Pebble Morphogenesis and Paleocurrent Pattern as Signatures of Tide- dominated Marginal Marine Environment: A Case Study from the Nanka Formation, Niger Delta Basin, Nigeria

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ABSTRACT

Pebble morphometry and Paleocurrent analyses were carried out on Nanka Formation for the purpose of environmental discrimination. The morphometric analysis of four hundred and ten (410) pebbles from the formation indicated that pebble forms are dominanted by compact (50.05%), compact platy (27.42%) and compact bladed (10.09%). Other pebble forms comprise of platy (8.96%), compact elongate (1.92%), bladed (1.26%) and elongate (0.30%). This suggests dominance of fluvial pebbles over the beach ones. 88% of the pebbles plot near the upper parts of the Sphericity Form diagrams, thereby supporting dominance of the fluvial deposits. The bivariate scatter plots of maximum projection sphericity index (MPSI) vs oblate- prolate index (OPI) and flatness index (FI) vs OPI show that over 95% of the pebbles indicated river process and less than 5% are beach pebbles. This result is consistent with the form diagrams for the pebbles. The occurrence of small proportion of the beach pebbles suggests that the ancient river flow reached the marginal marine environment. The Paleocurrent data indicated a bimodal- bipolar pattern in the northeasterly and southwesterly directions. Nanka Formation was laid down in a tide- dominated marginal marine environment.

Keywords: Morphometry, Azimuths, Nanka, Pebbles, Form, Sphericity

INTRODUCTION

Nanka Formation belongs to the Ameki Group of the outcropping Niger Delta Basin (Nwajide, 2022). Previous sedimentological work done on the formation focused on interpretation of the environment of deposition of the formation based on lithofacies, granulometric and Paleocurrent data (e.g Nwajide, 1979; Onuigbo et al., 2010; Oguadinma et al., 2014; Odumodu and Mode, 2014; Ekwenye and Onyemesili, 2018; Ogbe and Osokpor., 2021). The environment of deposition of the Nanka Formations has been interpreted as tidally dominated marginal marine environment.

Pebble Morphometry has been successfully applied in the interpretation of environment of deposition of sediments (e.g Nwajide and Hoque, 1982; Olugbemiro and Nwajide, 1997; Ogala et al., 2010; Okoro et al., 2012; Odumodu and Israel, 2014; Ocheli et al., 2018; Onyemesili and Odumodu, 2019; Madi and Ndlazi, 2020; Oluwajana et al., 2021; Ogbe et al., 2023; Ojong et al., 2023).

This paper will integrate pebble morphometry and paleocurrent data in the delineation of the environment of deposition of the Nanka Formation.

1.1 The Study Area

Umuawulu and environs lie between longitudes 7°3'36"E and 7°6'0"E and latitudes 6°5'0"N and 6°13'0"N. Town covered include Amawbia, Nibo, Nise, Mbaukwu, Agulu, Awgu, Umuawulu, Isiagu and Ndiagu. The study area is underlain by the Imo and Nanka Formations (Fig. 1) of the outcropping Niger Delta Basin.

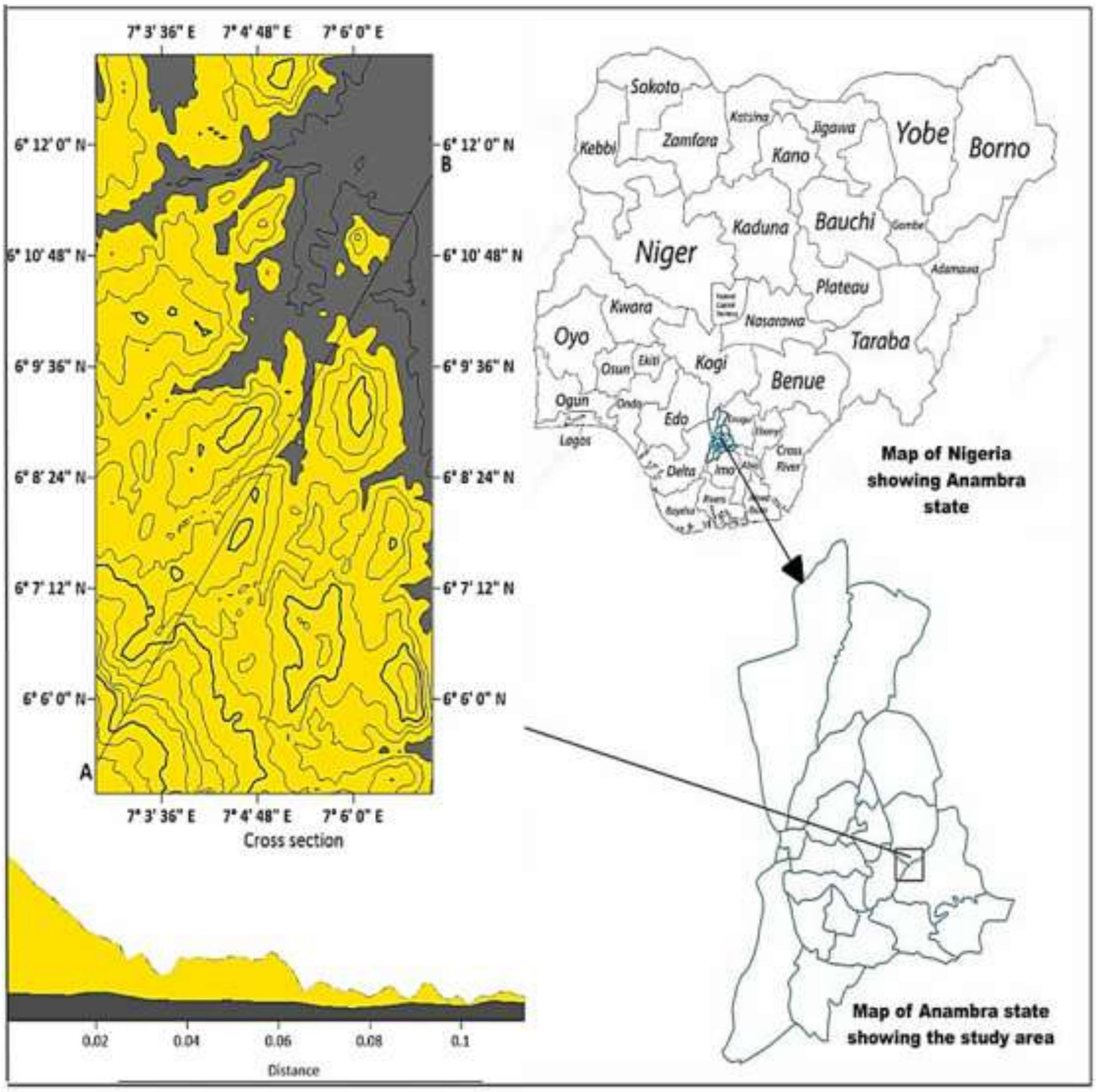

Fig.1: Geologic Map of the Study Area (dark color represents Imo Formation and yellow, the Nanka Formation)

1.2 Regional Tectonics and Stratigraphic Setting

Evolution of the Niger Delta Basin has been linked to the development of the Benue Trough as a failed arm of a trilete (aulocogen) fracture system, during the break up of the Gondwana supercontinent and the opening up of the southern Atlantic and Indian Oceans in the Jurassic (Burke et al., 1972; Olade, 1975; Hoque and Nwajide, 1984; Benkhlil, 1989). Sedimentation commenced in the Benue Trough during the Aptian to early Albian. Two cycles of marine transgressions and regressions from the middle Albian to Coniacian filled the trough with mudrocks, sandstones and limestones (Murat, 1972; Hoque, 1977). The sediments underwent folding and uplifting into Abakaliki Anticlinorium with the simultaneous subsidence of the Anambra Basin and Afikpo sub basin during the Santonian tectonic episode (Murat, 1972; Burke, 1972; Obi et al., 2001; Mode and Onuoha, 2001).

Anambra Basin after installation was filled up with Campano- Maastrichtian to early Paleocene (Danian) sediments. Further subsedence led to the development of the Niger Delta Basin. Nwajide (2022) noted that the three southern Nigerian sedimentary basins are tier basins. Imo Formation is the basal lithostratigraphic unit of the outcropping Niger Delta and lateral equivalent of the Akata Formation in the subsurface Niger Delta. The formation is followed upwards by the Ameki Group, Ogwashi- Asaba and then the Benin Formation (Wright et al., 1985; Nwajide, 2022). Figure 2 shows the three southern Nigerian sedimentary basins, described by Nwajide (2022) as tier basins.

