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RESEARCH ON TASMANITE OIL SHALE

- Second Quarterly Report to Endeavour Resources Limited

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SUMMARY

1. Research on the Tasmanite concentrate in IR 991R has been extended in this report to include new petrological, chemical and trace element data on cores from China Flat and Sassafras.

2. The inorganic minerals present in the Tasmanite shale are quartz, muscovite, kaolinite/chlorite, dolomite, magnesium calcite, gypsum, pyrite and feldspar.

3. The macroscopic appearance (e.g. fissility) of the cores supplied varies greatly and is associated with the degree of layering of the Tasmanites.

4. The volume percentage of Tasmanites in the cores ranges up to 53% (c.f. 84% in the concentrate) and appears to be directly related to the oil or tar yield on pyrolysis.

5. Scanning electron microscope and electron microprobe analyser work shows that 4-5% organic sulfur is evenly distributed throughout each algal body.

6. Chemical analyses on relatively rich samples highlight the low organic content of the bulk of the material in the China Flat and Sassafras areas.

7. Sieving of crushed material gives an increased organic concentration in the -150 +200 mesh fraction but the beneficiation achieved is inadequate for most practical applications.

8. The trace element content of the shale and its ash shows no unusual features when compared with other coals, shales and soils.

9. Research is in progress or planned in the following areas:

(a) hydrogenation of tasmanite with a chemical and microscopic examination of the gaseous, liquid and solid products

(b) flash pyrolysis of Tasmanite

(c) comparison of Fischer and Gray-King oil yields from Tasmanite

(d) isolation and characterization of Tasmanite kerogen

(e) upgrading of Tasmanite by flotation.

Results of these and other studies will be included in later reports.

1. INTRODUCTION

This is the second quarterly report for Endeavour Resources Limited on the Tasmanite Oil Shale Project. It contains the details of work completed since the first report in January 1979 (IR 991R).

Eight bore cores from the Sassafras and China Flat areas were sent to CSIRO Institute of Earth Resources by the Tasmanian Department of Mines for analysis. Further work has also been done on the tasmanite concentrate received from Endeavour Resources last year.

Microscopic examinations (section 3) have been carried out on the core samples to typify this material, and to add to our observations about the character of the algal matter itself. This included qualitative analyses using the scanning electron microscope and the electron microprobe analyser to locate accurately the sulfur in the oil shale.

The above samples, i.e. bore cores, are much more appropriate for a comprehensive study of the oil shales than those four samples previously reteived. The quantity in each of the latter samples was too small for the full range of tests to be carried out.

Chemical analyses have been carried out on the samples used in the petrological work and the results are discussed in section 4. The basic data so far obtained will form the basis for our future research on pyrolysis, hydrogenation, beneficiation and utilization of Tasmanite. Section 4 also contains a discussion of trace elements in Tasmanite.

2. SAMPLES

BORE CORES

The bore cores were received in December 1978. They consisted of half and quarter cores, very few pieces having marked depths, apart from the depth intervals on the bags containing them. The cores were arranged according to information in the Mayhew Drilling Report of 1975; it is assumed that these are the drill cores referred to in that report. Where it was not possible to follow the report, the three broad categories of mudstone, pebbly mudstone, and Tasmanite-bearing shale were used to arrange the cores. Of the eight bores and twelve intervals received, all the bores contained some tasmanite shale, but this was restricted to nine intervals.

For this report, analyses have been concentrated on the Tasmanite-bearing material from these cores, focusing attention first on the economically important part of the cores. Work will follow on the complete bore intersections. (For sample details see Appendix 1.)

METHODS

Tasmanite-rich pieces were chosen from each core for thin-sectioning.

Two solid blocks, an inch in diameter from two cores were set in a cold-setting plastic, coated with carbon for use in the scanning electron microscope and electron microprobe*. X-ray diffraction was carried out on the crushed powder of the above two samples to determine the mineralogy of the rock.

The remainder of each sample was crushed to -1.5 mm and a representative fraction taken for petrographic analyses. The point-counting method of analysis was used in reflected light with an air lens. This method gives a semi-quantitative analysis of the tasmanite percentages in the rock, by volume.

3. PETROLOGY, SCANNING ELECTRON MICROSCOPE AND ELECTRON MICROPROBE ANALYSES

PETROLOGY OF THE THIN SECTIONS

The mineralogy in these samples is very similar to that already noted in the first quarterly report (IR 991R). However the actual form and texture of the material differs from sample to sample. Fissility varies from being very obvious (where the algal bodies are banded) to absent. Megascopically the oil shale is banded to massive.

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* For methodology see:
Hearle J.W.S. et al. - The Use of the Scanning Electron Microscope, 1972.
Andersen C.A. - Microprobe Analysis, 1973.

The quantities and distribution of the Tasmanites in the samples vary not only between cores but also within the same drilling interval. This variation will influence the yield of hydrocarbons. (See Appendix 2 for descriptions of thin sections.)

PETROLOGY OF GRAIN MOUNTS

An estimation of volume percentage of Tasmanites in the different cores is given in Table 1. A detailed description of the minerals counted was given in report IR 991R.

Again the large variation in algal body content is apparent, confirming that variations of the Tasmanites in the shale beds occur frequently both vertically and horizontally. This heterogeneity provides a measure of the likely variation in oil yield from shale as it would be mined.

It has been found (see Figure 15) that an approximate estimate of product yield may be forecast from a knowledge of the proportion of Tasmanites in a particular sample. The points on Fig. 15 are based on CSIRO determinations of volume percentages of Tasmanites plotted against the oil yield in gallons per ton. The oil yield figures were obtained from the Mayhew Drilling Program results found in F.L. Hunt's Feasibility Study, 1975. Details of these figures are found in Table 2 of this report. The ability to forecast possible yields from Tasmanites volume percentages will be helpful in assessing the economics of mining and processing a particular shale body.

SCANNING ELECTRON MICROSCOPE AND ELECTRON MICROPROBE ANALYSES

An analysis of the distribution of the three elements, sulfur, iron and silica within the oil shale was carried out on a scanning electron microscope (S.E.M.) and an electron microprobe analyser (E.M.A.). This was done to determine whether the sulfur was in the algal bodies or not, whether it is in organic or inorganic form, and its overall distribution.

Two different rock samples were used. One was cut along the bedding plane, so exposing complete algal body surfaces, Bore No. 27, Interval 21'2" - 26'7" (6.5 - 8.1 metres) (LN 78643). The other sample was cut normal to the bedding planes revealing a cross-section of the algal bodies, Bore No. 13B, Interval 70'8½" - 75'10" (21.6 - 23.1 metres) (LN 78644).

Figures 1 to 3 show an S.E.M. scan of sample LN 78643. A complete Tasmanites body, surrounded by the matrix is in Figure 1. Figure 2 shows a sulfur map trace, in dot form. The major sulfur concentration is within the algal body (located centrally in the picture). Figure 3 shows an iron map trace over the same area as Figures 1 and 2. This shows that very little iron coincides with the sulfur in the algal body, a good indication that the sulfur is organic within the bodies. By way of contrast, some of the most concentrated areas of sulfur in the matrix overlap with concentrated areas of iron. This indicates that this sulfur is most likely inorganic, in the form of pyrite.

To confirm these results the two samples were analysed in an electron microprobe, which is even more sensitive to elemental distributions than the S.E.M.

Figures 4 to 8 deal with sample LN 78643. Figure 4 shows the whole algal body. In Figure 5 a sulfur map scan again shows a concentration of the sulfur throughout the algal body with an even distribution. The next photograph shows a vertical profile trace of the sulfur from the top to the bottom of the body. The first two large peaks are pyrite peaks, coming down to a plateau-like area above the baseline corresponding to the algal body. [See explanatory diagram, Figure 6(a)]. Figure 7 shows an iron map scan, with very little iron in the algal body. Figure 8 is a vertical profile trace showing the iron concentration, which is again minimal over the algal body area. [See explanatory diagram, Figure 8(a)].

Figures 9 to 14 are of sample LN 78644, which is a cross-section of a Tasmanites body. Figure 9 shows the cross-section of the particular algal body, which appears as the dark line down the centre of the photograph. Figure 10 is a silica trace, showing that, while there is little or no silica in the Tasmanites, it is very widespread throughout the matrix. Figure 11 is a sulfur map scan of the same body, showing the high level of concentration and even distribution of sulfur in the algal body. The next figure, Figure 12, shows a horizontal profile trace across the matrix, giving a large sulfur peak, and then another one where the profile crosses the algal body (with a plateau top). [Explanatory diagram, Figure 12(a)].

Figure 13 is the iron map scan, again showing little iron in the algal tody, but with major concentrations coinciding in most cases with the major concentrations of sulfur in the matrix (pyrite), (the white masses in Fig. 13). The other concentrations which are not pyrites are most likely to be iron silicates or oxides. Figure 14 is the iron profile trace of this area. [Explanatory diagram, Figure 14(a)].

A spot analysis of the sulfur in three algal bodies, randomly chosen from each sample is also included [Table 3]. Three points in each body were chosen and a weight percentage of sulfur at each analysis point was obtained by comparison with a pyrite standard. From these a mean content of sulfur for the entire body was obtained. It appears from these analyses that there is very little difference in sulfur concentration through each algal body, and all three bodies are similar to one another in both samples.

The conclusion reached from these analyses is that the sulfur appears to be concentrated within the Tasmanites bodies, is organic in nature and is well distributed throughout the bodies with no areas of preferential concentration. There is generally a consistent weight percentage both in the individual algal bodies and amongst all the algal bodies.

The results of X-ray diffraction analyses of these two samples is summarized in Table 4; this gives the mineral composition of the matrix.

4. CHEMICAL ANALYSIS OF TASMANITE-RICH SAMPLES

Some of the spore-rich samples used in the petrological work have been chemically analysed. Six samples from the China Flat area and ten samples from the Sassafras area were crushed and ground and then analysed to give the data in Tables 5-7. Details of bore numbers and sample depths are given in Appendix 1. Comparable data on an air-dried basis for the flotation concentrate supplied earlier by Endeavour Resources (LN 77591) are moisture 3.5%, ash 32.6%, volatile matter 60.2% and fixed carbon 3.7%. The following comments can be made on the data in Tables 5-7.

(i) The moisture content of all samples is low and this is a favourable factor from the point of view of most types of utilization. No clear relationship between organic/inorganic ratios and moisture content appears to exist.

(ii) Despite the fact that all these samples were chosen because of their richness in Tasmanites, the ash contents are all quite high. This reinforces the need for research into the most effective means of concentrating tasmanite.

(iii) The measured volatile matter shows the expected inverse relation with ash. With the exception of the concentrate (LN 77591), the sum of volatile matter and ash falls in the range 99±2% for all samples.

(iv) The carbon values represent total carbon and hence include a small contribution from carbonates such as dolomite (see Table 4). The hydrogen results for such clay-rich samples are likely to be a little high due to water in the clays. This is confirmed by atomic H/C ratios which tend to be higher than that for mineral-free tasmanite kerogen (∿1.5).

(v) The uniform and relatively high sulfur values confirm that sulfur will be a problem in any utilization scheme leading to a petrochemical-type product. A major proportion of the sulfur is organically bound and uniformly distributed throughout algal bodies (see Section 3). There may be some hope of removing the minor amounts of sulfur present as pyrite, anhydrite or gypsum during beneficiation.

