Wind-facetted Stones from the Marlborough Strand-Plain, New Zealand

By L. C. KING, Ph.D., Natal University College, Pietermaritzburg, South Africa.

[*Read before the Wellington Philosophical Society, April 22, 1936; received by the Editor, May 20, 1936; issued separately, December, 1936.*]

THE OCCURRENCE.

WIND-FACETTED stones have previously been recorded from the Marlborough strand-plain north of the mouth of the Ure River,* where they are cut from irregularly shaped fragments of fine-grained limestone. From this point southwards they occur sporadically on the coast as far as least as the Deadman's Creek, but in general are poorly developed. Immediately south of the Clarence River, where

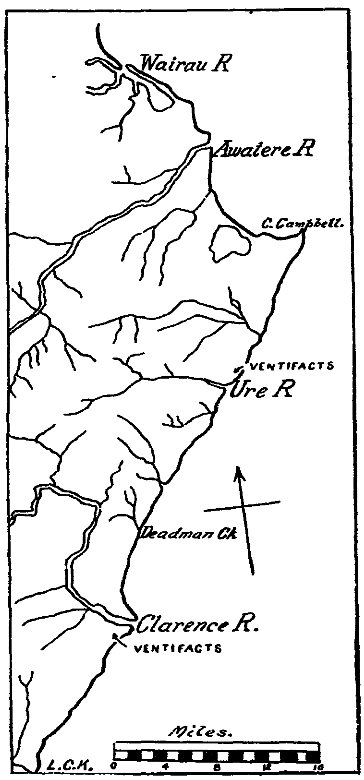

FIG. 1.—Sketch-map of the Coastline of Eastern Marlborough.

the strand-plain assumes a greater width, they are again present in abundance with great variety both of form and composition. The material from which they are carved has evidently been derived

* King, L. C., *Jour. Geol.*, vol. 44, pp. 201-213, 1936.

largely from that brought down by the Clarence River in the past and comprises greywacke, argillite, Amuri limestone, and various igneous types. Here *windkanter* are found at several different levels corresponding with the development of bedded sands. These sands, on weathering, yield worn boulders which form the raw material upon which facets are cut. The levels higher and farther inland usually exhibit specimens with the largest and most perfect facets. On the lowest levels only small fragments show facetting, and only the relatively soft limestone has developed into fully shaped (mature) specimens, the harder greywacke and igneous material apparently taking longer to cut. On the intermediate levels these latter also assume in the case of smaller specimens, the typical *windkanter* shapes. The higher levels are sometimes characterized by an almost entire absence of limestone specimens, while quite large boulders of greywacke a foot in diameter and measuring six inches or more along the facet-slopes may show fully developed facets. The absence of limestone examples may possibly be due to an original lack of such material; but the presence in localized patches of abundant facetted limestone pebbles indicates rather that, where they are rare or absent, they have been abraded and dissolved away while the greywacke boulders were being cut, and that their presence in other patches is due to being covered for long periods by sand-dunes.

Conditions of wind abrasion are very similar to those at the Ure, the north-east and south-west winds exercising a far greater power of abrasion than any others.*

The Material.

Comparison with the specimens from the Ure District reveals many points of difference, some of which can readily be referred to a general contrast in the shape of the fragments provided. Whereas those north of the Ure River are mainly cut from polygonal plates characterized by sharp angles, typical of material freshly shed from an outcrop, the majority of the specimens at the Clarence locality are developed from originally rounded, river-worn boulders exposed by the weathering of the bedded sands in which they occur. This fundamental difference is in great measure reflected in the form of the subsequent *windkanter*. Consequently, some of the principles enunciated in the writer's previous paper require some adaptation when applied to the new material. In particular no discussion was there instituted as to the sequence of forms which might be expected to develop from rounded fragments or stream-worn boulders. Rounded material undoubtedly offers greater opportunity for the direction of the facets to be governed by wind-direction than does angular material on which plane surfaces are already developed; and in this connection it may be noted that "roof-shaped" pebbles *(Firstkanter)* are by far the commonest type developed at the Clarence locality (Table V) (Figs. 2, 4). In the writer's previous

* King, L. C., *loc. cit.*, p. 202.

classification no account was taken of the form generally referred to as "Brazil Nut," as specimens of the type were not found among the Ure material. It now appears that such are, in some cases at least, formed by the cutting of one strong facet on a rounded pebble that rests on a flattish base.

THE LOWER LIMIT OF SIZE.

