CHAPTER 5

SHAPE STUDIES OF THE CLASTS OF THE KEEPIT CONGLOMERATE

A. INTRODUCTION

If "pebble shapes are characteristic of the environment which produced them or last acted upon them" (Drake, 1970, p.1356), then shape studies upon ancient conglomerates should provide useful information which may contribute to a better understanding of the dispersal history and the depositional environment of such conglomerates.

Shape studies upon the Keepit Conglomerate were undertaken with the aim of contributing towards an understanding of the sedimentation history of this unit. The Keepit Conglomerate is a first cycle polymictic deposit, the clast population consisting on average of 89% volcanic, 8% intrusive and 3% clastic lithologies. The volcanics are both fine-grained and porphyritic. No internal structures, such as jointing, layering, schistosity or foliation which could affect the initial clast shape, were observed. Flow banding in the volcanics was uncommon, occurring mainly in ash flow tuffs, but when present had no apparent effect on clast shape. Thus with no apparent initial shape controls, and lithologies which are essentially texturally isotropic, the present shapes of the clasts of the Keepit Conglomerate may readily reflect the environment which produced or last acted upon them.

The shape of detrital grains in sedimentary rocks is usually defined by the following parameters; roundness, sphericity, form and surface texture. Of these the first three are the most commonly used in shape studies of gravels and conglomerates.

Roundness refers to the sharpness of the corners and edges of a grain, and is related to the degree of abrasion the particle has undergone. It should thus be of considerable significance in interpreting the type and length of transport or reworking the particle has suffered (Blatt *et al.*, 1972, p.65). Sphericity measures the degree to which a particle approaches a spherical shape. Form describes the three dimensional aspect of a particle, and thus serves to distinguish rodlike from disclike particles which may both have the same numerical sphericity values. A variety of shape parameters have been proposed to describe the roundness, sphericity and form of detrital grains (e.g., Wentworth, 1919; Wadell, 1932; Zingg, 1935; Cailleux, 1945; Sneed and Folk, 1958; Luttig, 1962; Dobkins and Folk, 1970). Visual comparison charts also exist for determining roundness of sand grains (Powers, 1953) and pebbles (Krumbein, 1941). Reviews of the various shape parameters include Fleming (1965), Humbert (1968), Dobkins and Folk (1970), Whalley (1972) and Swan (1974).

The shape of detrital grains is the result of a variety of factors of varying degrees of importance. These include the nature of the source rock, its composition, internal characteristics, and size and shape upon liberation from the outcrop, the nature of weathering experienced by the source rock, the nature and energy of the transporting medium, relating to processes of abrasion and breakage, the distance and duration of transport, and a number of more obscure factors referred to by Sneed and Folk (1958) as "chance".

Given these variables the question exists as to whether the shapes of detrital grains can still reflect the environment which produced or last acted upon them. This possibility of using shape as an environmental indicator has long been recognised, and debated. Dobkins and Folk (1970) cite Stephenson (p.274 in Clark *et al.*, 1912) as being the first to consider flat clasts to be an indicator of a beach environment. In contrast, his contemporary Gregory (1915) considered shape to be unreliable in distinguishing sedimentary environments.

A large number of studies have employed grain shape parameters for environmental determination, with varying degrees of success. Dobkins and Folk (1970) give a good summary of the conflict as to whether well rounded discs characterise beach gravels or not. They conclude that abrasion produces abundant discs on beaches. Luttig (1962) distinguished a variety of environments using his shape parameters of roundness and flatness. He added that further definitive work on recent deposits was needed. Sames (1966), using Luttig's parameters of roundness and elongation, was able to distinguish littoral from fluviatile deposits. Stratten (1975), however, found Luttig's flatness parameter more useful than his elongation parameter in differentiating between beach and river deposits. King and Buckley (1968) utilised the roundness and flatness parameters of Cailleux and the sphericity of Krumbein as an aid in distinguishing a variety of glacial, glacial outwash and beach deposits. They concluded that shape analysis was a useful aid to environmental determination, with roundness being the most useful parameter. Elson (1971) used a silhouette comparison roundness method to successfully distinguish and correlate old glacial-lake beach deposits. Gregory and Cullingford (1974), using the same roundness parameter as King and Buckley (1968), were able to distinguish tills from fluvioglacial deposits. Glover (1975) attempted to correlate river terraces by shape analysis of the gravels, using indices of flatness, sphericity and roundness. Differentiation of various terraces within an area was possible but correlation of terraces between areas was unsuccessful.

An excellent study in the application of shape parameters to environmental determination, and considered relevant to the Keepit Conglomerate, is that of Dobkins and Folk (1970). They studied the shape of basalt clasts in river and beach environments on Tahiti-nui and were able to successfully distinguish the two environments on the basis of roundness, sphericity and, to a lesser extent, the oblate-prolate index. A significant feature was the "magic line" for sphericity values of 0.65-0.66 (Dobkins and Folk, 1970, p.1201) which served to distinguish beach from river gravels, not only for the basalt clasts but also for quartz clasts from other localities. Dobkins and Folk considered a plot of sphericity against oblate-prolate index gave clear separation of beach and river gravels. Stratten (1975), using the same sphericity parameter, also found a value of 0.65 successfully separated massive quartzite clasts of river and beach origin. He plotted sphericity against Luttig's flatness index for separation of beach and river deposits.

