CHAPTER 4

FABRIC STUDIES ON THE KEEPIT CONGLOMERATE

A. CONGLOMERATE FABRIC STUDIES

1. Introduction:

The existence within gravels and conglomerates of an anisotropic fabric has long been recognised (Jamieson, 1860, p.349; Becker, 1893, p.54). The first quantitative fabric studies were made upon tills and glacial gravels by Richter (1932,1933). Since then, numerous fabric studies have been undertaken, not only upon gravels and conglomerates but also upon sands and sandstones (e.g., see Potter and Pettijohn, 1963, p.40-48). Amongst the rudaceous deposits the fabric of tills and tillites has received the most attention. Comprehensive reviews of fabric studies include those of Potter and Pettijohn (1963) and Johansson (1965).

The aims of fabric studies of rudaceous deposits are twofold:

1. determining palaeocurrent directions in conglomerates often devoid of other directional structures.
2. as an aid to understanding the origin or transport mechanism of the deposit.

Potter and Pettijohn (1963, p.23) state "The principle object of the study of sedimentary, primary fabrics has been the reconstruction of current direction, ... fabric studies of sedimentary rocks have been little used to understand the transport process itself." More recently, however, fabric studies have been used to understand the transport processes or to aid in determining the origin of some conglomerate deposits (Lindsay *et al.*, 1970; Davies and Walker, 1974; Rust, 1975; Hendry, 1976).

Directional sedimentary structures are not common in the Keepit Conglomerate. Fabric studies were therefore undertaken with the primary aim of providing palaeocurrent data. A secondary aim was to use the resultant fabric data, wherever possible, as an aid to understanding the transport process(es) and depositional environment(s) of the Keepit Conglomerate. The fabrics measured from the Keepit Conglomerate are original primary sedimentary fabrics; no evidence was found for later tectonic modification of these fabrics.

This section discusses fabric studies in general and the results of such as they apply to palaeocurrent interpretation. The significance of the depositional fabrics with respect to conglomerate sedimentation will be discussed in Chapter 7.

2. Techniques:

Gravel fabrics may be readily measured due to the size of the fabric elements. The major problem with such fabric studies is the time required to measure an adequate sample. Two aspects of the sample are usually recorded; the dip and dip direction of the AB plane and the dip and azimuth of the A axis.* In some instances the attitude of the C axis, equivalent to the pole to the AB plane, may be recorded.

Techniques for the study of gravel fabrics, mostly relating to unconsolidated deposits, are reviewed in Potter and Pettijohn (1963, p.28-31). Fabric studies upon indurated deposits are more difficult and may require the measurement of the apparent longest axis, A', or, less commonly, the apparent maximum projection plane A'B'. Fabric studies of A' or A'B' require suitable outcrop faces parallel and/or perpendicular to bedding. Clasts are usually selected for measurement such that the ratio A':B' is at least 2:1 (Pettijohn, 1962; Lindsey, 1966) in order to reduce any possible error between A' and A. The data is non-vectorial two dimensional and is usually presented for A' in the form of rose diagrams. Specification of the upcurrent direction may be difficult if imbrication or some other criterion is unavailable. Fabric studies utilising A' include White (1952), Schlee (1957), Pettijohn (1962), Lindsey (1966), Nilsen (1969), Nilsen and Simoni (1973), Davies and Walker (1974) and Walker (1975). Schlee (1957) proposed a method which involved measuring the apparent dip of the apparent A axes on adjacent outcrop faces and plotting of the results on a stereographic projection. Fabric studies using the A'B' plane are less common and include those of Nilsen and Simoni (1973), Rocheleau and Lajoie (1974) and Hendry (1976), of which only

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* The terminology of clast axes follows that of Kalterherberg (1956) cited in Potter and Pettijohn (1963, p.28). The longest axis is termed A, the intermediate one B, and the shortest C. The AB plane is the maximum projection plane, containing both the A and B axes. All three axes are mutually perpendicular.

Hendry details the procedure used. The results are usually presented on a stereographic projection.

An alternative to measuring A' or A'B' is the removal of the clasts from the matrix, or the scraping of the matrix away from the clasts, in order to identify and measure the A axis and the AB plane. This technique was employed in this study and is discussed in more detail below. Due to the three dimensional nature of the data the results are usually plotted as stereographic projections. Both polar and equal area (Schmidt) nets have been used. Fabric studies involving this method include Lindsay (1964), White (1966), Lindsay *et al.* (1970) and Walker (1975a, p.741).

3. Interpretation:

By far the greater amount of fabric studies are aimed at determining palaeocurrent directions through the orientation of the A axis and AB plane. Johannson (1965, Table 1) summarises the various orientations of the A axis for deposits of different origins. The two situations most applicable to this study are fluvial and resedimented conglomerates and the nature of their fabrics will therefore be discussed in more detail.

Fluvial gravel fabrics are widely documented, e.g., Krumbein (1939,1940,1942) Schlee (1957), Johansson (1963,1965), Sedimentary Petrology Seminar (1965), Sengupta (1966), Kelling and Williams (1967), Rust (1972b, 1975), Ryder and Scholten (1973), Liboriussen (1975); additional references are cited by Potter and Pettijohn (1963, p.35).

The most obvious feature of fluvial fabrics is a strong upstream imbrication of the AB plane, reflecting the unidirectional flow. When plotted on a Schmidt net a prominent mode exhibiting monoclinic symmetry results (e.g., Schlee, 1957; Potter and Pettijohn, 1963, Plate 1b; Sedimentary Petrology Seminar, 1965). Instances of downstream imbrication are rare, and mostly result from clasts deposited upon foreset beds (Johansson, 1963, p.110; Sengupta, 1966; Bandyopadhyay, 1971; Liboriussen, 1975). Measurement of the attitude of the AB plane is therefore considered to give a reliable indication of current flow direction.

