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into line with the Sulphur Spring Range Devonian column and correlated with the Union Mountain and Telegraph Canyon Members (Fig. 3). It is proposed that the McColley Canyon (Fig. 2), originally defined as a member of the Nevada Formation (Carlisle *et al.*, 1957), be elevated to formation rank.

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DUNE CROSS-BEDDING ON MUSTANG ISLAND, TEXAS¹

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INTRODUCTION

Cross-beds of eolian, marine, and fluvial origin may differ sufficiently in shape, dip angle, standard deviation of dip azimuths, or thickness to be useful in reconstructing environments of deposition. This idea can only be tested when enough data on cross-beds from different environments have been gathered. Previously published information on eolian cross-bedding concerns only ancient rocks; the lack of published data on Recent eolian cross-beds is probably due to difficulty in observing cross-bedding in uncemented dunes. This note presents data on Recent eolian cross-bedding obtained during a rare opportunity to examine the internal structure of dunes on Mustang Island, Texas (Fig. 1), one of a series of barrier bars that extends most of the length of the

Texas coast. The island is approximately 16 miles long and 1-3 miles wide.

The September, 1961, hurricane ("Carla") that struck the northwest Gulf Coast exposed dune cross-beds. During the hurricane, waves accompanying a 10-foot flood tide removed a belt of fore-dunes 20-50 yards wide from the seaward face of the island and attacked a belt of larger dunes that are partly stabilized by vegetation. The large dunes were left with wave-cut cliffs up to 10 feet high, and many were deeply excavated along their flanks where waves breached inland. After the storm, while the dunes were still wet, the internal structure of the dunes was well displayed (Figs. 2, 3); but sliding sand obscured most of the structure as soon as the surface of the dunes dried.

CROSS-BEDDING

A total of 130 cross-bed dip azimuths and dip angles were recorded at 7 stations along an 11-

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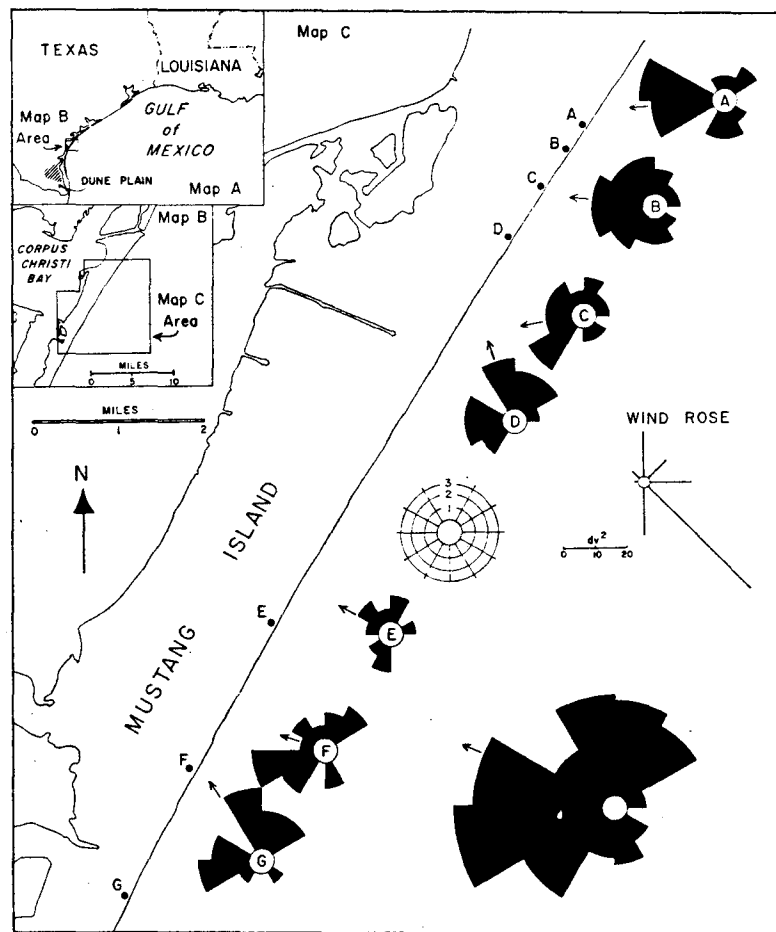


