CHAPTER 7

MINERALOGICAL ATTRIBUTES

7.1 SAND GRAIN SURFACE TEXTURES

7.1.1 INTRODUCTION

The surface textures of quartz sand grains from Permian deposits south of the Ovens-King River Valley may give some additional indication of the palaeoenvironment, transport and depositional history for the northeastern district. The technique is reported (see earlier discussion ch. 2, p.41) to be more limited when ancient sediments are being investigated. Surface textures generated by glacial and fluvio-glacial processes are thought to be unique and provide a valuable method by which these environments can be identified.

Using a Cambridge S10 stereoscopic scanning electron microscope (Electron microscope facility : Australian National University) quartz grain surface textures are recorded for selected quartz sand grains taken from an artificial crush of a quartz crystal: these textures are used as controls. Other textures are recorded for selected quartz sand grains from three separate Permian deposits with the view to determining there likely palaeoenvironment.

Not all those textures encountered have been recorded nor have many of the vast array of textures presented in the literature been seen in the samples examined. It is very likely that some textures were present but I did not recognise them, nevertheless those which I could confidently recognise from the previous work of Krinsley and others, I have recorded.

7.1.2 SAMPLE PRE-TREATMENT AND PREPARATION

Two samples (No.77/26 and 77/29 : see plate 9, p.92) from the Lower Road cutting were chosen along with sample 77/21 (about 1 km south of the Moyhu pavement) for surface texture examination. Sample 77/21 is probably stratigraphically one of the lowest units in the area although it is not found directly on the pavement.

All three samples were disaggregated with a rubber improvised mortar and a standard ceramic pestle. Minimal force was used during the process of dry disaggregation. The samples were then added to a carrier vessel suitable for use with a mechanical stirring apparatus. A standard dispersing agent (sodium hexametaphosphate) was added to each sample. Samples 77/26 and 29 were then stirred with a mechanical stirrer on an intermittant low speed for a total of ten minutes. Sample 77/21 was prepared some time later by using a glass rod with a protected rubber stirring tip: the sample had soaked overnight in the dispersant.

In all three samples the dispersed clay particles and silt were elutriated from the sand sized particles with controlled streams of water in a 2 litre measuring cylinder. The remaining material was then dried rapidly using sequential alcohol and acetone washes. The dried samples were then viewed with a binocular microscope and a selection of angular and subangular to rounded quartz grain made. About 15 to 25 grains were chosen for each sample. A deliberate preference for single mono-crystalline grains was exercised so that interpretation and further sample preparation was not unduly complicated.

The control sample was a fresh well-formed clear quartz crystal about 3 cm long and about 0.5 cm thick. This sample was crushed with a steel mortar and pestle and then examined with a binocular microscope to remove the sand sized grains for surface texture examination. About 10 to 15 grains were selected, and a preference was exercised for equant grains rather than slivers.

All samples chosen for examination were further prepared by mounting them on a special holder using a thin film of nail varnish. S.E.M. facility staff then coated the grains with a thin film of conductive gold. The samples were then examined with the S.E.M.

7.1.3 DESCRIPTION AND DISCUSSION OF THE TEXTURES

7.1.3.1 SAMPLE NO. 77/26

Plates No.63 to No.68 relate to sample 77/26.

The textures encountered on the grains from sample 77/26 were almost exclusively related to a large variation of conchoidal breakage patterns, semi-parallel and arc shaped steps, imbricate breakage blocks, precipitation and solution. By far the most difficult feature to recognise appears to be irregular small scale indentations - these features I could not identify with real confidence: it seemed to me to be far too subjective.

Plate No.64 seemed to be the best grain to show large scale variation in conchoidal breakage patterns. Precipitation textures are interpreted in Plate 63.The area of precipitation is annotated [p] and enclosed by dotted lines. The smooth blotchy textures on an otherwise angular grain seem to me to correspond with descriptions and photographs shown by Krinsley and Doornkamp (1973).

Plate No.65 shows small scale arc shaped steps which are seen to bifurcate in the top left section of the photograph. These features appear to resemble semi-parallel steps or even imbricate breakage blocks but I make the distinction on the basis of the scale only. It seems from Krinsley's and Margolis' (1969) work they make the distinction on the same basis.

Plate No. 66 shows semi-parallel steps intersecting almost at 90° on an otherwise quite smooth surface. The whitish flecks I suspect are cleavage flakes. The black hexagonal patterns I interpret as solution effects.

Plate No. 67 shows large scale arc shaped features which I interpret simply as large scale arc shaped steps similar to the feature shown in plate 65, but not as regular nor as smooth.

Plate No. 68 represents the last of the recorded textures pertaining to sample 77/26 from the Lower road cutting. This plate is a convincing texture showing imbricate breakage blocks [Ib], arc shaped steps [As] and semi-parallel steps [Ss].

The textures depicted in plates 63 to 68 are representative of textures encountered throughout the scanning of samples. These textures were not difficult to recognise nor were they infrequent. I did not

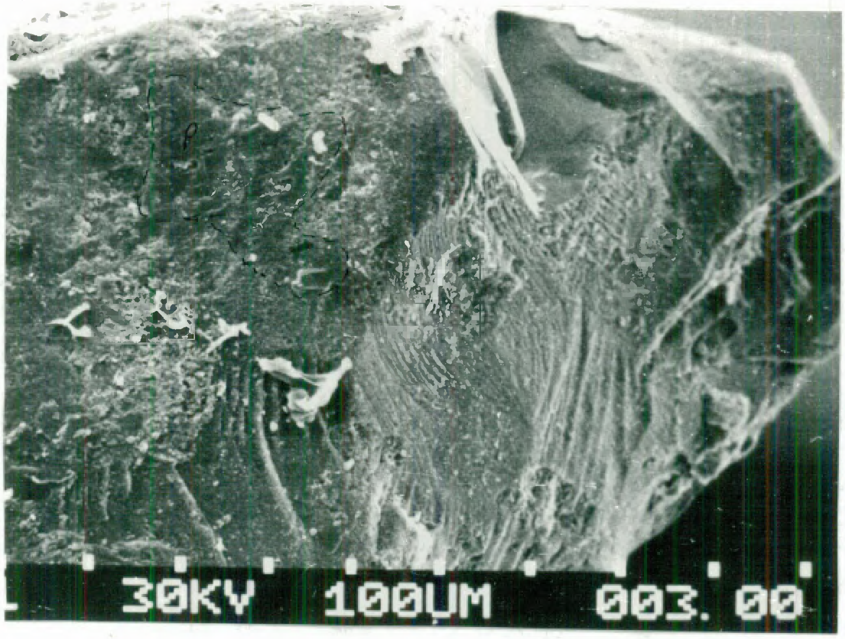


Plate 63 Conchoidal breakage patterns and a precipitation surface on a quartz sand grain viewed with a S.E.M. (scanning electron microscope). Sample 77/26