That this is not the complete answer to environmental determination by shape analysis can be seen by inspecting the data of Sneed and Folk (1958, e.g. mean sphericity values in Fig. 11, p.131) for fluvial gravels. Chert and quartz clasts fall within the river range but the limestone clasts fall well within the beach range. This, however, is related to the original slab-like shape of the limestone clasts. Similarly, the data of Carr *et al.* (1970) for beach gravels may be plotted on Stratten's (1975, Fig. 4) diagram. The quartzite clasts plot within the beach field but the flint and chert clasts plot within the river field. No reason for the obvious shape difference is given in this or earlier papers (Carr, 1969; Carr and Blackley, 1969), so no explanation for this situation may be offered. Disagreement with this "magic line" thus reflects at least in part an original structural control.

The shape data of Bradley *et al.* (1972, Table 3) for fluvial clasts also illustrates the effect of original structural controls. Quartz clasts possess sphericity and flatness values which would plot within the River field of Stratten (1975, Fig. 4), while foliated clasts possess values which fall clearly within the Beach field. The greywacke clasts possess sphericity values typical of fluvial clasts but may also possess flatness values comparable to beach clasts. The latter presumably reflects the weak foliation which these greywackes occasionally exhibit.

Brock (1974) attempted to determine by shape study the depositional environments of a number of conglomerate occurrences. He used the parameters of roundness, flatness, dissymetry, oblateness, sphericity and form from a variety of sources. He found no consistent result for any one deposit and concluded shape studies to be of doubtful use in environmental determination. Brock's criticism of Dobkin and Folk's (1970) sphericity against oblate-prolate index plot on the basis of two anomalous samples warrants comment. His positioning of the line separating the beach and river fields (Brock, 1974, Fig. 1) is in error; replotting of one anomalous sample on Fig. 12 of Dobkins and Folk (1970) places such clearly within the beach field. The other sample lies within that part of Dobkins and Folk's diagram where no points exist to define the position of the line separating the beach and river fields. A sphericity value in the order of 0.67 is consistent with the supposed fluvial origin for this sample (Brock, 1974, p.667).

In conclusion, it is considered that environmental determination is possible by the methods of shape analysis. The lithologies used in shape studies must be capable of attaining the shape characteristics typical of a particular environment, with as little initial shape control as possible, an isotropically weathering character, and adequate time in a particular environment.

B. METHOD

A total of 1083 clasts ranging in size from 1.23 cm to 26.20 cm were measured for shape analysis. Clast samples ranging in number from 50 to 100 were collected from eleven localities, providing a total of 683 clasts. In addition, the axial lengths of clasts were recorded from eight of the fabric study localities, providing an additional 400 clasts. Roundness measurements were not carried out on these latter eight localities.

The clasts were selected under the conditions that any one sample was taken entirely from one sedimentation unit, and that the individual clasts could be easily freed from the matrix. Due to the difficulty often encountered of obtaining a sample of suitable size, lithology and clast size could not be used as restrictions upon the samples collected. In general the bulk of the clasts sampled fell into the size ranges 32-64 mm and 64-128 mm, that is, large pebble and small cobble grade. Because of the high volcanic, dominantly andesitic, content of the clast population (volcanics average 89% of the clasts) the samples may be considered to be relatively uniform with respect to lithology.

The lengths of the A, B and C axes were measured with a vernier caliper, or where too big with a tape. The clast was oriented such that the maximum projection plane was being viewed, and the position and length of the A axis determined. The B axis, perpendicular to A within the AB plane, was then located and measured. The clast was then turned onto its side for measurement of the C axis, perpendicular to A and B. All three axes are thus mutually perpendicular but need not intersect at the same point. In some studies the long, intermediate and short axes are designated by L, I and S in place of A, B and C respectively.

From the axial lengths were calculated the axial ratios B/A, C/B, C/A (=S/L), and $\frac{L-I}{L-S}$. The maximum projection sphericity (Sneed and Folk, (1958) was calculated from the formula

$$\psi p = \sqrt[3]{\frac{S^2}{LI}}$$

The oblate-prolate ($\bar{O}\bar{P}$) index (Dobkins and Folk, 1970) was calculated from the formula

$$\bar{O}\bar{P} = \frac{10\left(\frac{L-I}{L-S} - 0.50\right)}{S/L}$$

All calculations were done with the aid of an Hewlett-Packard HP 25 programmable calculator.