The orientation of the A axis in fluvial deposits is more variable and has thus been considered less reliable as a palaeocurrent indicator (Schlee, 1957; p.166; Johansson, 1965, p.38-39; Sedimentary Petrology Seminar, 1965, p.281; Liboriussen, 1975, p.236). Rust (1972b) however, considers the A axis to be a reliable current indicator, especially when larger elongate clasts isolated upon sandy beds may be measured. The A axis in fluvial gravel fabrics may parallel the sediment transport direction *a* (Potter and Pettijohn, 1963, p.24) and be imbricate upstream, may be perpendicular to *a*, or may be both parallel and perpendicular to *a*. In this last instance, and especially if the modes are less well developed, the A axes plot on a stereographic projection as a girdle striking perpendicular to *a* and dipping in an upcurrent direction (e.g., Schlee, 1957; Sedimentary Petrology Seminar, 1965; Liboriussen, 1975). Interpretation of the relationship of the A axis to the current direction *a* depends in part upon the number and strength of the modes, and the ability to distinguish the A//*a* from the A⊥*a* modes. The latter is usually possible due to the upcurrent imbrication of A when parallel to *a*. The variable orientation of the A axis has been attributed to a number of factors including the clast size and shape, the density of clasts in the deposit, the sandy or gravelly nature of the substrate, the angle of slope of the sedimentation surface, the method of clast movement, and the depth and velocity of the flow.

Quantitative studies on the fabric of resedimented conglomerates are few. Such have been reviewed and summarised by Walker (1975a, Table 1) who concludes "When all of the available data are studied, six out of seven examples show the long axis dipping upstream and parallel to flow". (Walker, 1975a, p.742). Resedimented conglomerates not cited by Walker and exhibiting the A axis parallel to the flow direction are described by Wieser (1954) and Ksiazkiewicz (1958, p.130). Mudflow fabrics have been studied by Lindsay (1964,1966,1968) and Lindsay *et al.* (1970). Lindsay (1968, p.1249) states "The most distinctive feature of the mudflow A axis fabrics is the (upcurrent) dipping girdle". An A axis parallel to flow direction has also been described from avalanche boulder tongue deposits by Rapp (1959). Piper (1970) described resedimented conglomerates in which A axes were oriented transverse to flow direction.

Where measured, the AB planes of clasts in resedimented conglomerates are imbricate upcurrent (e.g., Moors and Schleiger, 1971; Nilsen and Simoni, 1973; Rocheleau and Lajoie, 1974; Walker, 1975a, p.741;

Hendry, 1976). Resedimented conglomerates in which the clasts exhibit no imbrication have been described by, e.g., Aalto and Dott (1970, p.59) and Fisher (1971). Such orientation has been attributed to laminar flow (Fisher, 1971). In conclusion, resedimented conglomerates may often exhibit a preferred orientation of the A axis and/or AB plane which is of use in palaeocurrent studies.

B. FABRIC STUDIES OF THE KEEPIT CONGLOMERATE

1. Method:

A total of 14 localities from 12 sections were the subject of fabric studies. For each locality a suitable outcrop face was selected such that fifty clasts could be extracted from one sedimentation unit. This usually involved an area in the order of two or more square metres. The clasts were extracted with the aid of a hammer and cold chisel. Very indurated and very weathered outcrops were not considered suitable.

The clasts selected for measurement ranged in size from 3.4 cm to 26.2 cm. Large pebbles ranged from 3% to 54% of individual samples, small cobbles from 44% to 86% and large cobbles from 0% to 16%. With respect to clast shape, Potter and Pettijohn (1963, p.30) state "Use of all particles tends to increase variability and, in extreme cases, to obscure the current direction". The more spherical clasts were assumed to be more variable in their orientation, thus elongate and discoidal clasts have been preferentially used by many authors in fabric studies of the A axis and AB plane respectively (e.g., Schlee, 1957; Sengupta, 1966; Rust, 1972b, 1975). The tendency for the clasts to plot towards the Compact apex of the Sneed and Folk (1958) form triangle (Fig. 5.2) combined with the common difficulty of obtaining fifty clasts of all shapes from any one locality prevented such an approach being used in this study.

Once extracted from the outcrop, the position of the A axis and the AB plane were marked with a felt pen upon the clast. The clast was then repositioned in the outcrop face and the attitude of the A axis and the AB plane were measured with a Brunton compass. A small rigid plastic board was aligned coplanar with the AB plane to enable easier and more accurate measurement of the attitude. This is similar to the method described by Yeakel (1962) for the measurement of crossbeds. The time required for one operator to measure one sample of fifty clasts was usually three to four hours.

The data were plotted upon the lower hemisphere of an equal area (Schmidt) net. Correction for tectonic tilt was made by rotating the beds about the strike to the horizontal. The points were contoured using the squared grid method of Stauffer (1966). As this technique is less satisfactory for situations where the points lie about the periphery (e.g., A axis diagrams) a Schmidegg contourer was used for contouring the A axis diagrams (see Turner and Weiss, 1963, p.60). Use of the same technique for contouring the poles to the AB plane gave results comparable to those obtained by the somewhat quicker Stauffer method. The contoured diagrams are presented in Fig. 4.1.