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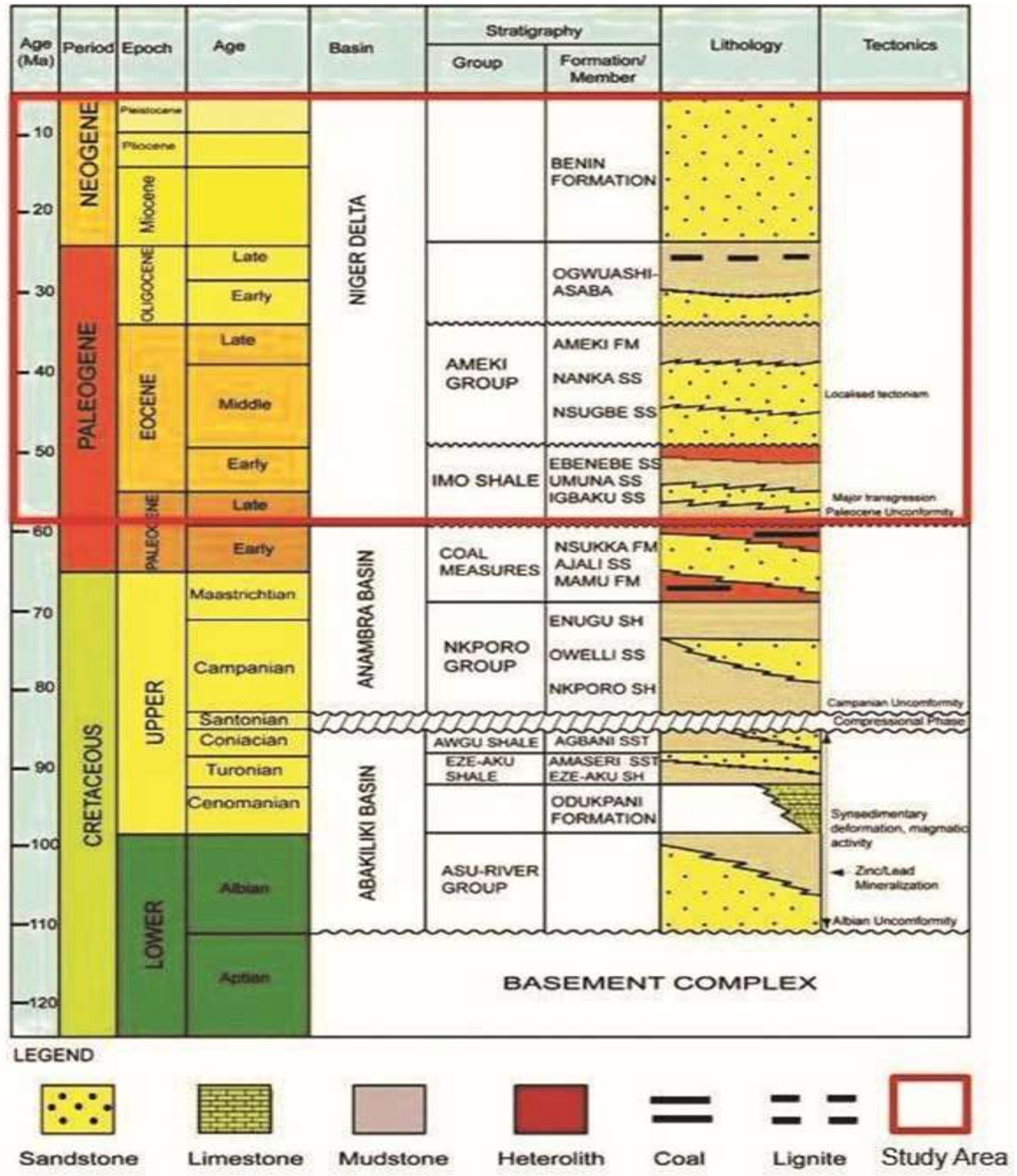

Fig.2: Stratigraphic succession in the Benue Trough, Anambra and Niger Delta basins (Short and Stauble,1967; Ekwenye et al.,2014).

MATERIALS AND METHOD

2.1 Pebble Morphometry

The long (L), intermediate (I), and short (S) axes of four hundred and ten (410) pebbles from the Nanka Formation were measured using a vernier caliper. The roundness of the pebbles was estimated using the chart by Sames (1966). The computed morphometric parameters are presented in Table 1

Table1: Mophometric Parameters and their formulars

Morphometric Parameters	Formulas
Flatness Ratio (Fr)	S/L (Luttig, 1962)

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Elongation Ratio (ER)	I/L
Coefficient Of Flatness	S/L * 100 (Luttig, 1962)
Maximum Projectin Sphericity (MPSI)	(S2/L*I)1/3 (Sneed and Folk, 1958)
Oblate-Prolate Index (OPI)	10[(L-I)/(L-S) - 0.5] / [S/L]1/3 (Dobkin and Folk, 1970)
Flatness Index (Fi)	S/I

The form of the Pebbles was determined using the sphericity form diagram of Sneed and Folk (1958).For the environmental discrimination, the bivariate scatter plots of M.P.S.I vs OP index, flatness index vs MPSI and sphericity form diagram were employed.

The bivariate plot of MPSI vs OPI (Dobkins & folk, 1970) is based on the proposition that 0.66 MPSI line best separates beach from river pebbles whereas values above 0.66 suggest fluvial origin.

2.2 Paleocurrent Analysis

Azimuths of sixty- six (66) planar cross beds measured from the Nanka Formation in the study area were plotted into a rose diagram using the class interval of 20°. The analysis provided significant insights into the paleoenvironment of deposition of the Nanka Formation.

RESULTS AND DISCUSSION

3.1 Pebble Morphometry

Figure 2 shows the pebbly sandstone unit of the Nanka Formation exposed along St. Lawrence Anglican Church Road Mbaukwu. The pebbles are sub- angular to sub- rounded in shape and of varying sizes and consists predominantly of quartz pebbles.

The values of the three axes (long, intermediate and short) of all the four-quartz pebble sets from the formation, their axial ratios, morphometric parameters and pebble forms are presented in Tables 2- 5. Averaged values of the pebble forms for the four pebble sets (Table 5) indicated that 50.05% of the pebbles are compact (C), 27.42% are compact platy (CP), 10.09% are compact bladed (CB), 8.96% are Platy (P), 1.92% are compact elongate (CE), 1.26% are bladed (B) and 0.3% are elongate (E). This shows that majority of the pebbles are compact, compact platy and compact bladed.

Fig. 3: Pebbly sandstone of the Nanka Formation exposed along St. Lawrence Anglican Church Road Mbaukwu (Latitude: 6°9’8.88” N and Longitude: 7°4’5.66” E)

Table 2: The values of the three axes of Pebbles set 1, their axial ratios and morphometric parameters

S/N	L(cm)	I(cm)	S(cm)	S/L	I/L	(L-I)/(L-S)	MPSI	S/L * 100	OPI	FORM
1	2.50	2.20	1.70	0.68	0.88	0.38	0.81	68.00	-1.84	CB
2	1.10	0.80	0.70	0.64	0.73	0.75	0.82	63.64	3.93	CE
3	1.60	1.40	0.90	0.56	0.88	0.29	0.71	56.25	-3.81	CP
4	1.30	1.20	0.90	0.69	0.92	0.25	0.80	69.23	-3.61	CP
5	1.50	1.40	0.80	0.53	0.93	0.14	0.67	53.33	-6.70	CP
6	1.20	1.00	0.90	0.75	0.83	0.67	0.88	75.00	2.22	C
7	1.40	1.30	0.90	0.64	0.93	0.20	0.76	64.29	-4.67	CP
8	0.90	0.80	0.60	0.67	0.89	0.33	0.79	66.67	-2.50	CP
9	2.50	2.10	1.10	0.44	0.84	0.29	0.61	44.00	-4.87	P
10	2.80	2.60	1.40	0.50	0.93	0.14	0.65	50.00	-7.14	P
11	2.40	2.30	1.30	0.54	0.96	0.09	0.67	54.17	-7.55	CP
12	1.60	1.40	1.10	0.69	0.88	0.40	0.81	68.75	-1.45	C
13	1.30	1.10	0.80	0.62	0.85	0.40	0.76	61.54	-1.63	CB
14	1.70	1.30	0.80	0.47	0.76	0.44	0.66	47.06	-1.18	B
15	1.90	1.70	1.30	0.68	0.89	0.33	0.81	68.42	-2.44	CP
16	1.30	1.30	0.60	0.46	1.00	0.00	0.60	46.15	-10.83	P
17	1.90	1.60	1.40	0.74	0.84	0.60	0.86	73.68	1.36	C
18	2.30	2.20	1.50	0.65	0.96	0.13	0.76	65.22	-5.75	CP
19	1.50	1.30	1.00	0.67	0.87	0.40	0.80	66.67	-1.50	CB
20	1.70	1.60	1.30	0.76	0.94	0.25	0.85	76.47	-3.27	C
21	1.50	1.40	0.80	0.53	0.93	0.14	0.67	53.33	-6.70	C
22	1.30	1.20	0.70	0.54	0.92	0.17	0.68	53.85	-6.19	CP
23	2.00	1.80	0.80	0.40	0.90	0.17	0.56	40.00	-8.33	P
24	1.00	0.90	0.90	0.90	0.90	1.00	0.97	90.00	5.56	C
25	1.90	1.90	1.00	0.53	1.00	0.00	0.65	52.63	-9.50	CP
26	1.20	1.00	0.90	0.75	0.83	0.67	0.88	75.00	2.22	C
27	1.20	1.10	1.10	0.92	0.92	1.00	0.97	91.67	5.45	C
28	0.90	0.70	0.40	0.44	0.78	0.40	0.63	44.44	-2.25	B
29	1.20	1.10	0.90	0.75	0.92	0.33	0.85	75.00	-2.22	C
30	2.20	2.00	1.10	0.50	0.91	0.18	0.65	50.00	-6.36	CP
31	1.60	1.30	1.00	0.63	0.81	0.50	0.78	62.50	0.00	CB
32	0.80	0.70	0.60	0.75	0.88	0.50	0.86	75.00	0.00	C
33	1.70	1.50	0.80	0.47	0.88	0.22	0.63	47.06	-5.90	P
34	1.40	1.20	0.90	0.64	0.86	0.40	0.78	64.29	-1.56	CB