Roundness was determined by the method outlined by Dobkins and Folk (1970). The clast was oriented with the AB plane horizontal, held with plasticene for stability if necessary. A nest of concentric circles on transparent plastic film (Dobkins and Folk, 1970, Fig. 8) was used as an overlay to measure the diameter of the sharpest corner (Dk) and of the largest inscribed circle (Di). Roundness was then calculated from the formula

$$Rwt = \frac{Dk}{Di} \quad \text{(Dobkins and Folk, 1970)}$$

C. RESULTS AND DISCUSSION

The mean results for roundness, sphericity and oblateness for each sample are given in Table 5.1. The sphericity values range from 0.69 ± 0.09 to 0.78 ± 0.07, with a mean value for all samples of 0.73 ± 0.02. Dobkins and Folk (1970, p.1183) state "if the mean (sphericity) is over .65 one can be 76% sure it is a river". The $\bar{OP}$ values range from -0.89 ± 4.23 to +0.77 ± 4.15, with a mean value for all samples of -0.07 ± 0.42. Dobkins and Folk (1970, p.1188) state "if $\bar{OP}$ is between -1 and +5, it is 69% certain that they are fluvial". A plot of ψp against $\bar{OP}$ (Fig. 5.1a), after Dobkins and Folk (1970, Figs. 12,23) results in all samples falling well within the river field. A similar plot of ψp against C/A x 100 (Luttig's (1962) coefficient of flatness), after Stratten (1975, Fig. 4) also has all samples falling well within the river field (Fig. 5.1b).

The roundness values range from 0.39 ± 0.19 to 0.62 ± 0.19, with a mean for all samples of 0.50 ± 0.06. Compared to the roundness values given by Dobkins and Folk (1970) this indicates a range from rivers to high energy beaches. This is not necessarily in conflict with the results of the sphericity and $\bar{OP}$ index as Dobkins and Folk (1970, p.1178) state "With longer rivers, pebbles would presumably approach very closely the roundness of beach pebbles and discrimination would be more difficult". They also add that prolonged fluvial transport leads to an increase in sphericity. The sphericity values obtained in this study are markedly higher than those for river gravels of Tahiti-nui (mean for all sizes is

Table 5.1. Mean ($\bar{x}$) and Standard Deviation (σ) of Roundness (Rwt), Sphericity (ψ) and $\bar{O}\bar{P}$ Index for all Samples

	S1-3	S2-3	S3-4	S4-4	S5-5	S6-5	S7-8	S8-8	S9-8	S10-9	S11-14	S12-20	S13-21	S14-28	S15-29	S16-29	S17-31	S18-39	S19-39	$\bar{x}$	σ
n =	51	50	52	50	55	50	50	50	50	54	50	61	100	100	55	55	50	50	50		
Roundness																					
$\bar{x}$	0.49		0.39		0.45		0.48			0.51		0.56	0.48	0.50	0.46	0.51		0.62		0.50	0.06
σ	0.19		0.19		0.20		0.13			0.17		0.16	0.16	0.17	0.19	0.14		0.19			
Sphericity																					
$\bar{x}$	0.74	0.71	0.73	0.73	0.71	0.72	0.78	0.75	0.75	0.75	0.71	0.71	0.75	0.74	0.71	0.73	0.69	0.76	0.74	0.73	0.02
σ	0.11	0.08	0.09	0.09	0.09	0.09	0.07	0.08	0.09	0.09	0.11	0.09	0.09	0.08	0.09	0.08	0.09	0.07	0.07		
$\bar{O}\bar{P}$ Index																					
$\bar{x}$	+0.19	-0.10	+0.12	+0.24	-0.64	+0.22	+0.66	-0.07	0.00	+0.77	-0.08	-0.22	-0.10	-0.27	-0.89	-0.17	+0.14	-0.57	-0.56	-0.07	0.42
σ	4.32	5.44	3.88	3.94	5.13	3.87	3.71	4.65	3.85	4.15	4.06	4.21	3.74	4.21	4.23	4.26	4.53	3.29	3.32		

Table 5.2. Percentage of Clasts in the Compact, Compact-Bladed, Compact-Elongate, The Platy, Very Platy, Very Bladed, and the Bladed Form Class Categories