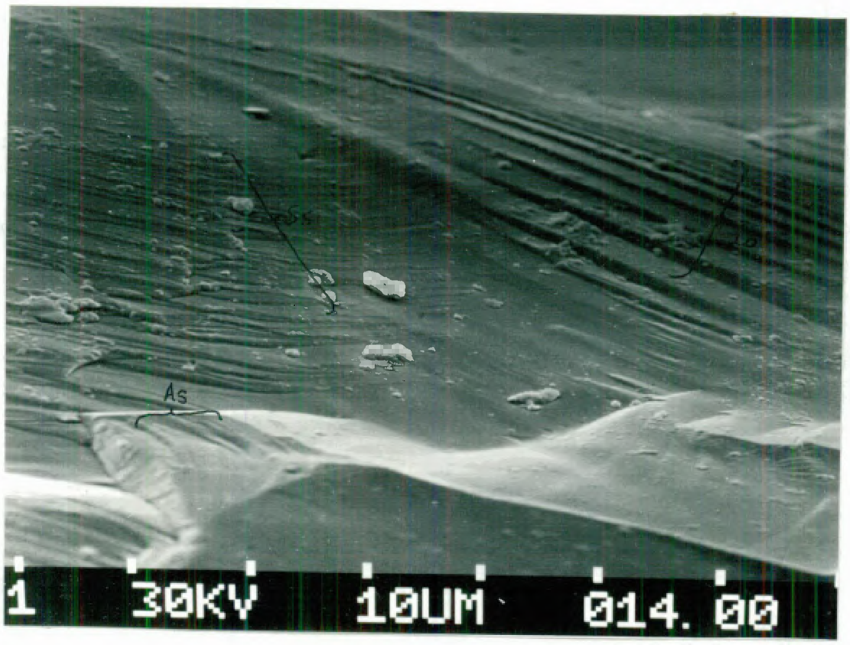


Plate 64 Imbricate breakage blocks (Ib), arc-shaped steps (As) and semi-parallel steps (Ss). Sample 77/26