(vi) One sample from each area (LN 78614 from China Flat and LN 78615 from Sassafras) was crushed and hand-sieved to give a -200 mesh sample and a +200 mesh sample. Analyses on these samples (Table 7) show that, although the +200 mesh product is richer than the original, simple sieving is unlikely to be a suitable upgrading procedure. From the weights of each fraction, calculated values for the original total samples (which were not analysed) can be obtained:

78716(a) (20.4 g, 40.3% VM, 55.7% ash) 78716(b) (74.0 g, 16.3% VM, 79.4% ash)	21.5% VM, 74.3% ash (calculated values for LN 78614)
78717(a) (38.0 g, 39.5% VM, 58.1% ash) 78717(b) (149.0 g, 22.1% VM, 76.1% ash)	25.6% VM, 72.4% ash (calculated values for LN 78615)

TRACE ELEMENTS IN TASMANITE

The following six samples were chosen from those used in the petrological and chemical work and were analysed by emission spectroscopy to determine their trace element contents:

Area	Sample	Ash (%)
China Flat	LN 78614 (whole sample)	76.3
	LN 78716(a) (-150 +200 mesh from 78614)	56.6
	LN 78716(b) (-200 mesh from 78614)	81.9
Sassafras	LN 78615 (whole sample)	73.9
	LN 78717(a) (-150 +200 mesh from 78615)	60.7
	LN 78717(b) (-200 mesh from 78615)	79.5

The ash values given above were obtained by ashing one gram of air-dried material in a silica dish at 450°C for 16 hours and agree well with results calculated above and in Table 7.

Measurements were carried out on a Hilger Large Quartz Spectrograph (E 492) using a D.C. open arc in the spectral region 248-360 nm. Samples were prepared for arcing in two ways:

(a) The ashed material was added to a graphite/LiF buffer in the ratio, ash : LiF : graphite, 20 : 1 : 59. 12 mg of ash were weighed into a 13 x 25 mm polystyrene vial containing a 3 mm diam. methacrylate ball, together with 36 mg of the buffer. The vial was capped and the materials mixed using a Wig-L-Bug amalgamator. 40 mg of the mixture were firmly tamped into the 105-D type electrode, using an aluminium rod. The electrode was then placed in an air oven at 110°C until required for arcing. The samples were arced to completion.

(b) Approximately 30 mg of ashed sample were mixed with an equal amount of buffer, consisting of Al_2O_3 : $CaCO_3$: K_2CO_3 in the ratio 14 : 6 : 3. Mixing was performed using the Wig-L-Bug amalgamator. 50 mg of the mixture were transferred to a U2-1672 electrode, which was placed in an air oven at 110°C until arced. Arcing was restricted to 40 sec. so that the spectra of the volatile elements were preferentially recorded.

Values of the trace-element contents of the samples were estimated visually, using a Judd-Levis comparator, against standards prepared by adding elements (mainly as oxides) to a suitable base. A 1% mixture in base is first prepared and then successively diluted with the base to give standards down to 0.1 ppm.

DISCUSSION OF RESULTS

The results for the 2 size fractions and for the whole shale sample are given in Table 8 on an ash basis and in Table 9 on a whole shale basis. There are only minor differences between the two samples and between the fractions, except for the higher manganese in sample 78615, on an ash basis. When the results are expressed on the whole-shale basis, there are slightly lower contents for some elements in the -150 +200 mesh fractions, and manganese is higher in sample 78615.

It is interesting to compare the results (Table 10) for the whole shale, with the mean for shale (calculated by Turekian and Wedepohl, 1961), bituminous coal (Swaine, 1977a) and soil (Swaine, 1955). Several elements, for example boron, beryllium, copper, gallium, lead, tin and zinc, are in concentrations similar to those in shale, coal and soil. Manganese is at the low end of the range for soil and lower than the shale. Chromium contents are slightly higher than the shale and coal, but within the range for soil. Molybdenum is at the high end of the ranges for coal and soil and higher than the shale. Vanadium is higher than in coal, but within the range for soil and close to the shale. These results indicate that the trace element contents in the tasmanite samples are mostly similar to those in related earth materials.

In consideration of the disposal of shale ash it is helpful to compare results on an ash basis with the shale (mean), fly-ash and soil (Table 11). Similar trends are seen to those discussed above. The slightly higher chromium and molybdenum should not give rise to plant problems if the spent ash was put on soil. However, if fodder plants were grown on such areas, it would be wise to check molybdenum levels in the plants, especially if the soil pH was above 6.5-7, to ensure that untoward effects would not occur with the ingestion of the plants by animals. Boron could possibly affect some plants, but this depends on solubility which may well be low in the spent shale. There are generally low levels of several elements of environmental interest.

5. REFERENCES

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6. ACKNOWLEDGEMENTS

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TABLE 1. PETROGRAHIC ANALYSES OF TASMANITE SAMPLES

(Results are given as percentages by volume*.)

Bore, Interval	Lab. No.	Tasmanites	Other Organic Material	Clay	Carbon-ate	Pyrite	Quartz	Sphal-erite	Total No. of counts
Kerogen concentrate	77591	84	Tr	12	Tr	Tr	4	-	464
Bore No. 7,23'-25'6"(7-7.8m)	78691	22	1	52	2	2	20	1	519
Bore No. 8,27'10"-33'10"(8.5-10.3m)	78616	30	Tr	51	1	3	15	Tr	545
" " " " " "	78692	53	Tr	31	1	1	14	Tr	526
Bore 11B,4'6"-7'2"(1.4-2.2m)	78614	26	Tr	52	1	2	19	Tr	650
" " " " "	†78716(a)	19	Tr	56	1	2	22	Tr	554
" " " " "	†78716(b)	5	1	45	2	2	45	Tr	569
Bore No. 13B,70'8½"-75'10"(21.6-23.1m)	78693	32	1	45	2	2	18	Tr	558
" " " " " "	78694	35	Tr	46	2	2	14	1	601
" " " " " "	78695	22	1	51	3	2	21	Tr	595
Bore No. 27B, 21'2"-26'7"(6.5-8.1m)	78696	35	Tr	39	2	1	23	Tr	497
" " " " " "	78697	34	1	48	2	2	14	Tr	531
" " " " " "	78698	32	1	41	2	2	22	Tr	482
Bore No. 27B, 26'7"-31'5"(8.1-9.6m)	78699	31	Tr	51	2	4	12	Tr	654
Bore No. 28B, 12'11"-18'4"(3.9-5.6m)	78615	27	1	47	1	2	22	Tr	439
" " " " " "	†78717(a)	15	Tr	47	2	3	32	1	623
" " " " " "	†78717(b)	19	Tr	47	2	1	30	1	100
" " " " " "	78700	17	Tr	53	1	3	26	Tr	476
" " " " " "	78701	34	Tr	43	2	2	19	Tr	491
Bore No. 29B, 22'-32'(6.7-9.8m)	78702	24	Tr	53	1	1	21	Tr	495
Bore No. 30B, 25'-34'1"(7.6-10.4m)	78703	41	Tr	39	1	2	17	Tr	561
" " " " " "	78704	34	1	46	2	2	14	1	328
" " " " " "	78705	31	Tr	45	2	2	20	Tr	510

† Hand sieved samples:

78716(a)-(-150#, +200#) } From 78614
78716(b)-(-200#)

78717(a)-(-150#, +200#) } From 78615
78717(b)-(-200#)

* Tr - Trace

TABLE 2

DATA ON TASMANITES CONCENTRATIONS AND OIL YIELDS

(used in Fig. 15)

Bore 7 - Interval 23' - 25'6" (7-7.8 m)
Tasmanite % = 22
Yield: gal./ton = 6.6

Bore 8 - Interval 27'10" - 33'10" (8.5 - 10.3 m)
Average Tasmanite % = 42
Yield: gal./ton = 33

Bore 11B - Interval 4'6"-7'2" (1.4-2.2 m)
Tasmanite % = 26
Yield: gal./ton = 21.1

Bore 13B - Interval 70'8½"-76'10" (21.6-23.1 m)
Average Tasmanite % = 30
Yield: gal./ton = 22.2

Bore 27B - Interval 21'2"-31'5" (6.5-9.6 m)
Average Tasmanite % = 33
Yield: gal./ton = 22.4

Bore 28B - Interval 12'11"-18'4" (3.9-5.6 m)
Average Tasmanite % = 26
Yield: gal./ton = 21.1

Bore 29B - Interval 22'-32' (6.7-9.8 m)
Tasmanite % = 24
Yield: gal./ton = 19.8

TABLE 3

SULFUR SPOT ANALYSIS OF TASMANITE SAMPLES

Bore, interval	Point at centre (wt% of S)	Point at top (wt% of S)	Point at bottom (wt% of S)	Mean wt% of sulfur for over-all algal body
Bore No. 27B (LN 78643)				
21'2"-26'7" (6.5-8.1m)				
Algal body 1	5.0	4.2	4.6	4.6
Algal body 2	4.2	4.7	4.6	4.5
Algal body 3	4.3	4.7	4.3	4.4
Bore No. 13B (LN 78644)				
70'8½"-75'10"(21.6-23.1m)				
Algal body 1	5.7	5.4	5.3	5.5
Algal body 2	5.1	4.7	5.2	5.0
Algal body 3	4.5	4.5	5.2	4.7

Sulfur-Pyrite standard - Weight % = 53.41

TABLE 4

Minerals Detected by X-Ray Diffraction Analysis

in Tasmanite Samples

Bore No. 27B, Interval 21'2"-26'7" (6.5-8.1 m)
LN 78643 - (S.E.M. and Probe Sample)
quartz, muscovite, dolomite, chlorite, pyrite, gypsum, anhydrite, and trace feldspar.

Bore No. 13B, Interval 70'8½"-75'10" (21.6-23.1 m)
LN 78644 - (S.E.M. and Probe Sample)
quartz, muscovite, gypsum, dolomite, chlorite, pyrite, anhydrite, and trace feldspar.

TABLE 5

TASMANITE OIL-SHALES FROM CHINA FLAT AREA

LAB NO.	78691	78692	78693	78694	78695
AIR-DRIED BASIS					
MOISTURE	2.0	1.7	1.3	1.4	1.3
ASH	85.9	63.0	80.4	79.3	81.6
VOLATILE MATTER	10.1	32.2	18.6	18.7	16.4
FIXED CARBON	2.0	3.1	*	0.6	0.7
SULFUR-TOTAL	2.26	2.84	2.45	2.67	2.41
CARBON (uncorr.)	6.3	4.5	11.3	12.7	10.2
HYDROGEN	1.1	3.6	1.6	1.8	1.4
NITROGEN	0.1	0.3	0.2	0.2	0.2
SULFUR (total)	2.3	2.8	2.5	2.7	2.4
OXYGEN (diff)	2.3	4.1	2.7	1.9	2.9
DRY ASH-FREE BASIS					
VOLATILE MATTER	84.1	91.3	*	96.6	95.8
FIXED CARBON	15.9	8.7	*	3.4	4.2
CARBON (uncorr.)	52.0	69.6	61.6	65.6	59.7
HYDROGEN	9.4	10.2	9.0	9.3	8.3
NITROGEN	0.9	0.7	0.8	0.9	0.9
SULFUR (total)	18.7	8.1	13.4	13.8	14.1
OXYGEN (diff)	19.0	11.4	15.2	10.4	17.0
H/C =	2.17	1.76	1.75	1.69	1.68

* Fixed carbon is estimated by difference. Since the calculated value is negative for this sample, the actual fixed carbon must be very small.

TABLE 6

TASMANITE OIL-SHALES FROM SASSAFRAS AREA

LAB NO.	77696	77697	77698	77699	77700
AIR-DRIED BASIS					
MOISTURE	1.0	1.0	1.0	1.1	1.2
ASH	80.9	78.3	79.5	76.5	86.7
VOLATILE MATTER	17.4	20.2	18.9	21.5	12.2
FIXED CARBON	0.7	0.5	0.6	0.9	*
SULFUR-TOTAL	2.31	2.63	2.34	3.16	2.29
CARBON (uncorr.)	11.4	13.6	12.7	14.5	7.3
HYDROGEN	1.7	2.1	1.8	2.2	1.2
NITROGEN	0.2	0.2	0.2	0.2	0.1
SULFUR (total)	2.3	2.6	2.3	3.2	2.3
OXYGEN (diff)	2.5	2.2	2.5	2.3	1.2
DRY ASH-FREE BASIS					
VOLATILE MATTER	95.8	97.4	96.6	95.9	*
FIXED CARBON	4.2	2.6	3.4	4.1	*
CARBON (uncorr.)	62.8	65.8	65.0	64.8	60.5
HYDROGEN	9.6	9.9	9.4	9.6	10.1
NITROGEN	0.8	0.8	0.8	0.8	0.9
SULFUR (total)	12.8	12.7	11.9	14.1	18.9
OXYGEN (diff)	14.0	10.8	12.9	10.7	9.6
H/C =	1.82	1.81	1.74	1.78	2.01

* Fixed carbon is estimated by difference. Since the calculated value is negative for this sample, the actual fixed carbon must be very small.

