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MINERALS RESEARCH LABORATORIES

FUEL GEOSCIENCE UNIT

COAL PETROGRAPHY OF TWELVE COAL SAMPLES
FROM THE YUKON TERRITORY, CANADA

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1. INTRODUCTION

Twelve coal samples were submitted for petrographic analysis by the Robertson Research Group of Companies* on behalf of the Cyprus Anvil Mining Corporation. These coals, which are of Mesozoic or Tertiary age, were collected from outcrops at various localities in the Yukon Territory, Canada.

It is quite likely that the coals have undergone some degree of oxidation and weathering, since they represent outcrop samples. As a result, the measured values for certain of the coal utilization parameters might be expected to be at variance with the values for these parameters as determined on unweathered coal. It is possible that predicted values for coal utilization parameters, based on the coal petrographic data, may provide a more reliable assessment of coal quality than the results of chemical and physical testwork carried out on weathered coal.

Therefore, Cyprus Anvil Mining Corporation requested that vitrinite reflectivity and maceral analyses of the twelve coal samples be undertaken in order to compare the predicted coal utilization parameters with the measured values for these parameters.

In addition to the petrographic analyses, moisture, ash and sulphur values were determined for each coal in order that the maceral analyses could be corrected for calculated mineral matter.

2. GEOLOGICAL SETTING

Latour (1972) has listed the principal coal occurrences in the Yukon Territory; these occurrences may be summarized as follows:

- | | | |
|----------------|---|-------------------------------------------------------------------------------------------------------------------------------------------|
| TERTIARY COALS | } | (a) White River and Yukon River drainage area
(southwestern and west Yukon) |
| | | (b) Bonnet Plume area (north Yukon) |
| | | (c) Upper Liard River (southeastern Yukon) |
| MESOZOIC COALS | } | (d) Southwestern Yukon - Laberge (Lower
Jurassic - ? Upper Jurassic) and Tantalus
(Upper Jurassic - Lower Cretaceous)
Formations |

* In this instance Robertson Research (Australia) Pty Ltd and Robertson Research (North America) Ltd.

The Mesozoic coals are described as being mostly bituminous in rank, whereas, the Tertiary coals are described as being lignitic in rank.

Although, no locality maps were available at the time of writing, Cyprus Anvil Mining Corporation provided the following information in respect of sample location, sample age and the presence of intrusive rocks.

DM - 1	}	Upper Jurassic
DM - 2		
DM - 3		
FF - 1		Lower/Middle Jurassic (Middle Tertiary)
GC - 1		Jurassic - Cretaceous (possible intrusives)
JC - 1		Cretaceous (Tertiary ?)
LP - 1		Middle/Upper Jurassic - Lower Cretaceous (possible intrusives)
PC - 1	}	Upper Jurassic - Lower Cretaceous (possible intrusives)
PC - 2		
PR - 3		Upper Cretaceous
PR - 8		Lower Cretaceous
RR - 1		Tertiary (Jurassic - Cretaceous ?)

DM = Division Mountain

LP = Lone Pine Mountain

FF = Five Fingers

PC = Porters Coal

GC = Gudders Coal

PR = Peel River

JC = Jump Out Creek

RR = Ross River

Cyprus Anvil Mining Corporation indicated that the ages in parenthesis are possible alternative ages to those indicated on the geological maps, based presumably on their geologists' field observations.

3. COAL PETROGRAPHIC DATA

The vitrinite reflectivity and maceral analyses were carried out in accordance with the recommendations of the International Committee for Coal Petrology (I.C.C.P.), as set out in the I.C.C.P. Handbook (1963, 1971) (also, see Stach, 1975). Separate maceral analyses were performed on the low rank coals under incident-light, blue-light excitation. The

resultant fluorescence of the liptinite/exinite group macerals permits a distinction to be made between the various macerals within this group and between the maceral group and very low reflectivity mineral matter, in particular finely divided quartz and clay minerals. (I.C.C.P., 1976; Spackman *et al.*, 1976).

The details of the petrographic analyses for the coals are presented in an Appendix, together with a number of photomicrographs illustrating the petrography of these coals.

Coal Type:

The results of the petrographic analyses are summarized in Table 1. On the basis of their petrographic composition the coals may be divided into vitrinite-rich and vitrinite-poor types.

(A) Vitrinite-rich Coals

The Peel River (PR-3 and PR-8), Jump Out Creek (JC-1) and Five Fingers (FF-1) samples contain in excess of 90% of (vitrinite + exinite) on a mineral matter free basis; the inertinite content of the Peel River samples is 1% or less. The petrographic composition of these samples is similar to the restricted petrographic composition for uppermost Cretaceous (Senonian) and Tertiary coals of the western circum-Pacific region; in terms of coal rank and type the four samples are similar to the Neogene coals of Indonesia (Strauss *et al.*, 1976). The I.C.C.P. Handbook (1971) notes that inertinite is a minor component of most Tertiary brown coals and lignites, with the exception of certain individual occurrences in India and the Balkans. Furthermore, sclerotinite is the important, if not dominant, component of the inertinite found in these coals.

Although the ages assigned to the vitrinite-rich coals range from lower Jurassic to ? Tertiary, it seems likely that, on the basis of their petrographic composition, these coals are Upper Cretaceous to Tertiary in age. The petrography of these samples is illustrated in Plates I and 2.

(B) Vitrinite-poor Coals

With two exceptions, the remaining coal samples contain less than 36% of (vitrinite + exinite) on a mineral matter free basis. The Lone Pine Mountain (LP-1) sample represents a coked coal (natural coke).

Sample PC-2 is a high rank anthracite, with a maximum reflectivity (\bar{R}_0 max) in excess of 3%, and, as such, it is difficult to carry out a meaningful maceral analysis on this coal. Reference to Table 1 shows the marked contrast in petrographic composition of samples PC-1 and PC-2, which have been assigned the same age (Upper Triassic - Lower Cretaceous) and which were collected from the same general locality.

In terms of their petrographic composition and degree of coalification, the vitrinite-poor coals broadly resemble coals from the Oaklands (Permian, New South Wales), Galilee Basin (Permian, Queensland), Blair Athol (Permian, Queensland), Callide (Triassic, Queensland) and Leigh Creek (South Australia, Triassic) deposits in Australia (Bennett and Taylor, 1970; Strauss *et al.*, 1976).

Cook (1975) notes that the inertinite-rich, Cretaceous coals of the Maryborough and Styx Basins (Queensland) are very similar in maceral composition to the Cretaceous coals of British Columbia and Alberta. In particular, with respect to the abundant semifusinite/fusinite derived from well-preserved, thick-walled, woody tissue. Data presented by Cameron (1972) indicate a wide range in vitrinite content, i.e. 35-96%, for the Upper Jurassic - Lower Cretaceous coals in the Kootenay Formation in British Columbia and Alberta. The average value of 63% vitrinite is much higher than that for the Yukon samples examined. Vitrinite was distinguished from semifusinite of similar reflectivity (very low reflectivity semifusinite) by the presence of open slitlike cell lumens and/or the presence of granular (mottled) anisotropy in the semifusinite (Bennett, 1968).

The ages assigned to the vitrinite-poor coals range from Upper Jurassic to Lower Cretaceous. The Tertiary age given for sample RR-1 is based on the available geological map; however, it is understood that this coal is of Jurassic-Cretaceous age. The petrography of these samples is illustrated in Plates 3 and 4.

It appears that, in very general terms, the petrographic composition of the Yukon coal samples reflects their age, i.e. vitrinite-poor, Upper Jurassic - Lower Cretaceous coals and vitrinite-rich, ? Upper Cretaceous - Tertiary coals (see Figure 1).

Coal Rank

Reference to Table 1 indicates that the coal samples may be divided into two groups on the basis of their vitrinite reflectivity, namely lignite-subbituminous/high-volatile bituminous coal (\bar{R}_O max = 0.29-0.64%) and semianthracite - anthracite (\bar{R}_O max = 1.98-3.10%). None of the samples examined fall within the coking coal range of high- to low-volatile bituminous coals.

(A) Low-rank Coals

The vitrinite-rich coals, presumed to be of Upper Cretaceous-Tertiary age, exhibit a slightly lower range of vitrinite reflectivity values (\bar{R}_O max = 0.29-0.51%) than those exhibited by the vitrinite-poor coals (\bar{R}_O max = 0.56-0.64%), which are Upper Jurassic - Lower Cretaceous in age. This observation would be consistent with regional coalification in relatively undeformed sediments, the differences in degree of coalification reflecting the different ages of the two groups of coal samples.