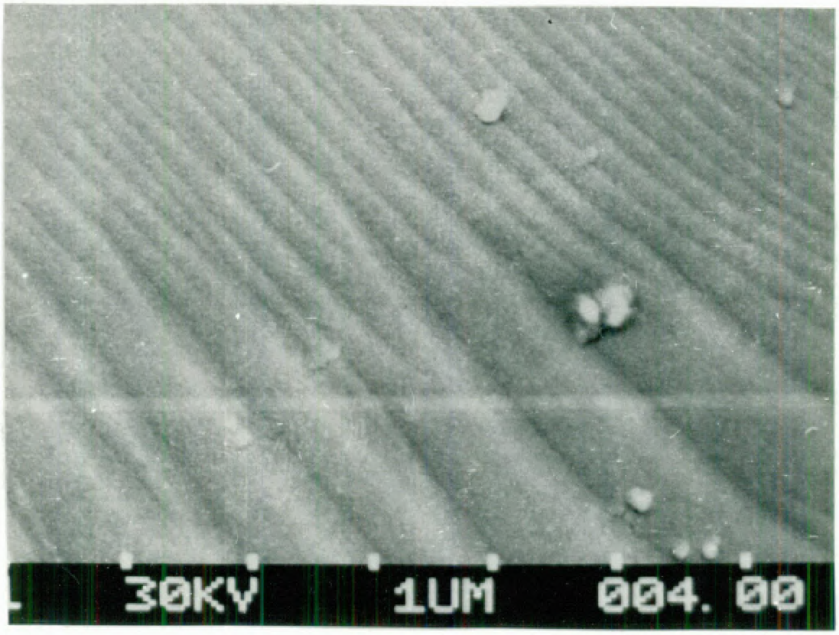


Plate 65 Portion of arc-shaped steps (As)
Sample 77/26

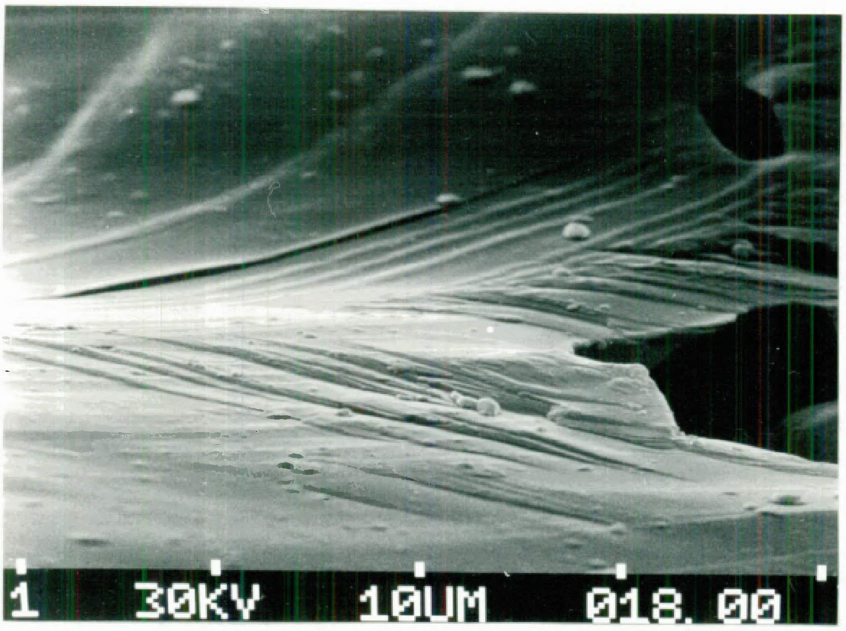


Plate 66 Semi-parallel steps with hexagonal
solution holes. Sample 77/26

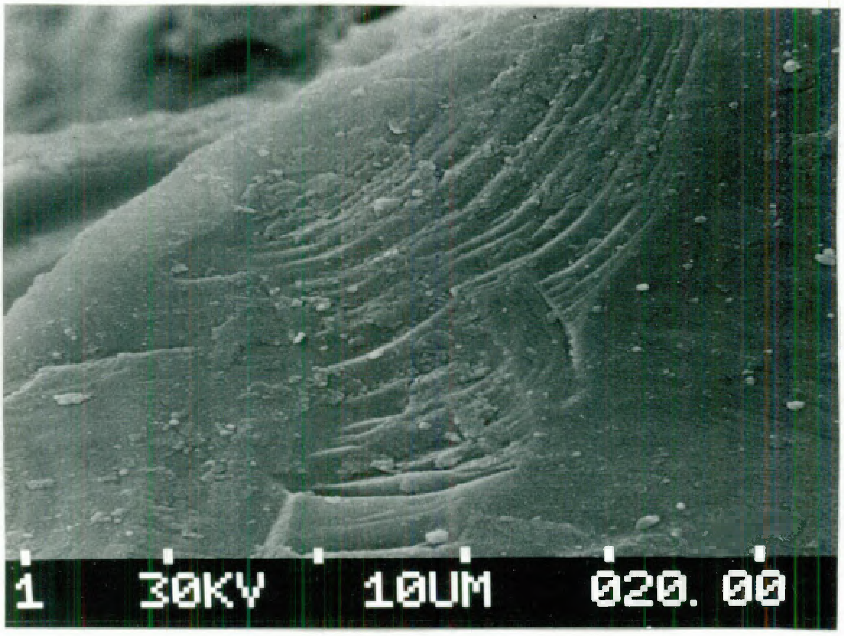


Plate 67 Large scale arc-shaped steps.
Sample 77/26.

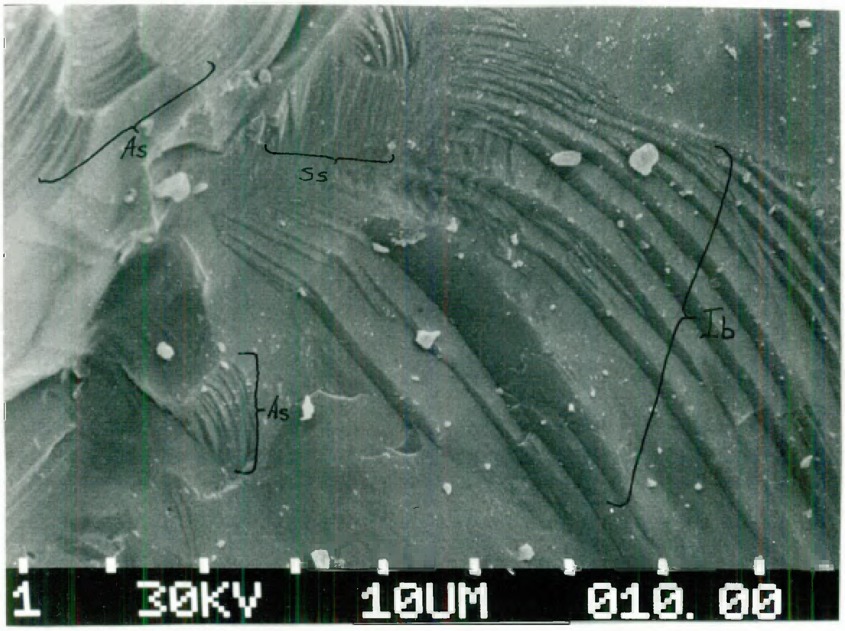


Plate 68 Imbricate breakage blocks (Ib), semi-parallel steps (Ss) and arc-shaped steps (As). Sample 77/26.

estimate with any statistical measure in mind, at the time of scanning, the total incidence of the textures found in the grain population examined. Not all the grains were suitable subjects due to "charging" or foreign matter covering the grain surfaces. Some grains were considerably pitted due to, I expect, diagenetic alteration. Of the grains scanned in detail about 5 or 6 contained well defined textured surfaces

7.1.3.2 SAMPLE NO. 77/29

Plates 69 to 73 relate to sample No. 77/29

Sample No. 77/29 is from a unit stratigraphically lower than sample No. 77/26 by approximately 10 to 13 m, but located in the same road cutting (the Lower road cutting). The textures encountered on quartz sand grain surfaces were essentially the same as those found on grains from sample No. 77/26. However, parallel striae were recorded on grains from sample No. 77/29 and were not recognised on grains from sample No. 77/26.

Plate No. 69 is representative of the arc shaped steps [As] and the semi-parallel steps [Ss] found on surfaces ; they are very small compared with those shown in plate 67. Others were present at a very much larger scale.

Plate 70 and 71 show what I interpret as parallel striae; I base this interpretation on the similarity of the texture in Plates 70 and 71 and the texture shown in figure 12, page 471 from Krinsley and Margolis (1969). Plates 70 and 71 are suitably aligned to permit stereoscopic

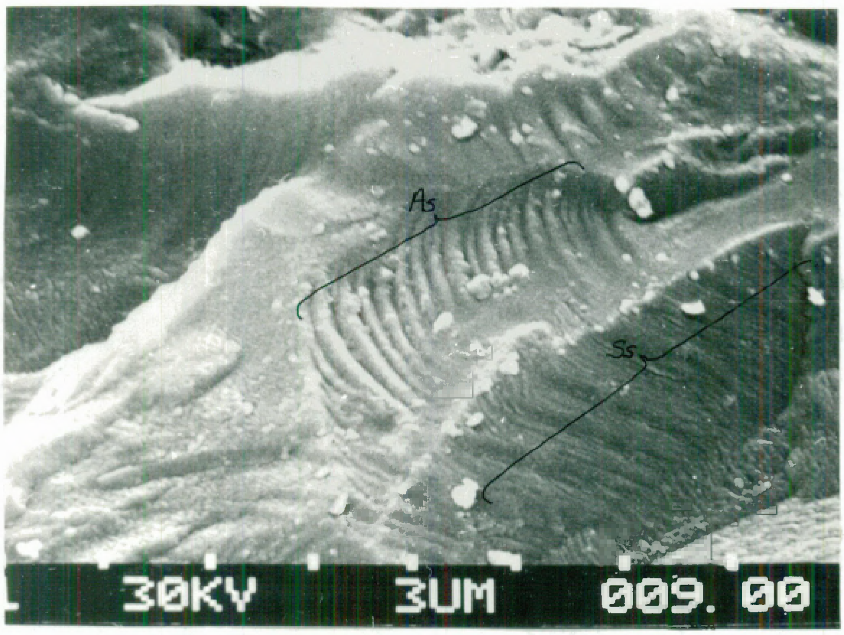


Plate 69 Arc-shaped steps (As) and semi-parallel steps (Ss). Sample 77/29.