TABLE 6 (Cont'd)

TASMANITE OIL-SHALES FROM SASSAFRAS AREA

LAB NO.	77701	77702	77703	77705
AIR-DRIED BASIS				
MOISTURE	1.1	2.1	1.2	1.2
ASH	79.8	84.1	75.9	83.4
VOLATILE MATTER	18.5	12.1	21.1	15.2
FIXED CARBON	0.6	1.7	1.8	0.2
SULFUR-TOTAL	2.69	1.86	2.40	1.89
CARBON (uncorr.)	12.4	8.0	15.8	10.6
HYDROGEN	1.8	1.4	2.4	1.8
NITROGEN	0.1	0.1	0.2	0.1
SULFUR (total)	2.7	1.9	2.4	1.9
OXYGEN (diff)	2.1	2.4	2.1	1.0
DRY ASH-FREE BASIS				
VOLATILE MATTER	96.7	87.2	92.4	97.9
FIXED CARBON	3.3	12.8	7.6	2.1
CARBON (uncorr.)	64.8	57.4	69.0	68.3
HYDROGEN	9.6	9.9	10.6	11.3
NITROGEN	0.7	0.9	0.8	0.9
SULFUR (total)	14.1	13.4	10.5	12.2
OXYGEN (diff)	10.8	18.4	9.1	7.3
H/C =	1.77	2.08	1.85	1.99

TABLE 7

TASMANITE SAMPLES FROM CHINA FLAT AND SASSAFRAS AREAS

AREA	CHINA FLAT		SASSAFRAS	
LAB NO.	78716(a)	78716(b)	78717(a)	78717(b)
AIR-DRIED BASIS				
MOISTURE	1.7	2.1	1.2	1.4
ASH	55.7	79.4	58.1	76.1
VOLATILE MATTER	40.3	16.3	39.5	22.1
FIXED CARBON	2.3	2.2	1.2	0.4
SULFUR-TOTAL	2.74	2.31	3.06	2.88
CARBON (uncorr.)	33.3	11.8	30.6	15.3
HYDROGEN	4.6	1.8	4.2	2.2
NITROGEN	0.3	0.2	0.3	0.2
SULFUR (total)	2.7	2.3	3.1	2.9
OXYGEN (diff)	1.7	2.4	2.5	1.9
DRY ASH-FREE BASIS				
VOLATILE MATTER	94.6	87.9	97.0	97.8
FIXED CARBON	5.4	12.1	3.0	2.2
CARBON (uncorr.)	78.3	63.5	75.2	67.8
HYDROGEN	10.9	9.6	10.3	9.7
NITROGEN	0.8	0.9	0.7	0.8
SULFUR (total)	6.4	12.5	7.6	12.8
OXYGEN (diff)	3.6	13.5	6.2	8.9
H/C =	1.67	1.81	1.66	1.72

(a):- minus 150 plus 200 fraction

(b):- minus 200 fraction

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TABLE 8

TRACE ELEMENTS IN TASMANITE SHALE

(as ppm in ash*)

	78716(a)	78716(b)	78614	78717(a)	78717(b)	78615
Ag	n0.1	n0.1	n0.1	n0.1	n0.1	n0.1
As	n60	n60	n60	n60	n60	n60
B	150	200	150	150	150	150
Be	n6	n6	n6	n6	n6	n6
Bi	n10	n10	n10	n10	n10	n10
Cd	n8	n8	n8	n8	n8	n8
Co	n10	n10	n10	n10	n10	n10
Cr	200	200	200	200	200	200
Cu	80	80	60	40	40	40
Ga	20	20	20	20	20	20
Ge	0.2	0.2	0.2	0.3	0.2	0.2
In	n0.1	n0.1	n0.1	n0.1	n0.1	n0.1
La	80	80	80	80	80	80
Li	n60	n60	n60	n60	n60	n60
Mn	150	200	100	400	400	400
Mo	8	6	6	10	10	8
Ni	20	20	30	30	30	30
Pb	40	40	40	20	20	40
Sb	n10	n10	n10	n10	n10	n10
Sc	n30	n30	n30	n30	n30	n30
Sn	6	6	6	6	6	6
Ti	4000	4000	4000	4000	4000	4000
Tl	n3	n3	n3	n3	n3	n3
V	150	150	150	150	150	150
W	n10	n10	n10	n10	n10	n10
Y	40	30	30	40	30	40
Yb	4	4	4	4	4	4
Zn	150	150	150	150	150	150
Zr	400	300	400	300	300	300

* n(x) means no line seen (if present, is less than our detectability x ppm)

No lines were seen for Au, Hf, Pd, Pt, Th, U.

TABLE 9

TRACE ELEMENTS IN TASMANITE SHALE

(as ppm in whole shale)*

	78716(a)	78716(b)	78614	78717(a)	78717(b)	78615
Ag	n0.06	n0.08	n0.08	n0.06	n0.08	n0.07
As	n35	n50	n45	n35	n50	n45
B	85	160	110	90	120	110
Be	n4	n5	n5	n4	n5	n4
Bi	n6	n8	n8	n6	n8	n7
Cd	n5	n7	n6	n5	n6	n6
Co	n6	n8	n8	n6	n8	n7
Cr	110	160	150	120	160	150
Cu	45	65	45	25	30	30
Ga	10	15	15	10	15	15
Ge	0.1	0.15	0.15	0.2	0.15	0.15
In	n0.06	n0.08	n0.08	n0.06	n0.08	n0.07
La	45	65	60	50	60	60
Li	n35	n50	n45	n35	n50	n45
Mn	85	160	75	240	320	300
Mo	5	5	5	6	8	6
Ni	10	15	25	20	25	20
Pb	25	35	30	15	15	30
Sb	n6	n8	n8	n6	n8	n7
Sc	n15	n25	n25	n20	n25	n20
Sn	4	5	5	4	5	4
Ti	2500	3000	3000	2500	3000	3000
Tl	n2	n3	n2	n2	n2	n2
V	85	120	110	90	120	110
W	n6	n8	n8	n6	n8	n7
Y	25	25	25	25	25	30
Yb	2	3	3	3	3	3
Zn	85	120	110	90	120	110
Zr	230	250	300	180	240	220

* n(x) means no line seen (if present, is less than our detectability x ppm)
No lines were seen for Au, Hf, Pd, Pt, Th, U.

TABLE 10

TRACE ELEMENTS IN TASMANITE SHALE

(as ppm in dry whole shale)*

	78614	78615	Shale (mean)	Coal (common range)	Soil (common range)
Ag	n0.08	n0.07	0.07	<0.2-0.6	<1
As	n45	n45	13	<1-13	1-60
B	110	110	100	4-200	2-100
Be	n5	n4	3	<0.4-5	0.4-10
Co	n8	n7	19	<0.6-20	1-40
Cr	150	150	90	<1.5-20	4-1000
Cu	45	30	45	6-30	2-100
Ga	15	15	19	1.5-10	10-70
Ge	0.15	0.15	1.6	1-30	up to 10
La	60	60	92	<4-30	up to 200
Li	n45	n45	66	- -	5-200
Mn	75	300	850	4-600	200-3000
Mo	5	6	2.6	0.3-4	0.2-5
Ni	25	20	68	3-50	5-500
Pb	30	30	20	2-40	2-200
Sc	n25	n20	13	1-10	up to 20
Sn	5	4	6	0.9-7	up to 10
Ti	3000	3000	3500	500-3000	1000-10000
V	110	110	130	10-60	20-500
Y	25	30	26	2-20	up to 200
Yb	3	3	2.6	-	-
Zn	110	110	95	<15-200	10-300
Zr	300	220	160	15-300	60-2000

* n (x) means no line seen (if present, is less than our detectability x ppm)
Shale (mean) from Turekian and Wedepohl (1961); Coal (common range) from Swaine (1977); Soil (common range) from Swaine (1953)

TABLE 11

TRACE ELEMENTS IN TASMANITE SHALE ASH

(as ppm in ash)*

	78614	78615	Shale (mean)	Fly-ash (common range)	Soil (common range)
Ag	n0.1	n0.1	0.07	-	<1
As	n60	n60	13	8-11	1-60
B	150	150	100	100-250	2-100
Be	n6	n6	3	6-10	0.4-10
Co	n10	n10	19	10-20	1-40
Cr	200	200	90	40-80	4-1000
Cu	60	40	45	40-80	2-100
Ga	20	20	19	30-100	10-70
Ge	0.2	0.2	1.6	20-60	up to 10
La	80	80	92	-	up to 200
Li	n60	n60	66	-	5-200
Mn	100	400	850	600-1500	200-3000
Mo	6	8	2.6	8-15	0.2-5
Ni	30	30	68	20-40	5-500
Pb	40	40	20	30-100	2-200
Sc	n30	n30	13	-	up to 20
Sn	6	6	6	<10-10	up to 10
Ti	4000	4000	3500	-	1000-10000
V	150	150	130	100-250	20-500
Y	30	40	26	40-80	up to 200
Yb	4	4	2.6	-	-
Zn	150	150	95	up to 1000	10-300
Zr	400	300	160	800-1000	60-2000

* n (x) means no line seen (if present, is less than our detectability x ppm) Shale (mean) from Turekian and Wedepohl (1961); fly-ash (common range from Swaine (1977); Soil (common range) from Swaine (1955).

EXPLANATORY DIAGRAMS FOR ELECTRON MICROPROBE ANALYSES

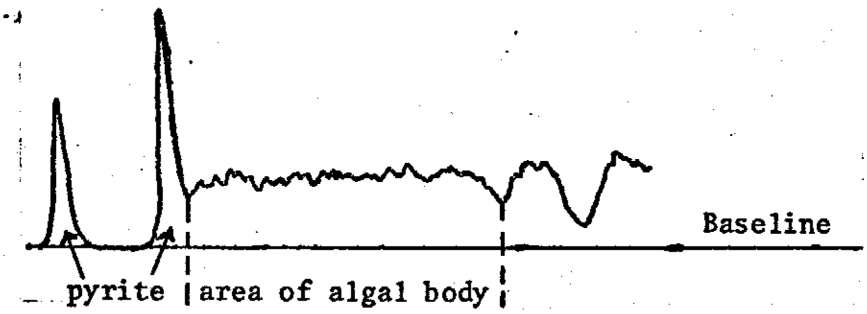

Figure 6(a)

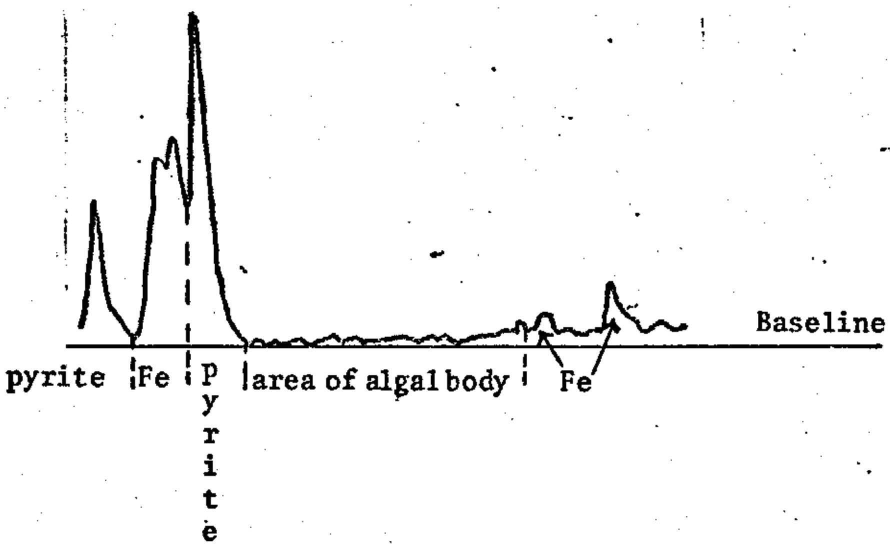

Figure 8(a)