An examination was made of the deposits with a view to ascertaining the lower limit of size that may be attained by wind-facetted stones. Small, very perfect examples of *firstkanter* were found in great abundance on many of the lower levels, but were relatively less common on the higher. Below a length of ⅜ in. no examples were found (Fig. 3), though specimens measuring from ⅜ in. to ½ in. are so common in places as literally to form the surface of the ground. The lower limit of size seems, therefore, to be here sharply defined. Probably smaller material is actively blown along by the wind, and joining the moving stream of abrading material is shattered by impact on the larger stones. The question here arises whether much of this material is derived by the wearing down of formerly much larger stones or whether the bulk of it is derived from originally small rock-fragments. On the lower exposures the general absence of facets on the larger pebbles suggests that the second proposition is true, a conclusion which is strengthened by the rarity of pebbles of the "multi-facetted" or rolled type. Evidently, as abrasion proceeds, many of the smaller *windkanter* will disappear and the deposit as a whole will undergo a change in the proportions of large and small-facetted stones in the direction of a smaller number of examples, with a greater percentage of large specimens. This conclusion was well supported by field observations on the proportions of material according to size at various levels.

QUANTITATIVE DATA.

With a view to obtaining quantitative data on problems of facet-size, position and relative abundance a detailed examination was made of every definitely facetted pebble in a small, restricted area. In this way it was hoped to eliminate the possibilty of error which would be present if selected material only were studied. The area chosen was on one of the highest levels, a small rectangular patch ten feet by eleven in the most typical portion of the deposit, forming the source of the data tabulated below. In this area 332 specimens in all were considered to bear definite wind-cut facets, the size of the specimens measured along the longest horizontal axis being set out in Table I.

TABLE I.

Size.	Number of specimens examined of				
	Greywacke.	Igneous.	Argillite.	Flint.	Limestone.
Less than one inch	83	11	1	2	—
One to two inches	128	12	3	2	—
Two to three inches	44	4	1	1	—
Three to four inches	24	1	—	—	—
Four to five inches	8	—	—	—	—
Five to six inches	2	—	—	—	—
Over six inches	5	—	—	—	—
	294	28	5	5	0

Size of *Windkanter* Measured along the Longest Axis (332 specimens).

This is fairly representative of the proportions of the material in the Clarence River bed to-day, except for the absence of the limestone, a change that has already been ascribed to the relatively soft and soluble nature of the rock itself.

The relation of facets to wind-directions is set out in Table II, a minor facet being defined as one relatively very small compared with the size of the larger facets on the specimen examined.

TABLE II.

Quadrant.	No. of major facets.	No. of minor facets.	Totals.
North-east ..	205	16	221
South-west ..	195	17	212
North-west ..	120	30	150
South-east ..	119	20	139

Relation of Facets to Wind-direction taken on 332 specimens.

From this table it at once becomes apparent that more facets are cut perpendicular to the north-east and south-west (or effective) wind-directions than are parallel, and one must conclude that wind-direction definitely exercises a controlling influence on the direction of facets cut on *originally rounded materials.* Of course there is great variation of direction within each quadrant, facets varying from squarely across wind to the limit of the quadrant. The minor facets, as might be expected, show a greater number parallel to the effective wind-directions than across.

To ascertain whether rock-composition affected the direction in which facets are cut, the facets on greywacke pebbles only were considered and the results (Table III) compared with Table II.

TABLE III.

Quadrant		No. of major facets.	No. of minor facets.
North-east	..	180	13
South-west	..	170	15
North-west	..	108	27
South-east	..	103	18

Facets on Greywacke Fragments only.

Little difference is apparent, though this may be due to the overwhelming proportion of greywacke pebbles (294 out of 332) included in the compilation of Table II. However, results based on any of the other rock-types must, owing to their scarcity, have been even less reliable. Although the test cannot be regarded as more than very rough, from the material available rock-composition seems to have little or no influence on the direction in which facets are cut on homogenous rocks.

TABLE IV.

Size.	Specimens showing			
	1 minor facet.	2 minor facets.	3 minor facets.	Total.
Less than 1 inch	12	7	—	19
1 to 2 inches ..	10	14	2	26
2 to 3 inches ..	2	3	—	5
3 to 4 inches ..	2	—	—	2
4 to 5 inches ..	3	—	—	3
	29	24	2	55

Specimens showing Minor Facets.

In Table IV the relation of the number of minor facets to the size of the pebble is considered. First of all it will be noted that almost all the specimens on which minor facets were developed showed only one or two such secondary forms. This is perhaps not surprising as most of the material under discussion was originally rounded; but where the original detritus is angular one may confidently expect that a large number of small facets will be developed.