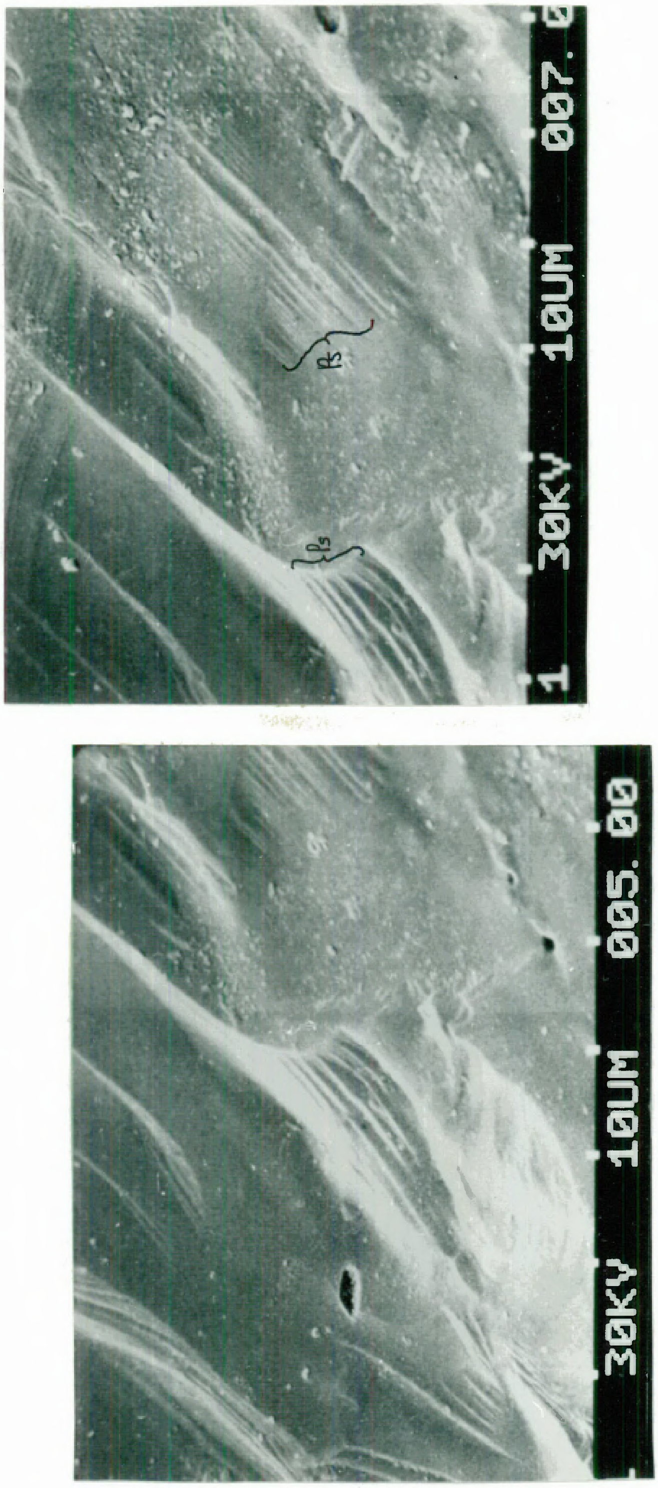
viewing of the two areas of parallel striae.

Plates 72 and 73 represent sequential records of one grain. The textures are arc shaped steps [As], semi-parallel steps [Ss] and solution features. Plate No. 73 is from the area in plate 72 shown by the black dotted outlines. The solution pits [Sp] are only visible in plate 72.

7.1.3.3 SAMPLE NO. 77/21

Plate 74 relates to sample No. 77/21.

Only two significant textures could be recognised after careful examination of about 5 grains. The five grains chosen for examination were selected because they looked to be the most angular available. The general texture was quite dissimilar to those of grains examined from other samples. The typical whole grain from other samples is shown in plate 63, p.194, and is usually not quite so well endowed with such pronounced conchoidal breakage variation. The typical grain from sample No. 77/21 is extensively etched and has regular developed crystal terminations. I interpret those textures as the result of solution-precipitation effects to such an extent that any former glacial textures are now probably unrecognisable. One set of arc shaped steps is identifiable, however, this is hardly sufficient to prove the sample to be clearly glacial.



Plates 70 and 71 A stereoscopic pair with parallel striae (Ps). Sample 77/29

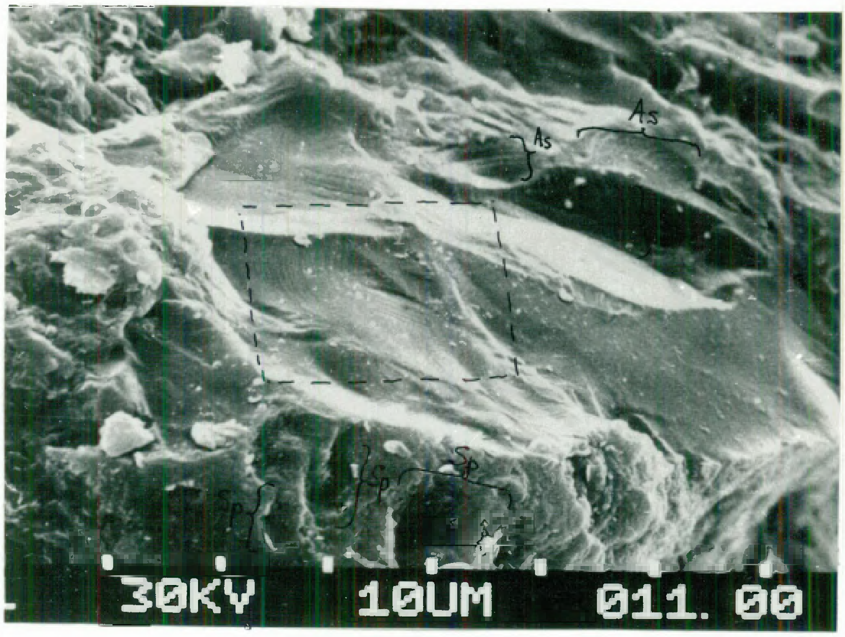


Plate 72 Arc-shaped steps (As), semi-parallel steps (Ss) and solution pits (Sp). Sample 77/29.