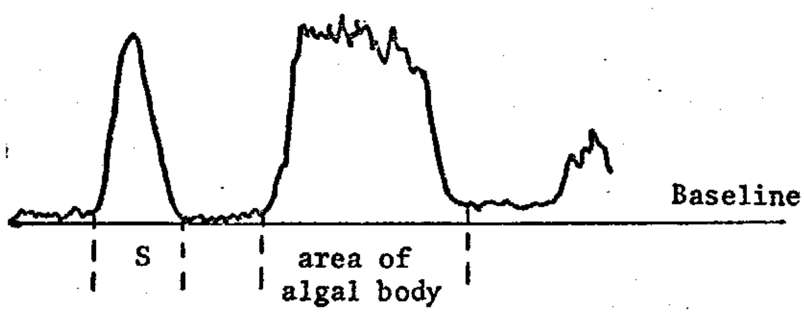

Figure 12(a)

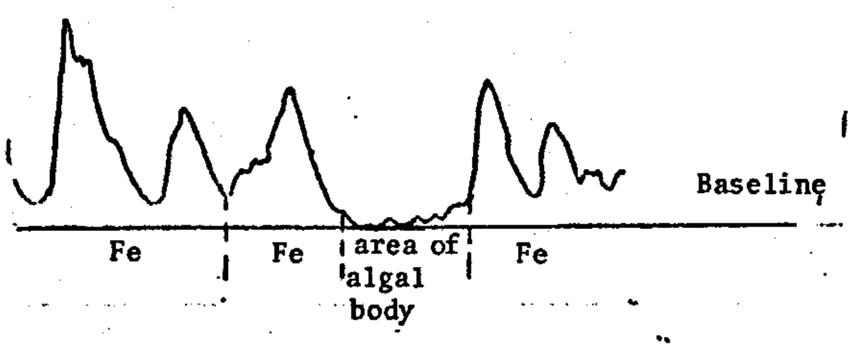

Figure 14(a)

CAPTIONS TO PHOTOGRAPHS

(Figures 1 to 14 inclusive)

Figures 1 to 3 are photographs which have been taken using a scanning electron microscope. Figures 4 to 14 have been taken using an electron microprobe analyser. Figures 1 to 8 - Bore No. 27B, Interval 21' 2" - 26'7" (6.5 - 8.1 metres), LN 78643. Figures 9 to 14 - Bore No. 13B, Interval 70'8½" - 75'10" (21.6 - 23.1 metres), LN 78644.

FIGURE 1. Tasmanites algal body, completely collapsed form, surrounded by mineral matrix.

2. Sulfur map scan (in dot form) of same algal body (same magnification as Fig. 1).

3. Iron map scan of same algal body (same magnification).

4. Tasmanites, surface of the body studied, in matrix (x 115).

5. Sulfur map scan, showing sulfur concentrated within the algal body area (x 115).

6. Sulfur trace profile, vertical - from top to bottom of body, showing large sulfur peaks of pyrite in matrix, and plateau effect above the base line coinciding with the algal body (x 115).

7. Iron map scan, showing very little iron within the algal body area (x 115).

8. Iron profile trace, following the sulfur profile route, showing two pyrite peaks, as well as other iron peaks. Over the algal body there is a base line pleateau, indicating little iron present here (x 115).

9. Cross-section of a Tasmanites body. Dark band down the centre is the algal body (x 380).

10. Silica map scan, showing little silica in the algal body, but well distributed throughout matrix. Areas on either side of major body, where silica points are low in number, are smaller, less obvious algal bodies (x 380).

11. Sulfur map scan showing the sulfur concentrated throughout the major body and the smaller ones. The most concentrated sulfur-containing areas are pyrite (x 380).

12. Sulfur profile trace horizontally across algal body. First a large sulfur peak; the second peak with the plateau top is the algal body area (x 380).

13. Iron map scan, showing little iron within the major algal body. Areas that are concentrated masses of iron, but are not coincident with the sulfur masses, may be iron silicates or oxides. (x 380).

14. Iron profile trace, following trace route of sulfur scan, again shows little iron associated with the major algal body (x 380).