35	2.10	1.90	1.30	0.62	0.90	0.25	0.75	61.90	-4.04	CP
36	1.40	1.20	0.60	0.43	0.86	0.25	0.60	42.86	-5.83	P
37	1.20	1.10	0.80	0.67	0.92	0.25	0.79	66.67	-3.75	CP
38	2.10	1.90	1.40	0.67	0.90	0.29	0.79	66.67	-3.21	CP
39	1.20	1.00	0.50	0.42	0.83	0.29	0.59	41.67	-5.14	P
40	1.30	1.20	0.80	0.62	0.92	0.20	0.74	61.54	-4.88	CP
41	1.50	1.40	1.20	0.80	0.93	0.33	0.88	80.00	-2.08	C
42	1.60	1.30	1.30	0.81	0.81	1.00	0.93	81.25	6.15	C
43	1.40	1.30	1.00	0.71	0.93	0.25	0.82	71.43	-3.50	C
44	1.60	1.40	1.00	0.63	0.88	0.33	0.76	62.50	-2.67	CP
45	1.40	1.20	1.10	0.79	0.86	0.67	0.90	78.57	2.12	C
46	1.20	1.00	0.60	0.50	0.83	0.33	0.67	50.00	-3.33	CB
47	1.50	1.40	1.10	0.73	0.93	0.25	0.83	73.33	-3.41	C
48	0.70	0.60	0.50	0.71	0.86	0.50	0.84	71.43	0.00	C
49	2.60	2.20	1.00	0.38	0.85	0.25	0.56	38.46	-6.50	P
50	4.80	3.50	2.10	0.44	0.73	0.48	0.64	43.75	-0.42	B
51	2.00	1.60	1.20	0.60	0.80	0.50	0.77	60.00	0.00	CB
52	1.60	1.40	1.10	0.69	0.88	0.40	0.81	68.75	-1.45	CB
53	1.40	1.20	0.70	0.50	0.86	0.29	0.66	50.00	-4.29	CP
54	1.40	1.40	1.30	0.93	1.00	0.00	0.95	92.86	-5.38	C
55	2.40	2.30	1.80	0.75	0.96	0.17	0.84	75.00	-4.44	C
56	1.90	1.50	1.20	0.63	0.79	0.57	0.80	63.16	1.13	CB
57	2.40	2.10	1.20	0.50	0.88	0.25	0.66	50.00	-5.00	P
58	1.40	1.20	0.70	0.50	0.86	0.29	0.66	50.00	-4.29	P
59	1.10	1.00	0.90	0.82	0.91	0.50	0.90	81.82	0.00	C
60	2.20	2.00	1.30	0.59	0.91	0.22	0.73	59.09	-4.70	CP
61	1.90	1.70	1.30	0.68	0.89	0.33	0.81	68.42	-2.44	CB
62	1.70	1.50	0.90	0.53	0.88	0.25	0.68	52.94	-4.72	CB
63	1.40	1.30	1.30	0.93	0.93	1.00	0.98	92.86	5.38	C
64	1.30	1.20	0.90	0.69	0.92	0.25	0.80	69.23	-3.61	CP
65	1.20	1.10	0.90	0.75	0.92	0.33	0.85	75.00	-2.22	C
66	1.20	1.00	0.70	0.58	0.83	0.40	0.74	58.33	-1.71	CB
67	1.80	1.60	1.00	0.56	0.89	0.25	0.70	55.56	-4.50	CP
68	1.10	1.10	0.70	0.64	1.00	0.00	0.74	63.64	-7.86	CP
69	1.10	0.90	0.70	0.64	0.82	0.50	0.79	63.64	0.00	CB
70	1.30	1.20	1.00	0.77	0.92	0.33	0.86	76.92	-2.17	C
71	1.30	1.00	0.80	0.62	0.77	0.60	0.79	61.54	1.63	CB

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72	1.00	0.80	0.60	0.60	0.80	0.50	0.77	60.00	0.00	CB
73	2.10	1.80	1.70	0.81	0.86	0.75	0.91	80.95	3.09	C
74	1.70	1.50	1.40	0.82	0.88	0.67	0.92	82.35	2.02	C
75	1.20	1.10	0.90	0.75	0.92	0.33	0.85	75.00	-2.22	C
76	1.70	1.60	1.30	0.76	0.94	0.25	0.85	76.47	-3.27	C
77	1.60	1.50	1.50	0.94	0.94	1.00	0.98	93.75	5.33	C
78	1.50	1.30	1.00	0.67	0.87	0.40	0.80	66.67	-1.50	CB
79	1.80	1.50	1.20	0.67	0.83	0.50	0.81	66.67	0.00	CB
80	1.30	1.20	1.10	0.85	0.92	0.50	0.92	84.62	0.00	C
81	1.10	0.90	0.90	0.82	0.82	1.00	0.94	81.82	6.11	C
82	0.80	0.80	0.70	0.88	1.00	0.00	0.91	87.50	-5.71	C
83	1.00	0.80	0.60	0.60	0.80	0.50	0.77	60.00	0.00	CB
84	1.00	0.70	0.60	0.60	0.70	0.75	0.80	60.00	4.17	CE
85	1.40	1.30	1.00	0.71	0.93	0.25	0.82	71.43	-3.50	C
86	1.70	1.60	0.70	0.41	0.94	0.10	0.56	41.18	-9.71	P
87	1.40	1.40	1.10	0.79	1.00	0.00	0.85	78.57	-6.36	C
88	1.40	1.20	0.60	0.43	0.86	0.25	0.60	42.86	-5.83	P
89	1.60	1.50	0.90	0.56	0.94	0.14	0.70	56.25	-6.35	P
90	1.30	1.30	0.80	0.62	1.00	0.00	0.72	61.54	-8.13	CP
91	1.50	1.40	1.00	0.67	0.93	0.20	0.78	66.67	-4.50	CP
92	1.60	1.50	1.30	0.81	0.94	0.33	0.89	81.25	-2.05	C
93	1.10	1.00	1.00	0.91	0.91	1.00	0.97	90.91	5.50	C
94	1.10	1.00	1.00	0.91	0.91	1.00	0.97	90.91	5.50	C
95	1.00	0.90	0.60	0.60	0.90	0.25	0.74	60.00	-4.17	CP
96	0.90	0.70	0.50	0.56	0.78	0.50	0.73	55.56	0.00	CB
97	0.90	0.80	0.50	0.56	0.89	0.25	0.70	55.56	-4.50	CP
98	0.80	0.70	0.70	0.88	0.88	1.00	0.96	87.50	5.71	C
99	1.00	0.80	0.60	0.60	0.80	0.50	0.77	60.00	0.00	CB
100	1.90	1.50	1.00	0.53	0.79	0.44	0.71	52.63	-1.06	CB
101	1.40	1.20	0.90	0.64	0.86	0.40	0.78	64.29	-1.56	CB
102	1.20	1.10	0.80	0.67	0.92	0.25	0.79	66.67	-3.75	CP
103	1.30	1.20	1.10	0.85	0.92	0.50	0.92	84.62	0.00	C
104	1.30	1.20	0.90	0.69	0.92	0.25	0.80	69.23	-3.61	CP
105	1.60	1.20	0.90	0.56	0.75	0.57	0.75	56.25	1.27	CE
106	1.30	1.20	0.90	0.69	0.92	0.25	0.80	69.23	-3.61	CP
107	1.00	0.90	0.80	0.80	0.90	0.50	0.89	80.00	0.00	C
108	1.60	1.40	1.40	0.88	0.88	1.00	0.96	87.50	5.71	C

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109	1.20	0.90	0.80	0.67	0.75	0.75	0.84	66.67	3.75	CE
110	1.20	0.90	0.60	0.50	0.75	0.50	0.69	50.00	0.00	CB
111	1.20	0.90	0.80	0.67	0.75	0.75	0.84	66.67	3.75	CE
112	1.20	1.10	1.00	0.83	0.92	0.50	0.91	83.33	0.00	C
113	1.30	1.20	0.90	0.69	0.92	0.25	0.80	69.23	-3.61	CP
114	1.00	0.90	0.70	0.70	0.90	0.33	0.82	70.00	-2.38	C
115	1.20	1.10	0.70	0.58	0.92	0.20	0.72	58.33	-5.14	CP
116	0.90	0.80	0.70	0.78	0.89	0.50	0.88	77.78	0.00	C
117	1.00	0.90	0.60	0.60	0.90	0.25	0.74	60.00	-4.17	CP
118	1.20	1.10	0.70	0.58	0.92	0.20	0.72	58.33	-5.14	CP
119	1.00	0.90	0.90	0.90	0.90	1.00	0.81	68.00	-1.84	C