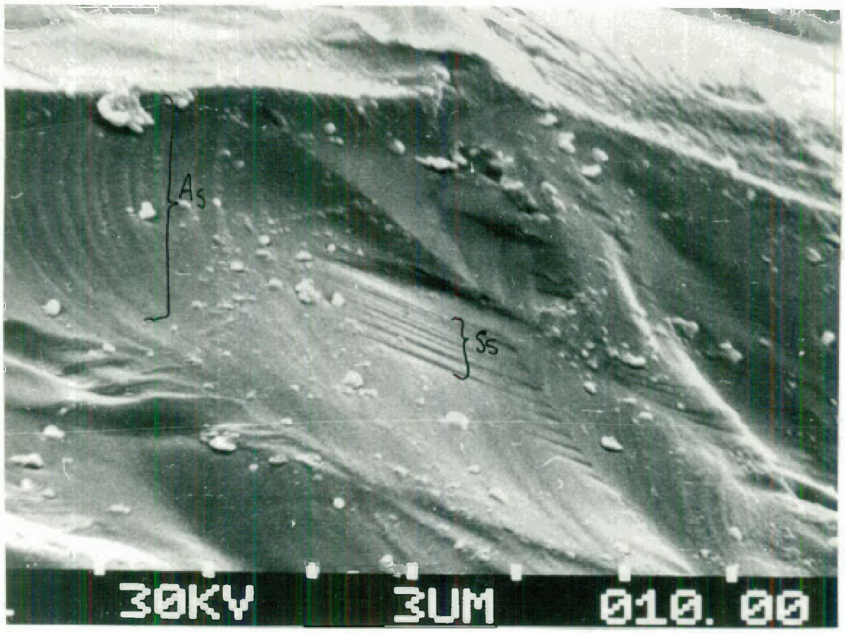


Plate 73 An enlargement of the area indicated in plate 72. Sample 77/29.

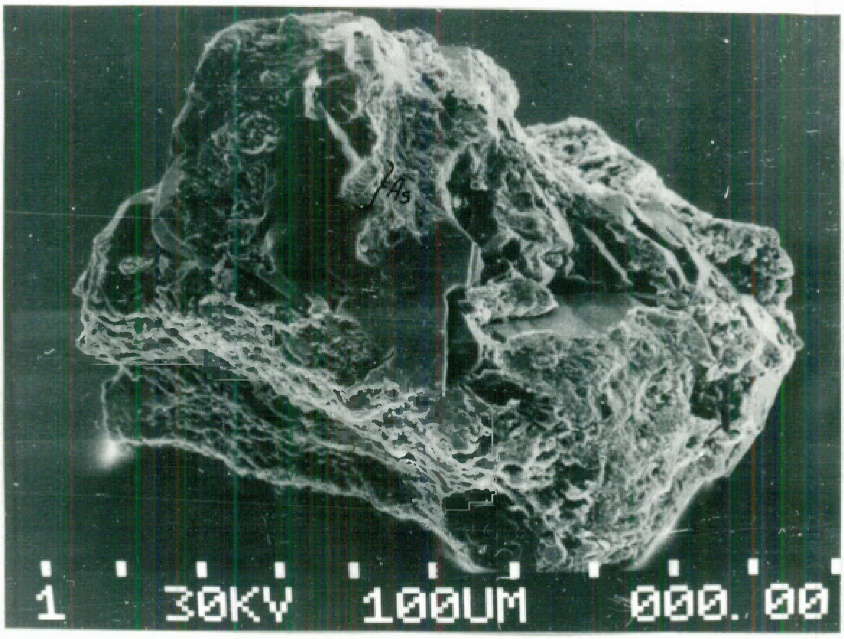


Plate 74 A single quartz sand grain with crystal faces with the remainder of the grain highly etched. Sample 77/21.

7.1.3.4 CONTROL SAMPLE

Plates 75 to 79 represent those textures which have been produced artificially on the surface of a quartz grain. A crystal was crushed and examined and plate 75 shows a typically angular grain. Plate 76 shows the detailed surface texture of the area dotted on plate 75. and also shows an irregular texture which I interpret as being upturned cleavage plates, as shown and discussed by Krinsley and Doornkamp (1973).

Plate No. 77 shows what could be called parallel striae [Ps], arc shaped steps [As] and semi-parallel steps [Ss]. However, the sample is not a glacially entrained grain. Both plate 78 and 79 show semi-parallel steps.

7.1.4 THE SIGNIFICANCE OF THE TEXTURES

The textures encountered in samples 77/26 and 29 show a high degree of similarity with those recorded by Krinsley and Margolis (1969), Krinsley and Donahue (1968) and Krinsley and Doornkamp (1973).

Of early concern was that textures I have recorded are relatively unmodified but this concern has been somewhat offset by the relatively unmodified appearance of textures shown by Hamilton and Krinsley (1967) for textures from the Permian Dwyka Tillite and by Krinsley and Doornkamp (1973) for textures of glacial grains from Miocene deposits. However, the textures produced by the hammer crushing of quartz seems to be identical to those textures thought to be indicative of a glacial environment.The range of sizes is no greater for samples 77/26 and 77/29

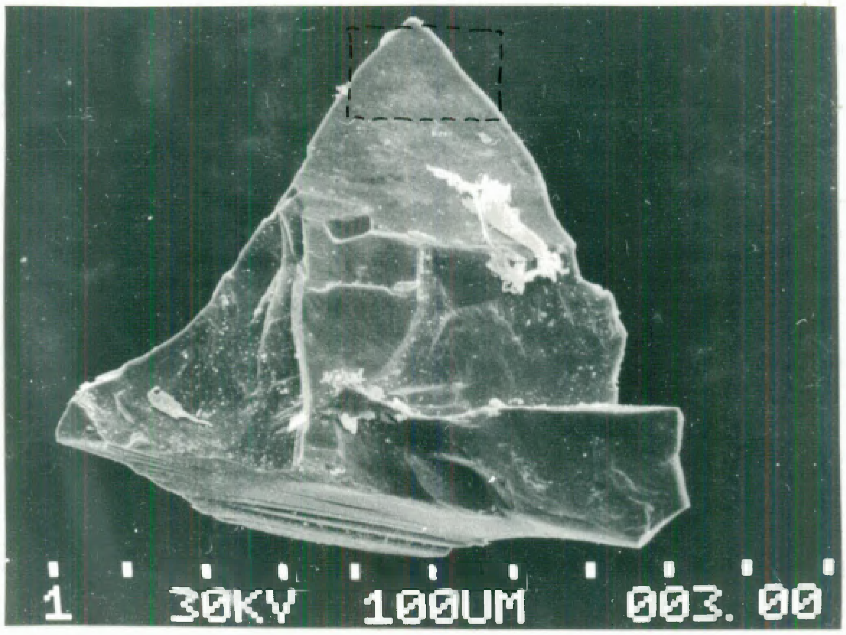


Plate 75 Grain from a crushed quartz crystal. Control sample.