FIG. 1.—Index maps of Mustang Island, Texas (Maps A and B), and Map (C) showing cross-bed histograms, station localities, and wind rose pattern. Histograms are based on number of readings. The scale for the station histograms is given in the center of the map; the summary histogram has one-half this scale. Arrows indicate the mean direction for each histogram. Wind rose after Price (1933, Fig. 9).

mile stretch of beach (Fig. 1). Most Brunton-compass readings were taken on the flat side of an aluminum notebook holder stuck into the sand in the plane of cross-bed surfaces, although several readings were taken directly on exhumed cross-bedding planes. The latter revealed curved surfaces (convex up) characteristic of "festoon-type" cross-beds. The largest surfaces exposed were about 5 feet wide by 3 feet long with depths of exposure of less than 3 inches.

Figure 1 shows current roses for each station and a summary rose for all stations. Each rose indicates a net W. to NW. transport of sand; the mean direction of all readings is WNW. (292°). A net direction of sand transport is suggested by

longitudinal dunes on the dune plain south of Corpus Christi (Fig. 4) that show a striking NW. lineation (Price, 1958, p. 49, 53). This net NW. transport of sand is correlative with modern wind conditions; the strongest winds of the north-western Gulf of Mexico blow toward the NW. quadrant 6 months of the year (Lohse, 1955, Fig. 4), and a duration-velocity (dv^2) diagram (Price, 1933) for wind data collected at the Corpus Christi weather station shows the highest reading in the SE. quadrant (wind blowing to the NW.).

The summary rose diagram and the diagrams of Stations D and G show significant bimodal distributions, with one mode to the WSW. and another to the N. Possible explanations for this pattern in-

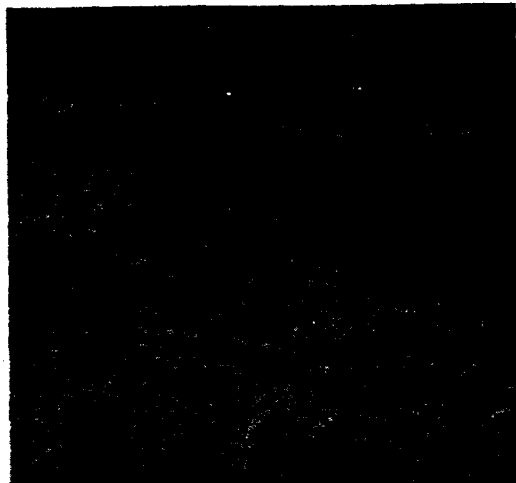


FIG. 2.—Cross-bedding in seaward facing cliff of dune on Mustang Island, Texas.

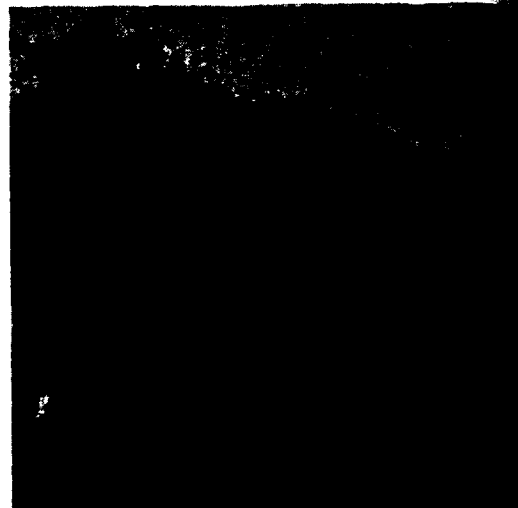


FIG. 3.—Cross-bedding exposed in Mustang Island dune. High-angle (38°) seaward dipping cross-beds are visible.

clude: (1) error resulting from too small a sample; (2) a real variation in the wind direction resulting in the migration of barchanoid dunes in the direction of each mode during different seasons; and (3) the migration of dunes that have slip-off faces dipping at oblique angles to the major wind direction. It is difficult to evaluate possibilities (2) and

(3) because the original dunes have been partly stabilized by vegetation and have been eroded by waves and by runoff after rain so as to modify the original shapes. A few dunes are barchanoid and thus lend support to explanation (2). The writers,