(B) High-rank Coals

The occurrence of semianthracite - anthracite in a region containing low rank coals of the same age suggests the presence of intrusive rocks which have resulted in localized thermal alteration of the coal. Reference to Stach (1975) suggests carbonization temperatures of 400°C to 500°C for the semianthracite - anthracite samples with vitrinite reflectivity values of 1.98% to 3.10%, assuming that the original coals were of low rank and that the thermal alteration occurred in the absence of excess pressure. The bireflectance (\bar{R}_O max % - \bar{R}_O min %) values of 0.59% to 1.03% indicate that the samples were not subjected to excess pressure during carbonization.

The Lone Pine Mountain (LP-1) sample consists of a natural coke that exhibits the development of small spherical vesicles and a very fine-grained anisotropic (see Plate 5 a & b) mosaic structure which suggests that the original coal falls outside the coking coal range, i.e. a relatively low rank coal. Data presented in British Carbonization Research Association (B.C.R.A.) Report 25 (1976) suggest that development of a fine-grain anisotropic mosaic is associated with the carbonization of caking coals in the 400-600 class (N.C.B. 1964). The reflectivity

value of 6.2% for the vitrinite coke in sample LP-1 indicates a carbonization temperature of 650°C to 700°C.

It is understood that intrusive rocks occur in the Porters Coal and Lone Pine Mountain localities. Although no intrusive rocks appear to be recorded from the area of the locality of sample RR-1, it is likely that the high rank of this coal is the result of local thermal alteration.

Reference to Barnes (1961) and Rao (1975) reveals the presence of subbituminous coal in neighbouring Alaska. The Eagle Field lies close to the Yukon-Alaska border where the Yukon River crosses the frontier between Canada and the U.S.A. The Jarvis Creek and Nenana Field in Central Alaska and the Susitna, Beluga and Kenai Fields in South Central Alaska contain lignite and subbituminous coal. Higher rank coals are also recorded in Alaska. The Bering River Field, which is located about 100 miles from the southwestern corner of the Yukon Territory, contains semianthracite-anthracite. The latter is reported to be badly crushed and faulted: in view of the mechanical deformation of the coal the high rank is probably due to regional metamorphism, rather than localized, thermal metamorphism. In the Matanuska Field, South Central Alaska, the coal rank ranges from subbituminous, through bituminous, to semianthracite-anthracite moving from west to east over a distance of about 60 miles. Both Tertiary and Cretaceous coals are known to occur in Alaska. The lower rank coals (subbituminous-bituminous) of the Matanuska Field include Tertiary coals which are characterized by their very high contents of vitrinite (CSIRO, 1964).

4. PREDICTION OF COAL UTILIZATION PARAMETERS

FROM THE COAL PETROGRAPHIC DATA

Coal utilization parameters can be predicted on the basis of coal petrographic data using graphs published by Bennett and Taylor (1970). These graphical solutions have proved to be quite successful in the prediction of the properties of Australian Gondwana (Permian) coals; however, caution should be exercised when attempting to predict the properties of other coals. In this study no attempt has been made to calculate composition balance index (CBI) or strength index (SI) in order to predict coke stability using the method of Schapiro *et al.* (1961).

In order to improve the quality of the predictions it is advisable to correct the maceral analysis to a calculated mineral matter basis. This correction avoids the problems inherent in accurately determining the mineral matter component by microscopic methods. The calculated mineral matter value is derived from the moisture, ash and total sulphur contents using a modification of Parr's equation (see Francis, 1961) as follows: -

$$\text{Calculated Mineral matter (volume \%)} = \frac{\left(\begin{array}{l} \text{Ash (wt.\%)} \times 1.08 + \text{Sulphur (wt.\%)} \times 0.55 \\ \text{(dry basis)} \qquad \qquad \qquad \text{(dry basis)} \end{array} \right)}{2}$$

Table 2 presents the values for the moisture, ash and sulphur determinations, the calculated mineral matter values and the corrected values for the maceral analysis for each sample.

Table 3 presents a comparison between the results of the moisture, ash and total sulphur analyses carried out by CSIRO and the results for these analyses provided by the Cyprus Anvil Mining Corporation. There appears to be a considerable discrepancy between the values for the ash analyses. This probably indicates that the subsamples forwarded to CSIRO for petrographic analysis are not representative of the subsamples analysed by the Cyprus Anvil Mining Corporation. The difference in composition between subsamples renders difficult the prediction of coal utilization parameters from the petrographic data.

Table 4 presents predicted coal utilization parameters for eight of the Yukon coal samples and measured values for the same parameters for six of these samples. The closest agreement between predicted and measured values for coal utilization parameters are yielded by samples PR-3 and PR-8, for which there is the closest agreement between CSIRO values for moisture and ash and the values for these analyses provided by the Cyprus Anvil Mining Corporation. Although some evidence of slight oxidation was observed in the low-rank coal samples, the discrepancies between predicted and measured values for coal utilization parameters appears to reflect a sampling problem rather than the influence of oxidation. Strong oxidation was observed in the semi-anthracite - anthracite samples, GC-1, PC-1 and PC-2 (see Plates 5c & 5d); however, the prediction of coal utilization parameters for coals with a reflectivity in excess of 2% is not possible with the graphical

solutions available. It is doubtful whether there is much value in attempting this exercise for coals that have undergone severe thermal alteration and which exhibit evidence of strong oxidation.

Figure 2, based on data presented by Bennett and Taylor (1970), Strauss *et al.* (1976) and Taylor and Shibaoka (1976), illustrates the petrographic data for the Yukon coal samples by comparison with that for Australian coals and their potential utilization. The high vitrinite Yukon coals, PR-3, PR-8 and FF-1 may have some application as potential feedstock for coal-oil conversion, although the rank of PR-3 is very low, i.e. high moisture and oxygen contents; the remaining coal samples can only be considered as thermal coals for electricity generation.

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TABLE 1. PETROGRAPHIC DATA FOR THE YUKON COAL SAMPLES

Sample Information			Maceral Analysis							Reflectivity Analysis	
Field identification	Laboratory number	Petrographic number	Vitrinite	Exinite	Resinite	Fusinite	Semifusinite	Micrinite	Mineral matter	Mean maximum reflectivity in oil at 546 nm	Bireflectance (\bar{R}_0 max. - \bar{R}_0 min)
DM-1	59503	29424	30	4	7	1	43	12	3	0.56	-
DM-2	59511	29432	18	5	1	2	62	11	1	0.58	-
DM-3	59513	29434	6	3	1	2	70	11	7	0.64	-
FF-1	59508	29429	83	2	5	trace	4	3	3	0.51	-
GC-1	59507	29428	3	-	-	3	90	3	1	2.71	0.97
JC-1	59506	29427	59	1	6	1	3	1	29	0.48	-
LP-1	59505	29426	Coked Coal (Natural coke)							6.20	1.47
PC-1	59504	29425	21	-	-	3	73	1	2	2.79	1.03
PC-2	59512	29433	82	-	-	-	16	-	2	3.10	0.97
PR-3	59502	29423	87	4	2	-	1	trace	6	0.29	-
PR-8	59510	29431	97	1	1	-	trace	trace	1	0.43	-
RR-1	59509	29430	6	-	-	2	86	5	1	1.98	0.59

TABLE 2. CORRECTION OF MACERAL ANALYSES TO A CALCULATED
MINERAL MATTER BASIS

Field identification	Laboratory number	Petrographic number	Air-dried moisture (wt. %)	Ash (wt. %)	Total sulphur (wt. %)	Calculated mineral matter (vol. %)	Vitrinite	Exinite	Inertinite	Total "Reactives"*	Total "Inerts"†
DM-1	59503	29424	11.5	12.6	0.28	8	29	10	53	39	61
DM-2	59511	29432	10.7	8.1	0.32	5	17	6	72	23	77
DM-3	59513	29434	8.4	15.3	0.26	9	6	4	81	10	90
FF-1	59508	29429	5.2	19.2	0.24	11	77	6	6	83	17
GC-1	59507	29428	9.9	13.6	0.60	8	3		89	3	91
JC-1	59506	29427	3.8	63.0	0.22	35	54	6	5	60	40
LP-1	59505	29426	3.4	4.6	0.15	3	Natural Coke				
PC-1	59504	29425	4.9	6.6	0.94	4	21		75	21	79
PC-2	59512	29433	3.3	6.5	1.04	4	80		16	80	20
PR-3	59502	29423	12.3	7.8	0.26	5	88	6	1	94	6
PR-8	59510	29431	11.6	4.4	0.22	3	95	2	-	97	3
RR-1	59509	29430	2.6	7.5	0.34	4	6		90	6	94