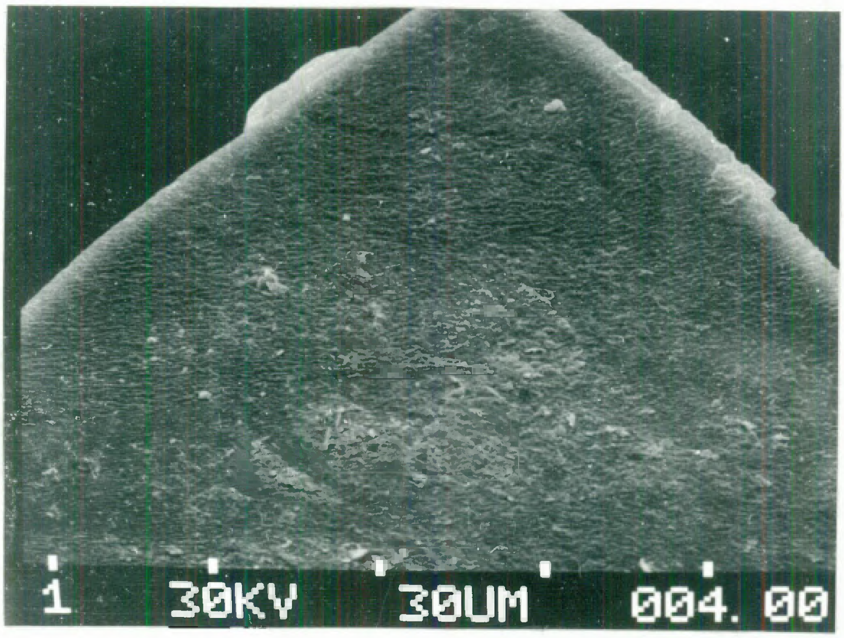


Plate 76 Irregular fracture surface from crushed crystal. Control sample.

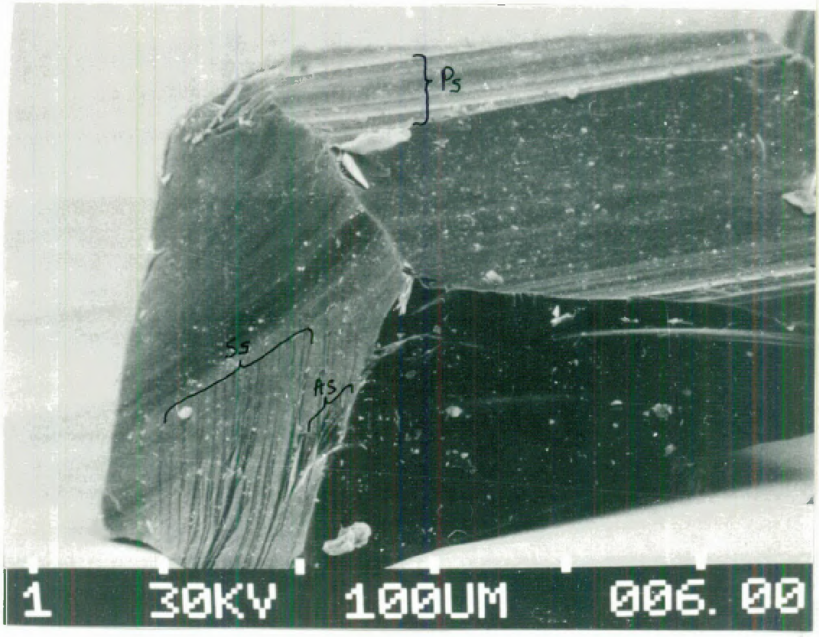


Plate 77 Parallel striae (Ps), arc-shaped steps (As) and semi-parallel steps (Ss). Control sample.

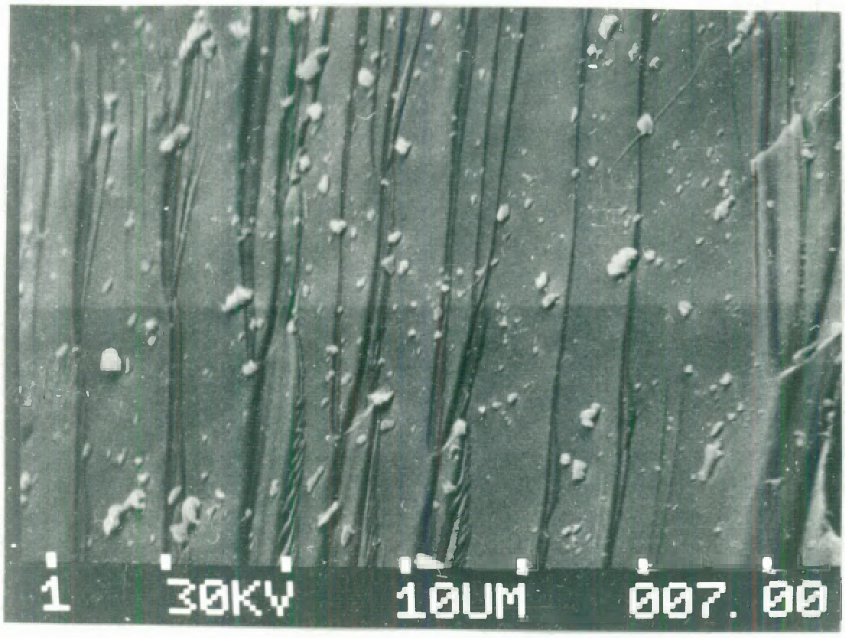


Plate 78 Semi-parallel steps shown in plate 77. Control sample.

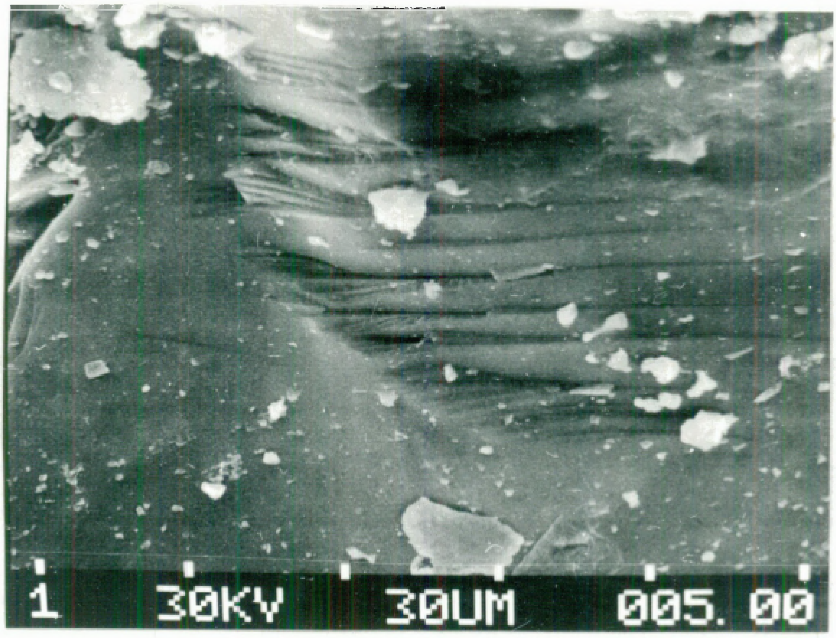


Plate 79 Semi-parallel steps. Control sample.