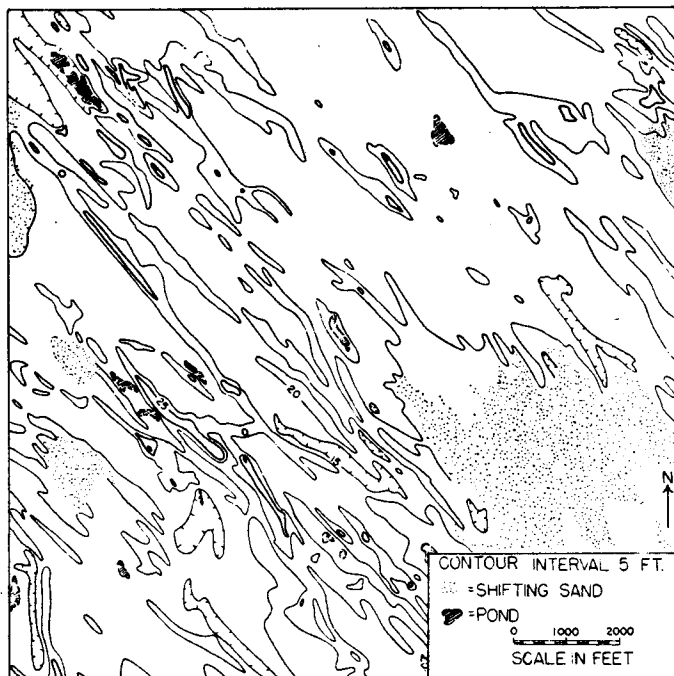


FIG. 4.—Typical longitudinal dunes of the eolian dune plain (for location, see Fig. 1), Kenedy County, Texas (taken from the Sarita 4 SE Quadrangle, 7.5 minute series). These dunes demonstrate the northwest transport direction of sand in this area.

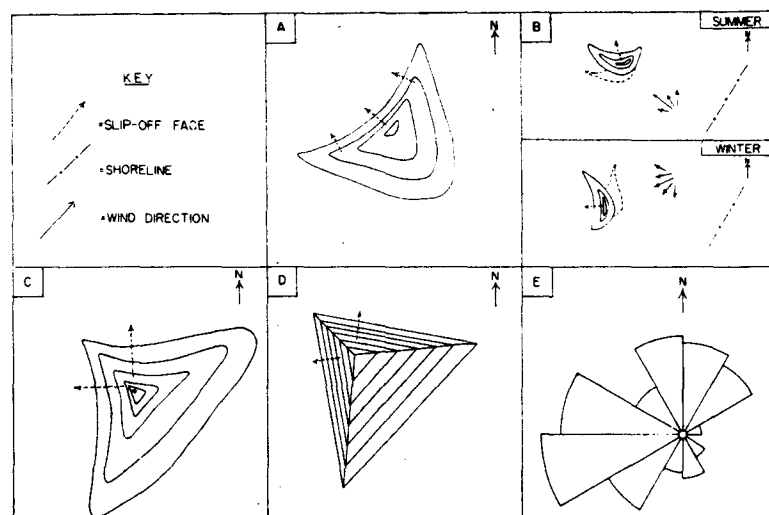


FIG. 5.—Sketches A through C illustrate a hypothesis to explain the bimodal dip directions of cross-beds on Mustang Island. *Asymmetrical pyramidal dunes* (C) are thought to form from barchan dunes (A) as an intermediate step in the formation of longitudinal dunes. The ideal asymmetric pyramid (D) has N and WSW slip-off faces that correspond with the cross-bed modes (E).

