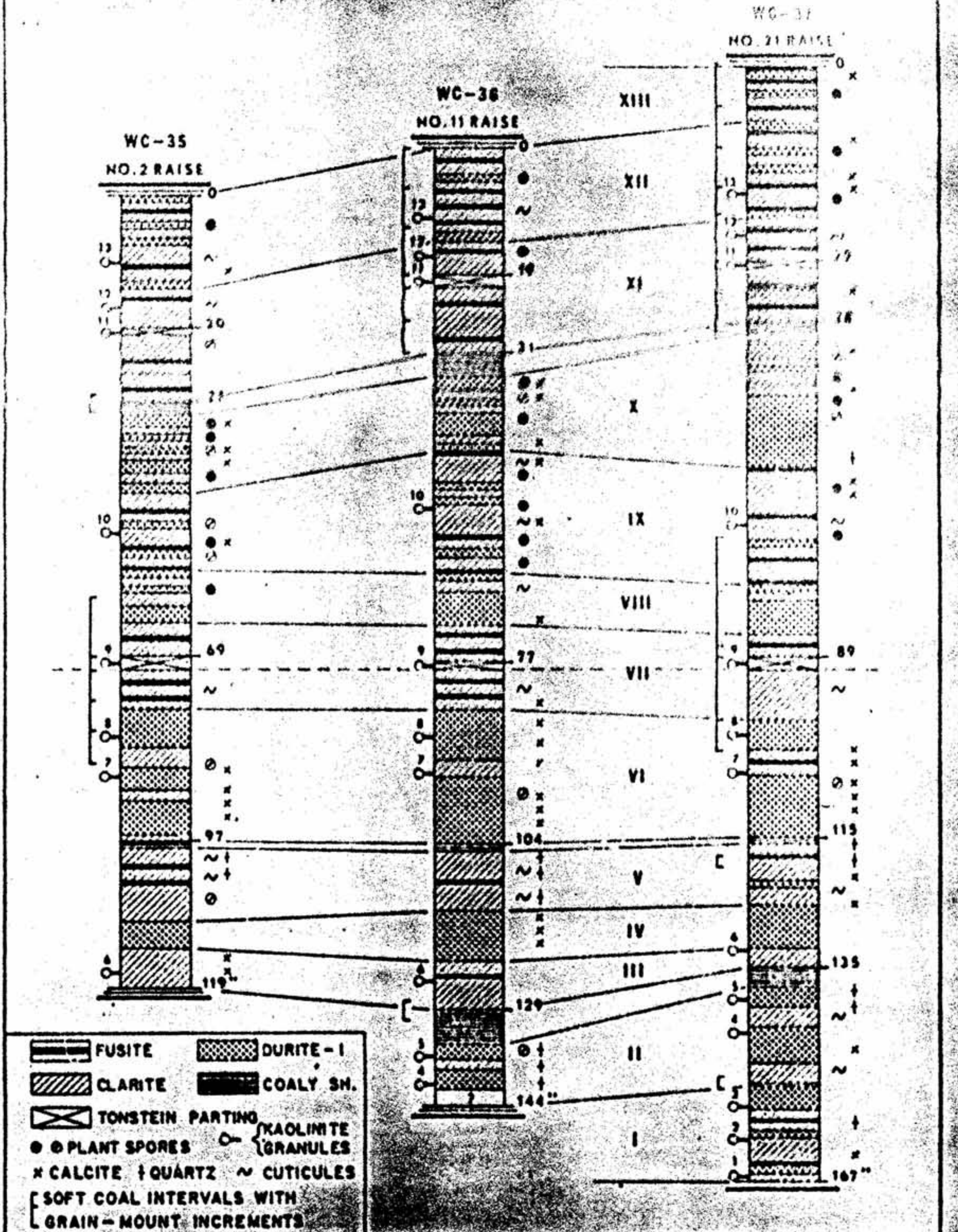
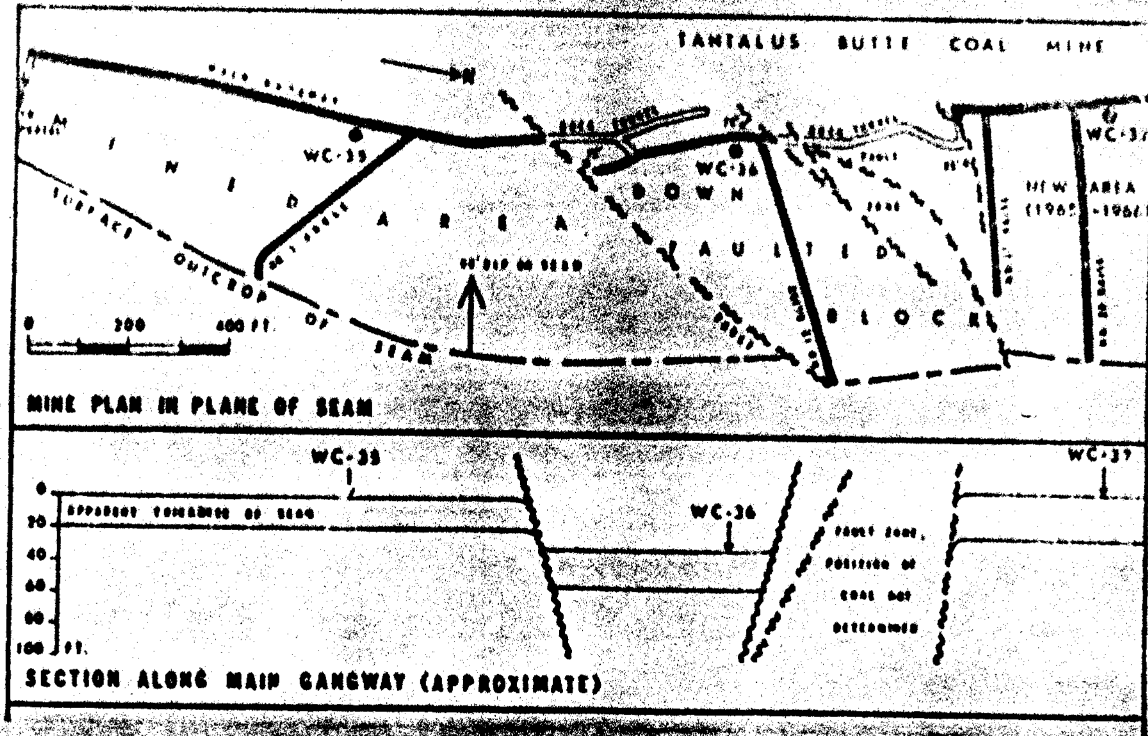


FIGURE I. PETROGRAPHIC CORRELATION OF COLUMN SAMPLES FROM MAIN GANGWAY AT NO. 2, NO. 11 AND NO. 21 RAISE IN TANTALUS BUTTE COAL MINE, CARMACKS, Y.T.


TANTALUS BUTTE COAL MINE
MINED AREA
DOWN FAULTED BLOCK
NEW AREA (1965-1966)
WC-35
WC-36
WC-37
SURFACE OUTCROP OF SEAM
0 200 400 FT.
MINE PLAN IN PLANE OF SEAM
WC-35
WC-36
WC-37
APPARENT THICKNESS OF SEAM
0
20
40
60
80
100 FT.
FAULT ZONE, POSITION OF COAL NOT DETERMINED
SECTION ALONG MAIN GANGWAY (APPROXIMATE)

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