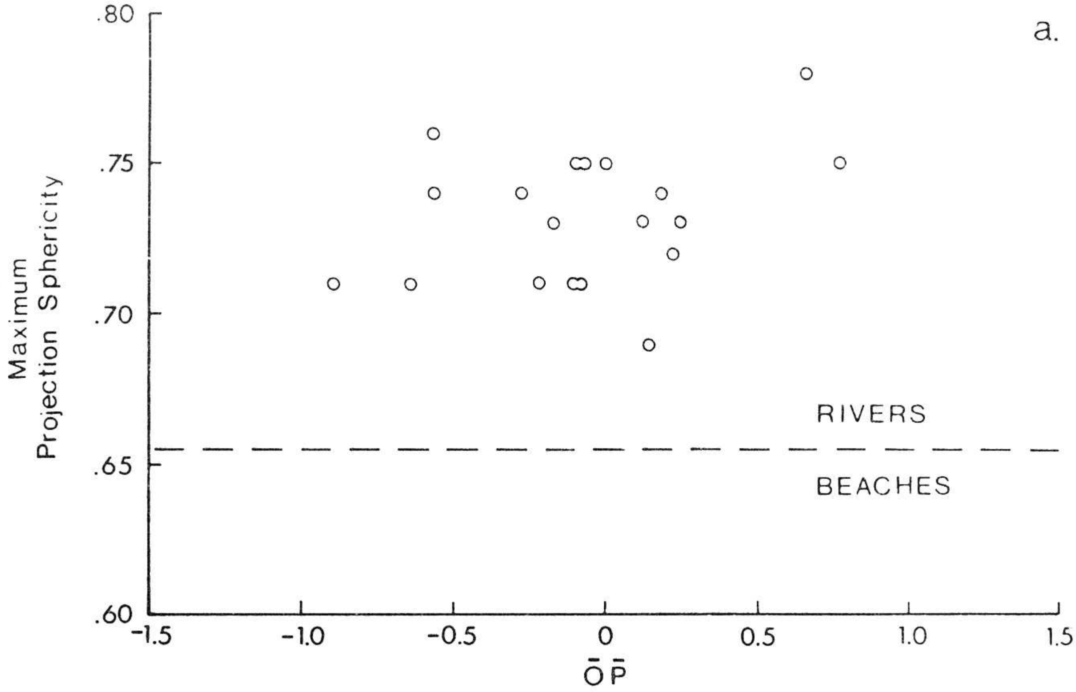
	S1-3	S2-3	S3-4	S4-4	S5-5	S6-5	S7-8	S8-8	S9-8	S10-9	S11-14	S12-20	S13-21	S14-28	S15-29	S16-29	S17-31	S18-39	S19-39
% C/CB/CE	64.7	40.0	46.1	56.0	38.1	44.0	74.0	62.0	62.0	53.7	52.0	45.9	57.0	56.0	44.0	52.0	38.0	68.0	70.0
% P/VP/VB	13.8	16.0	3.9	2.0	12.7	12.0	2.0	4.0	6.0	7.5	14.0	6.6	7.0	7.0	15.0	4.0	4.0	2.0	6.0
% B	13.7	16.0	25.0	24.0	20.0	24.0	6.0	6.0	14.0	7.4	24.0	29.5	17.0	14.0	22.0	15.0	28.0	6.0	8.0

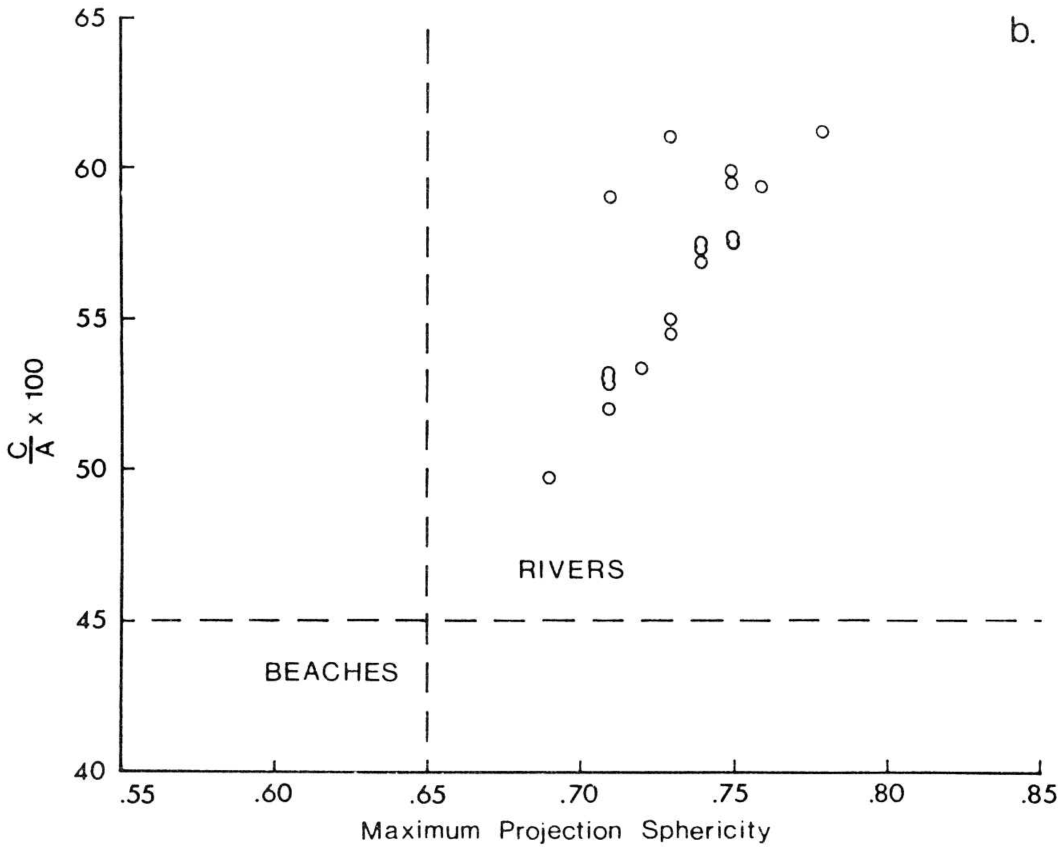
n = number of clasts per sample.