however, favor explanation (3) and propose that much sand on the island moves in the form of an *asymmetrical pyramidal dune* having two faces that, in general, dip in the direction of the cross-bed modes. The asymmetrical pyramidal dunes may be an intermediate step in the transformation of barchan to longitudinal dunes during the movement of sand inland. Figure 5 (A through D) illustrates the writers' hypothesis. Figure 5 (A) represents the presumed first stage, a barchan formed by sand moving NW. Because the seasonal winds vary in strength and direction and possibly because vegetation partly stabilizes the dune, the barchan is modified (B) so as to develop an asymmetrical pyramidal dune (C). The pyramidal dune develops a longitudinal projection but retains north-facing and south-facing horns until it has migrated far enough to change completely into a

longitudinal dune. Observations that support this hypothesis include: (1) an estimated 10-15 per cent of the nearshore dunes are pyramidal shaped (Fig. 6), whereas most other dunes lack diagnostic shape; (2) the N. and NW. faces of most pyramidal dunes dip in the direction of the cross-bedding modes (Fig. 5, E); and (3) barchan and pyramidal dunes are common along the barrier island but rare inland, whereas the reverse is true of longitudinal dunes.

Table I gives the mean, standard deviation, and consistency ratio of cross-bed azimuths for each station. The mean and standard deviation were calculated by the trigonometric vector method (Curry, 1956). The consistency ratios (Reiche, 1938) are listed because all reports of ancient eolian cross-bedding have used this parameter as a measure of dispersion instead of stand-

TABLE I. DATA ON EOLIAN CROSS-BEDS, MUSTANG ISLAND, TEXAS

Station	Mean Azimuth	Standard Deviation	Consistency Ratio	Mean Dip Angle (Degrees)	Number of Cross-Beds Measured
A	264	72	0.43	20.5	20
B	278	75	0.38	21.6	26
C	262	81	0.31	23.0	17
D	341	66	0.47	24.2	19
E	301	69	0.43	26.1	9
F	285	72	0.26	25.0	19
G	328	65	0.48	27.6	20
Averages	292	75	0.35	23.7	130

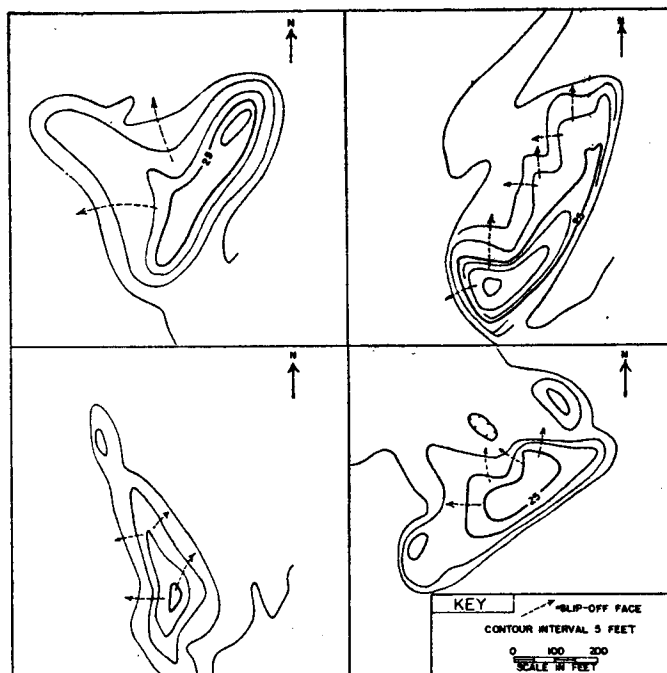


FIG. 6.—Examples of *asymmetrical pyramidal dunes* taken from Port Aransas Quadrangle, 4 SE, 7.5 minute series. Some of these dunes now have steeper stoss (windward) faces than slip-off faces due to post-dune-formation erosion.

ard deviation. The standard deviation of dip directions ranges from 65° to 81° and average 75° .

Figure 7 shows the distribution of the measured dips of cross-beds. Angles of dip range from 2° to

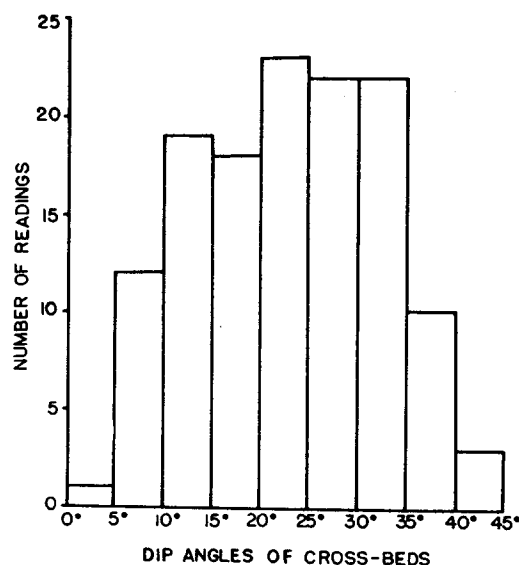


FIG. 7.—Histogram of cross-bed dip angles from dunes on Mustang Island, Texas (130 stations).