The number of specimens (55) is small to generalize upon, but the table apparently makes another point clear. Comparison with Table I reveals that the average size of specimens on which minor facets are developed is smaller than the average size of specimens on which the facets are all of approximately the same order of magnitude. In other words, smaller specimens seem to have the facets of more varied size. The significance of this is not immediately apparent. Perhaps, being smaller and projecting less from the ground, they receive less of the directed force of the wind and are subjected to side and eddy-currents round the larger boulders. In some cases, however, where a small size is indicative of long exposure, and the area is one where only certain wind-directions are effective for cutting, facets which are more nearly at right angles to these directions may have had a better chance for development.

TABLE V.

Size.	1 facet.	2 facets.	3 facets.	4 facets.	Total.
Less than 1 inch	6	73	13	5	97
1 to 2 inches	10	101	22	12	145
2 to 3 inches	5	35	3	7	50
3 to 4 inches	5	18	1	1	25
4 to 5 inches	4	3	1	—	8
5 to 6 inches	—	2	—	—	2
Over 6 inches	2	3	—	—	5
Totals ..	32	235	40	25	332

Relation of Number of Facets to Size of Pebbles.

Table V shows to some degree, though less clearly than Table II, the influence of directional winds on rounded material; and, secondly, it illustrates the scarcity of even irregular pyramidal forms. The conditions for the formation of a normal *firstkanter* are simple, two facets inclining towards each other and meeting to form a ridge. In the case of a four-sided pyramid the conditions are infinitely more complex and mathematically more difficult to realise. Thus of four-sided *windkanter* cut from rounded boulders very few attain a perfect form, even in areas where winds are variable and blow with more or less equal intensity from all directions.

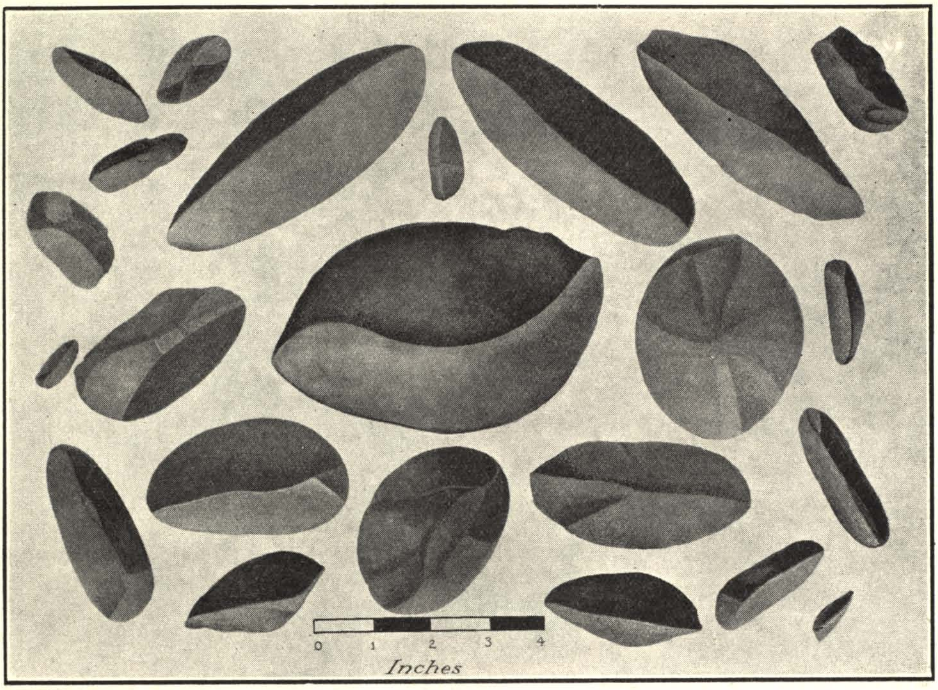

FIG. 2.—Greywacke Pebbles facetted by wind-action. All pebbles orientated as found, the scale being in the south-west quadrant.