C= 36.97%, CP= 26.89%, CB= 19.33%, P= 10.92%, CE= 3.36% and B= 2.52%

Table 3: The values of the three axes of Pebbles set 2, their axial ratios and morphometric parameters

S/N	**L(cm)**	**I(cm)**	**S(cm)**	**S/L**	**I/L**	**(L-I) / (L-S)**	**MPSI**	**S/L * 100**	**OPI**	**FORM**
1	2	1.9	1.5	0.75	0.95	0.20	0.84	75.00	-4.00	C
2	1.4	1.2	1	0.71	0.86	0.50	0.84	71.43	0.00	C
3	2	1.6	1.1	0.55	0.80	0.44	0.72	55.00	-1.01	CB
4	1.7	1	0.7	0.41	0.59	0.70	0.66	41.18	4.86	E
5	2.3	1.9	1.9	0.83	0.83	1.00	0.94	82.61	6.05	C
6	1.5	1.3	1.1	0.73	0.87	0.50	0.85	73.33	0.00	C
7	1.7	1.6	1.6	0.94	0.94	1.00	0.98	94.12	5.31	C
8	1.6	1.5	0.8	0.50	0.94	0.13	0.64	50.00	-7.50	P
9	2.1	1.7	1.2	0.57	0.81	0.44	0.74	57.14	-0.97	CB
10	2	1.5	1.2	0.60	0.75	0.63	0.78	60.00	2.08	CB
11	2.6	1.5	1.3	0.50	0.58	0.85	0.76	50.00	6.92	CE
12	1.2	1.1	1	0.83	0.92	0.50	0.91	83.33	0.00	C
13	2.2	2.1	1	0.45	0.95	0.08	0.60	45.45	-9.17	P
14	1.5	1.1	0.8	0.53	0.73	0.57	0.73	53.33	1.34	CB
15	1.2	1.1	1	0.83	0.92	0.50	0.91	83.33	0.00	C
16	1.4	1.2	1	0.71	0.86	0.50	0.84	71.43	0.00	C
17	1.6	1.5	1	0.63	0.94	0.17	0.75	62.50	-5.33	CP
18	1.4	1	0.9	0.64	0.71	0.80	0.83	64.29	4.67	CB
19	1.4	1.1	0.9	0.64	0.79	0.60	0.81	64.29	1.56	CB
20	1.3	1.2	0.4	0.31	0.92	0.11	0.47	30.77	-12.64	P
21	1.4	1.3	1	0.71	0.93	0.25	0.82	71.43	-3.50	C

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22	1.3	1.2	0.5	0.38	0.92	0.13	0.54	38.46	-9.75	P
23	1.4	1.3	0.5	0.36	0.93	0.11	0.52	35.71	-10.89	P
24	0.7	0.6	0.4	0.57	0.86	0.33	0.72	57.14	-2.92	CP
25	1.4	1.2	0.8	0.57	0.86	0.33	0.72	57.14	-2.92	CP
26	0.8	0.7	0.4	0.50	0.88	0.25	0.66	50.00	-5.00	P
27	0.9	0.8	0.4	0.44	0.89	0.20	0.61	44.44	-6.75	P
28	1.6	1.2	1	0.63	0.75	0.67	0.80	62.50	2.67	CB
29	1.2	1.1	0.9	0.75	0.92	0.33	0.85	75.00	-2.22	C
30	0.8	0.6	0.5	0.63	0.75	0.67	0.80	62.50	2.67	CB
31	1.4	1.3	1.1	0.79	0.93	0.33	0.87	78.57	-2.12	C
32	0.8	0.6	0.5	0.63	0.75	0.67	0.80	62.50	2.67	CB
33	1.5	1.3	0.6	0.40	0.87	0.22	0.57	40.00	-6.94	P
34	1.3	1.1	0.6	0.46	0.85	0.29	0.63	46.15	-4.64	P
35	1.3	1.2	0.6	0.46	0.92	0.14	0.61	46.15	-7.74	P
36	1.3	1.2	0.8	0.62	0.92	0.20	0.74	61.54	-4.88	CP
37	1.7	1.6	1.3	0.76	0.94	0.25	0.85	76.47	-3.27	C
38	1.6	1.4	1.2	0.75	0.88	0.50	0.86	75.00	0.00	C
39	1	0.8	0.7	0.70	0.80	0.67	0.85	70.00	2.38	C
40	0.9	0.6	0.4	0.44	0.67	0.60	0.67	44.44	2.25	B
41	1	0.8	0.6	0.60	0.80	0.50	0.77	60.00	0.00	CB
42	1.1	1	0.7	0.64	0.91	0.25	0.76	63.64	-3.93	CP
43	0.9	0.8	0.6	0.67	0.89	0.33	0.79	66.67	-2.50	CP
44	0.9	0.8	0.7	0.78	0.89	0.50	0.88	77.78	0.00	C
45	1	0.9	0.5	0.50	0.90	0.20	0.65	50.00	-6.00	P
46	1	0.8	0.4	0.40	0.80	0.33	0.58	40.00	-4.17	P
47	1	0.9	0.9	0.90	0.90	1.00	0.97	90.00	5.56	C
48	1	0.9	0.6	0.60	0.90	0.25	0.74	60.00	-4.17	CP
49	0.9	0.8	0.6	0.67	0.89	0.33	0.79	66.67	-2.50	CP
50	0.9	0.8	0.8	0.89	0.89	1.00	0.96	88.89	5.63	C
51	1	0.9	0.6	0.60	0.90	0.25	0.74	60.00	-4.17	CP
52	1.9	1.7	0.5	0.26	0.89	0.14	0.43	26.32	-13.57	P
53	0.9	0.7	0.5	0.56	0.78	0.50	0.73	55.56	0.00	CB
54	1	0.8	0.5	0.50	0.80	0.40	0.68	50.00	-2.00	B
55	0.8	0.7	0.5	0.63	0.88	0.33	0.76	62.50	-2.67	CP
56	1	0.8	0.7	0.70	0.80	0.67	0.85	70.00	2.38	C
57	1	0.7	0.5	0.50	0.70	0.60	0.71	50.00	2.00	CE
58	0.8	0.7	0.4	0.50	0.88	0.25	0.66	50.00	-5.00	P

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59	0.9	0.7	0.6	0.67	0.78	0.67	0.83	66.67	2.50	CB
60	0.7	0.6	0.4	0.57	0.86	0.33	0.72	57.14	-2.92	CP
61	0.7	0.6	0.6	0.86	0.86	1.00	0.95	85.71	5.83	C
62	0.9	0.7	0.5	0.56	0.78	0.50	0.73	55.56	0.00	CB
63	0.6	0.5	0.3	0.50	0.83	0.33	0.67	50.00	-3.33	P
64	0.7	0.6	0.4	0.57	0.86	0.33	0.72	57.14	-2.92	CP
65	0.8	0.6	0.5	0.63	0.75	0.67	0.80	62.50	2.67	CE
66	0.8	0.7	0.4	0.50	0.88	0.25	0.66	50.00	-5.00	P
67	0.8	0.7	0.5	0.63	0.88	0.33	0.76	62.50	-2.67	CP
68	0.7	0.6	0.5	0.71	0.86	0.50	0.84	71.43	0.00	C
69	0.7	0.5	0.4	0.57	0.71	0.67	0.77	57.14	2.92	CB
70	0.7	0.6	0.5	0.71	0.86	0.50	0.84	71.43	0.00	C
71	0.7	0.6	0.4	0.57	0.86	0.33	0.72	57.14	-2.92	CP
72	0.6	0.6	0.5	0.83	1.00	0.00	0.89	83.33	-6.00	C
73	0.7	0.6	0.4	0.57	0.86	0.33	0.72	57.14	-2.92	CP
74	0.6	0.5	0.5	0.83	0.83	1.00	0.94	83.33	6.00	C
75	0.7	0.6	0.6	0.86	0.86	1.00	0.95	85.71	5.83	C
76	0.7	0.6	0.2	0.29	0.86	0.20	0.46	28.57	-10.50	P
77	0.7	0.6	0.5	0.71	0.86	0.50	0.84	71.43	0.00	C
78	0.8	0.6	0.6	0.75	0.75	1.00	0.91	75.00	6.67	C
79	0.8	0.7	0.3	0.38	0.88	0.20	0.54	37.50	-8.00	P
80	0.8	0.7	0.5	0.63	0.88	0.33	0.76	62.50	-2.67	P