42° and average 24° . Inasmuch as the commonly cited angle of repose of dry sand is 33° – 34° , the large number of recorded cross-bed dips greater than 34° is puzzling. There may be errors of measurement of a few degrees; nevertheless, 13 dips exceed 34° . Although there were a few small slumped blocks in the area, the cross-beds measured showed no signs of deformation or tilting. How surfaces of deposition with dips greater than 34° could form is uncertain. One possibility is that salt spray along the beach gives a brine coating to the grains that acts as a "glue" to permit high angles of repose. Only a weak adhesive force would be necessary, for the dunes are composed of fine sand (mean size is $2.86\phi = 0.138\text{mm}$) that is very well sorted (graphic standard deviation is 0.273ϕ ; Mason and Folk, 1958).

The measurements of cross-bed thickness were too few for significant analysis because they came from cross-bed sets whose tops had been eroded. Of 20 beds measured, all are less than 3 feet thick.

CONCLUSIONS

The most diagnostic features of the eolian cross-bedding of Mustang Island are: (1) the large percentage (27%) of cross-beds that have dip

angles greater than 30° and the high mean inclination (24°); and (2) the bimodality of dip directions with modes to the N. and WSW. Whether these features are peculiar to Mustang Island or are typical of dunes on barrier bars with a similar wind pattern must await the results of studies of other areas.

The standard deviation of cross-bed azimuths show promise in helping to distinguish between fluvial (low σ) and marine (high σ) cross-beds (Pryor, 1960, Table 4). The mean standard deviation (75°) of Mustang Island cross-beds is intermediate between most fluvial and marine cross-beds; it is based, however, on a bimodal distribution. The Mustang Island dunes indicate that eolian cross-bedding need not be either highly unidirectional or highly dispersed.

One criterion cited as evidence for an eolian origin of ancient rocks is the great thickness of cross-bed sets (McKee, 1933, p. 81; Reiche, 1938, p. 917-918; Opdyke and Runcorn, 1960, p. 963). The Mustang Island dunes show that not all eolian cross-beds are characterized by sets of great thickness.

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WHEN WAS PETROLEUM FIRST NOTICED IN UNITED STATES?¹

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The French were the first to explore central and western New York, and it is to the records of their work, especially that of the missionary-priests, that we expect to look for notices of the occurrence of petroleum and natural gas. In 1876, W. J. Buck of Titusville, Pennsylvania, published a little pamphlet on accounts of petroleum in the United States, in which he stated that the earliest record is found in a letter by Père Joseph de la Roche Daillon, a Recollect, dated 18 July, 1627, and published in 1636 by Gabriel Sagard Theodat in *Histoire du Canada*. Since then most authorities seem uncritically to have accepted this as the earliest date of petroleum in this country (Leitch, 1881, v. 1, p. 270; Ashburner, 1887, p. 2; Hall, 1887, p. 575; Bacon and Harmor, 1916, p. 10; Clarke, 1925, p. 28; Herrick, 1949, p. 8;).

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Kreidler, 1953, p. 38; Westervelt, 1958, p. 2, *int. al.*). A recent newspaper filler repeats the story that Père Daillon was led by Seneca Indians to the famous oil spring near Cuba, New York, in 1627.

Two things are questionable about this supposed discovery: was Père Daillon actually in New York and anywhere near Cuba, and did he definitely refer to petroleum in his letter? As for the first, the late Dr. Nellis Crouse, in his exhaustive study of the contributions of the French missionaries to geographical knowledge, notes that "the exact extent of Daillon's wanderings through the country is uncertain," and that at the most he may have gotten eastward in Ontario as far as the Niagara River. There is nothing in Daillon's letter to show that he saw or even heard of an oil spring. With reference to the second question, there follows the passage from his letter that has been in-