* "Reactives" = (vitrinite + exinite)%

† "Inerts" = (inertinite + mineral matter)%

TABLE 3. COMPARISON OF CHEMICAL ANALYSES

Sample Data			CSIRO Analyses			Analyses Provided by Cyprus Anvil Mining Corporation					
Field identification	Laboratory number	Petrographic number	Moisture %	Ash %	Total sulphur %	Moisture %	Ash %	Total sulphur %	Volatile matter %	Calorific value (Btu/lb)	British swelling index
DM-1	59503	29424	11.5	12.6	0.28	9.83	19.73	-	28.48	8100	0
DM-2	59511	29432	10.7	8.1	0.32	7.97	19.54	-	29.96	8500	0
DM-3	59513	29434	8.4	15.3	0.26	7.20	29.90	-	27.53	7390	0
PR-3	59502	29423	12.3	7.8	0.26	10.41	13.91	0.30	36.26	9070	-
PR-8	59510	29431	11.6	4.4	0.22	9.29	4.70	0.22	36.81	10740	-
RR-1	59509	29430	2.6	7.5	0.34	3.55	17.6	0.30	18.52	10940	-

TABLE 4. COMPARISON OF PREDICTED AND MEASURED VALUES FOR COAL UTILIZATION PARAMETERS FOR THE YUKON COAL SAMPLES

Sample Data			Petrographic Data		Predicted Values for Utilization Parameters				Measured Values for Utilization Parameters		
Field Identification	Laboratory number	Petrographic number	Coal rank \overline{R}_O max %	Coal type "reactives" %	Volatile matter % (d.a.f.)	Calorific value (Btu/lb) (d.m.m.f.)	British swelling index	Hydrogen % (d.a.f.)	Volatile matter % (d.a.f.)	Calorific value (Btu/lb) (d.m.m.f.)	British swelling index
DM-1	59503	29424	0.56	39	42	13600	-	5.1	40	11809*	0
DM-2	59511	29432	0.58	23	34	13800	-	4.7	41	12027*	0
DM-3	59513	29434	0.64	10	26	14100	-	4.5	44	12312*	0
FF-1	59508	29429	0.51	83	47	13400	2	6.1	-	-	-
JC-1	59506	29427	0.48	60	47	13200	-	5.6	-	-	-
PR-3	59502	29423	0.29	94	(56)	(12000)	-	-	52	12187	-
PR-8	59510	29431	0.43	97	51	12800	-	6.4	43	12542	-
RR-1	59509	29430	1.98	6	16	15400	-	< 4.2	24	14171	-

d.a.f. = dry ash free basis

d.m.m.f. = dry mineral matter free basis

$$\text{Volatile Matter (dry ash free)} = \frac{100(\text{Volatile Matter (air dried)})}{100 - (\text{Moisture} + \text{ash})}$$

The Queensland Coal Board (1972) employs the following equation to convert calorific value (air dried basis) to calorific value (d.m.m.f.).

$$\text{Calorific Value (d.m.m.f.)} = \frac{100 \left\{ \begin{array}{l} \text{Calorific Value} \\ \text{(air dried basis)} \end{array} - \begin{array}{l} 54 \text{ Sulphur} \\ \text{(pyritic)} \end{array} \right\} \text{Btu/lb}}{100 - (\text{Moisture} + 1.1 \text{ ash (air dried basis)})}$$

(* CSIRO total sulphur values were used to calculate the calorific value (d.m.m.f.) since the sulphur values were not made available for samples DM-1, DM-2 and DM-3).