The apparent A axis, A', was able to be measured in a number of localities (10) where low dips resulted in suitable bedding plane exposures. The azimuth of clasts with the ratio A':B' at least 2:1 were recorded. The conglomerates were clast supported with the exception of sample f13-5, a matrix supported conglomerate. It was hoped that in the absence of readily measurable directional sedimentary structures the orientation of A' would be of use in palaeocurrent studies. The results, discussed below, were not completely satisfactory and led to the undertaking of the three-dimensional fabric study outlined above. Also measured were the orientations of the apparent long axes of elongate plant fragments (f12-22) and mudstone fragments (f10-24, f11-22) present in very thick coarse sandstones. The results are presented as rose diagrams in Fig. 4.2.

For each sample was calculated the direction and degree of preferred orientation and the probability that this preferred orientation was not due solely to chance, after the methods described by Curray (1956). The calculations were done by computer and the results are presented in Table 4.1.

The vector mean represents the direction of preferred orientation and is calculated from the formula

$$\tan \bar{\theta} = \frac{\Sigma n \sin\theta}{\Sigma n \cos\theta}$$

where θ = azimuth from 0° to 360° of each observation

$\bar{\theta}$ = azimuth of the resultant vector

n = observation vector magnitude

Table 4.1. Orientation data for fabric study of A axes and AB planes

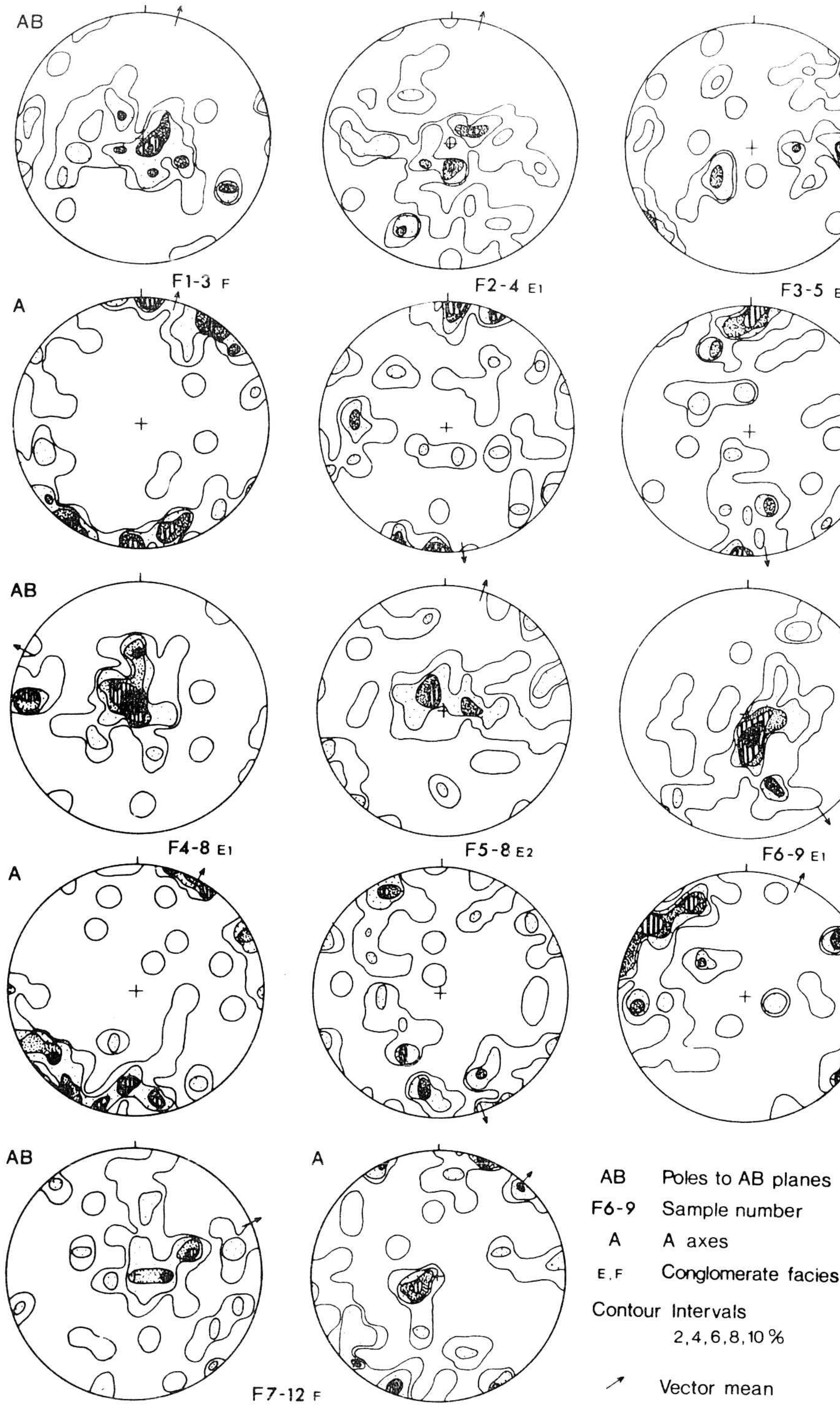
	AB Plane			A Axis		
Sample*1	Vector Mean (θ^o)	Vector Magnitude (L%)	p*2	Vector Mean (θ^o)	Vector Magnitude (L%)	p*2
F1-3	014.56	23.82	0.058	015.60	21.11	0.11
F2-4	013.09	20.66	0.12	172.33	3.26	0.95
F3-5	078.36	14.02	0.37	171.03	41.53	0.00018
F4-8	297.47	32.67	0.005	028.58	35.22	0.002
F5-8	017.34	18.79	0.17	160.20	18.53	0.18
F6-9	144.30	40.01	0.00034	024.09	38.03	0.00073
F7-12	065.26	31.15	0.0078	041.34	29.84	0.012
F8-14	108.08	39.56	0.0004	147.13	18.76	0.17
F9-21	113.11	56.77	0.1×10^{-6}	019.06	22.40	0.081
F10-28	063.88	78.52	0.4×10^{-13}	168.80	20.23	0.13
F11-29	056.92	84.71	0.26×10^{-15}	041.83	24.58	0.049
F12-29	059.57	81.17	0.49×10^{-14}	003.97	33.16	0.0041
F13-31	018.51	71.23	0.96×10^{-11}	006.46	29.93	0.011
F14-39	056.84	50.51	0.29×10^{-5}	007.94	19.12	0.16