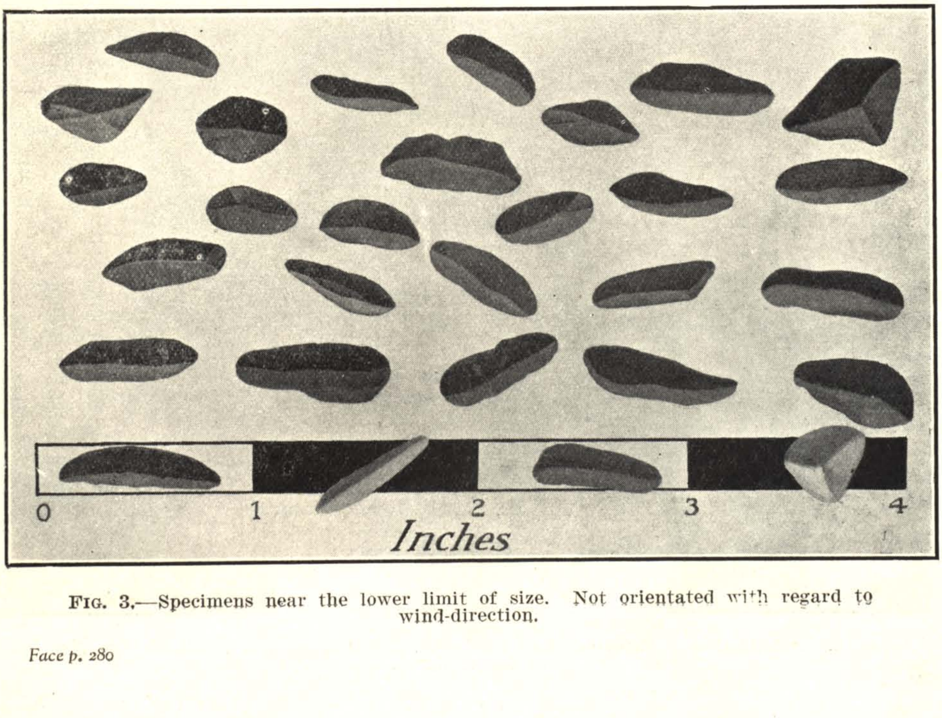

FIG. 3.—Specimens near the lower limit of size. Not orientated with regard to wind-direction.

Face p. 280

FIG. 4.—A representative selection of *Firstkanter* cut in limestone. All orientated as found, the north-eastern side being that at the right-hand side of the page.

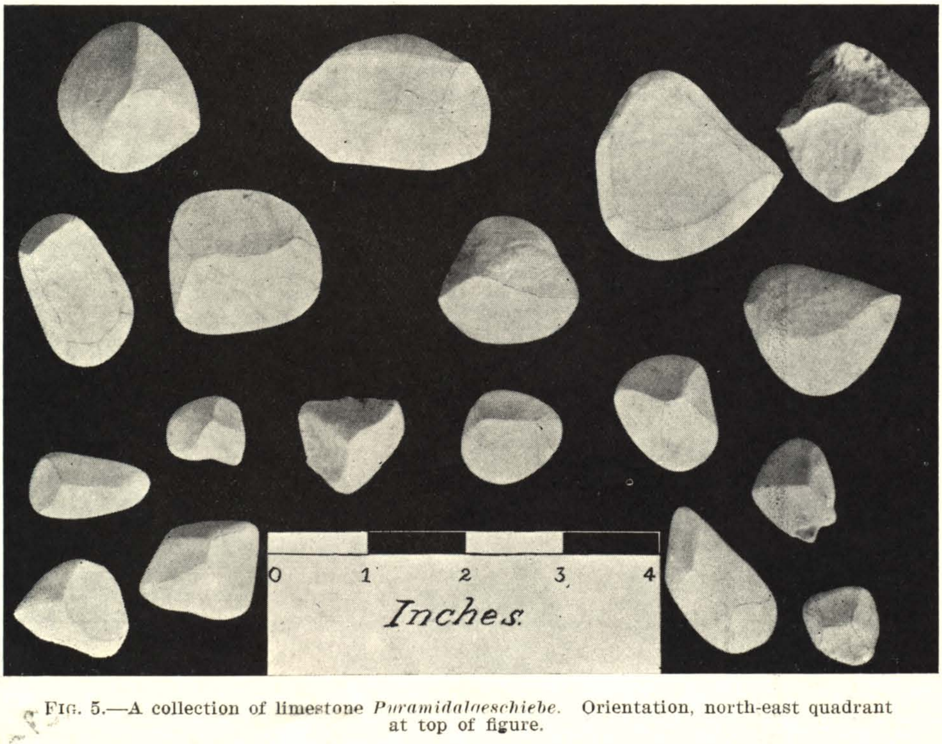

FIG. 5.—A collection of limestone *Pyramidalgeschiebe*. Orientation, north-east quadrant at top of figure.