C= 33.75%, P = 23.75%, CB= CP= 17.50%, CE= 3.75%, B= 2.50% and E= 1.25%

Table 4: The values of the three axes of Pebbles set 3, their axial ratios and morphometric parameters

S/N	**L(cm)**	**I(cm)**	**S(cm)**	**S/L**	**I/L**	**(L-I) / (L-S)**	**MPSI**	**S/L * 100**	**OPI**	**FORM**
1	2.10	1.90	1.20	0.57	0.90	0.22	0.71	57.14	-4.86	CP
2	2.50	2.40	1.40	0.56	0.96	0.09	0.69	56.00	-7.31	CP
3	1.10	1.00	0.90	0.82	0.91	0.50	0.90	81.82	0.00	C
4	1.90	1.70	1.60	0.84	0.89	0.67	0.93	84.21	1.98	C
5	1.10	1.00	0.80	0.73	0.91	0.33	0.83	72.73	-2.29	C
6	1.60	1.40	0.90	0.56	0.88	0.29	0.71	56.25	-3.81	CP
7	1.50	1.40	1.30	0.87	0.93	0.50	0.93	86.67	0.00	C
8	1.40	1.20	0.90	0.64	0.86	0.40	0.78	64.29	-1.56	CB
9	2.30	2.10	1.40	0.61	0.91	0.22	0.74	60.87	-4.56	CP

10	1.80	1.70	1.60	0.89	0.94	0.50	0.94	88.89	0.00	C
11	2.30	2.10	1.70	0.74	0.91	0.33	0.84	73.91	-2.25	C
12	1.10	0.90	0.50	0.45	0.82	0.33	0.63	45.45	-3.67	P
13	1.45	1.40	1.30	0.90	0.97	0.33	0.94	89.66	-1.86	C
14	1.50	1.30	1.20	0.80	0.87	0.67	0.90	80.00	2.08	C
15	1.80	1.70	1.60	0.89	0.94	0.50	0.94	88.89	0.00	C
16	2.10	1.90	1.30	0.62	0.90	0.25	0.75	61.90	-4.04	C
17	1.20	1.10	0.90	0.75	0.92	0.33	0.85	75.00	-2.22	C
18	1.60	1.40	1.10	0.69	0.88	0.40	0.81	68.75	-1.45	CP
19	1.10	1.00	0.90	0.82	0.91	0.50	0.90	81.82	0.00	C
20	1.50	1.40	1.00	0.67	0.93	0.20	0.78	66.67	-4.50	CP
21	1.20	1.10	0.90	0.75	0.92	0.33	0.85	75.00	-2.22	C
22	2.10	1.90	1.80	0.86	0.90	0.67	0.93	85.71	1.94	C
23	1.40	1.30	0.90	0.64	0.93	0.20	0.76	64.29	-4.67	C
24	1.60	1.30	1.20	0.75	0.81	0.75	0.88	75.00	3.33	C
25	1.90	1.70	1.20	0.63	0.89	0.29	0.76	63.16	-3.39	CP
26	1.60	1.40	1.20	0.75	0.88	0.50	0.86	75.00	0.00	C
27	1.30	1.20	1.00	0.77	0.92	0.33	0.86	76.92	-2.17	CP
28	0.90	0.80	0.70	0.78	0.89	0.50	0.88	77.78	0.00	C
29	2.20	2.10	1.60	0.73	0.95	0.17	0.82	72.73	-4.58	CP
30	1.10	0.90	0.80	0.73	0.82	0.67	0.86	72.73	2.29	C
31	1.40	1.30	1.10	0.79	0.93	0.33	0.87	78.57	-2.12	C
32	1.10	1.00	0.90	0.82	0.91	0.50	0.90	81.82	0.00	C
33	1.30	1.20	0.90	0.69	0.92	0.25	0.80	69.23	-3.61	CP
34	1.80	1.70	1.00	0.56	0.94	0.13	0.69	55.56	-6.75	CP
35	2.20	1.90	1.10	0.50	0.86	0.27	0.66	50.00	-4.55	CP
36	1.20	1.10	1.00	0.83	0.92	0.50	0.91	83.33	0.00	CP
37	1.40	1.20	0.80	0.57	0.86	0.33	0.72	57.14	-2.92	CP
38	2.00	1.80	1.50	0.75	0.90	0.40	0.85	75.00	-1.33	C
39	1.50	1.30	0.80	0.53	0.87	0.29	0.69	53.33	-4.02	CP
40	3.50	3.20	2.30	0.66	0.91	0.25	0.78	65.71	-3.80	CP
41	1.20	1.00	0.80	0.67	0.83	0.50	0.81	66.67	0.00	C
42	1.45	1.40	1.30	0.90	0.97	0.33	0.94	89.66	-1.86	C
43	1.20	1.10	1.00	0.83	0.92	0.50	0.91	83.33	0.00	C
44	1.70	1.50	1.00	0.59	0.88	0.29	0.73	58.82	-3.64	CP
45	1.30	1.10	0.80	0.62	0.85	0.40	0.76	61.54	-1.63	CP
46	1.30	1.10	1.00	0.77	0.85	0.67	0.89	76.92	2.17	C

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47	1.50	1.40	0.70	0.47	0.93	0.13	0.62	46.67	-8.04	P
48	1.70	1.50	1.25	0.74	0.88	0.44	0.85	73.53	-0.76	C
49	1.30	1.20	1.05	0.81	0.92	0.40	0.89	80.77	-1.24	C
50	1.90	1.70	1.20	0.63	0.89	0.29	0.76	63.16	-3.39	CP
51	0.95	0.90	0.85	0.89	0.95	0.50	0.95	89.47	0.00	C
52	1.00	0.90	0.85	0.85	0.90	0.67	0.93	85.00	1.96	C
53	1.35	1.20	1.00	0.74	0.89	0.43	0.85	74.07	-0.96	C
54	1.40	1.20	1.00	0.71	0.86	0.50	0.84	71.43	0.00	C
55	1.40	1.30	0.90	0.64	0.93	0.20	0.76	64.29	-4.67	C
56	0.80	0.70	0.55	0.69	0.88	0.40	0.81	68.75	-1.45	CP
57	1.25	1.10	1.00	0.80	0.88	0.60	0.90	80.00	1.25	C
58	1.40	1.20	0.80	0.57	0.86	0.33	0.72	57.14	-2.92	CB
59	1.25	1.15	1.00	0.80	0.92	0.40	0.89	80.00	-1.25	C
60	1.70	1.50	0.90	0.53	0.88	0.25	0.68	52.94	-4.72	CP
61	1.35	1.30	1.20	0.89	0.96	0.33	0.94	88.89	-1.88	C
62	2.70	2.40	1.50	0.56	0.89	0.25	0.70	55.56	-4.50	CP
63	1.00	0.90	0.85	0.85	0.90	0.67	0.93	85.00	1.96	CP
64	1.10	1.00	0.90	0.82	0.91	0.50	0.90	81.82	0.00	C
65	1.70	1.50	1.00	0.59	0.88	0.29	0.73	58.82	-3.64	CP
66	1.20	1.10	1.00	0.83	0.92	0.50	0.91	83.33	0.00	C
67	1.40	1.30	0.85	0.61	0.93	0.18	0.73	60.71	-5.24	CP
68	1.00	0.90	0.85	0.85	0.90	0.67	0.93	85.00	1.96	C
69	1.50	1.40	1.10	0.73	0.93	0.25	0.83	73.33	-3.41	C
70	1.60	1.45	1.10	0.69	0.91	0.30	0.80	68.75	-2.91	CP
71	0.90	0.85	0.80	0.89	0.94	0.50	0.94	88.89	0.00	C
72	1.40	1.20	1.15	0.82	0.86	0.80	0.92	82.14	3.65	C
73	1.00	0.90	0.70	0.70	0.90	0.33	0.82	70.00	-2.38	CP
74	1.20	1.10	0.90	0.75	0.92	0.33	0.85	75.00	-2.22	C
75	1.00	0.90	0.60	0.60	0.90	0.25	0.74	60.00	-4.17	CP
76	1.50	1.40	1.20	0.80	0.93	0.33	0.88	80.00	-2.08	C
77	2.10	2.00	1.60	0.76	0.95	0.20	0.85	76.19	-3.94	C
78	1.50	1.40	1.10	0.73	0.93	0.25	0.83	73.33	-3.41	C
79	1.30	1.20	1.10	0.85	0.92	0.50	0.92	84.62	0.00	C
80	1.30	1.20	1.10	0.85	0.92	0.50	0.92	84.62	0.00	C
81	1.50	1.40	1.10	0.73	0.93	0.25	0.83	73.33	-3.41	C
82	1.70	1.60	1.20	0.71	0.94	0.20	0.81	70.59	-4.25	C
83	1.20	1.10	0.95	0.79	0.92	0.40	0.88	79.17	-1.26	C