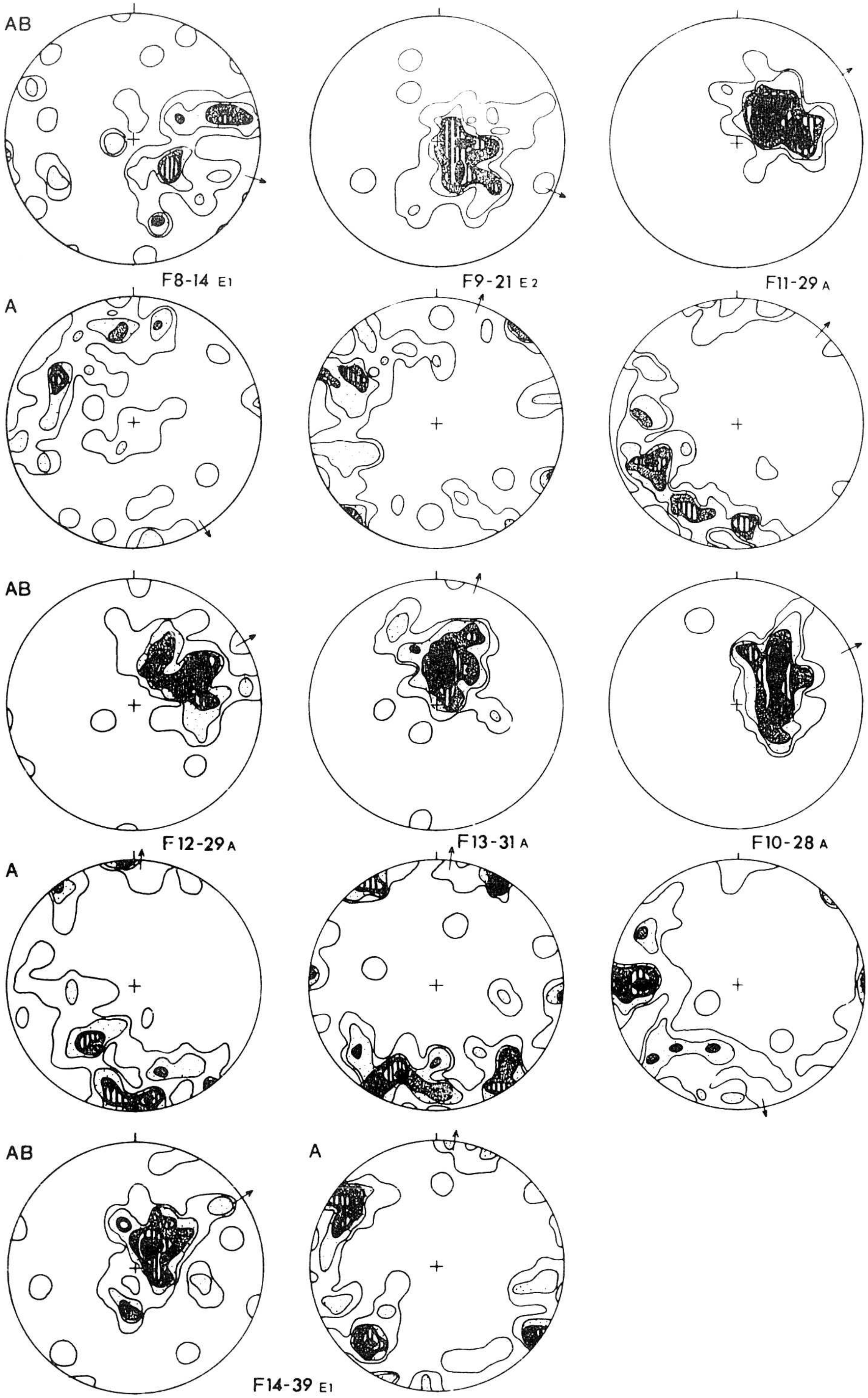
*1 each sample consists of 50 clasts.

*2 p - probability that this degree of preferred orientation resulted from random distribution.

Fig. 4.1. (2 pages)

Stereographic projections of poles to the AB Plane (AB) and A Axes (A). Data plotted on Schmidt nets, lower hemisphere projection. A reasonable to pronounced imbrication is evident in most AB plane plots, while A axes plots tend to be more dispersed. Contour intervals are 2,4,6,8 and 10%. North is indicated by a tick mark, vector means are shown by arrows. Vector mean results are given in Table 4.1. With the sample number, F denotes fabric study, 1 to 14 denote the sample number, and the end figure refers to the section in which the study was done. Also shown are the conglomerate facies types, e.g., A, E1, E2, F. (See Chapter 6).