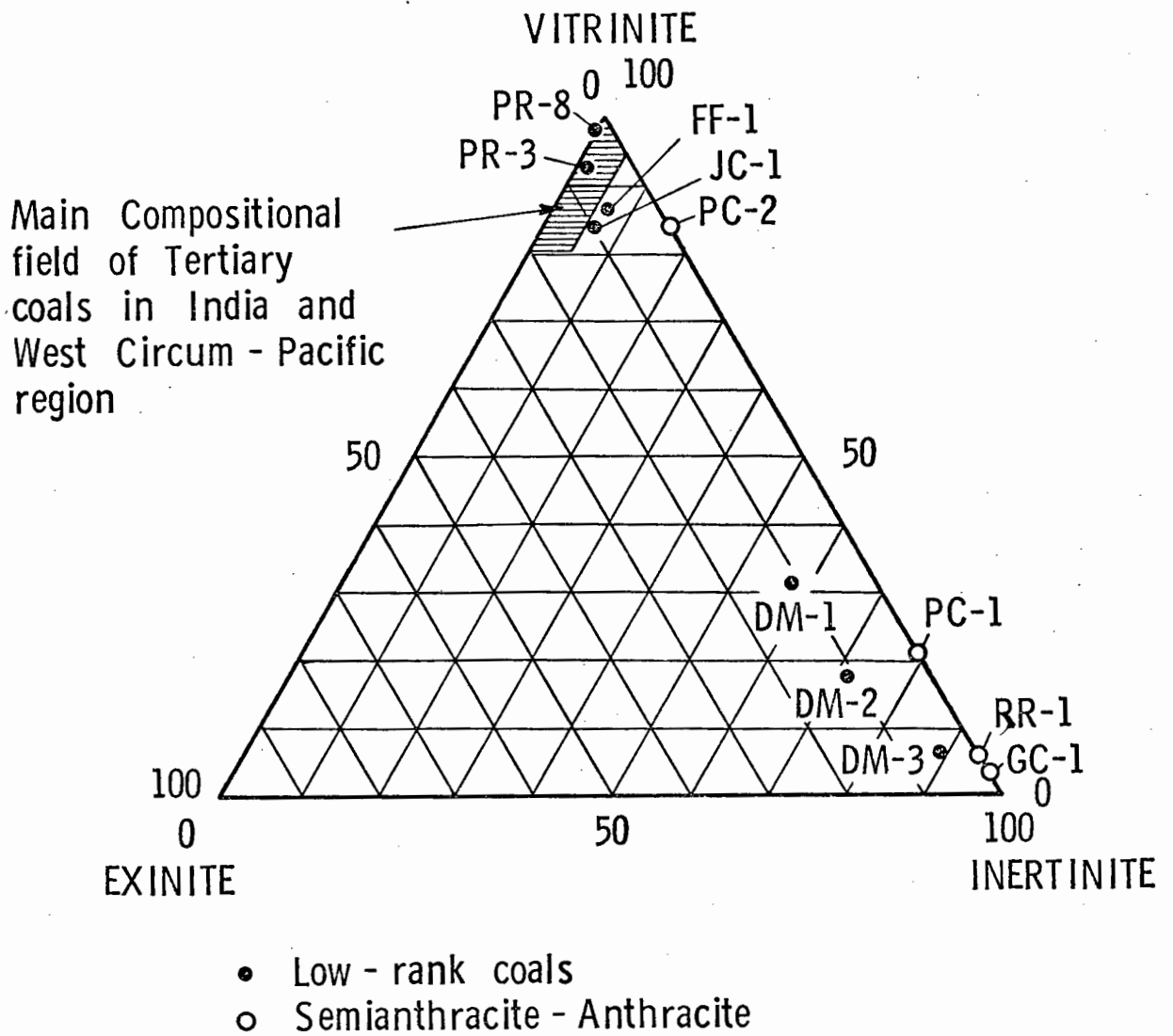


FIG. 1. PETROGRAPHIC COMPOSITION OF YUKON COAL SAMPLES

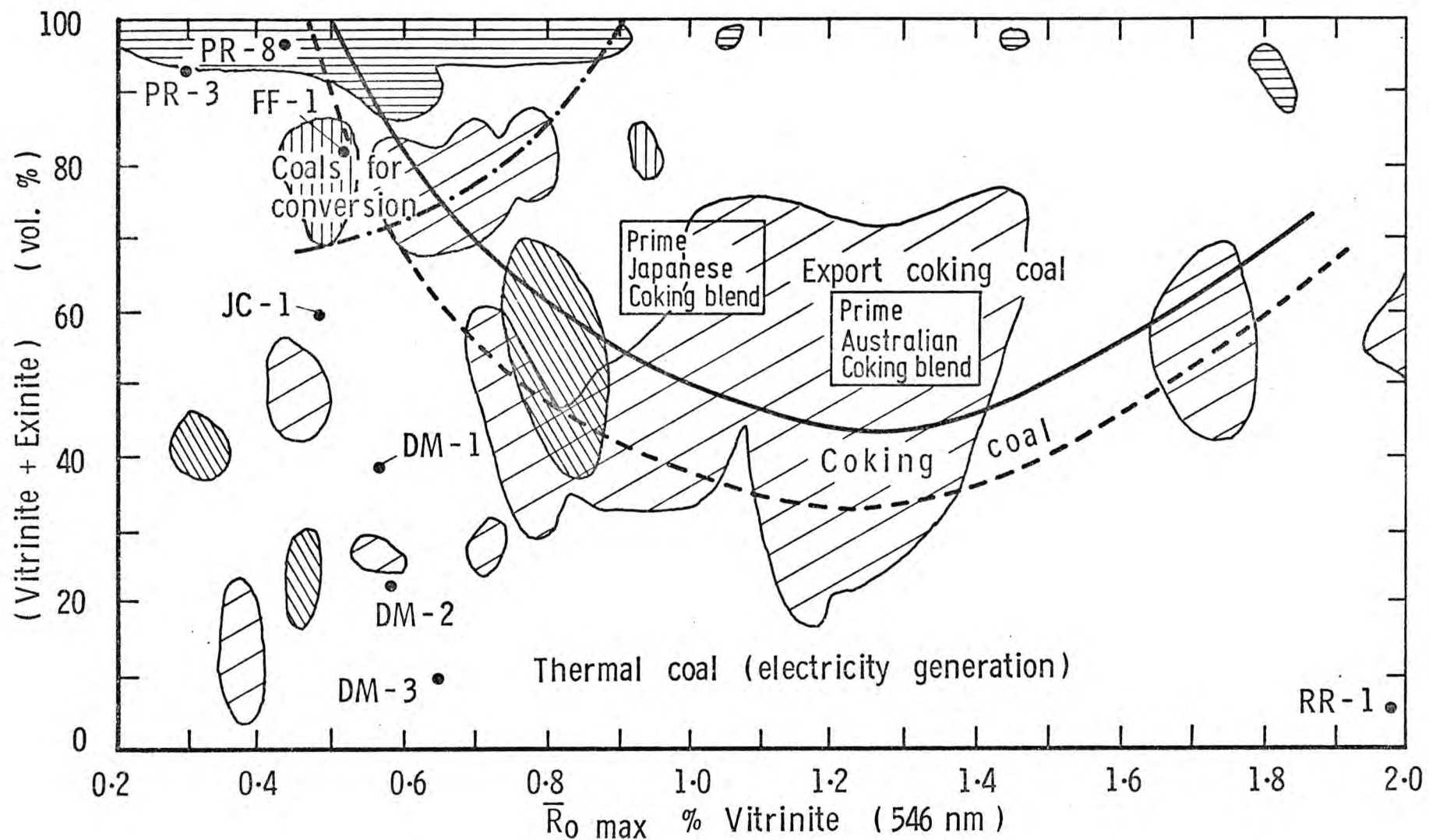


FIG.2. COMPARISON OF COAL PETROGRAPHY DATA OF THE YUKON COAL SAMPLES WITH THAT FOR AUSTRALIAN COALS AND THEIR POTENTIAL UTILIZATION

APPENDIX

DETAILS OF PETROGRAPHIC ANALYSES

PHOTOMICROGRAPHS

APPENDIX

VITRINITE RICH COALS:

PEEL RIVER SAMPLES:

	PR-3	PR-8
MACERAL ANALYSIS		
GROUNDMASS VITRINITE %	24	8
BAND VITRINITE %	3	79
RESINOUS (DARK) VITRINITE (NON-FLUORESCENT)	34	} 9
RESINOUS (DARK) VITRINITE (^a WEAKLY FLUORESCENT) %	17	
GELINITIC CELLS %	8	1
PORIGELINITE %	1	-
RESINOUS (DARK) VITRINITE CELLS %	trace	-
CORPOHUMINITE %	-	trace
TOTAL VITRINITE %	87	97
SPORINITE %	trace	1
CUTINITE %	-	-
RESINITE %	1	trace
SUBERINITE %	4	-
OTHER LIPTINITE/EXINITE %	^b 1	^c 1
TOTAL LIPTINITE/EXINITE %	6	2
FUSINITE %	-	-
SEMIFUSINITE %	1	trace
^d SCLEROTINITE %	trace	trace
TOTAL INERTINITE %	1	trace
QUARTZ %	-	-
CARBONATE %	-	trace
CLAY MINERAL %	5	1
SULPHIDE %	1	-
ALTERED IRON OXIDE %	-	trace
TOTAL MINERAL MATTER %	6	1
(VITRINITE + EXINITE) (m.m.f.) %	99	100
REFLECTIVITY DATA		
^e \bar{R}_0 max. %	0.29	0.43
Standard deviation \pm	0.07	0.03
Range of R_0 max % values	0.18 - 0.49	0.35 - 0.54
VITRINOID TYPES		
V ₁ %	6	-
V ₂ %	48	-
V ₃ %	39	4
V ₄ %	7	86
V ₅ %	-	10

APPENDIX

BLUE-LIGHT EXCITATION FLUORESCENCE OF LIPTINITE/EXINITE

FLUORESCENCE COLOURS	a PALE YELLOWISH GREEN TO YELLOW	YELLOW TO YELLOWISH ORANGE
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- a. Low-reflectivity (dark) vitrinite exhibits
a very weak pale brown fluorescence
- b. Principally exsudates (exsudatinite)
- c. Principally liptodetrinite
- d. Represented by characteristic fungal bodies, e.g. sclerotia,
teleutospores
- e. The reflectivity data may be subdivided as follows
- | | |
|---------------------------|----------------------------|
| resinous (dark) vitrinite | 0.23 ± 0.03 (0.18 - 0.30%) |
| vitrinite | 0.34 ± 0.05 (0.24 - 0.45%) |
| gelinitic cells | 0.34 ± 0.05 (0.27 - 0.49%) |

The resinous (dark) vitrinite component could be regarded as
a maceral transitional between vitrinite and liptinite/exinite,
in which case the vitrinite reflectivity value for sample DM-1
would be 0.34%.

APPENDIXJUMP OUT CREEK AND FIVE FINGERS SAMPLESVITRINITE-RICH COALS:JUMP OUT CREEK AND SAMPLES:

	JC-1	FF-1
MACERAL ANALYSIS		
GROUNDMASS VITRINITE %	trace	55
BAND VITRINITE %	40	20
VITRINITE PARTINGS IN CARBARGILLITE %	17	-
RESINOUS (DARK) VITRINITE %	2	8
TOTAL VITRINITE %	59	83
SPORINITE %	1	2
CUTINITE %	-	-
RESINITE %	trace	6
OTHER LIPTINITE/EXINITE %	a 6	b 1
TOTAL LIPTINITE/EXINITE %	7	7
FUSINITE %	1	trace
SEMIFUSINITE %	3	4
INERTODETRINITE %	1	2
MACRINITE %	-	1
FINE (GRANULAR) MICRINITE %	-	trace
SCLEROTINITE %	-	trace
TOTAL INERTINITE %	5	7
QUARTZ %	-	trace
CARBONATE %	-	trace
CLAY MINERAL %	29	3
SULPHIDE %	trace	-
ALTERED IRON OXIDE %	-	trace
TOTAL MINERAL MATTER %	29	3
(VITRINITE + EXINITE) (m.m.f.) %	93	93

REFLECTIVITY DATA

\bar{R}_0 max % VITRINITE	0.48	0.51
Standard deviation \pm	0.03	0.04
Range of R_0 max % values		
VITRINOID TYPES		
V ₄ %	74	30
V ₅ %	26	65
V ₆ %	-	5

BLUE-LIGHT EXCITATION FLUORESCENCE OF LIPTINITE/EXINITE

FLUORESCENCE COLOUR	PALE YELLOWISH GREEN TO YELLOW (FAINT BROWN)	YELLOW TO YELLOWISH ORANGE (ORANGE TO PALE BROWN)
---------------------	----------------------------------------------------	---------------------------------------------------------

- a. Principally yellowish-green fluorescent exsudatinite; minor amounts of weakly fluorescent bituminite. These macerals are concentrated in the clay mineral bands.
- b. Principally liptodetrinite and exsudatinite.

APPENDIX

VITRINITE-POOR COALS:

DIVISION MOUNTAIN SAMPLES

	DM-1	DM-2	DM-3
MACERAL ANALYSIS			
GROUNDMASS VITRINITE %	20	13	3
BAND VITRINITE %	7	3	3
RESINOUS VITRINITE %	3	2	-
TOTAL VITRINITE %	30	18	6
SPORINITE %	4	5	3
CUTINITE %	trace	trace	trace
RESINITE %	7	1	1
OTHER LIPTINITE/EXINITE %	trace	trace	trace
TOTAL LIPTINITE/EXINITE %	11	6	4
FUSINITE %	1	2	2
SEMIFUSINITE %	41	59	63
VERY LOW REFLECTIVITY SEMIFUSINITE %	2	3	7
INERTODETRINITE %	7	5	6
MACRINITE %	5	6	5
FINE (GRANULAR) MICRINITE %	trace	trace	trace
TOTAL INERTINITE %	56	75	83
QUARTZ %	trace	-	-
CARBONATE %	-	-	-
CLAY MINERAL %	2	1	7
SULPHIDE %	-	-	trace
FILTERED IRON OXIDE %	1	trace	trace
TOTAL MINERAL MATTER	3	1	7
(VITRINITE + EXINITE) (m.m.f.) %	42	24	11
REFLECTIVITY DATA			
\bar{R}_0 max % VITRINITE	0.56	0.58	0.64
Standard deviation \pm	0.05	0.04	0.05
Range of \bar{R}_0 max % values	0.41-0.70	0.47-0.72	0.55-0.79
VITRINOID TYPES			
V ₄ %	7	2	-
V ₅ %	73	69	21
V ₆ %	19	27	60
V ₇ %	1	2	19
BLUE-LIGHT EXCITATION FLUORESCENCE OF LIPTINITE/EXINITE			
FLUORESCENCE COLOURS	YELLOWISH-ORANGE TO ORANGE	ORANGE (YELLOWISH ORANGE)	ORANGE (YELLOWISH ORANGE)