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84	1.30	1.20	0.90	0.69	0.92	0.25	0.80	69.23	-3.61	CP
85	1.30	1.20	0.90	0.69	0.92	0.25	0.80	69.23	-3.61	CP
86	1.20	1.00	0.60	0.50	0.83	0.33	0.67	50.00	-3.33	CP
87	1.20	1.10	0.80	0.67	0.92	0.25	0.79	66.67	-3.75	CP
88	1.10	0.95	0.60	0.55	0.86	0.30	0.70	54.55	-3.67	CP
89	1.10	1.00	0.90	0.82	0.91	0.50	0.90	81.82	0.00	C
90	1.50	1.30	0.90	0.60	0.87	0.33	0.75	60.00	-2.78	C
91	1.20	1.10	0.80	0.67	0.92	0.25	0.79	66.67	-3.75	CP
92	1.40	1.30	1.10	0.79	0.93	0.33	0.87	78.57	-2.12	C
93	1.05	0.90	0.60	0.57	0.86	0.33	0.72	57.14	-2.92	CP
94	1.00	0.95	0.70	0.70	0.95	0.17	0.80	70.00	-4.76	CP
95	1.30	1.25	0.80	0.62	0.96	0.10	0.73	61.54	-6.50	CP
96	1.10	1.00	0.90	0.82	0.91	0.50	0.90	81.82	0.00	C
97	1.20	1.00	0.90	0.75	0.83	0.67	0.88	75.00	2.22	C
98	1.10	1.00	0.90	0.82	0.91	0.50	0.90	81.82	0.00	C
99	1.70	1.55	1.00	0.59	0.91	0.21	0.72	58.82	-4.86	CP
100	1.15	1.10	0.85	0.74	0.96	0.17	0.83	73.91	-4.51	C
101	1.40	0.90	0.70	0.50	0.64	0.71	0.73	50.00	4.29	CE
102	1.15	1.00	0.75	0.65	0.87	0.38	0.79	65.22	-1.92	CB
103	1.60	1.30	1.00	0.63	0.81	0.50	0.78	62.50	0.00	CB
104	1.30	1.15	1.10	0.85	0.88	0.75	0.93	84.62	2.95	C
105	1.15	1.00	0.90	0.78	0.87	0.60	0.89	78.26	1.28	C
106	1.10	1.00	0.75	0.68	0.91	0.29	0.80	68.18	-3.14	CP
107	1.40	1.30	0.90	0.64	0.93	0.20	0.76	64.29	-4.67	CP
108	1.70	1.60	1.30	0.76	0.94	0.25	0.85	76.47	-3.27	C
109	1.40	1.30	0.80	0.57	0.93	0.17	0.71	57.14	-5.83	CP
110	1.40	1.20	0.90	0.64	0.86	0.40	0.78	64.29	-1.56	CB
111	1.00	0.90	0.80	0.80	0.90	0.50	0.89	80.00	0.00	C
112	1.00	0.90	0.80	0.80	0.90	0.50	0.89	80.00	0.00	C
113	1.30	1.20	1.15	0.88	0.92	0.67	0.95	88.46	1.88	C
114	1.00	0.90	0.65	0.65	0.90	0.29	0.78	65.00	-3.30	CP
115	1.15	1.10	1.00	0.87	0.96	0.33	0.92	86.96	-1.92	C
116	1.60	1.45	1.00	0.63	0.91	0.25	0.76	62.50	-4.00	CP
117	1.10	1.05	0.90	0.82	0.95	0.25	0.89	81.82	-3.06	C
118	1.00	0.90	0.70	0.70	0.90	0.33	0.82	70.00	-2.38	CP
119	1.50	1.40	1.30	0.87	0.93	0.50	0.93	86.67	0.00	C
120	1.10	1.00	0.80	0.73	0.91	0.33	0.83	72.73	-2.29	C

121	1.00	0.90	0.75	0.75	0.90	0.40	0.85	75.00	-1.33	C
122	1.30	1.20	1.10	0.85	0.92	0.50	0.92	84.62	0.00	C
123	0.95	0.85	0.70	0.74	0.89	0.40	0.85	73.68	-1.36	C
124	1.10	1.00	0.90	0.82	0.91	0.50	0.90	81.82	0.00	C
125	1.30	1.20	0.65	0.50	0.92	0.15	0.65	50.00	-6.92	CP
126	0.90	0.85	0.80	0.89	0.94	0.50	0.94	88.89	0.00	C
127	1.20	1.10	0.90	0.75	0.92	0.33	0.85	75.00	-2.22	C
128	1.20	1.10	0.85	0.71	0.92	0.29	0.82	70.83	-3.03	C
129	1.20	1.10	1.00	0.83	0.92	0.50	0.91	83.33	0.00	C
130	1.00	0.90	0.85	0.85	0.90	0.67	0.93	85.00	1.96	C
131	0.90	0.85	0.80	0.89	0.94	0.50	0.94	88.89	0.00	C
132	1.30	1.05	0.70	0.54	0.81	0.42	0.71	53.85	-1.55	CB
133	1.20	1.10	1.00	0.83	0.92	0.50	0.91	83.33	0.00	C
134	1.25	1.15	0.75	0.60	0.92	0.20	0.73	60.00	-5.00	CP
135	1.05	1.00	0.70	0.67	0.95	0.14	0.78	66.67	-5.36	CP
136	1.15	1.05	0.85	0.74	0.91	0.33	0.84	73.91	-2.25	C
137	1.30	1.20	1.00	0.77	0.92	0.33	0.86	76.92	-2.17	C
138	1.10	1.00	0.70	0.64	0.91	0.25	0.76	63.64	-3.93	CP
139	0.80	0.70	0.55	0.69	0.88	0.40	0.81	68.75	-1.45	CP
140	0.95	0.90	0.70	0.74	0.95	0.20	0.83	73.68	-4.07	C
141	1.40	1.35	1.20	0.86	0.96	0.25	0.91	85.71	-2.92	C
142	1.00	0.95	0.85	0.85	0.95	0.33	0.91	85.00	-1.96	C
143	1.05	0.90	0.70	0.67	0.86	0.43	0.80	66.67	-1.07	CP
144	0.90	0.80	0.70	0.78	0.89	0.50	0.88	77.78	0.00	C
145	0.85	0.75	0.65	0.76	0.88	0.50	0.87	76.47	0.00	C
146	1.10	1.00	0.60	0.55	0.91	0.20	0.69	54.55	-5.50	CP
147	1.20	1.10	0.85	0.71	0.92	0.29	0.82	70.83	-3.03	C
148	1.25	1.15	0.95	0.76	0.92	0.33	0.86	76.00	-2.19	C
149	1.00	0.90	0.60	0.60	0.90	0.25	0.74	60.00	-4.17	CP
150	1.10	0.95	0.80	0.73	0.86	0.50	0.85	72.73	0.00	C
151	1.10	1.00	0.70	0.64	0.91	0.25	0.76	63.64	-3.93	CP
152	1.05	1.00	0.90	0.86	0.95	0.33	0.92	85.71	-1.94	C
153	0.80	0.70	0.60	0.75	0.88	0.50	0.86	75.00	0.00	C
154	0.85	0.80	0.70	0.82	0.94	0.33	0.90	82.35	-2.02	C
155	0.90	0.80	0.70	0.78	0.89	0.50	0.88	77.78	0.00	C
156	1.20	1.00	0.75	0.63	0.83	0.44	0.78	62.50	-0.89	CP
157	0.90	0.85	0.65	0.72	0.94	0.20	0.82	72.22	-4.15	C

158	0.65	0.60	0.50	0.77	0.92	0.33	0.86	76.92	-2.17	C
159	1.00	0.95	0.70	0.70	0.95	0.17	0.80	70.00	-4.76	CP
160	0.80	0.75	0.55	0.69	0.94	0.20	0.80	68.75	-4.36	CP
161	0.80	0.75	0.70	0.88	0.94	0.50	0.93	87.50	0.00	C
162	1.10	1.00	0.75	0.68	0.91	0.29	0.80	68.18	-3.14	CP
163	0.90	0.85	0.60	0.67	0.94	0.17	0.78	66.67	-5.00	CP
164	0.90	0.80	0.70	0.78	0.89	0.50	0.88	77.78	0.00	C
165	0.90	0.80	0.60	0.67	0.89	0.33	0.79	66.67	-2.50	CP
166	1.00	0.90	0.80	0.80	0.90	0.50	0.89	80.00	0.00	C
167	0.80	0.75	0.70	0.88	0.94	0.50	0.93	87.50	0.00	C
168	0.95	0.90	0.80	0.84	0.95	0.33	0.91	84.21	-1.98	C
169	0.85	0.70	0.60	0.71	0.82	0.60	0.85	70.59	1.42	C
170	0.90	0.85	0.50	0.56	0.94	0.13	0.69	55.56	-6.75	CP
171	0.70	0.65	0.60	0.86	0.93	0.50	0.92	85.71	0.00	C

C= 60.23, CP= 34.50%, CB= 3.51%, P= 1.17% and CE= 0.58%

Table 5: The values of the three axes of Pebbles set 4, their axial ratios and morphometric parameters