AB
F1-3 F
F2-4 E1
F3-5 E2
A
AB
F4-8 E1
F5-8 E2
F6-9 E1
A
AB
A
F7-12 F
AB Poles to AB planes
F6-9 Sample number
A A axes
E, F Conglomerate facies
Contour Intervals
2, 4, 6, 8, 10 %
Vector mean


AB
F8-14 E1
F9-21 E2
F11-29 A
A
AB
F12-29 A
F13-31 A
F10-28 A
A
AB
A
F14-39 E1

The degree of preferred orientation is known as the vector magnitude (r) and is given by the formula

$$r = \sqrt{(\Sigma n \sin\theta)^2 + (\Sigma n \cos\theta)^2}$$

The magnitude of the resultant vector in terms of percent (L) is given by the formula

$$L = \frac{r\ 100}{\Sigma n}$$

When the vector magnitude equals 0% the distribution of orientation is random, and no vector mean is able to be determined. When L equals 100% the orientation is perfect and all the orientation vectors will have the same azimuth. The vector magnitude L may therefore be considered as a measure of dispersion comparable to standard deviation or variance.

For data which is non-vectorial, e.g. A axes, the formulae are modified by replacing θ with 2θ. The rationale for this is given by Krumbein (1939) and Curray (1956).

The test of significance applied to the preferred orientation directions is known as the Rayleigh's Test, and is given by the formula

$$p = e^{(-L^2 n)(10^{-4})}$$

where L = the vector magnitude in terms of percent

n = number of observations

p = the probability that a greater percentage magnitude will be obtained by chance selection from randomly distributed data.

No distribution is accepted as being significantly different from randomness unless there are less than 5 chances in 100 (i.e., $p. < 0.05$) of its being due to chance. Thus a value for p of 0.0004 indicates only 4 chances in 10,000 of such being due to chance, while $p = 0.9$ indicates 9 chances in 10 of such being due to chance. In the first case the preferred orientation is significant, in the second case it is not significant.

2. Results:

The contoured stereographic plots of the A axes and the poles to the AB planes are presented in Fig. 4.1. The calculated vector means, vector magnitudes and levels of significance are given in Table 4.1. A brief comment upon each sample follows.

F1-3: A reasonable mode for the AB planes indicates current flow to the southeast. The A axes trend N-NE to S-SW, that is, perpendicular to the inferred current direction. The vector mean for the A axes (15.6^{o}) agrees with their trend, while that for the AB plane (14.56^{o}) bears no relationship to the inferred current direction. The vector magnitude values and low levels of significance, however, indicate the distributions are statistically not significantly different from randomness.

F2-4: The distribution for the AB planes is poor, with two weak modes indicating current flow to the east and south. The vector mean (13.09^{o}) bears little relationship to this inferred current direction. This presumably reflects the large spread of the distribution. The value of the vector magnitude is low (20.66%) and the orientation is considered not significant ($p = 0.12$). The A axes trend 0^{o}-25^{o} to 180^{o}-205^{o} with a minor secondary mode at 275^{o} and imbricate to the west. The A axis orientation thus appears to be perpendicular to flow with a minor imbricate parallel concentration. The vector mean for the A axes is 172.33^{o}, but with the very low vector magnitude and low level of significance the orientation is considered statistically not significant.

F3-5: The AB planes exhibit a good mode, with a very steep dip, indicating current flow towards the east. The A axes form a girdle dipping steeply to the west with the major modes lying essentially in the north-south position, indicating the dominant orientation to be perpendicular to the inferred current direction. The vector means agree with the modes exhibited by the diagrams, with the orientation of the A axis being considered statistically significant, while that of the AB plane is statistically not significant.

F4-8 and F5-8: These samples both have modes indicating a southeastward dip of the AB plane, and hence a northwesterly current flow. The vector mean for F5-8, which is a more dispersed distribution, is 17.34^{o}, but the vector magnitude is low (18.79%) and the orientation is not significant ($p = 0.17$). F4-8, however, has a very good mode with a vector mean of 297.47^{o} and $p = 0.005$ indicating the orientation is significant. The A axes for F5-8 lie on a girdle dipping essentially southwestward. This orientation is considered not significantly different from a random distribution. The A axes for F4-8, however, form a strong concentration perpendicular to the current direction indicated by the AB planes. The vector mean is 28.58°, essentially 90° from the AB plane vector mean, and with a reasonably good vector magnitude (35.22%) and p = 0.002 may be considered a significant orientation.

F6-9: A good mode for the AB plane indicates current flow towards the southeast, with the A axes being essentially parallel to flow and slightly imbricate upcurrent. The vector mean for the AB planes (144.30°) is in good agreement with the inferred flow direction, with a vector magnitude of 40.01 and p = 0.00034 indicating a significant orientation. The A axis vector mean (24.09°), despite being statistically significant, bears little relationship to the apparent flow direction.

F7-12: The AB planes plot mostly within the northeast quadrant with two fairly weak modes present, indicating current flow in this direction. The vector mean of 65.26° is in agreement and the orientation is considered significant (p = 0.0078). The A axes show an alignment in the direction 22° to 202° with minor secondary modes either side. The vector mean (41.34°) is in reasonable agreement with the inferred current flow direction. The A axes thus lie essentially parallel to flow direction, with the orientation being considered significant.

F8-14: The modes for the AB plane indicate flow to the east and southeast, with the A axes forming a girdle dipping to the northwest. The major mode of the A axes distribution indicates alignment predominantly with the flow direction. The vector mean for the AB plane is 108.08° and for the A axis is 147.13°. The orientation of the AB planes is considered significant (p = 0.004), but that of the A axes is not (p = 0.17).