HIGH RANK COALS:

	GC-1	PC-1	PC-2	RR-1
MACERAL ANALYSIS				
GROUNDMASS VITRINITE %	-	1	} 82	1
BAND VITRINITE %	3	20		5
TOTAL VITRINITE %	3	21	82	6
FUSINITE %	3	3	} 11	2
SEMIFUSINITE %	82	56		79
LOW REFLECTIVITY SEMIFUSINITE %	8	17	5	7
INERTODETRINITE %	2	trace	} trace	3
MACRINITE %	1	1		2
FINE (GRANULAR) MICRINITE %	-	-	-	trace
TOTAL INERTINITE %	96	77	16	93
QUARTZ %	-	-	-	-
CARBONATE %	-	-	trace	trace
CLAY MINERAL %	1	2	2	1
SULPHIDE %	-	-	-	trace
ALTERED IRON OXIDE %	-	trace	trace	-
TOTAL MINERAL MATTER %	1	2	2	1
(VITRINITE + EXINITE) (m.m.f.) %	3	21	84	6

REFLECTIVITY DATA

\bar{R}_O max % VITRINITE	2.71	2.79	3.10	1.98
Standard deviation \pm	0.10	0.09	0.09	0.08
Range of R_O max % values	2.53-2.98	2.67-2.96	2.95-3.25	1.79-2.19
Birefringence	0.97	1.03	0.97	0.59
VITRINOID TYPES				
V ₁₇ %	-	-	-	2
V ₁₈ %	-	-	-	10
V ₁₉ %	-	-	-	44
V ₂₀ %	-	-	-	34
V ₂₁ %	-	-	-	10
V ₂₅ %	12	-	-	-
V ₂₆ %	39	8	-	-
V ₂₇ %	35	51	-	-
V ₂₈ %	8	22	-	-
V ₂₉ %	6	19	15	-
V ₃₀ %	-	-	30	-
V ₃₁ %	-	-	43	-
V ₃₂ %	-	-	12	-

PLATESPLATE ISAMPLE PR-3

- 1a Dark humotelinite (texto-ulminite A transitional to eu-ulminite A) (medium grey) containing dark, resin-filled cell lumens (black) and light corpohuminite (eu-gelinite? cells) (pale grey) (x 500, incident white light, oil immersion)
- 1b As above. Bright fluorescing resin-filled cells, weakly-fluorescent humotelinite and non-fluorescent corpohuminite (gelinitic cells) (x 500, incident, blue-light excitation, oil immersion)
- 1c Suberinite (dark cell-wall tissue), containing corpoluminite (eu-gelinite?) and porigelinite filled cell lumens, associated with humotelinite (eu-ulminite) (x 500, incident, white light, oil immersion)
- 1d As above, bright fluorescing suberinite; non-fluorescent huminite (x 500, incident, blue-light excitation, oil immersion)

PLATE IISAMPLE PR-3

- 2a Humodetrinite (densinite) groundmass containing fungal bodies (multicellular sclerotium and single-celled teleutospores) and inertinite (lower part of photomicrograph) and dark liptinite/exinite and mineral matter (x 500, incident white light, oil immersion)
- 2b As above, brightly fluorescent sporinite and weakly fluorescent suberinite (upper left) and liptodetrinite. Mineral matter is non fluorescent in this photo-micrograph (x 500, incident, blue-light excitation, oil immersion)
- 2c Teleutospores (sclerotinite) in a humodetrinite groundmass. These fungal spores are typical of uppermost Cretaceous (Senonian) and Tertiary coals (x 500, incident white light, oil immersion)

SAMPLE PR-8

- 2d Details of botanical structure in vitrinite (x 500, incident white light, oil immersion)

PLATE IIISAMPLE DM-1

- 3a Semifusinite associated with dark liptinite/exinite or mineral matter (?)
(x 500, incident white light, oil immersion)
- 3b As above, fluorescence behaviour indicates low reflectivity material is liptinite/exinite (resinite)
(x 500, incident, blue-light excitation, oil immersion)
- 3c Narrow band of vitrinite (grey) associated with semifusinite, which is typical of this inertinite-rich coal
(x 500, incident white light, oil immersion)
- 3d Brightly fluorescent cutinite in vitrinite (dark)
(x 500, incident, blue-light excitation, oil immersion)

PLATE IVSAMPLE PC-1

- 4a Vitrinite and semifusinite (cell structure clearly defined)
(x 500, incident white light, oil immersion)
- 4b As above, semifusinite exhibits granular (undulose) anisotropy by comparison with even extinction of vitrinite
(x 500, incident white light, oil immersion, x polarizers)
- 4c Vitrinite, exhibiting oxidation fissures, and semifusinite
(x 200, incident white light, oil immersion)
- 4d As above, granular anisotropy serves to distinguish vitrinite from semifusinite with a similar reflectivity
(x 200, incident white light, oil immersion, x polarizers)

PLATE V

SAMPLE LP-1

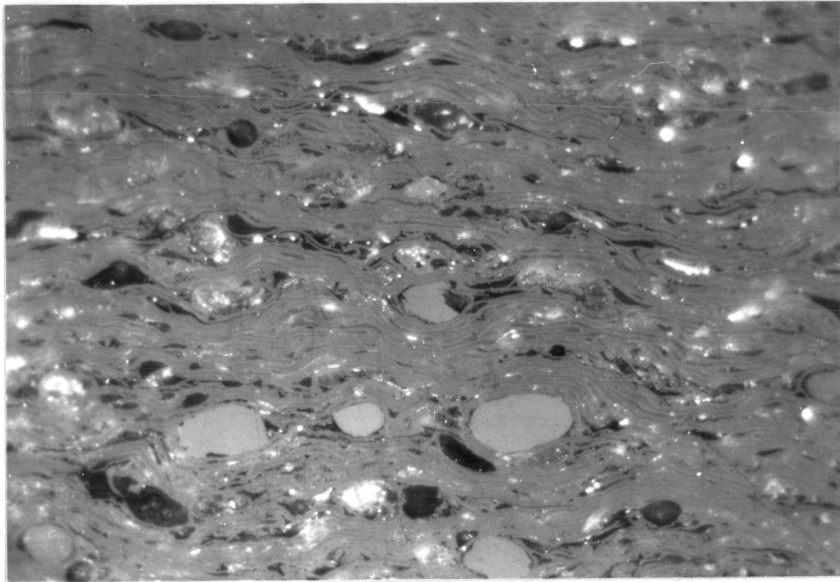
- 5a Vesicle structure in coked coal. Note thick coke walls
(x 500, incident white light, oil immersion)
- 5b As above. Fine grained anisotropic mosaic structure
(x 500, incident white light, oil immersion × polarizers)

SAMPLE PC-1

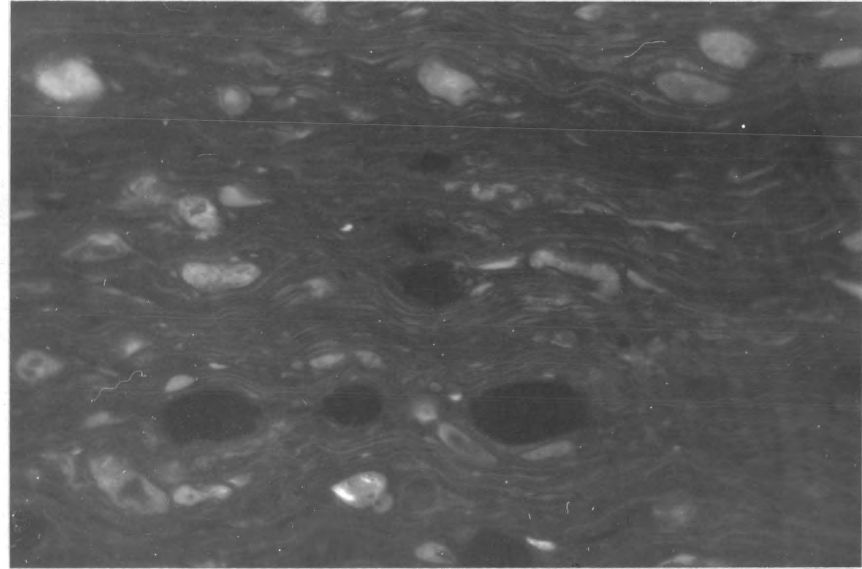
- 5c Oxidation cracks and associated lowering of reflectivity in
vitrinite in semianthracite-anthracite
(x 500, incident white light, oil immersion)