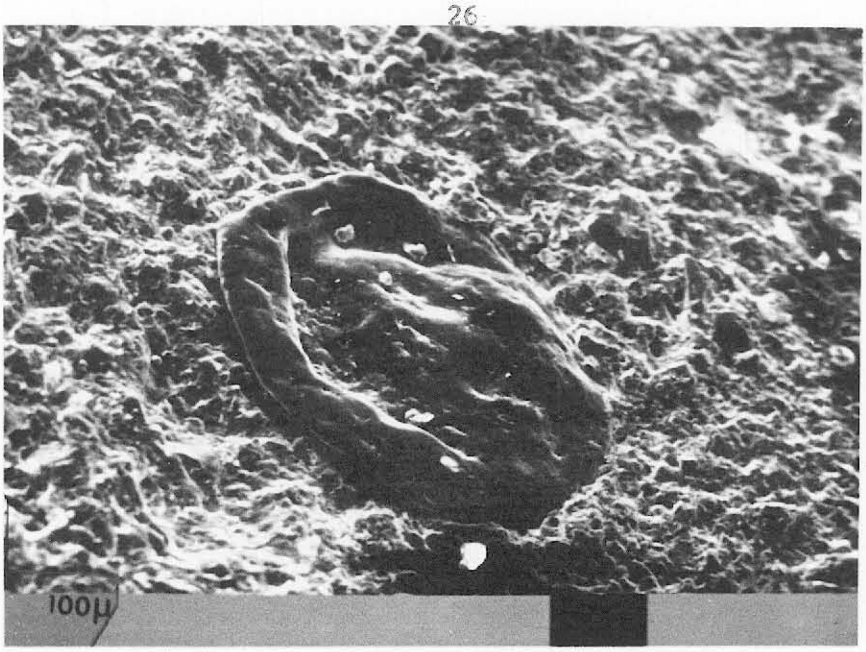

Figure 1

Figure 2

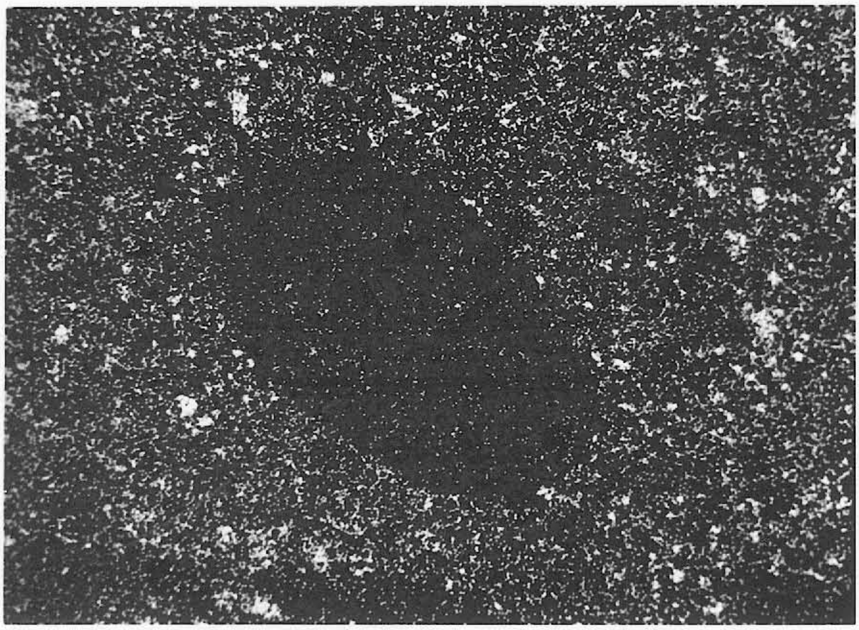

Figure 3

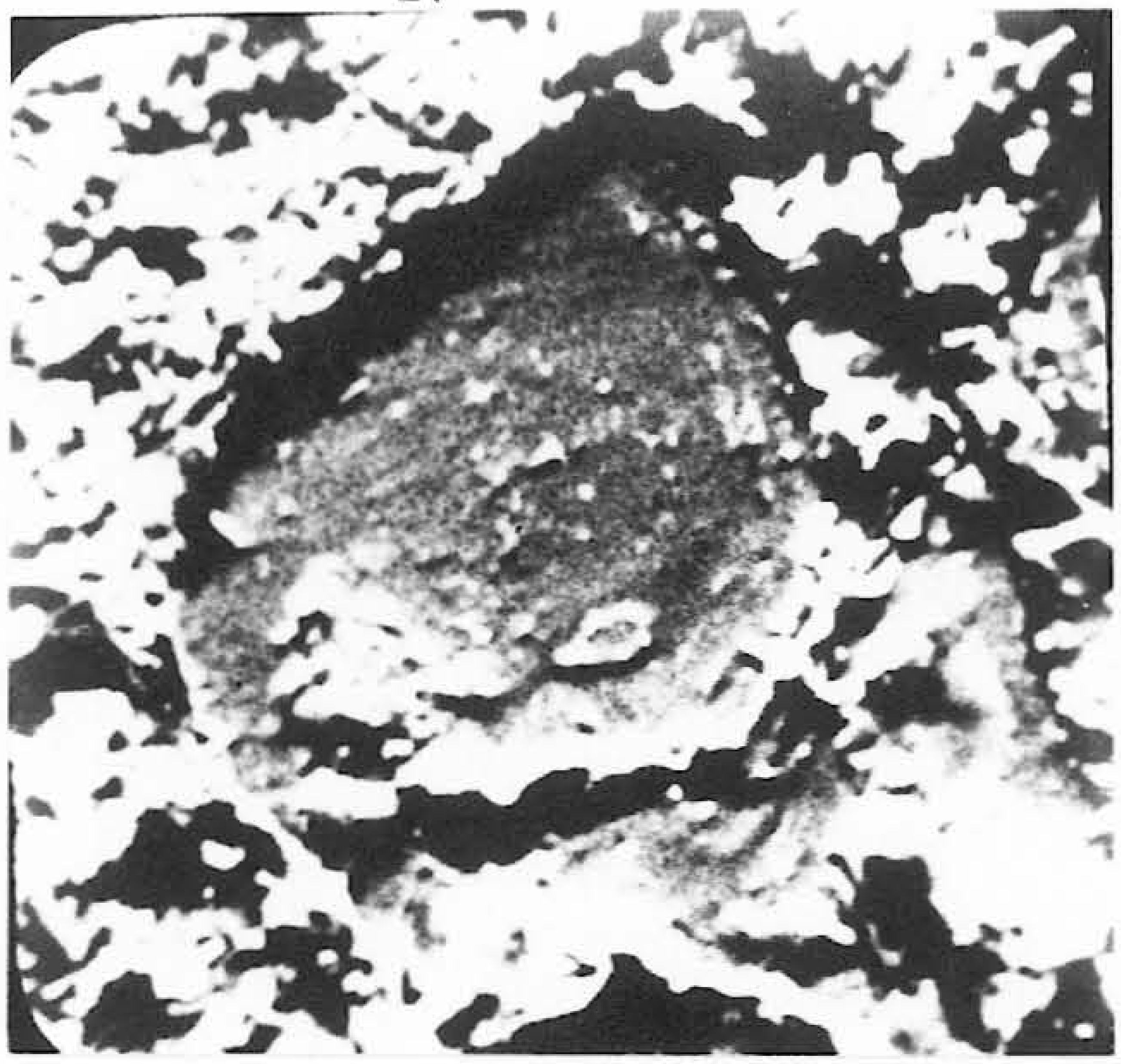

Figure 4

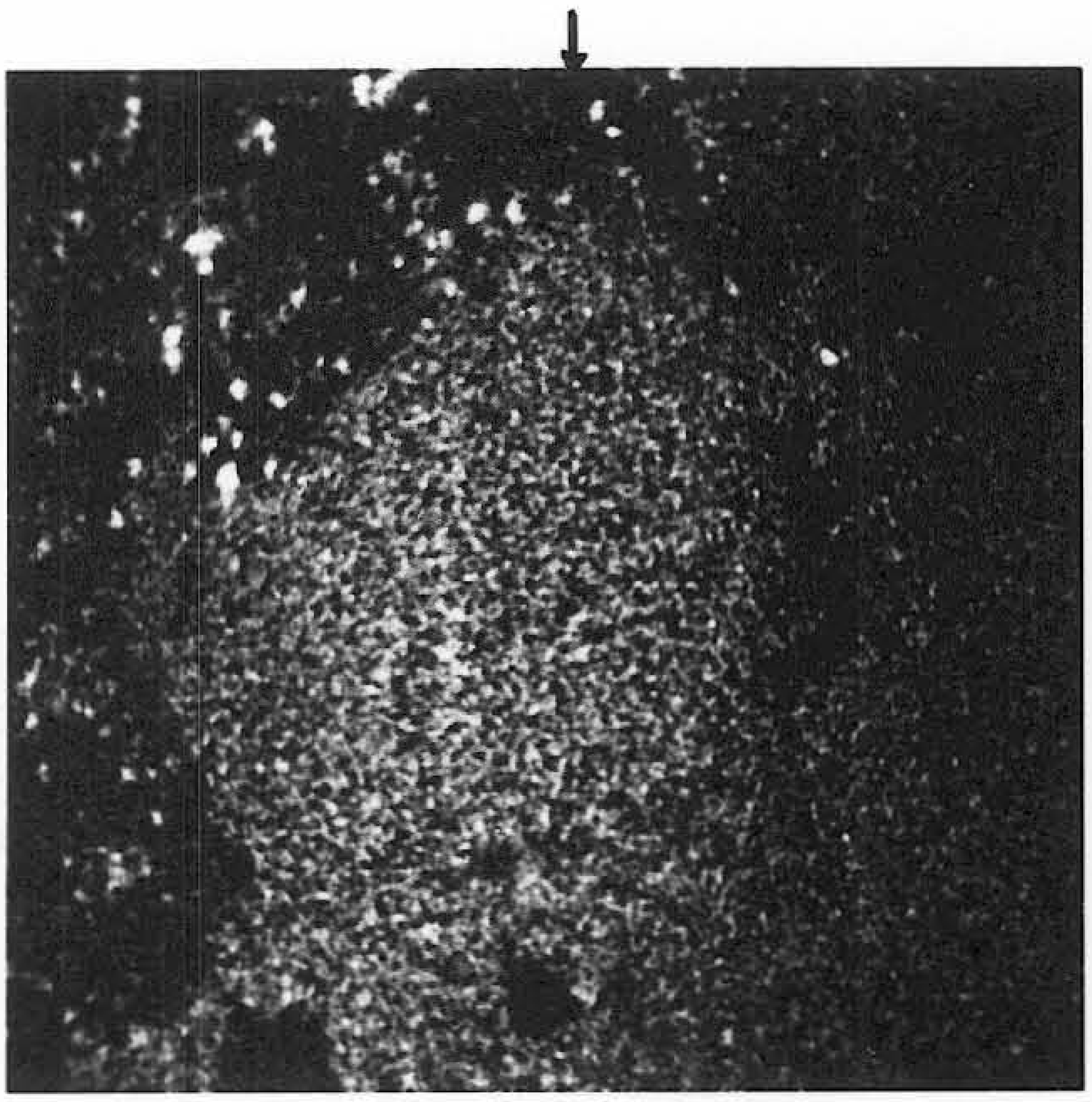

Figure 5

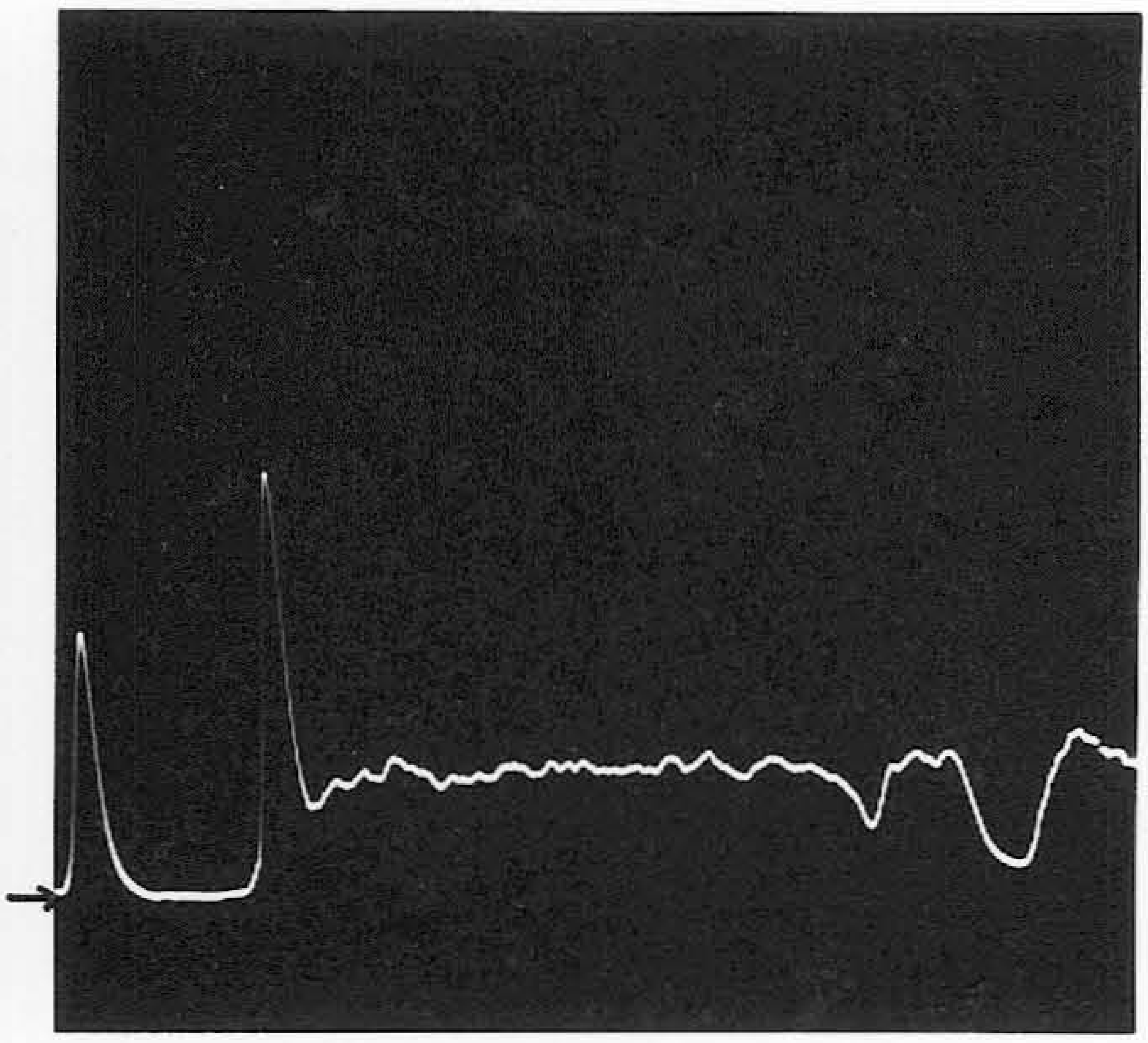

Figure 6

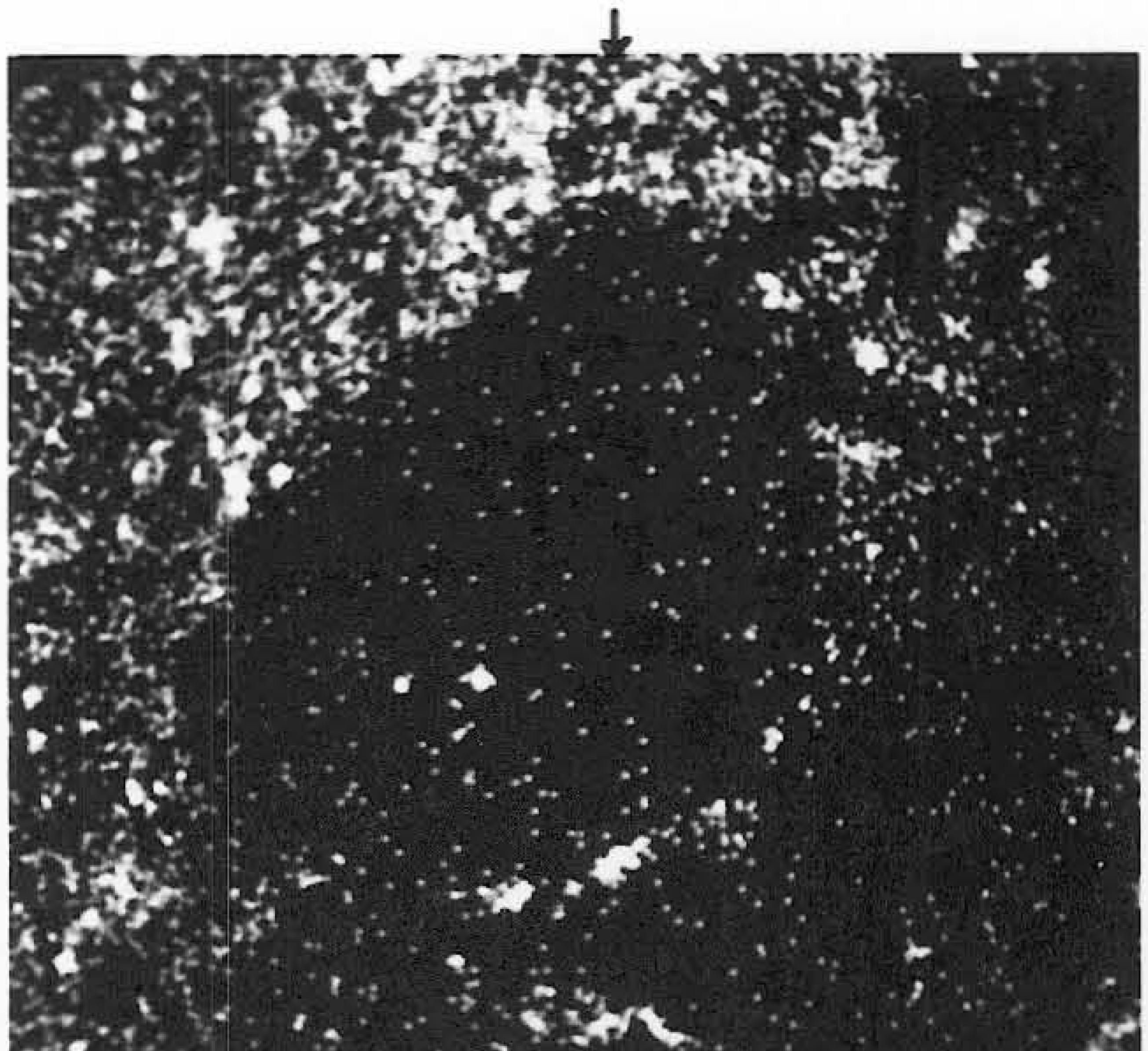

Figure 7

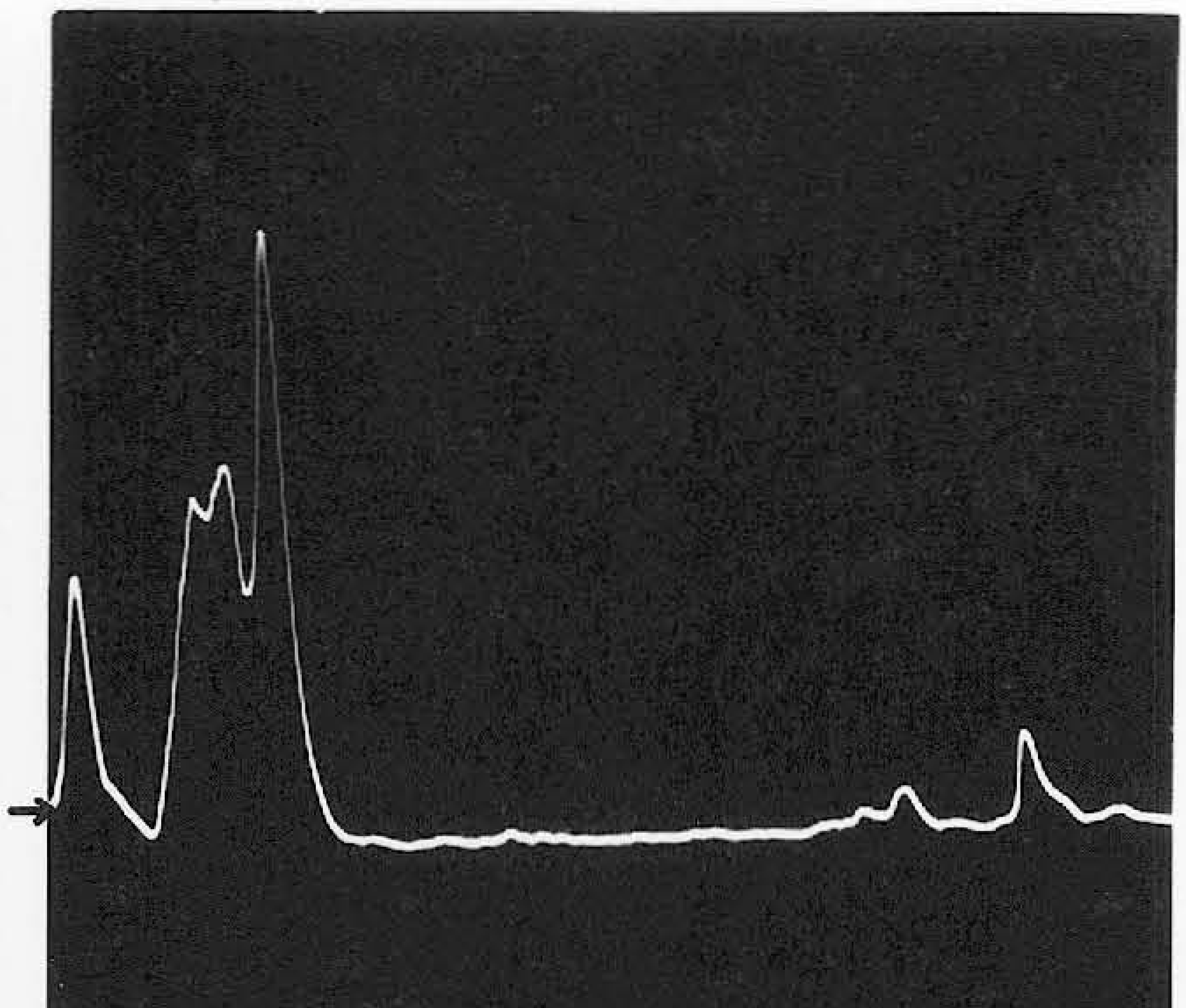

Figure 8

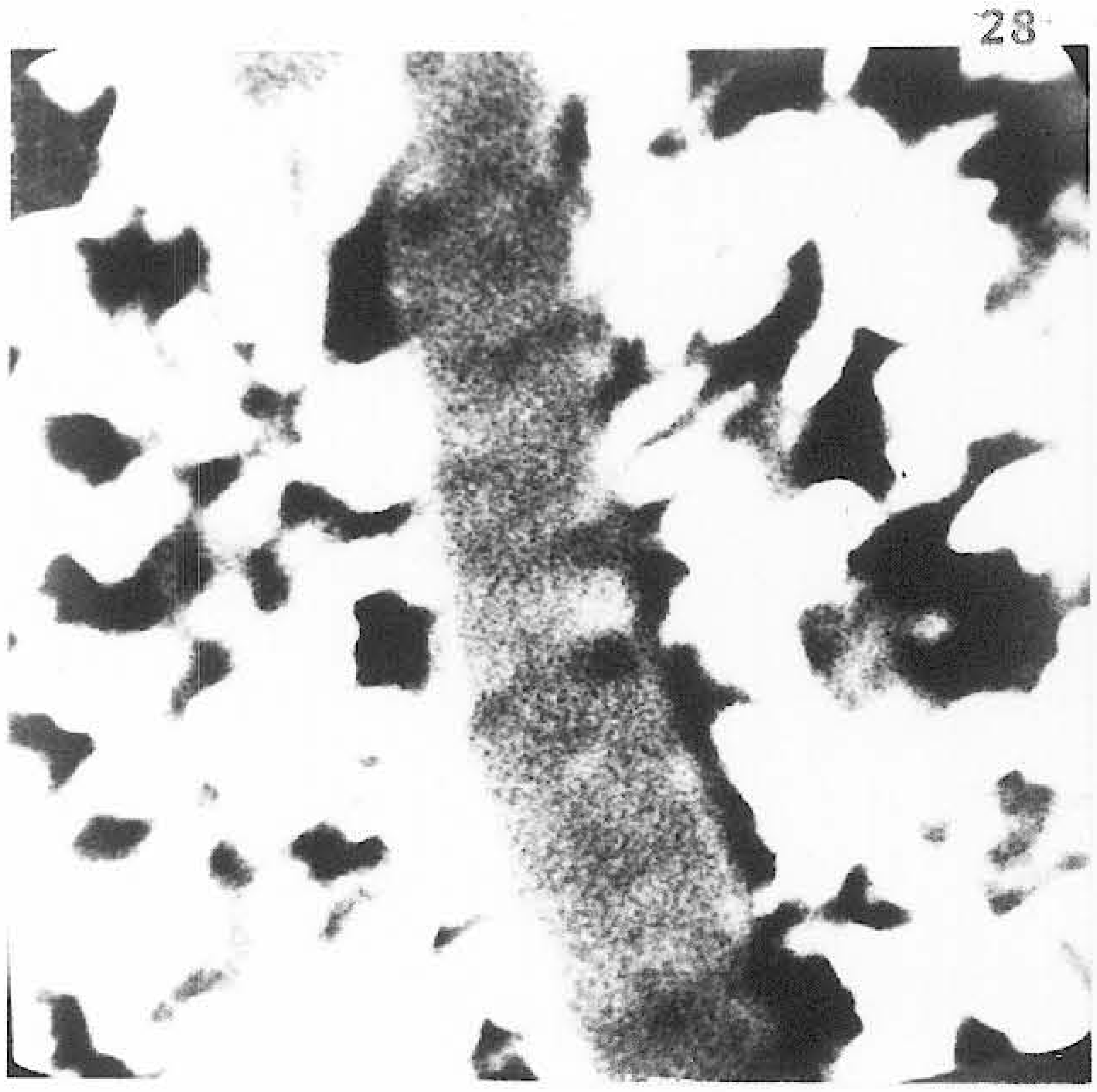

Figure 9

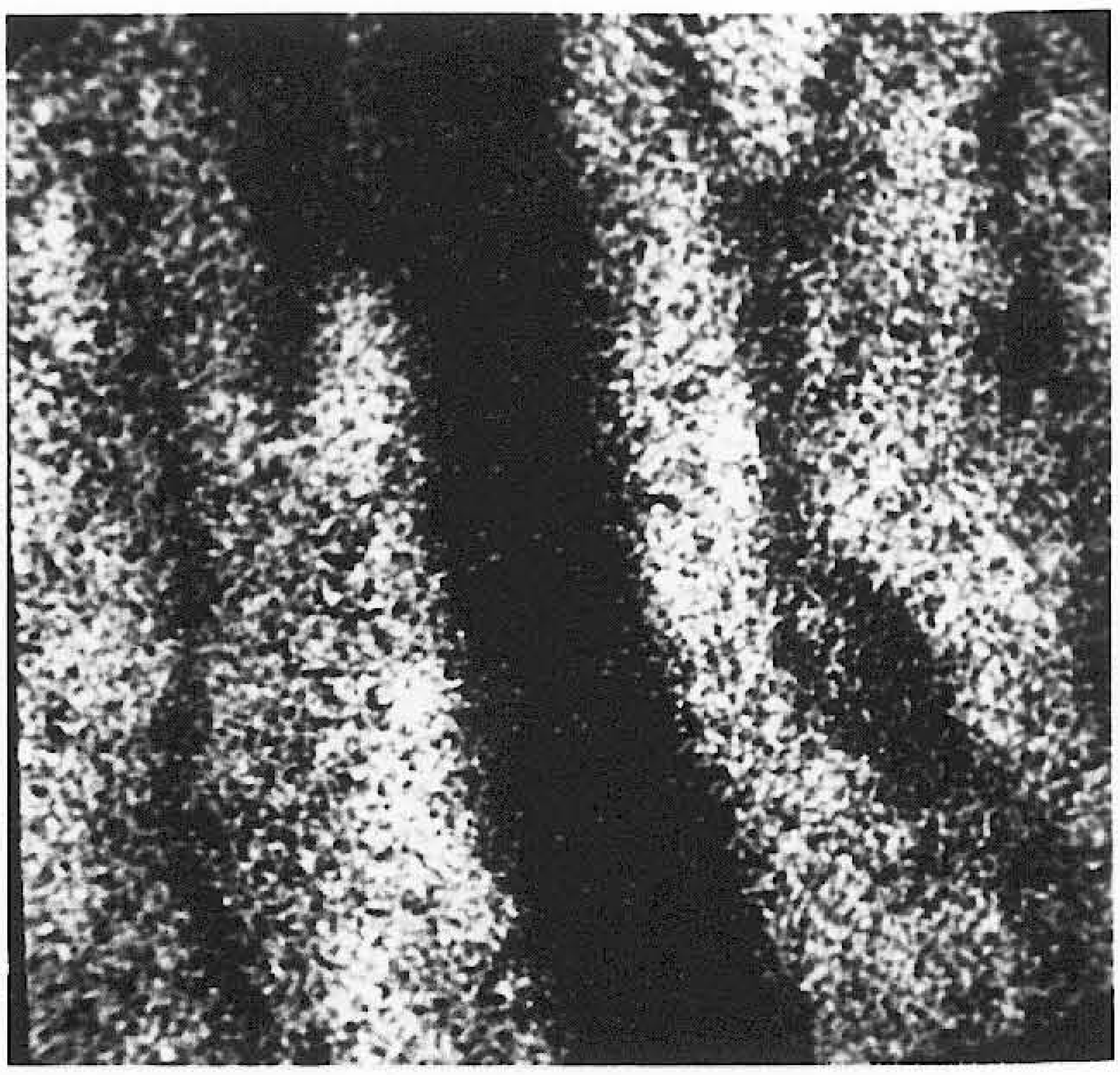

Figure 10

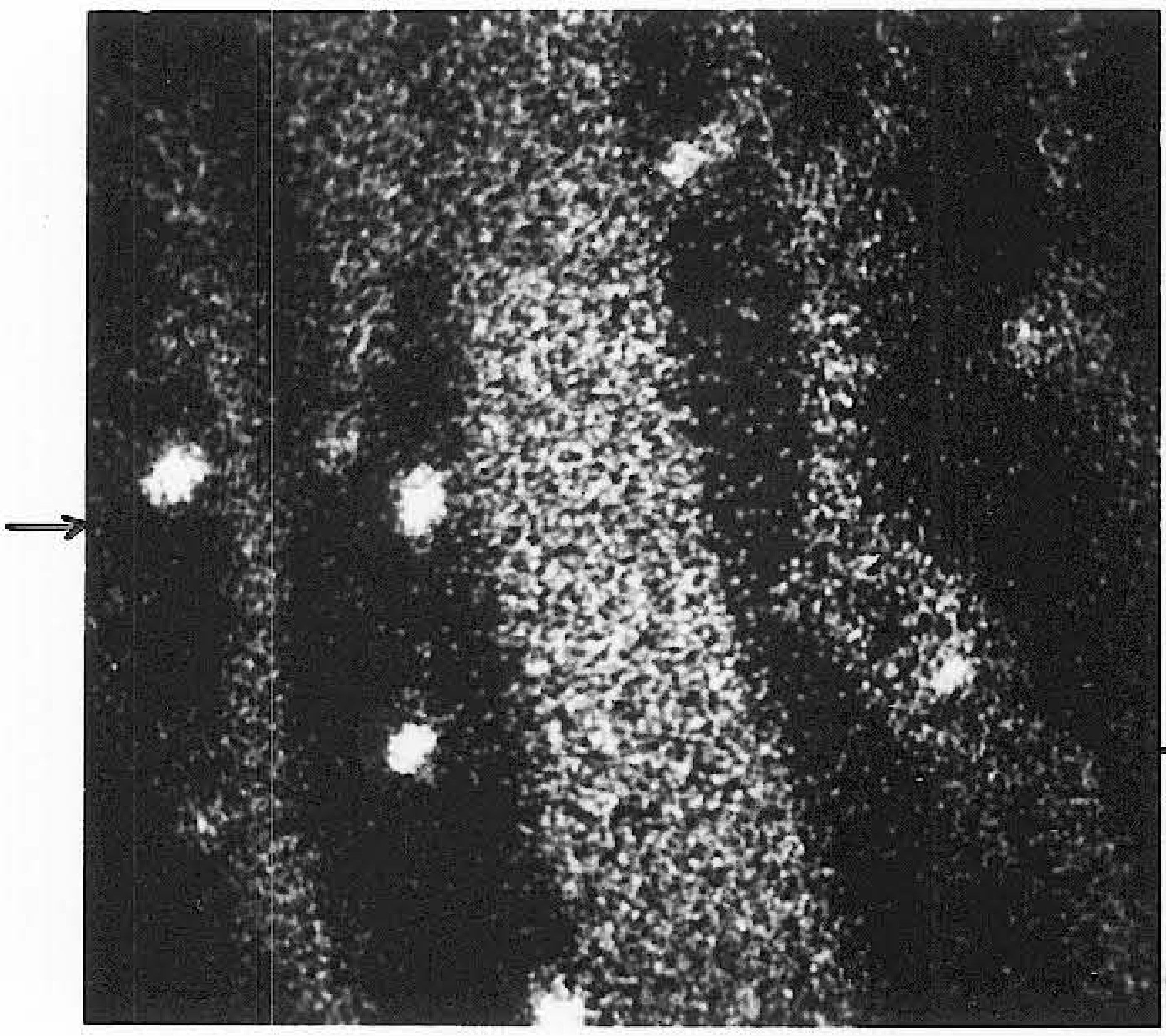

Figure 11

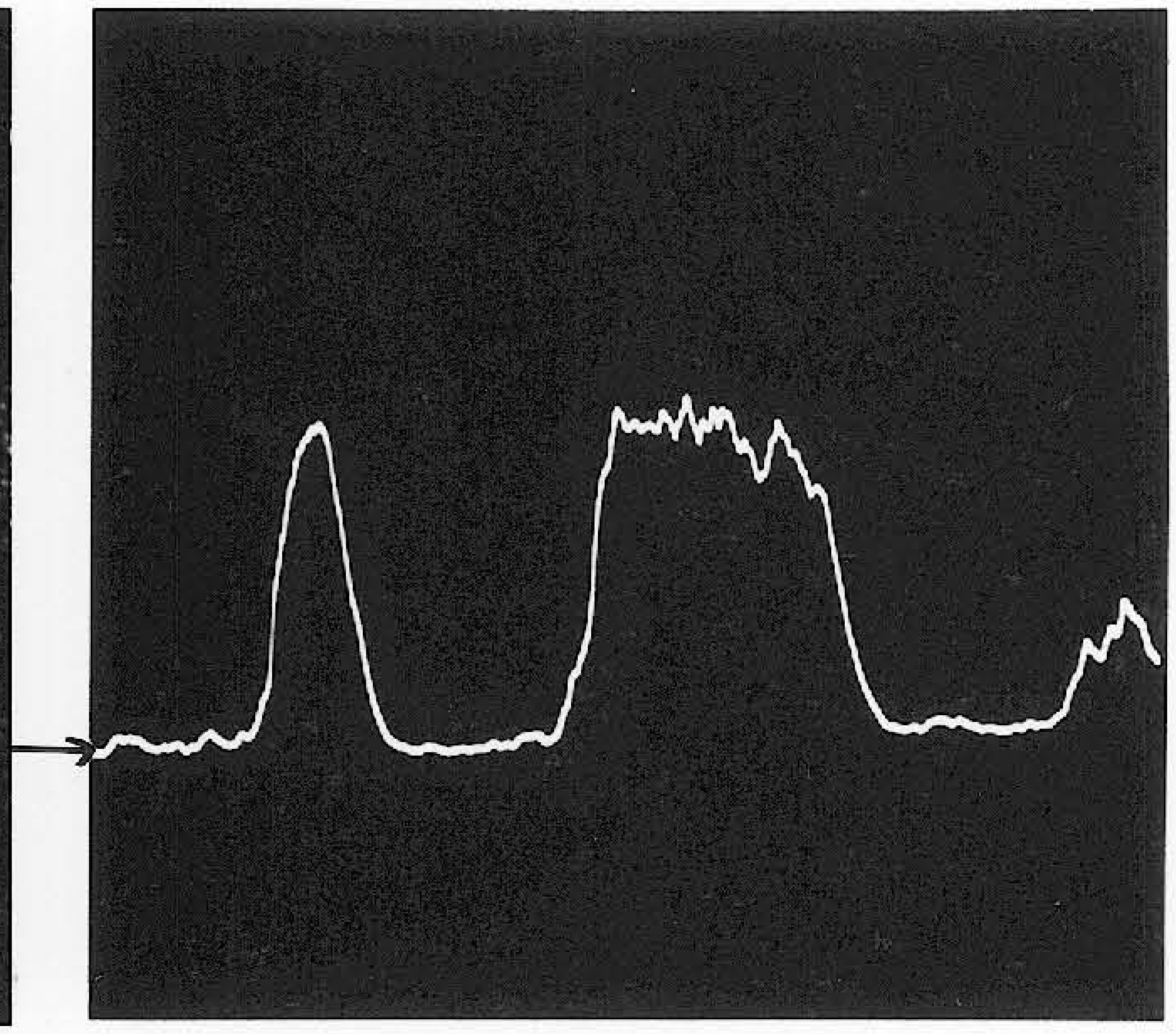

Figure 12

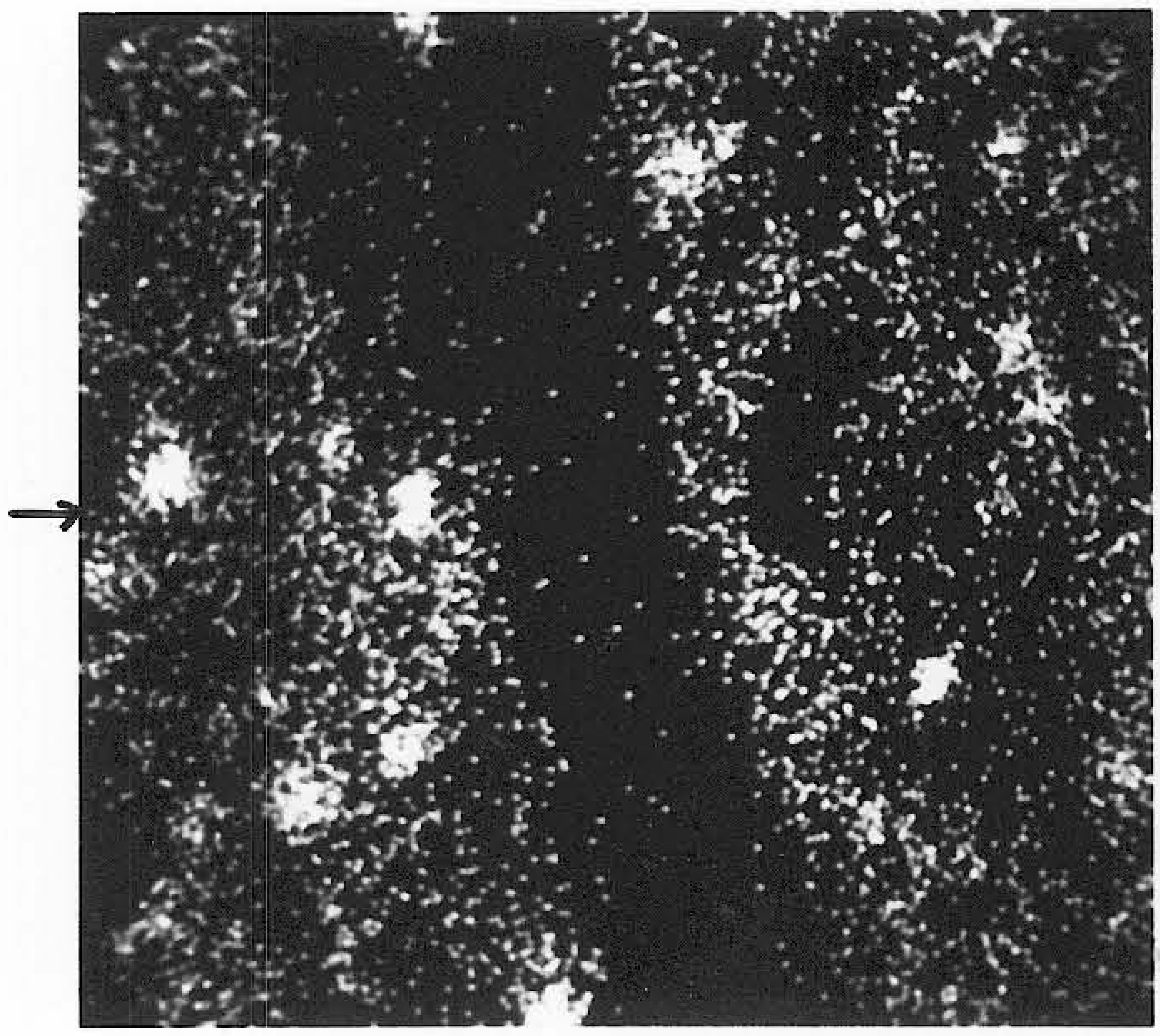

Figure 13

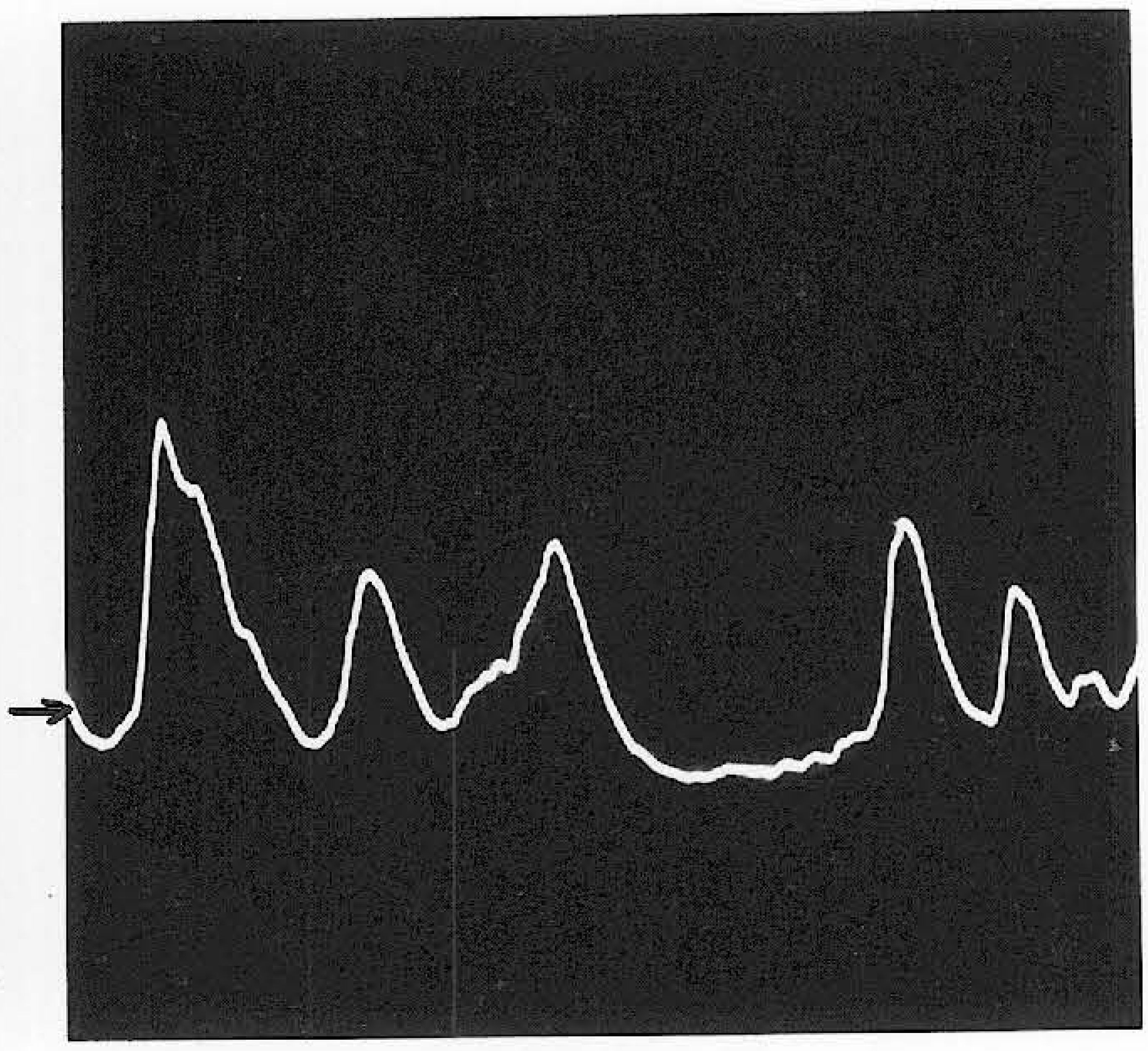

Figure 14

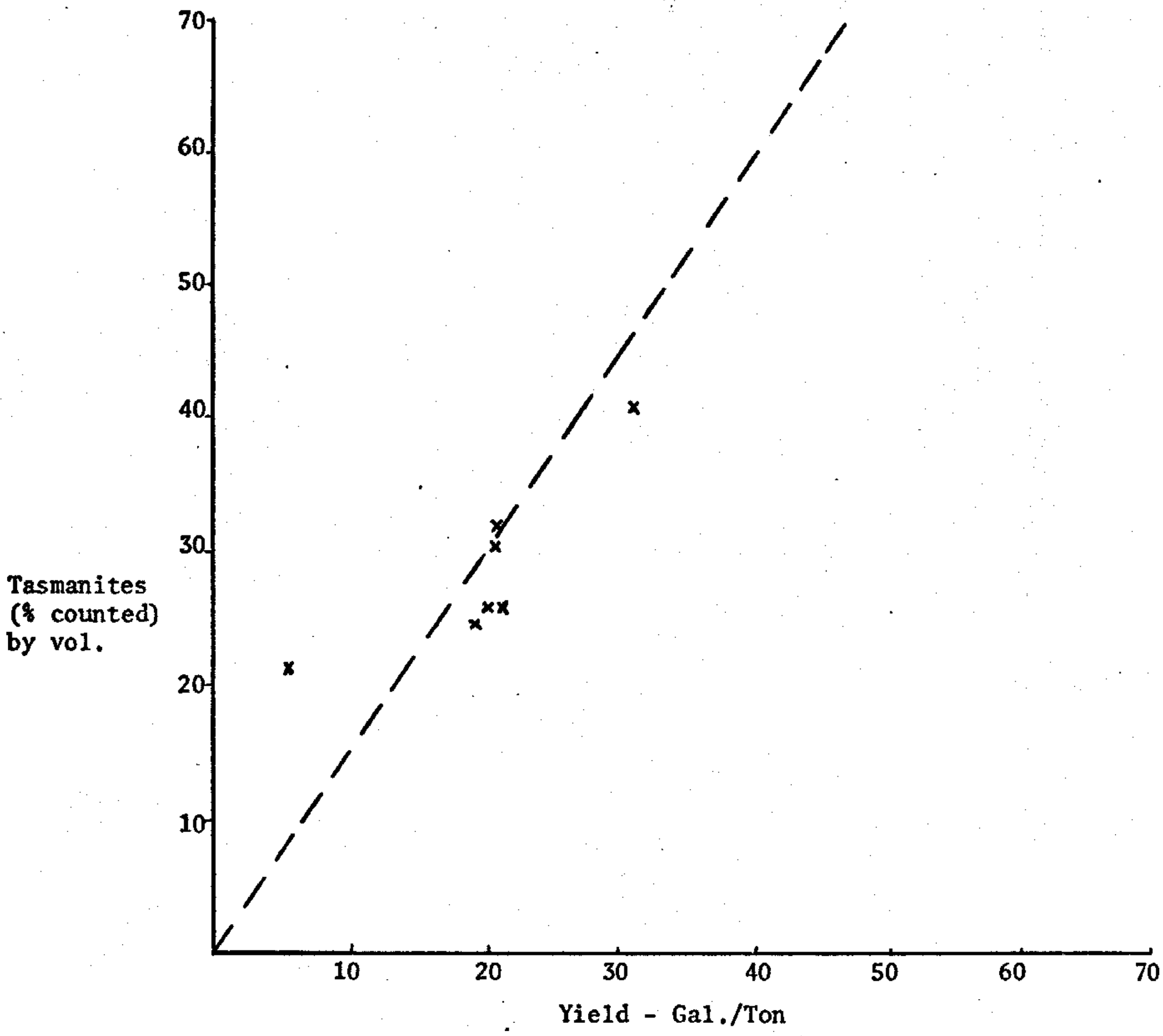

FIG. 15. Yield of oil* plotted against Tasmanites content† of shale.

*Oil yields taken from the results of the Mayhew Drilling Program - March-April 1975 (Table 7 in F.L. Hunt's report on a Feasibility study for Endeavour Oil Company).

†Tasmanites content from CSIRO work (see text, this report).

APPENDIX 1

SAMPLES AND MICROSCOPIC TECHNIQUES USED

Bore	Lab. No.	Pet. No.	Techniques Employed *