S/N	L(cm)	I(cm)	S(cm)	S/L	I/L	(L-I) / (L-S)	MPSI	S/L * 100	OPI	FORM
1	4	3.85	3.1	0.78	0.96	0.17	0.85	77.50	-4.30	C
2	4.6	4.1	3.8	0.83	0.89	0.63	0.91	82.61	1.51	C
3	1.7	1.6	1	0.59	0.94	0.14	0.72	58.82	-6.07	CP
4	2.5	2.3	1.5	0.60	0.92	0.20	0.73	60.00	-5.00	CP
5	3.25	3.2	2.75	0.85	0.98	0.10	0.90	84.62	-4.73	C
6	3.3	3	2.2	0.67	0.91	0.27	0.79	66.67	-3.41	C
7	2.4	2.3	1.4	0.58	0.96	0.10	0.71	58.33	-6.86	CP
8	4	3.7	2.6	0.65	0.93	0.21	0.77	65.00	-4.40	CP
9	3.95	3.9	2.25	0.57	0.99	0.03	0.69	56.96	-8.26	CP
10	2.7	2.5	1.6	0.59	0.93	0.18	0.72	59.26	-5.37	CP
11	4.7	4.25	2.45	0.52	0.90	0.20	0.67	52.13	-5.76	CP
12	3.4	3.4	2.5	0.74	1.00	0.00	0.81	73.53	-6.80	C
13	1.8	1.7	1.2	0.67	0.94	0.17	0.78	66.67	-5.00	CP
14	1.9	1.8	1.4	0.74	0.95	0.20	0.83	73.68	-4.07	C
15	3.4	3.2	2.4	0.71	0.94	0.20	0.81	70.59	-4.25	C
16	3	2.8	1.8	0.60	0.93	0.17	0.73	60.00	-5.56	CP
17	2.2	2.1	1.8	0.82	0.95	0.25	0.89	81.82	-3.06	C
18	2.7	2.55	1.85	0.69	0.94	0.18	0.79	68.52	-4.72	CP

19	1.8	1.7	1.2	0.67	0.94	0.17	0.78	66.67	-5.00	CP
20	1.6	1.5	1.05	0.66	0.94	0.18	0.77	65.63	-4.85	CP
21	2.6	2.4	1.8	0.69	0.92	0.25	0.80	69.23	-3.61	C
22	2.7	2.6	2.2	0.81	0.96	0.20	0.88	81.48	-3.68	C
23	2.8	2.75	2.2	0.79	0.98	0.08	0.86	78.57	-5.30	C
24	2.65	2.4	2.35	0.89	0.91	0.83	0.95	88.68	3.76	C
25	2	1.9	1.75	0.88	0.95	0.40	0.93	87.50	-1.14	C
26	2.05	1.8	1.7	0.83	0.88	0.71	0.92	82.93	2.58	C
27	2	1.8	1.6	0.80	0.90	0.50	0.89	80.00	0.00	C
28	2.5	2.4	2.3	0.92	0.96	0.50	0.96	92.00	0.00	C
29	2	1.9	1.45	0.73	0.95	0.18	0.82	72.50	-4.39	C
30	2.05	1.95	1.9	0.93	0.95	0.67	0.97	92.68	1.80	C
31	1.55	1.5	1.5	0.97	0.97	1.00	0.99	96.77	5.17	C
32	2.4	2.35	1.75	0.73	0.98	0.08	0.82	72.92	-5.80	C
33	2.15	1.9	1.8	0.84	0.88	0.71	0.93	83.72	2.56	C
34	2.8	2.6	2.2	0.79	0.93	0.33	0.87	78.57	-2.12	C
35	1.65	1.55	1.2	0.73	0.94	0.22	0.83	72.73	-3.82	C
36	1.65	1.55	1	0.61	0.94	0.15	0.73	60.61	-5.71	C
37	2.5	2.4	1.6	0.64	0.96	0.11	0.75	64.00	-6.08	C
38	2.05	1.95	1.8	0.88	0.95	0.40	0.93	87.80	-1.14	C
39	1.8	1.75	1.5	0.83	0.97	0.17	0.89	83.33	-4.00	C

C= 69.23% and CP= 30.77%

Table 5: Averaged form values (%) for pebbles sets 1- 4

Pebble Form	C	CP	CB	CE	P	B	E
Values (%)	50.05	27.42	10.09	1.92	8.96	1.26	0.30

Dobkin and Folk (1970) and Gale (1990) noted that some particle form classes occur much more frequently in one environment than they do in another. Platy, very platy and very bladed are more diagnostic of beach, bladed and platy predominate in high energy beaches while blade dare most common in low energy beaches. Compact, compact bladed and compact elongate are most indicative of fluvial origin. The dominance of compact, compact platy and compact bladed forms in the investigated pebbles of the Nanka Formation suggests fluvial origin.

3.1.1 Sphericity Form Diagrams for the Pebble Sets

According to Dobkin and Folk **(1970),** beach pebbles plot towards the left and bottom parts of the sphericity form diagram whereas fluvial pebbles plot near the upper parts of the form diagram.

The form diagrams for the Pebbles of Nanka Formation is presented as Figure 4. Over 88% of the pebbles are compact, compact platy and compact bladed and they plot near the upper parts of the form diagrams. This agrees with the fluvial origin for the pebbles. However, less than 12% of the pebbles are platy, bladed and elongate.

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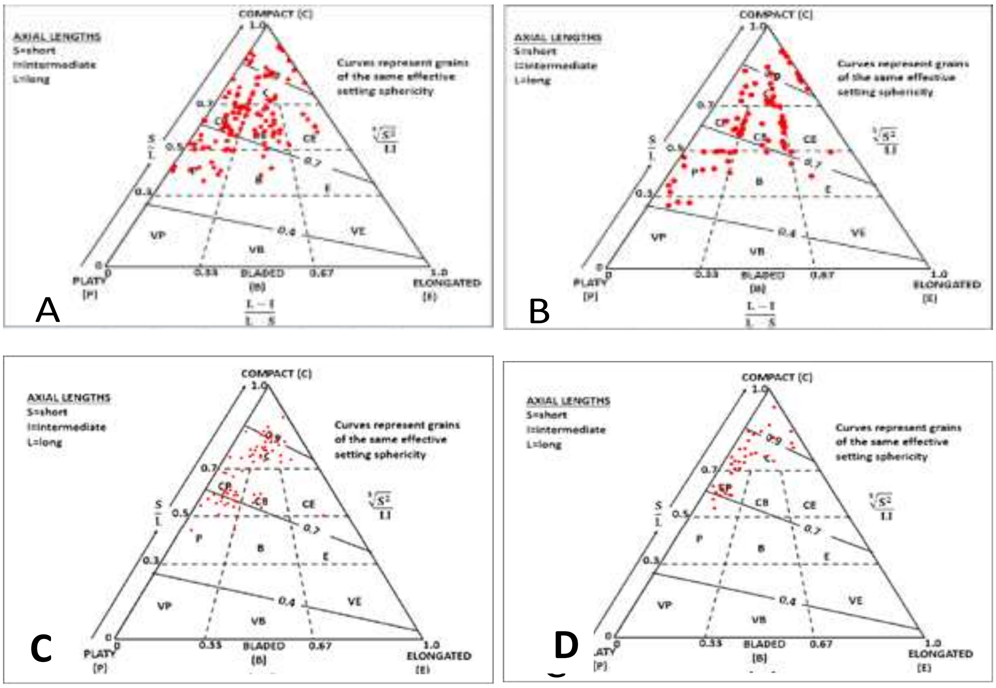

Fig 4: Sphericity Form diagrams for Nanka pebbles (A) For pebble set 1(B) For pebble set 2 (C)For pebble set 3 (D)For pebble set 4

3.1.2 Bivariate Scatter Plots

The bivariate scatter plots of MPSI vs OPI for the four pebble sets in this study (Fig.5) show that over 98% of the pebbles were deposited by river process and less than 2% by beach. The bivariate Scatter Plots of FI vs MPSI (Fig. 6) show that over 95% of the pebbles are fluvial deposits while less than 5% are deposited by beach process. This is in line with the sphericity form diagrams for the pebbles.

Madi and Ndlazi (2020) noted that the occurrence of a small proportion of beach pebbles in a river dominated pebbles suggests that the river reached the marginal marine environment during it's flow. Thus pointing the environment of deposition of the Nanka Formation to marginal marine.