Fig. 5.1.

a. Plot of Maximum Projection Sphericity against $\bar{O}\bar{P}$ index (after Dobkins and Folk, 1970) for the shape study samples of the Keepit Conglomerate. Each point represents the mean value for a sample, sample sizes range from 50 to 100 clasts. Note the definite concentration in the Rivers field. The line separating Rivers and Beaches, 0.65-0.66 from Dobkins and Folk, is drawn at a 0.655 value.

b. Plot of Maximum Projection Sphericity against $\frac{C}{A}$ x 100 (Flatness Index) after Stratten (1975). As with a, each point represents the mean value for a sample. Again, note the definite concentration in the Rivers field.


a.
Maximum Projection Sphericity
.80
.75
.70
.65
.60
-1.5
-1.0
-0.5
0
0.5
1.0
1.5
$\bar{O}\bar{P}$
RIVERS
BEACHES


b.
$\frac{C}{A} \times 100$
65
60
55
50
45
40
.55
.60
.65
.70
.75
.80
.85
Maximum Projection Sphericity
RIVERS
BEACHES

0.684 ± 0.006). It is thus considered that the fluvial transport undergone by these clasts exceeds that of those on Tahiti-nui where the average river length is in the order of 5 to 10 miles. An alternative, perhaps acting in association with greater river length, is that the processes of abrasion were more vigorous. No evidence exists for the clasts being recycled.

All clasts were plotted on the Sphericity-Form diagram of Sneed and Folk (1958) (Fig. 5.2). The frequency per form class is also shown in Fig. 5.2. The Compact-Bladed form is the modal class in almost all instances, with Blades usually occurring as the second modal class. Dobkins and Folk (1970, p.1190-1) state "the three shape classes that are most diagnostic of beach action are Platy, Very Platy and Very Bladed" and "The forms most indicative of fluvial action are Compact, Compact-Bladed and Compact-Elongate". Blades are common in both environments. Table 5.2 shows the percentages of clasts in these two groups, as well as the percentages of blades, for each sample. The data is overwhelmingly in favour of a river environment.

In conclusion it may be said that the clasts strongly reflect a fluvial environment, but have attained a greater degree of roundness and sphericity reflecting longer fluvial transport and/or more vigorous abrasion than, for example, the basaltic clasts of Tahiti-nui.

Many of the clast samples are from resedimented conglomerates of obvious marine occurrence. In these instances the form is taken to represent the environment which last acted upon the clast, namely a fluvial environment. As these clasts have presumably passed through a shoreline environment, and as the characteristic shapes of clasts in such an environment are considered to reflect abrasion rather than solely an original shape control (e.g. Dobkins and Folk, 1970), two conclusions may be drawn from the fluvial aspect of the clasts:

1. The beaches were of low energy conditions. Clasts were carried to these beaches by fluvial processes, but were not significantly reworked or redistributed by the lower energy beach processes. As a result, abrasion did not produce typical beach clast forms and the fluvial characteristics of the clasts were thus retained (cf. Dobkins and Folk, 1970, p.1177-8).

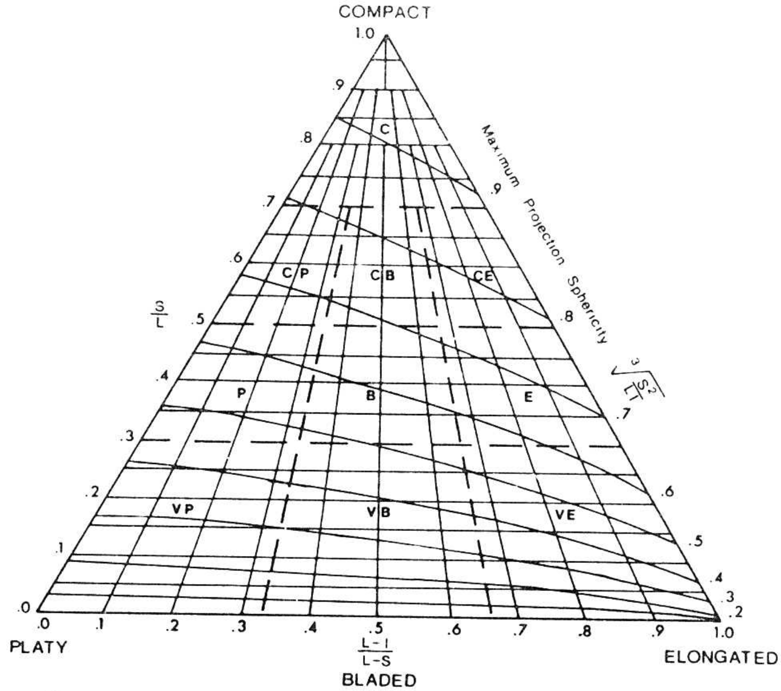
Fig. 5.2.

Sphericity-Form Diagrams for clasts from the Keepit Conglomerate (4 pages).

The first page shows the Sphericity-Form Diagram for Particle Shapes, after Sneed and Folk (1958), upon which all samples were plotted, and lists the ten form classes.