F9-21: A good mode for the AB planes indicates current flow towards the southeast with the vector mean (113.11°) in good agreement and the orientation being considered very significant ($p = 0.1 \times 10^{-6}$). The A axes exhibit a good mode indicating parallelism to flow with upcurrent imbrication and a secondary weak transverse mode. The vector mean (19.06°) bears no relationship with the inferred flow direction, possibly a result of the bimodality of the distribution, and the orientation is statistically not significant (p = 0.081).

F10-28: A strong mode for the AB planes indicates current flow to the eastnortheast. The A axes lie essentially east-west with a pronounced westward imbrication. The vector mean for the AB planes (63.88°) is in agreement with the inferred flow direction, the orientation being statistically significant ($p = 0.4 \times 10^{-13}$), but the results for the A axis distribution (168.80°) are neither in agreement with the inferred flow direction nor statistically significant ($p = 0.13$).

F11-29: A strong mode for the AB plane indicates flow towards the northeast, with the vector mean (56.92°) in good agreement and the orientation considered highly significant ($p = 0.26 \times 10^{-15}$). The A axes form a prominent girdle dipping to the southwest. The dominant mode on the girdle indicates A is parallel to the inferred northeasterly flow direction. The vector mean is in good agreement (41.83°) and the orientation is considered statistically significant ($p = 0.049$).

F12-29: A strong mode for the AB plane indicates flow towards the northeast with a vector mean of 59.57°. The vector magnitude of 81.17 and $p = 0.49 \times 10^{-14}$ indicate the orientation is very significant. The A axes indicate current flow in a north to northeast direction with a vector mean of 3.97°. The orientation is considered significant ($p = 0.0041$).

F13-31: The AB planes exhibit a strong mode indicating current flow to the northnortheast. The vector mean (18.51°) is in agreement and the degree of orientation is highly significant ($p = 0.96 \times 10^{-11}$). The A axes are dominantly aligned parallel to the flow direction as indicated by the AB planes, with subsidiary transverse modes. The vector mean (6.46°) is in agreement with the inferred flow direction and the orientation is considered to be statistically significant ($p = 0.011$).

F14-39: A very good mode for the AB planes distribution indicates current flow to the northeast (vector mean 56.84°) with a significant orientation ($p = 0.29 \times 10^{-5}$). The A axes form a girdle dipping to the southwest. The major mode indicates the A axes are aligned parallel to the inferred northeasterly flow direction and are imbricate upstream. A secondary mode occurs transverse to flow direction. The vector mean (7.94°) does not agree well with the inferred flow direction and statistically is not significant ($p = 0.16$). This probably reflects the bimodal distribution of the A axes.

3. Results of Apparent A Axis Studies:

Rose diagrams showing the orientation of these fabric elements (conglomerate clasts, mudstone fragments, plant fragments) are presented in Fig. 4.2. It should be noted that only a line of movement, and not a direction of movement, is indicated by these fabric diagrams.

The individual conglomerate clast rose diagrams exhibit considerable spread in clast orientation, but usually show an obvious modal class. One or more secondary modal classes are usually present. These secondary modes may be oblique to (e.g., f3-21, f7-20, f9-20, f13-5) or essentially perpendicular to (e.g., f5-21, f8-20, f13-5) the primary mode.

Imbrication was noted in two instances, indicating for F5-21 similar strength modes both parallel and perpendicular to flow direction, and for F6-20 the primary mode perpendicular to flow with subsidiary modes parallel and oblique. Palaeocurrent directions are thus to the northeast in both instances.

The relationship of the modal class of the other samples to flow direction is not clear. With conglomerate fabrics exhibiting A axes oriented either parallel or perpendicular to flow most samples would indicate two possible flow directions. In the case of those samples where the modal class is oriented essentially east-west (e.g., F3-21, F4-21, F9-20, F13-5) and in view of the general west to east nature of the palaeocurrents (Table 2.1), the A' axes may reasonably be assumed to lie parallel to flow direction.