than for the artificial crushed quartz. Krinsley and Doornkamp have already looked at this question of the similarity between glacially entrained quartz grains and artificial textures. They believe that fresh quartz released from a newly weathered source rock may contain conchoidal breakage patterns similar to those found on glacially entrained grains. They claim that fresh unmodified textures are rare and if found are apt to vary considerably. Both glacial grains and freshly released grains from a weathering source rock would have surface textures showing up-turned cleavage plates with flat upper and lower surfaces but again they claim the size variation of cleavage plates would be much greater for the non-glacial grain.

The explanation of these differences seems reasonable but it is the ease with which they can be distinguished that I doubt. Quartz grains that have fractured due to some stress at a predisposed plane [for example, in ways discussed by Moss (1966)] could complicate or even lead to errors in the interpretation of the palaeoenvironment of sediments.

7.1.5 CONCLUSIONS

I cannot confidently see substantial difference between the surface textures on grains from Permian sediments and those created by non-glacial processes. I doubt the conclusiveness of the technique at this stage as an absolute discriminator of any glacial environment but in view of other evidence there is perhaps some support to the nature of the sediments examined.

7.2 HEAVY MINERAL ASSEMBLAGES

7.2.1 INTRODUCTION

Heavy mineral assemblages in glacial deposits from Antarctica have been investigated by Badin (1981) in an attempt to assign age to the deposits. Others for example, Gravenor (1979), Gravenor and Gostin (1979) and Gravenor (1979) investigated the heavy mineral assemblages from mainly Permian glacial deposits from Gondwana but also some Late Precambrian tillites of Australia.

7.2.2 HEAVY MINERAL ANALYSES

By using standard dry sieving and bromoform separation techniques the heavy mineral assemblages were examined from the very fine sand fraction of some of the glacial deposits from the northeastern district.

Assemblages are from the following deposits:

* 77/28 — Lower Whitfield-Whitland road cutting(traction current deposits) locality: 78/43.

* 77/31 — Upper Whitfield-Whitlands road cutting(traction current deposits) locality: 78/44.

* 77/29 — Lower Whitfield-Whitlands road cutting(diamictite) locality: 78/43.

* 79/32 Magpie creek, Wooragee Valley
Beechworth(traction current deposit)
locality: 77/21.

Relatively unstable heavy mineral species persist in the diamictite along with highly stable species such as tourmaline, rutile and zircon. In contrast, the traction current deposits contain fewer unstable species and are dominated by the highly stable trinity: tourmaline, zircon and rutile.

7.2.3 THE RESULTS OF HEAVY MINERAL ANALYSES

The heavy mineral assemblages are compared for each deposit (by percentages, non-opaques, opaques and individual species frequency, see table 8, p.210.) These assemblages are unlike those listed by Gravenor (1979, 1142) for the Bacchus Marsh, Derrinal and Coleraine tillites from Victoria. The essential difference is that the heavy mineral assemblages listed by Gravenor are dominated mostly by garnets. Those from the northeastern district are very clearly dominated by zircons followed by rutile.

All samples except 77/29 are dominated by opaques rather than non-opaques (perhaps this may be a refection of weathering). Sample No. 77/31 (Lower cutting - traction current deposit) is dominated by magnetite; the remaining samples have only minor amounts. The assemblages for the northeastern district are quite different from other deposits elsewhere in Victoria and so the assemblages from the northeastern district were compare with each other to see if any special relationships exist between them. The non-opaque assemblages are compared in table 8 and figure 7 via cumulative frequency curves Vs

Table 8 A summary of heavy mineral species in selected samples from northeastern Victoria

SAMPLE	% OPAQUES	% NON-OPAQUES	% ZIRCON	% RUTILE	% TOURMALINE	% GARNET	% HORNBLENDE	% SPHENE	% PYROXENE	% MONAZITE	% ZOISITE	% SILLIMANITE	% STAUROLITE	% BIOTITE	% HERCYNITE	% BROOKITE	TOTAL COUNT
77/31 (Loc 78/44) Upper road cutting Whitfield-Whitlands (Fluvioglacial)	88.6 (1766)	11.4 (228)	35.09 (80)	28.07 (64)	29.39 (67)	0 -	4.82 (11)	1.75 (4)	0.44 (1)	0.44 (1)	0	0	0	0	0	0	1994
77/28 (Loc 78/43) Lower road cutting Whitfield-Whitlands (Fluvioglacial)	89.4 (1845)	10.6 (219)	58.45 (128)	19.63 (43)	17.81 (39)	3.20 (7)	0.91 (2)	0	0	0	0	0	0	0	0	0	2064
79/32 (Loc 77/21) Magpie Creek Wooragee Valley Beechworth (Fluvioglacial)	78.75 (926)	21.25 (250)	82.00 (205)	8.00 (20)	6.40 (16)	1.20 (3)	0.40 (1)	0.40 (1)	0.40 (1)	0	0.40 (1)	0	0	0.40 (1)	0	0.40 (1)	1176
77/29 Lower road cutting Whitfield-Whitlands Tillite	64.00 (390)	35.00 (219)	61.65 (135)	6.39 (14)	5.02 (11)	5.48 (12)	0.91	0	5.02 (11)	0	5.02 (11)	4.11 (9)	2.74 (6)	3.20 (7)	0.46 (1)	0	609

stability rating. The relationships are tested using Kolmogorov-Smirnov statistics (Siegel, 1956 and Taylor, 1977). The results of these tests are shown in table 9, p.213.

Samples 77/31 (Upper cutting - traction current deposit) and 77/32 (Magpie Creek -traction current deposit) are both strongly related (0.999 level of significance) to sample No. 77/28 (Lower cutting - traction current deposit) but not to each other nor to sample No. 77/29 (Lower cutting - diamictite).