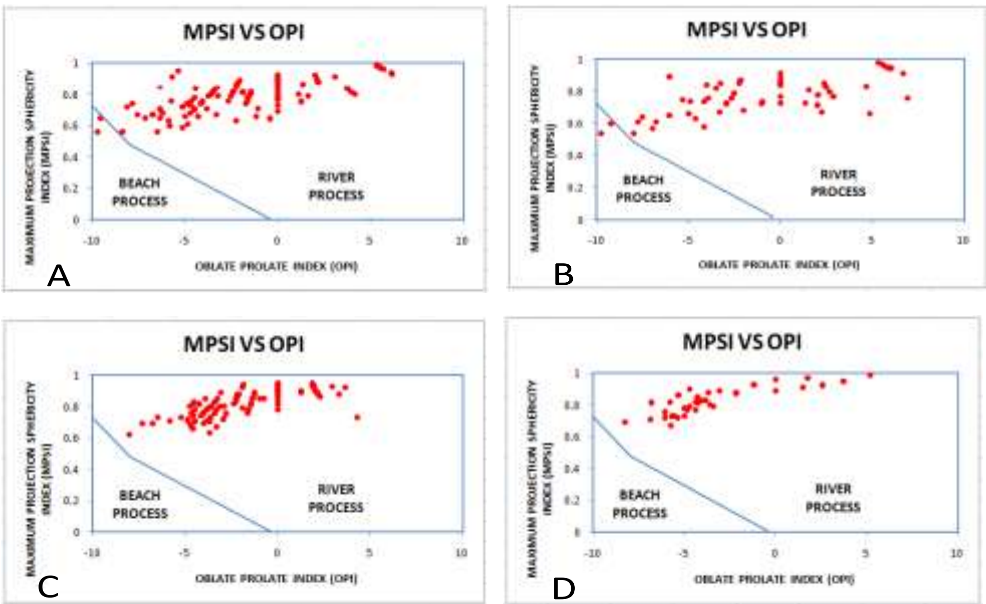

Fig 5: A plot of MPS versus OPI after (Dobkins and Folk 1970)): (A) For pebble set 1(B)For pebble set 2 (C)For pebble set 3 (D)For pebble set 4

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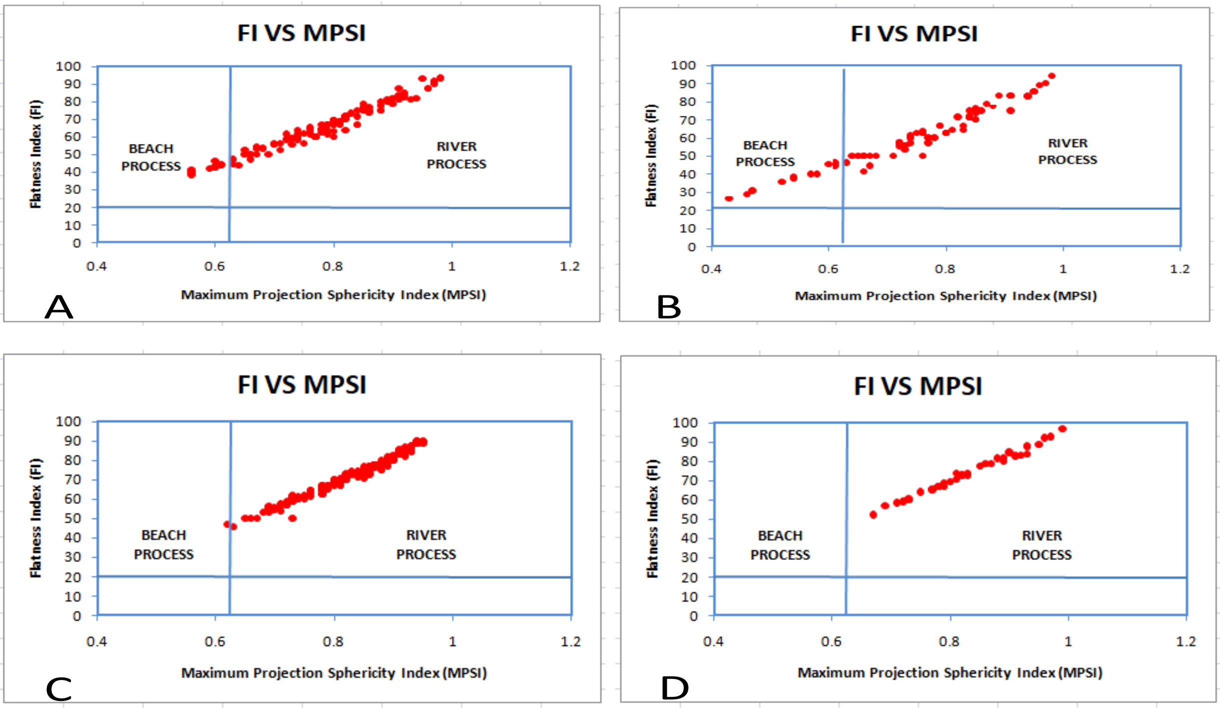

Fig 6: Plot of FI vs MPSI for Nanka Pebbles (A) For pebble set 1(B) For pebble set 2 (C)For pebble set 3 (D)For pebble set 4.

3.2 Paleocurrent Analysis

Table 6 shows the azimuths of the cross beds measured from the outcrops of the Nanka whereas Figure 7 is the rose plots of the cross-bed azimuths for paleocurrent evaluation. The rose diagrams indicated a bimodal- bipolar paleocurrent pattern which are in the northeasterly and southwesterly directions and thus, suggestive of tidal dominance.

Table 6ai: Azimuths of planar cross-beds from the Nanka Formation

SET 1				
S/N	**Azimuths(°)**		**S/N**	**Azimuths(°)**
1	21		22	42
2	40		23	37
3	29		24	56
4	37		25	78
5	40		26	54
6	26		27	64
7	50		28	94
8	83		29	64
9	62		30	44
10	85		31	39
11	60		32	54
12	88		33	32
13	54		34	46

14	90		35	35
15	60		36	49
16	79		37	30
17	45		38	8
18	20		39	40
19	30		40	10
20	66		41	21
21	47		42	40

Table 6aii: Azimuths of planar cross-beds from the Nanka Formation

SET 2	
S/N	**Azimuths (°)**
1	234
2	254
3	250
4	258
5	254
6	210
7	256
8	212
9	222
10	224
11	252
12	248
13	234
14	258
15	228
16	224
17	258
18	246
19	254
20	234
21	250
22	228
23	252
24	226

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Table 6bi: Azimuth and frequency distribution table

SET 1	
Azimuths	**Frequency**
1 - 20	3
21 – 40	15
41 - 60	14
61 – 80	5
80 - 100	5

Table 6bii: Azimuth and frequency distribution table

SET 2	
Azimuths	**Frequency**
200- 220	2
221-240	9
241-260	13

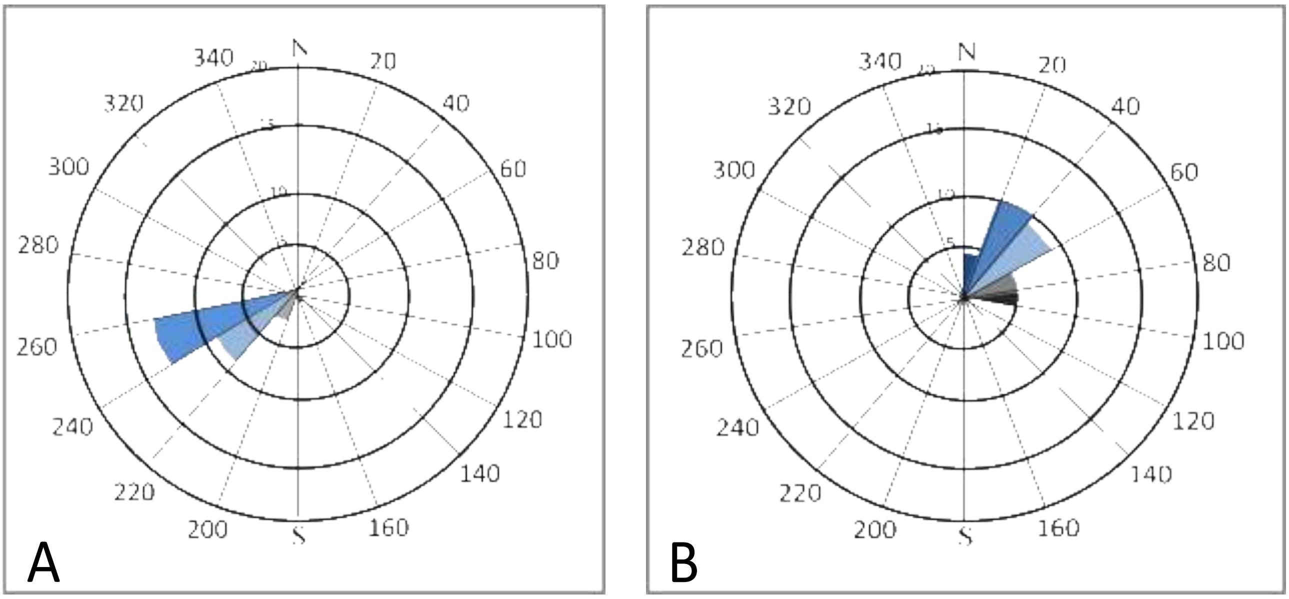

Fig. 7: Rose diagrams of planer cross beds for the Nanka Formation: (A) For set 2 (B) For set 1.

CONCLUSION

Pebble morphometry and paleocurrent data employed in this study for environmental diagnosis of the Nanka Formation have shown that the formation was deposited in a tide- dominated marginal marine environment. This interpretation is in agreement with the results from the lithofacies and particle size distribution data employed by previous workers.

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