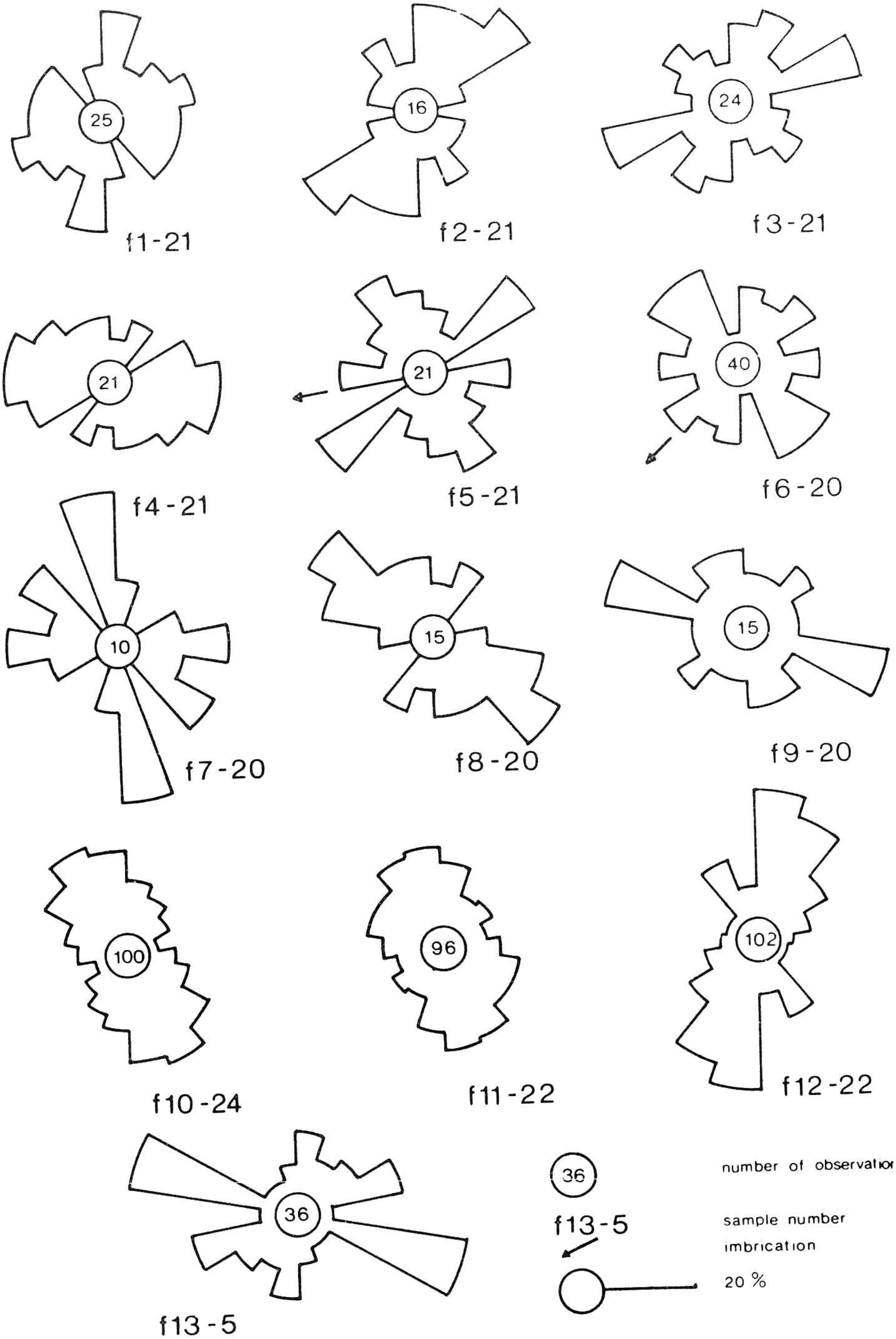
Vector means were calculated for the A' axis orientations, but mostly bore little relation to the modal classes. In all instances the degree of preferred orientation was decidedly statistically not significant (Rayleigh Test used). This presumably reflects the low population numbers and the considerable spread of most samples.

The shale fragment and plant fragment orientation diagrams each exhibit a pronounced modal class. The better preferred orientation and large population numbers resulted in vector means which are statistically significant. Sample F10-24 has a modal class midpoint of 150^{o}, with a vector mean of 159.45^{o}, $L = 39.54$ and $p = 0.162 \times 10^{-6}$. Sample F11-22 has a modal class midpoint of 170^{o}, with a vector mean of 157.04^{o}, $L = 22.54$ and $p = 0.0076$. Sample F12-22 has a modal class midpoint of 010^{o}, with a vector mean of 19.09^{o}, $L = 51.55$ and $p = 0.000$. A good correlation exists between the modal classes and the vector means. The

Fig. 4.2.

Rose diagrams of apparent A axes, A', conglomerate fabrics and the longest dimensions of shale clasts (f10-24, f11-22) and plant fragments (f12-22). See text for discussion. With the sample numbers, f denotes an apparent A axis fabric, 1 to 13 denote the sample number, and the final figure is the section in which the fabric was measured.

Note the direction of current flow is definitely established in only two instances, f5-21 and f6-20, in which samples imbrication was readily evident. The arrows point upcurrent.


25
f1-21
16
f2-21
24
f3-21
21
f4-21
21
f5-21
40
f6-20
10
f7-20
15
f8-20
15
f9-20
100
f10-24
96
f11-22
102
f12-22
36
f13-5
36
number of observatio
f13-5
sample number
imbrication
20 %

preferred orientations are all considered to be statistically significant.

The significance of these preferred orientations with respect to palaeocurrent directions is not clear. No other directional structures occur in close, or even nearby, association. Plant fragments may be aligned either parallel or perpendicular to flow direction (Potter and Pettijohn, 1963, p.39). Crowell (1955) and Hubert (1967) report charcoal fragments in resedimented sandstones to be oriented parallel to flow direction as indicated by other structures within the same bed. Diessel *et al.* (1967) report plant fragments in laminites oriented parallel to flow direction, but in the associated fluvial sandstones and conglomerates most fragments are oriented perpendicular to flow. Descriptions of oriented mudstone fragments and their relation to flow direction have not been found.

The essentially north-south orientation of the plant and mudstone fragments would lead one to suggest an orientation perpendicular to flow. However, this cannot be substantiated as no other palaeocurrent indicators are present in the two sections from which these samples were obtained.

4. Discussion:

The best indication of the palaeocurrents are obtained from the plots of the poles to the AB planes. The data is usually less dispersed and more easily interpreted with respect to flow direction than the data for the A axes. The vector means relate more readily to the flow direction inferred from the stereographic projections, and tend more often to be statistically significant. In contrast, the A axes are less easily related to the current direction, the vector means are less reliable as an indication of flow direction and the indicated orientations are more frequently statistically not significant. These conclusions are essentially in agreement with the opinions of others referred to above in the interpretation section (page 74). Use of both the A axis and AB plane stereographic projections provides adequate information on the palaeocurrent directions. The vector mean results must be interpreted in relation to the distribution pattern on the stereographic projections as in some instances (e.g., bimodal distributions) the vector mean results bear no relation to the inferred flow direction (see also Liboriussen, 1975, p.239).