SAMPLE PC-2

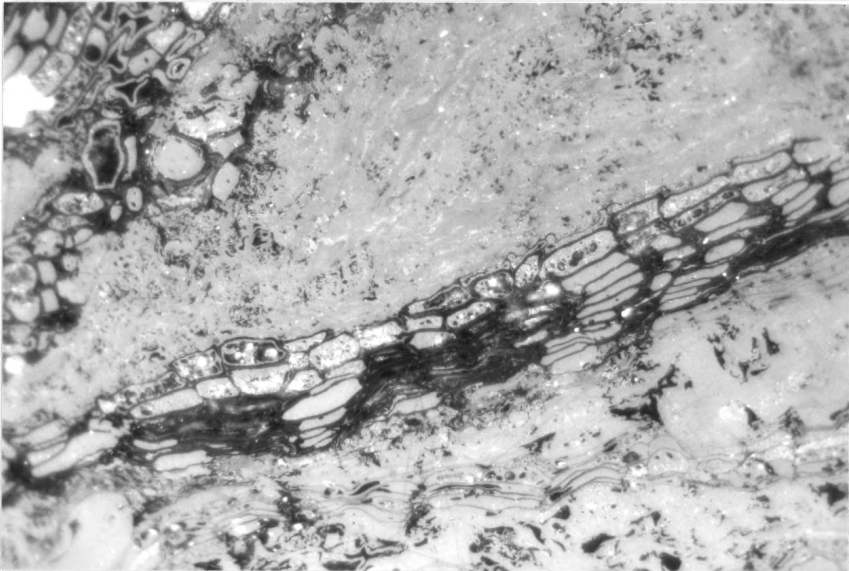
- 5d Oxidation cracks and low reflectivity margins in
semianthracite-anthracite vitrinite
(x 500, incident white light, oil immersion)