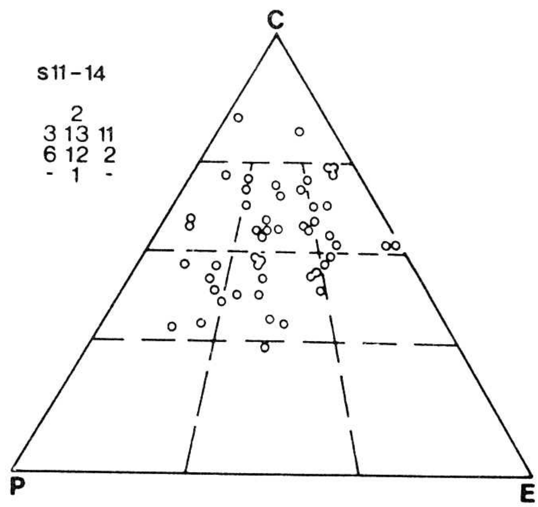
For each sample, the number of points in each form class is given to the upper left of the triangle, below the sample number. The S in the sample number denotes shape studies, the 1 to 19 denote the number of the sample and the final figure the section from which the sample was collected.

Note the strong tendency in all cases for the points to lie closer to the compact apex, falling predominantly in the Compact-Platy, Compact-Bladed and Compact-Elongate categories (see also Table 5.2). ⊙ indicates two points.