China Flat Area			
Bore No. 7 - Interval 23' - 25'6" (7 -7.8 m)	78640	31442	TS
	78691	31380	GM
Bore No. 8 - Interval 27'10" - 33'10" (8.5-10.3 m)	78616	31315	GM
	78641	31443	TS
	78692	31381	GM
Bore No.11B - Interval 4'6" - 7'2" (1.4-2.2 m)	78614	31313	GM
	† 78716(a)	31343	GM
	† 78716(b)	31344	GM
Bore No.13B - Interval 70'8½" - 75'10" (21.6-23.1 m)	78642	31444	TS
	78644	31300	SEM, EMA
	78693	31382	GM
	78694	31383	GM
	78695	31384	GM
Sassafras Area			
Bore No.27B - Interval 21'2" - 26'7" (6.5-8.1 m)	78639	31441	TS
	78643	31299	SEM, EMA
	78696	31385	GM
	78697	31386	GM
	78698	31387	GM
Bore No.27B - Interval 26'7" - 31'5" (8.1-9.6 m)	78637	31439	TS
	78699	31388	GM
Bore No.28B - Interval 12'11" - 18'4" (3.9-5.6 m)	78615	31314	GM
	† 78717(a)	31345	GM
	† 78717(b)	31346	GM
	78638	31440	TS
	78700	31389	GM
	78701	31390	GM
Bore No.29B - Interval 22' - 32' (6.7-9.8 m)	78702	31391	GM
Bore No.30B - Interval 25' - 34'1" (7.6-10.4 m)	78634	31437	TS
	78635	31438	TS
	78703	31392	GM
	78704	31394	GM
	78705	31393	GM

* GM - Grain mount; TS - Thin section; SEM and EMA - Scanning Electron Microscope and Electron Microprobe Analyser.