7.2.4 CONCLUSIONS

The heavy mineral assemblages are not the same as those in other parts of Victoria because of the strong influence of probably Lower Palaeozoic sedimentary rocks yielding tourmaline, and zircon, and metamorphic rocks yielding tourmaline, rutile and zircon. Garnets are notably absent but it is unlikely that they have been lost in the way Gravenor and Gostin (1979) account for the absence of garnet from late Precambrian tillites in the Adelaide geosyncline, because the northeastern glacial deposits presently show no evidence of interstratal solution (heavy mineral grains lack the characteristic saw-tooth edge and cocks-comb boundaries) nor have they been buried over any long time interval. The assemblage for the northeastern district is more likely to result from source rocks rich in the species now present. Some support to this point of view is seen because the northeastern deposits do contain some amphiboles and pyroxenes, unlike the Bacchus Marsh, Derrinal and Coleraine deposits.

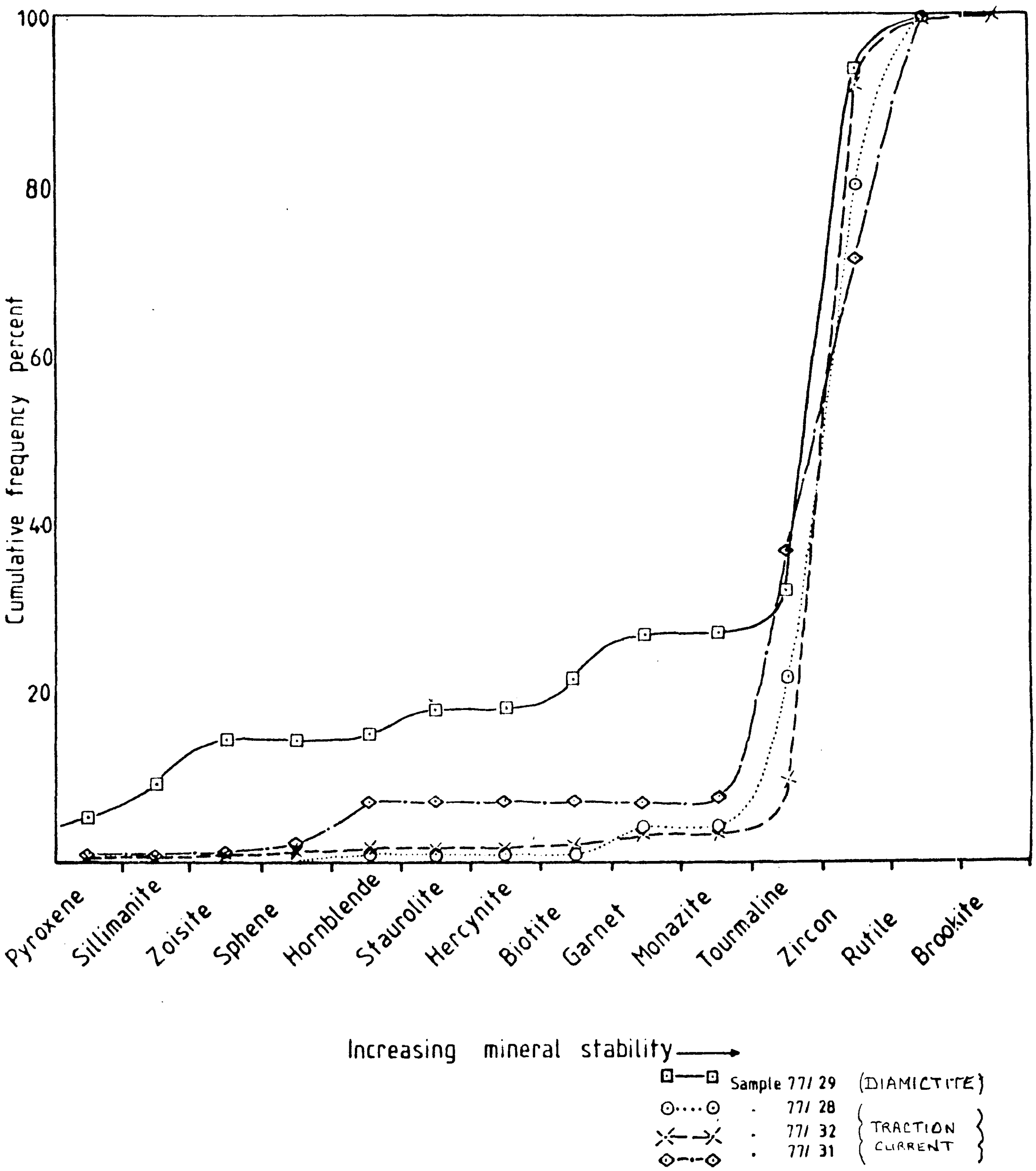


Figure 7 Cummulative frequency of heavy mineral species Vs heavy mineral stability series for selected samples from northeastern Victoria

Table 9 A significant difference matrix for comparison of heavy mineral suites using the Kolmogorov - Smirnov statistical test

α = 0.001 two-tailed tests $N > 40$. Use Table M

$$D_c = 1.95\sqrt{\frac{n_1 + n_2}{n_1 + n_2}} \quad : \text{ calculated critical value}$$

D_o = observed value

H_0 The heavy mineral assemblages of the two samples show no significant differences and may be considered to have been derived from the same populations

	77/28 n=219	UPPER WHITFIELD WHITLANDS ROAD CUTTING 77/31 n=228	MAGPIE CREEK WOORAGEE VALLEY BEECHWORTH 73/32 n=250	LOWER WHITFIELD WHITLANDS ROAD CUTTING 77/29 n=219
Lower Whitfield Whitlands Road Cutting 77/28 n = 219		D_o = 0.1492 D_c = 0.1845 Accept H_o	D_o = 0.1232 D_c = 0.1805 Accept H_o	D_o = 0.2284 D_c = 0.1863 Reject H_o
Upper Whitfield Whitland Road Cutting 77/31 n = 229			D_o = 0.2724 D_c = 0.1786 Reject H_o	D_o = 0.2168 D_c = 0.1845 Reject H_o
Magpie Creek Wooragee valley Beechworth 79/32 n = 250				D_o = 0.2374 D_c = 0.1805 Reject H_o

H_1 The heavy mineral assemblages are significantly different and appear to be derived from separate populations

These differences support the view that a SW source area is less likely than perhaps a more southerly source area. A view already suggested by other evidence.

In addition to possible source directions the comparison of the heavy mineral assemblages from within the northeastern district point to the similarity of the traction current deposits (see table 9). The traction current deposits contain fewer metastable heavy minerals than the diamictite. This difference, although statistically significant, cannot be given a satisfactory geological explanation.