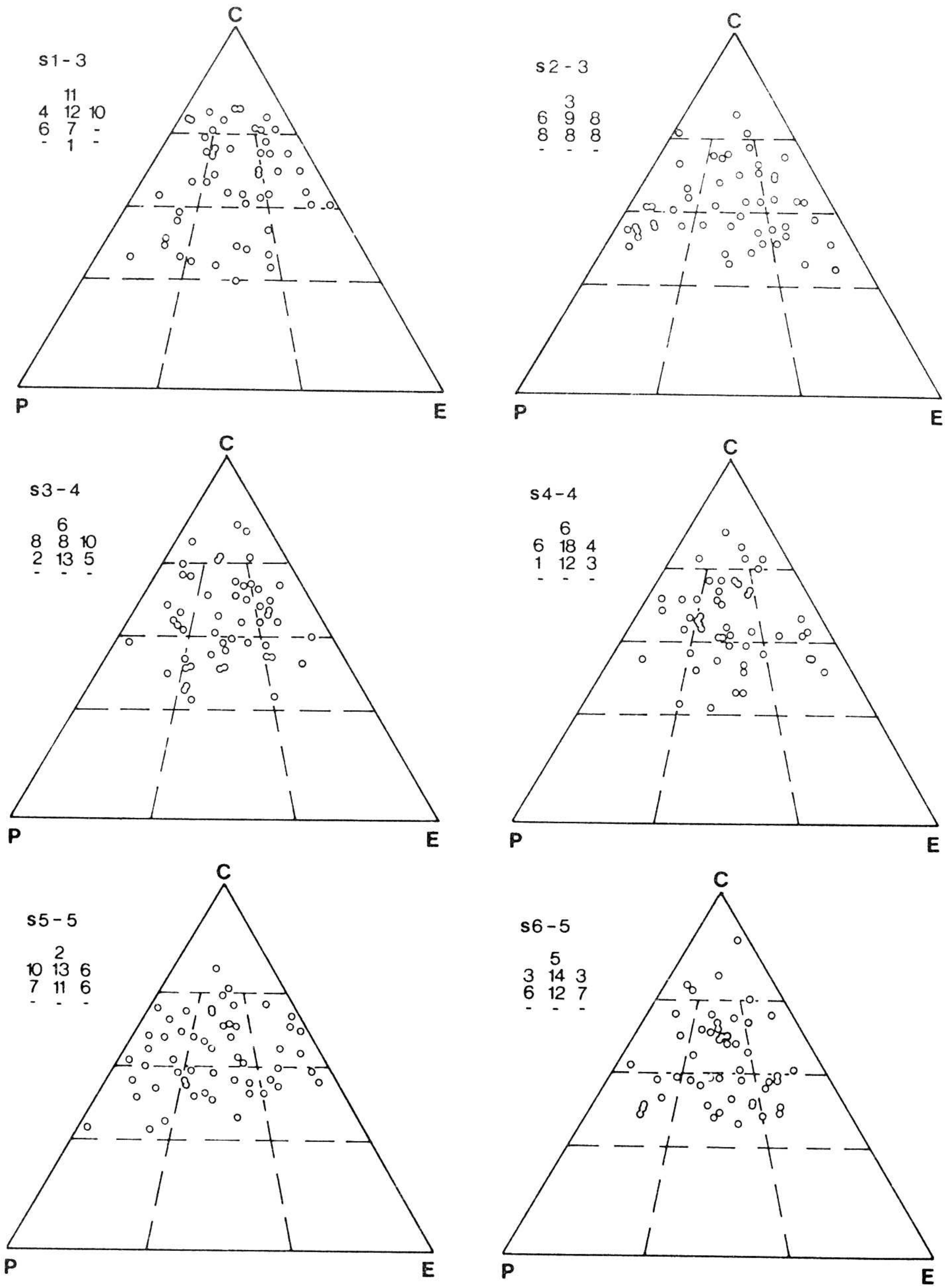
SPHERICITY-FORM DIAGRAM FOR PARTICLE SHAPES

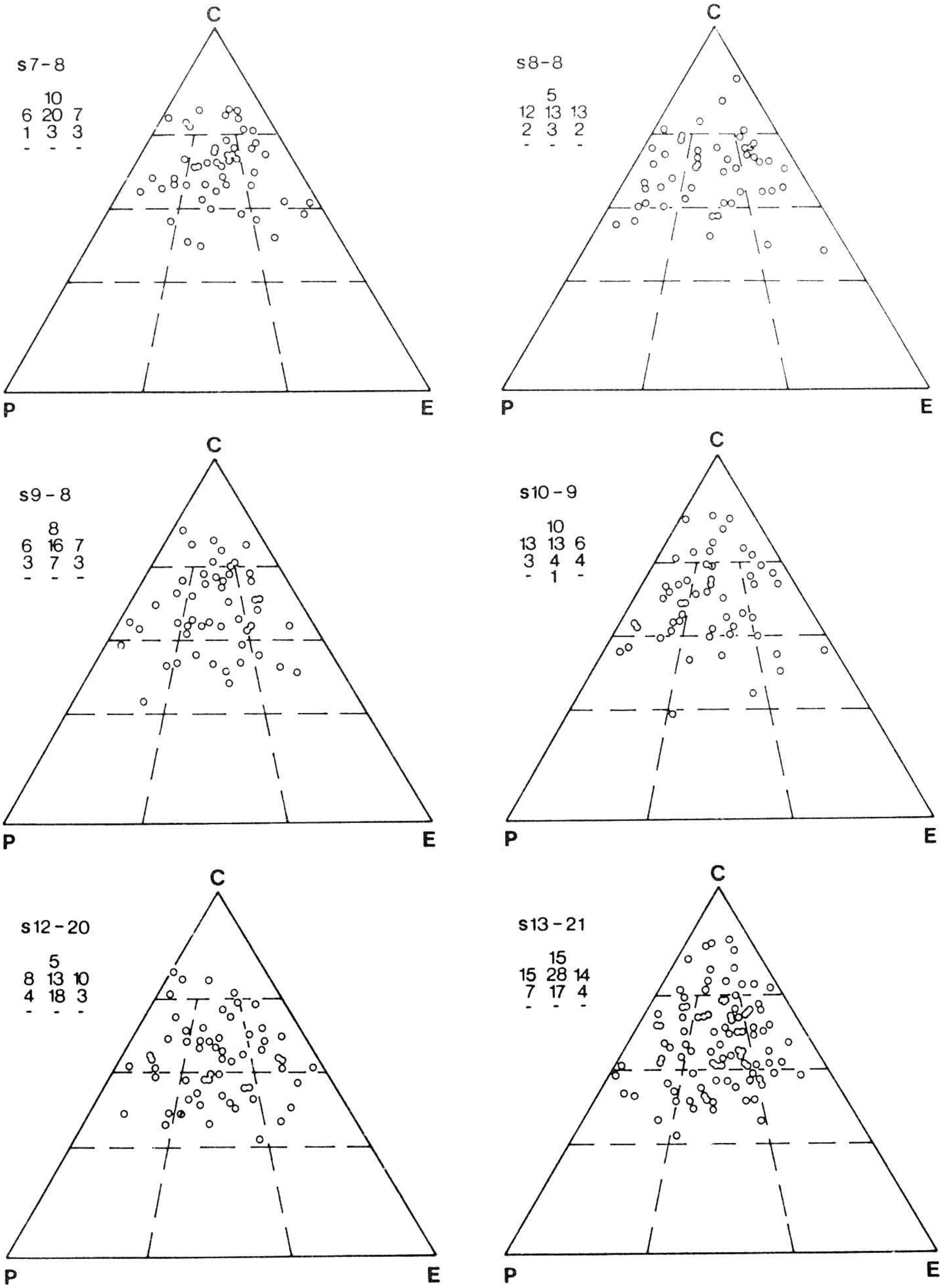
sample	s11-14
number per form class	2 3 13 11 6 12 2 - 1 -