† Hand-sieved samples: 78716(a) - (-150#, +200#) } From 78614
78716(b) - (-200#)

78717(a) - (-150#, +200#) } From 78615
78717(b) - (-200#)

APPENDIX 2

DESCRIPTIONS OF THIN SECTIONS

Bore No. 7 Interval 23'-25'6" (7-7.8 m) : (LN 78640)

- Occasional concentrated algal-rich bands. Larger bodies best preserved, smaller ones crushed and not easily recognised.

Bore No. 8 Interval 27'10"-33'10" (8.5-10.3 m) : (LN 78641)

- Very rich in Tasmanites. Sporadic compressed algal-rich bands, with some patches mineral-dominated. Otherwise the bodies are distributed throughout. Al sizes well preserved.

Bore No. 13B Interval 70'8½"-75'10" (21.6-23.1 m) : (LN 78642)

- Algal-rich, with compressed algal-rich bands and sporadic algal-poor areas. All sizes well preserved.

Bore No. 27B Interval 21'2"-26'7" (6.5-8.1 m) : (LN 78639)

- Some sporadic algal banding. Larger thick-walled bodies better preserved, smaller bodies crushed amongst mineral matter, not readily recognisable.

Bore No. 27B Interval 26'7"-31'5" (8.1-9.6 m) : (LN 78637)

- Algal bodies well distributed throughout the sample. No algal-rich-mineral-poor bands, only isolated algal-rich areas. Thicker walled bodies (∿20μ across) are better preserved than the thinner-walled ones (∿5μ across), which tend to have been crushed.

Bore No. 28B Interval 12'11"-18'4" (3.9-5.6 m) : (LN 78638)

- This is rich in Tasmanites. All sizes well preserved. Some concentrated banding is noticeable, although the remainder is also very rich.

Bore No. 30B Interval 25'-34'1" (7.6-10.4 m) : (LN 78634)

- Numerous algal bodies, well distributed throughout. Some banding but this is equally mineral and Tasmanites rich. Larger, thick-walled bodies better preserved than the thinner-walled ones which appear to have been deformed more to fit in with the mineral matrix. This is unlike the larger forms which have not been deformed.

Bore No. 30B Interval 25'-34'1" (7.6-10.4 m) : (LN 78635)

- This sample is mineral-matter dominated, with very little algal body matter. The majority are the larger bodies, about 125μ across and with walls 20μ wide. These are found either scattered as single entities or as clusters.

Thus variation in texture occurs in the same cores as both LN 78634 and LN 78635 prove.