The results of the apparent A axis study serve to illustrate the problems of using such for palaeocurrent studies. Unless independent palaeocurrent indicators are present (e.g., imbrication, Davies and Walker, 1974), or the expected A axis orientation is known (e.g., A axis fabric of tillites, Pettijohn, 1962; Lindsey, 1966; Casshyap, 1968; Young, 1968), the usefulness of the A' diagrams is limited. They do, however, serve to indicate the existence of a preferred orientation of clasts within the conglomerate. Such may be useful in a consideration of the sedimentation of the conglomerate. Similarly, a preferred orientation exists for plant and mudstone fragments, but there is no unequivocal indication as to the relationship of these fabrics to the original current direction.

One significant point arising from these fabric studies relates to the presence of imbrication in coarse conglomerates. Imbrication was rarely immediately obvious in the outcrops used for the fabric studies. This is due in part to the common high degree of sphericity of the clasts (Fig. 5.2, Table 5.1) and in part to the effect of observation of apparent imbrication angles rather than true imbrication angles in outcrop faces oblique to palaeoflow direction. Fabric studies, however, demonstrated the presence in all instances of a moderate to pronounced imbrication (Fig. 4.1). Thus for coarse conglomerates with abundant clasts of high sphericity, the actual presence or absence of a fabric can only be demonstrated by fabric studies.

5. Conclusions:

The palaeocurrent directions indicated for the Keepit Conglomerate by the fabric study vary from southeast to east of north. A westerly source area and an easterly dipping palaeoslope are thus indicated. This is in agreement with:

(a) palaeocurrent data obtained for the Keepit Conglomerate from other directional sedimentary structures (Table 2.1).

(b) the limited palaeocurrent data for the Keepit Conglomerate available from other sources. White (1966) infers easterly flowing palaeocurrents from three conglomerate fabrics from the north of the Tamworth Belt. Manser (1967) reports southeasterly flowing palaeocurrents from limited sole marks and cross stratification in the Timor area (Fig. 2.5).

(c) the existing limited palaeocurrent data for the Tamworth Belt sequence (Lower Devonian to Carboniferous) (Crook, 1964; McKelvey, 1966; White, 1966; Manser, 1967; McKelvey & White, 1968; Moore and Roberts, 1976). Such indicate a source to the west with essentially easterly flowing currents.

A westerly source is also indicated by the thickness, clast size and lithology trends for the Keepit Conglomerate (see Figs. 2.2, 2.3, 2.4).

Only two exceptions exist to this overall palaeocurrent pattern for the Keepit Conglomerate. Samples F4-8 and F5-8 display a southeasterly imbrication, opposite to all other samples. Possible explanations include:

(a) Failure to recognise cross stratification in the conglomerate at the sample location would result in the plot of the poles to the AB plane indicating a current direction opposite to the actual direction (e.g. Liboriussen, 1975). However, Sengupta (1966) shows the A axes on foresets to be parallel to the current direction, while the stereographic projections of Johansson (1963, Figs. 19,20) and Liboriussen (1975, Fig. 4) show girdles dipping in a downcurrent direction, with strong modes parallel to flow. The A axis fabrics for F4-8 and F5-8 appear to be perpendicular to inferred flow direction. This contrasts with the orientation of A axes of clasts deposited on foreset beds. Subsequent field checking failed to establish the presence of cross stratification.

(b) The eastward imbrication may be real. Beach gravels contain clasts which are usually imbricate sewards (Potter and Pettijohn, 1963, p.36). Stanley (1975, p.30) reports downslope imbrication in submarine valleys. Either of these situations would produce southeastward imbrication of the clasts. Features typical of beach gravels (Bluck, 1967) are absent. There is some indication, however, that these deposits are a channel fill (p.207).

ADDENDUM:

Not long after the final typing of Chapter 5 of this thesis, I received a copy of an article in which fabrics of resedimented conglomerates are well described (Walker, 1977).

The following method was used in the study by Walker. The clasts were measured in place, only those which projected far enough out of the outcrop face to enable alignment of a notebook with the A'B' plane being used; the attitude of the plane was measured off the notebook (this is comparable to the method used in this thesis). The conditions applied were that A' exceeded 1cm, the ratio A':C' was greater than or equal to 1.5, and no tectonically shattered clasts were used. The results were plotted on steronets. A strongly preferred fabric defined by the maximum dip direction of the A'B' plane, is evident in almost all samples. The relationship of the A' and B' axes to this fabric is unknown in almost all instances; where known, A' is predominantly parallel to flow direction.

The following results are significant:

1. The palaeocurrent direction from the conglomerate fabrics agrees with sole marks on associated turbidites. Fabrics of resedimented conglomerates are thus useful for palaeocurrent studies.

2. The degree of orientation and the imbrication angle are not related to clast size.

3. The imbrication angle decreases upwards within a bed, and the preferred alignment becomes better developed. There is no geological significance in the differences in orientation of clasts at various levels within a bed.

4. The agreement in palaeocurrent direction between those samples with highly significant vector means and those significant only at lower confidence limits, suggests that geological significance may be present even in the absence of statistical significance.

Walker explains the development of a fabric in which A axes are aligned predominantly parallel to flow and are imbricate upflow, by the shear stresses operating in flows of high grain concentrations. The positions adopted by the clasts reflect the most stable orientations under the prevailing shear stress conditions.