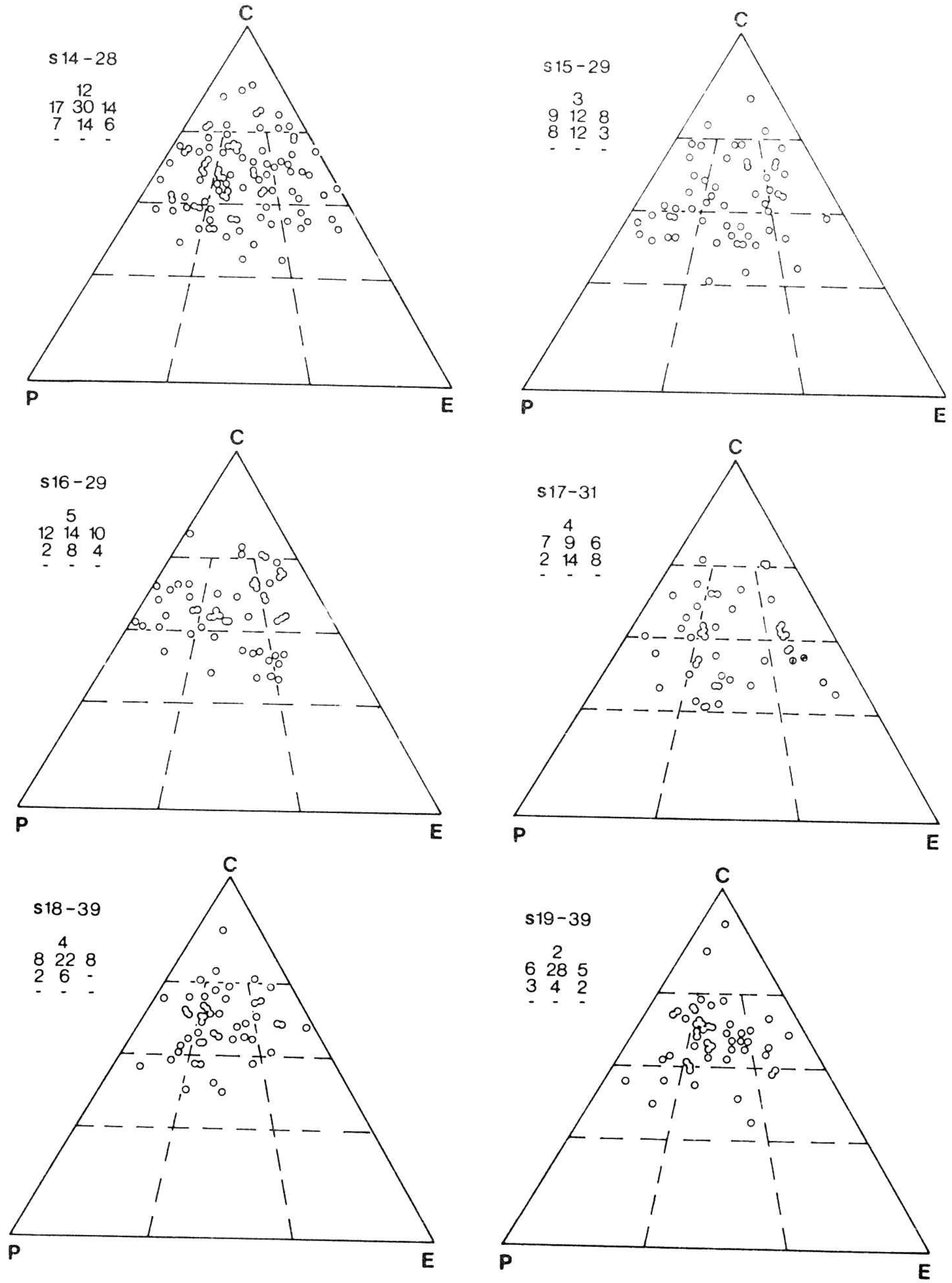


FORM CLASSES

- C COMPACT
- CP COMPACT-PLATY
- CB COMPACT-BLADED
- CE COMPACT-ELONGATE
- P PLATY
- B BLADED
- E ELONGATE
- VP VERY PLATY
- VB VERY BLADED
- VE VERY ELONGATE


C
s1 - 3
11
4 12 10
6 7 -
- 1 -
P
E
C
s2 - 3
3
6 9 8
8 8 8
- - -
P
E
C
s3 - 4
6
8 8 10
2 13 5
- - -
P
E
C
s4 - 4
6
6 18 4
1 12 3
- - -
P
E
C
s5 - 5
2
10 13 6
7 11 6
- - -
P
E
C
s6 - 5
5
3 14 3
6 12 7
- - -
P
E


s7-8
10
6 20 7
1 3 3
- - -
C
P
E
s8-8
5
12 13 13
2 3 2
- - -
C
P
E
s9-8
8
6 16 7
3 7 3
- - -
C
P
E
s10-9
10
13 13 6
3 4 4
- 1 -
C
P
E
s12-20
5
8 13 10
4 18 3
- - -
C
P
E
s13-21
15
15 28 14
7 17 4
- - -
C
P
E


C
s14-28
12
17 30 14
7 14 6
- - -
P
E
C
s15-29
3
9 12 8
8 12 3
- - -
P
E
C
s16-29
5
12 14 10
2 8 4
- - -
P
E
C
s17-31
4
7 9 6
2 14 8
- - -
P
E
C
s18-39
4
8 22 8
2 6 -
- - -
P
E
C
s19-39
2
6 28 5
3 4 2
- - -
P
E

2. The rate of sediment supply was too rapid for the typical beach clast forms to be produced (cf. Dobkins and Folk, 1970, p.1187). In this instance, beach conditions are assumed to be capable of abrading and modifying the clast forms if time was available. This situation is analagous to the "city dump" sedimentation of Folk (1968).

Both of these factors may have operated together, with rapid sediment supply to a low energy coastal environment.

Similar situations of clasts in resedimented conglomerates exhibiting fluvial form characteristics are described by McBride (1966) and Ricci Lucchi (1969), with similar conclusions having been drawn.