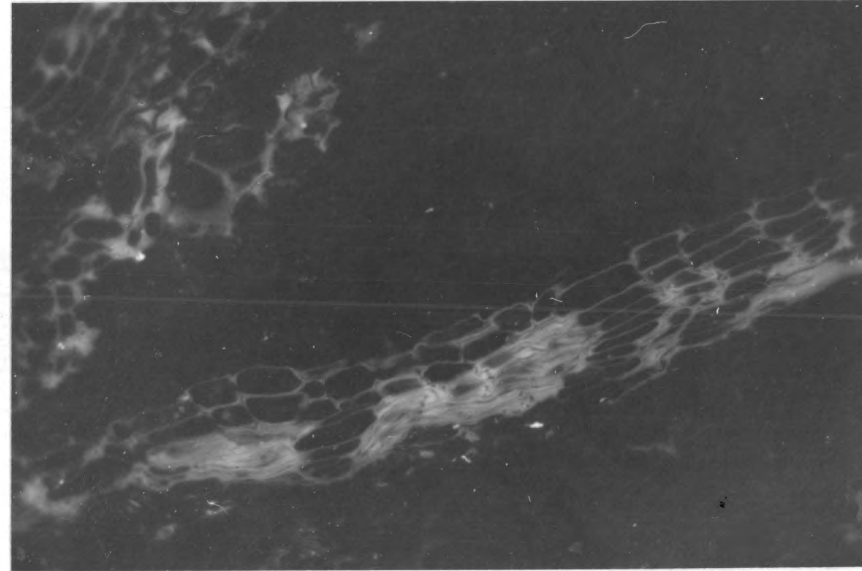
Ia



Ib



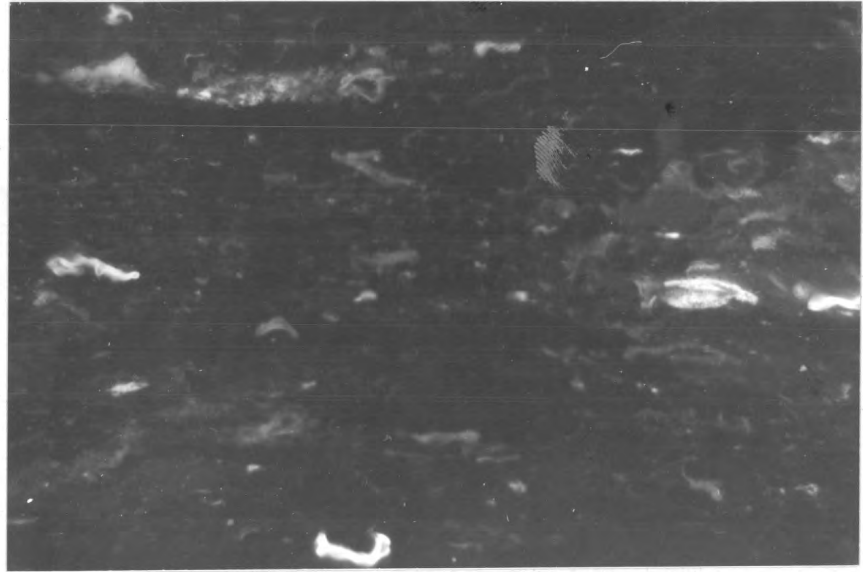
Ic



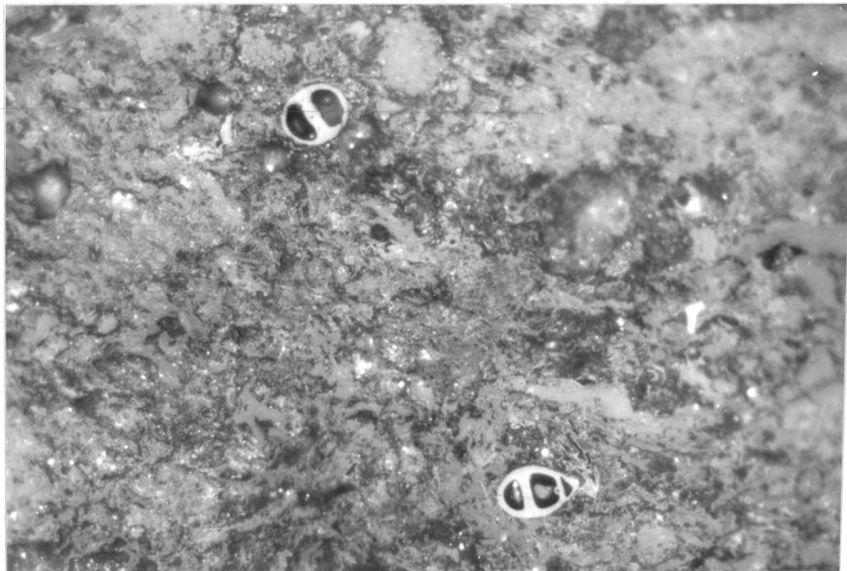
Id



IIa



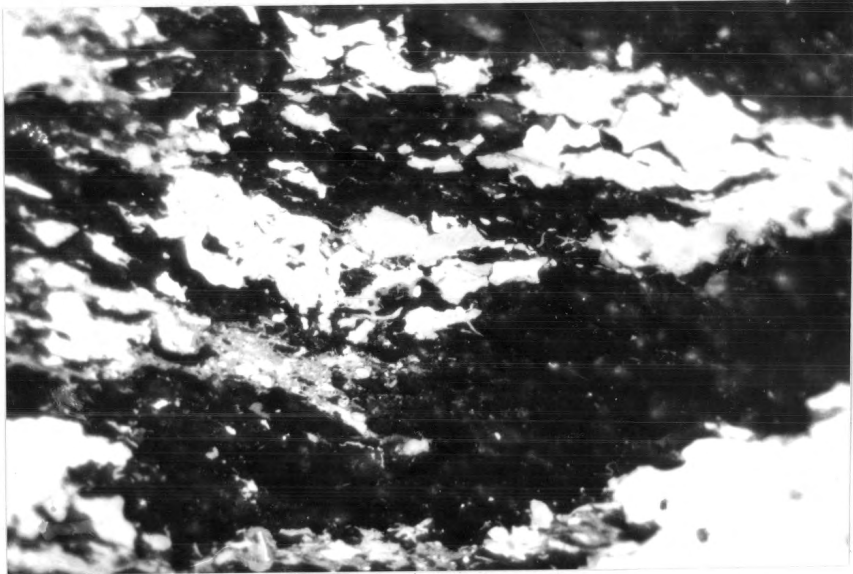
IIb



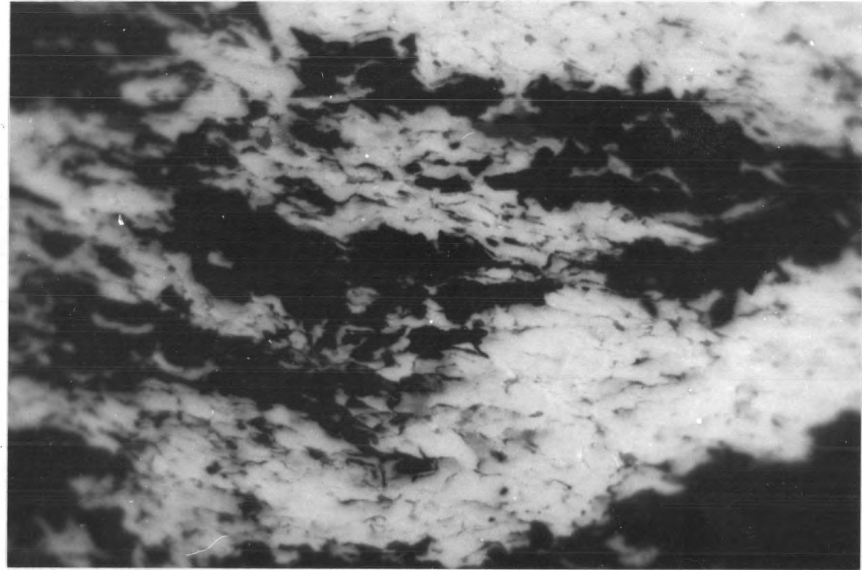
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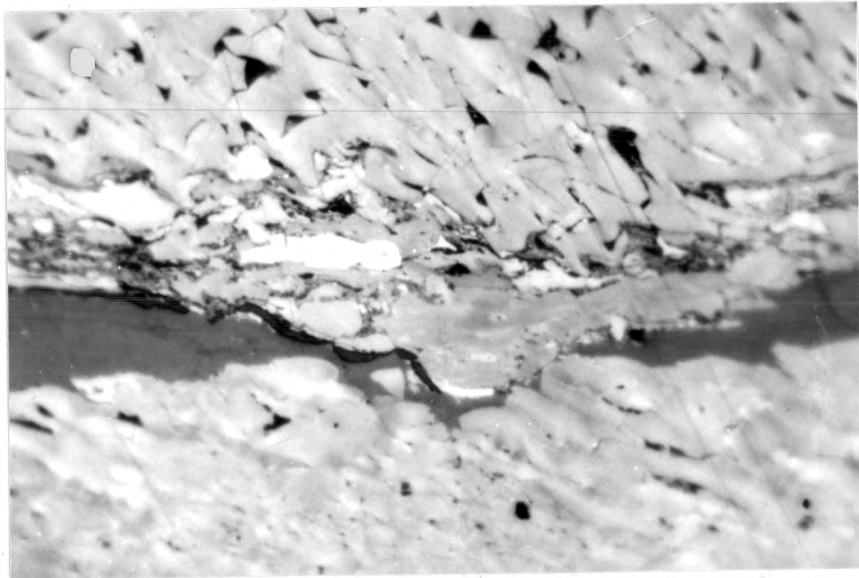
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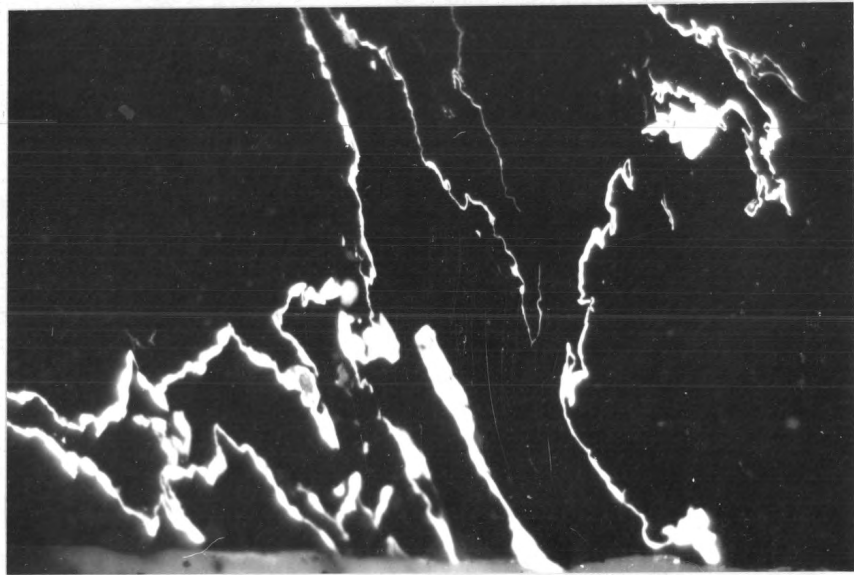
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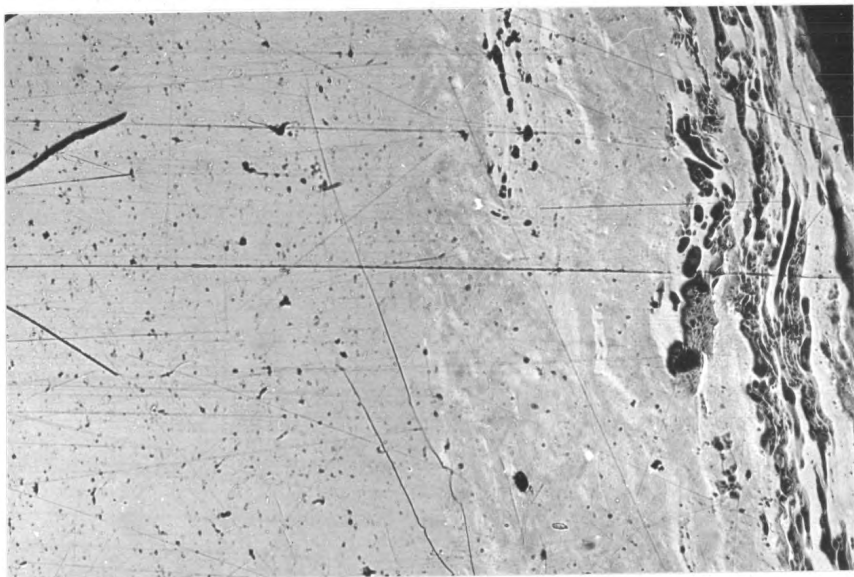
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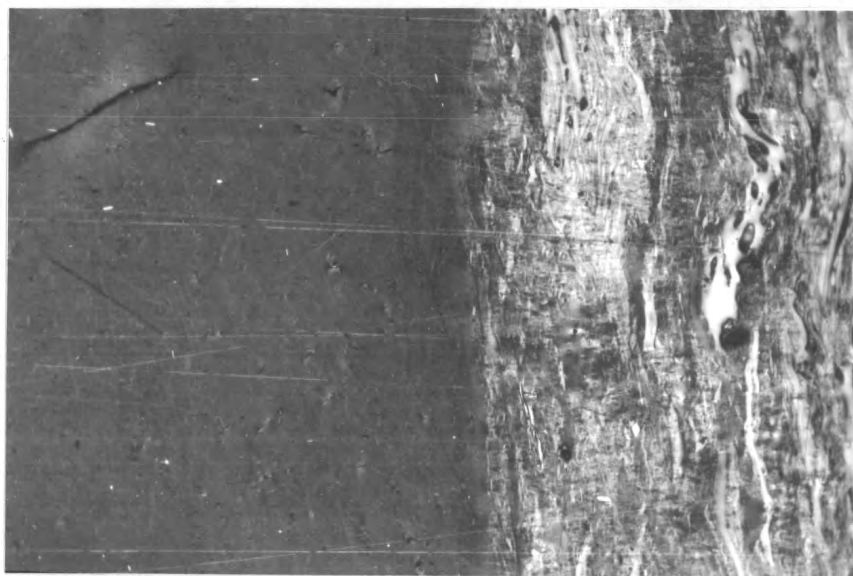
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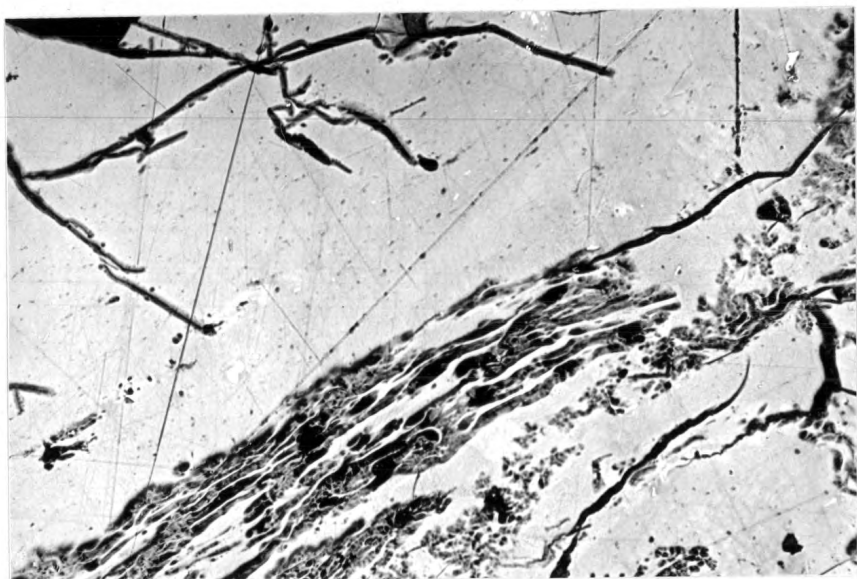
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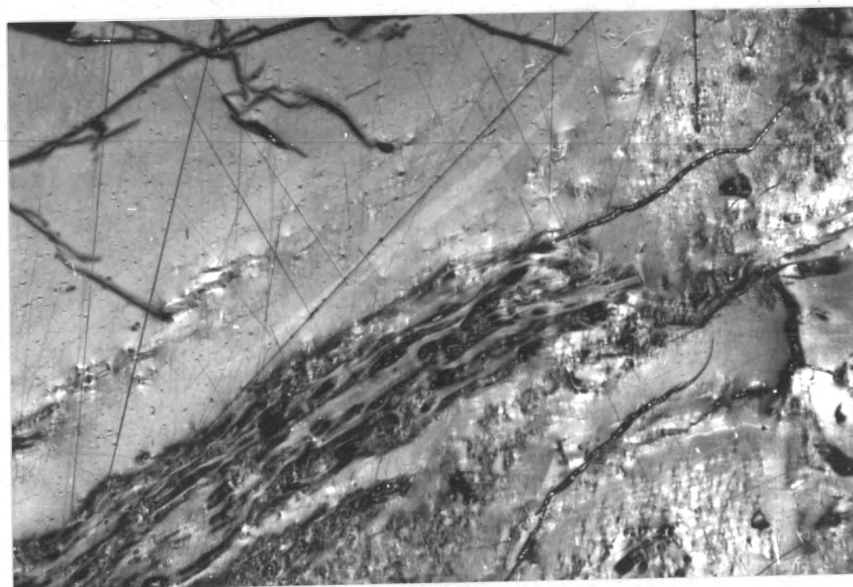
IVa



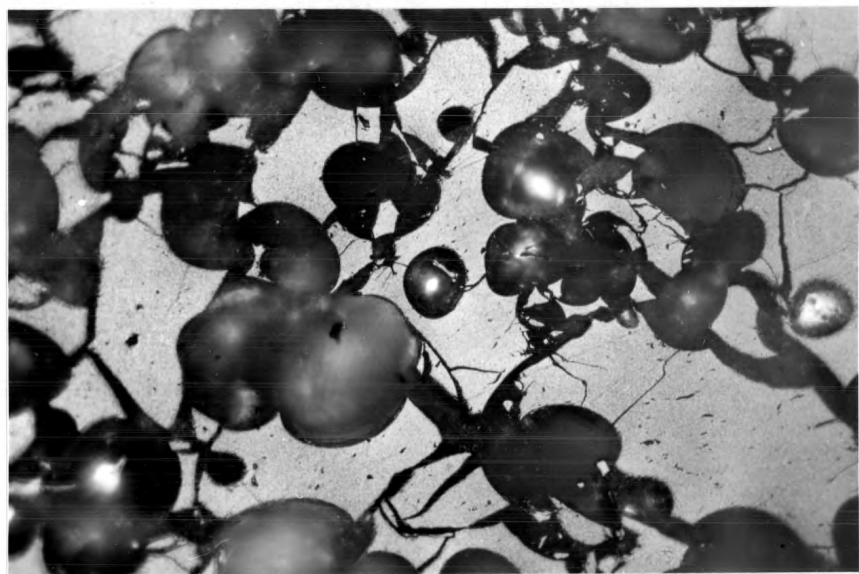
IVb



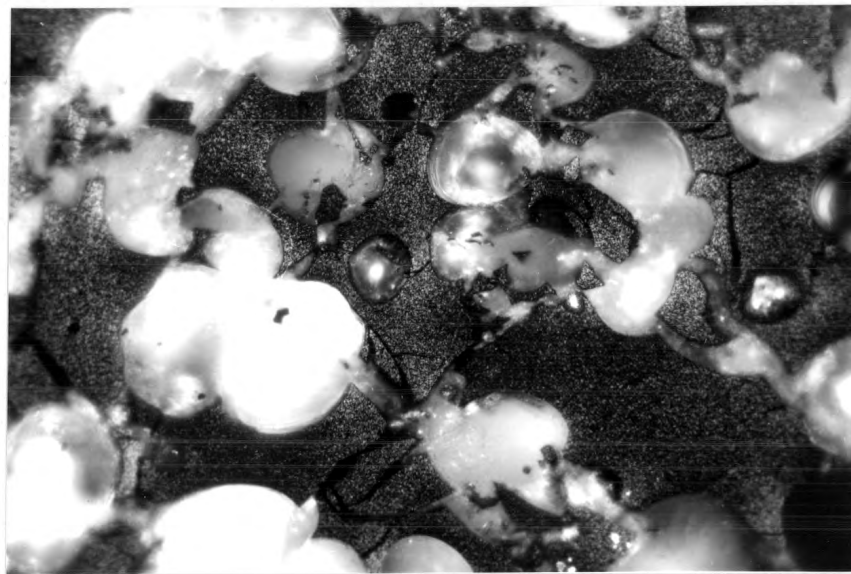
IVc



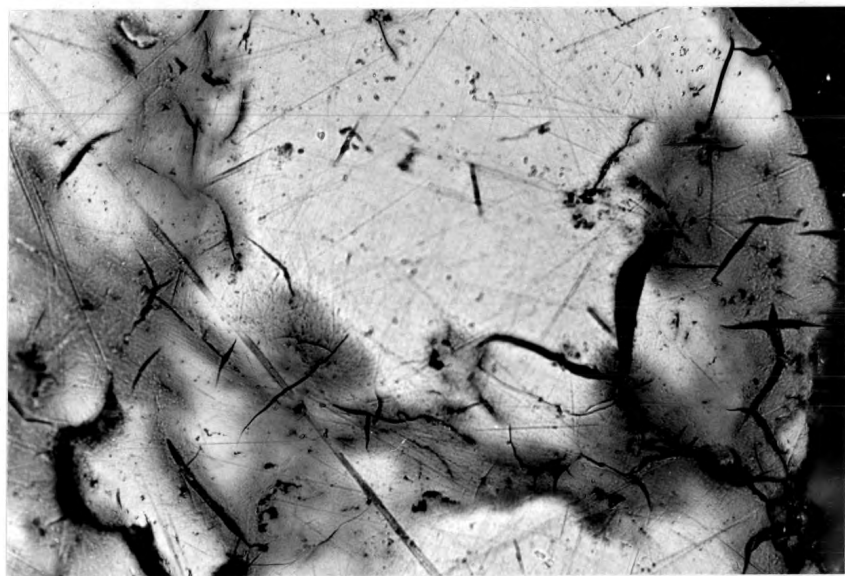
IVd



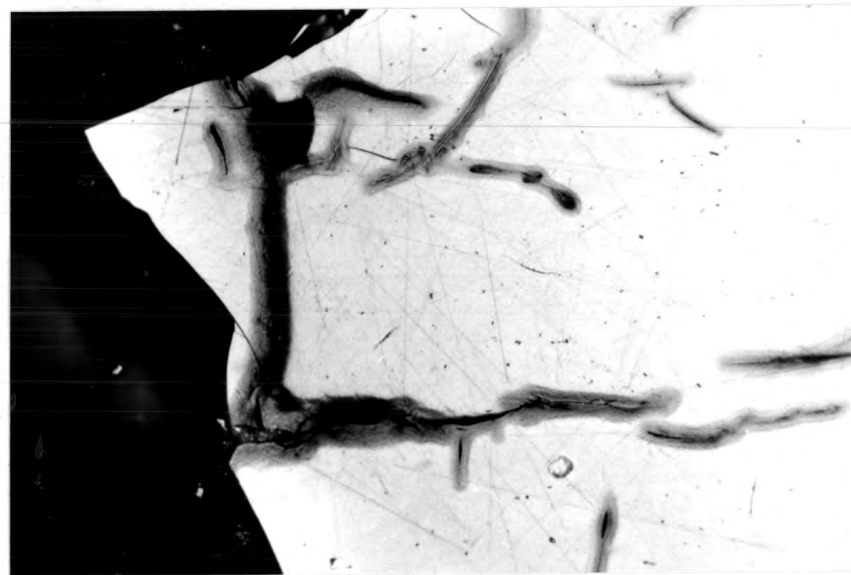
Va



Vb



Vc



Vd