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QUATERNARY SANDS ON THE SOUTHERN HIGH PLAINS OF WESTERN TEXAS.

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ABSTRACT. Aeolian sands around the railway station of Sand Hills, on the southern High Plains of Texas, are divisible into two formations. The Judkins, older body of sand, is typically reddish-brown in color, and is slightly indurated due to interstitial clay and fine silt. The younger Monahans sands are gray, unconsolidated, and largely lacking in clay and fine silt particles.

Within the area examined, the older sands are more widely distributed than are the younger. Where exposed at the surface, the older sands commonly occur as fixed dunes with simple contours. The younger sands form dunes which are in many places fixed by vegetation, but which have not been so greatly modified by erosion and mass wasting as have the older dunes of the Judkins. Where the formations are superimposed they are separated by a disconformity which indicates that a stage of erosion intervened between the two stages of sand accumulation.

As a step toward establishing a Quaternary chronology for the Southwest, it is suggested that the greater part of the Judkins sands accumulated during a relatively arid interval that separated the Neville and Calamity stages of alluviation in the nearby Davis Mountains of Trans-Pecos Texas. Likewise the greater portion of the Monahans may have accumulated during the arid time that intervened between deposition of the Calamity and Kokernot formations. According to these correlations, the fluvial Quaternary sequence in the Davis Mountains and the aeolian sequence of the southern High Plains are supplementary, with the breaks in the sequence of one area represented by the sedimentary deposits of the other.

INTRODUCTION.

ALONG a belt extending from Nebraska to Texas dune sands of Quaternary age cover large portions of the American Great Plains.[1] One of the larger patches of dune deposits lies north and east of the Pecos Valley, in southeastern New Mexico and western Texas. Whereas the greater part of this blanket of sand rests upon the High Plains, its margins extend down into the valley of the Pecos. A good

[1] Lobeck, A. K.: Geomorphology: 384, 1939. (Map of dune areas.)

view of the sand dune country can be had along U. S. Highway 80, particularly along the stretch of 50 miles between the small towns of Barstow and Judkins (Text Fig. 1).

During the summer of 1939 the writers studied the sections of the sands that are revealed in road cuts along Highway 80, especially those in the vicinity of the station of Sand Hills.

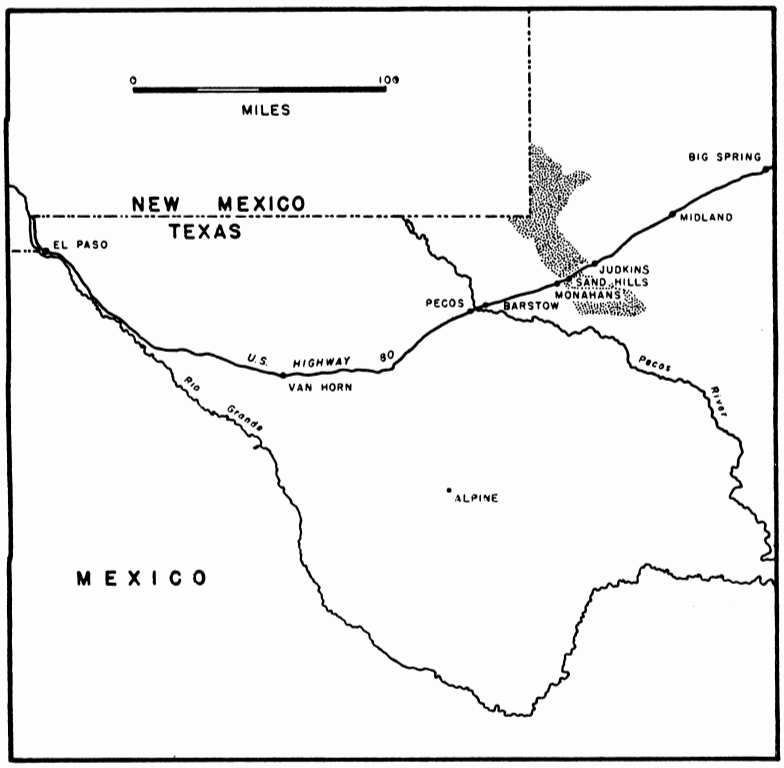

Fig. 1. Map of a portion of Texas. Dotted area on southern High Plains covered with relatively large dunes. (Data from 1937 edition of the geological map of Texas.)

The aeolian deposits in this area consist of two bodies of sand, which are of different ages, unlike in color and degree of cohesiveness, and which are separated by a disconformity wherever the younger sands rest upon the older. Presumably each body of sand records a time of general windiness and relative aridity in the region of the southern High Plains. The disconformity between the two bodies of sand indicates that after the older sands were laid down, deposition of sand ceased

for a time, and the older depositional surfaces were modified by erosion.

The sequence of events recorded in the Quaternary dune sands of the southern High Plains has interesting parallels with the sequence of events recorded in Quaternary alluvium of the Davis Mountain area, some 75 miles to the southwest. It is the writers' main purpose to describe the aeolian deposits in the vicinity of Sand Hills, and to present a tentative correlation of these deposits with the Quaternary alluvial formations in the Davis Mountains.

The writers wish to express their appreciation to Prof. Kirk Bryan for criticism of this paper, and also to Dr. H. T. U. Smith for providing them with a manuscript copy of his paper, "The Sand Dune Cycle in Western Kansas."

STRATIGRAPHY.

General Statement.

Within the area observed by the writers, the aeolian deposits consist of an older body of reddish-brown sand overlain in places by a younger body of lighter colored sand. For convenience in reference the sand bodies are here assigned formational names: Judkins for the older sands, and Monahans for the younger. Where the deposits are superimposed, as they are in the vicinity of Sand Hills, the surface of contact between them is sharply defined and irregular in profile.

The Judkins apparently crops out over a wider area than does the Monahans; it is also more compact and contains a greater percentage of silt and clay. The younger sands form dunes up to 25 or more feet in height. Some, perhaps most, of these dunes are fairly well covered with vegetation; others have relatively bare sandy surfaces (Plate I, Fig. 1). Where the older sands are exposed at the surface, they commonly form low, smoothly contoured mounds anchored by scrubby vegetation.

Judkins Formation.

Type locality and exposures.—The type locality of the Judkins formation is on the south side of Highway 80, 6.6 miles by road northeast of Monahans. The locality is pictured in Plate I, Fig. 2, which shows the relatively compact and dark Judkins sands cropping out as rounded embankments below

the drift fence. The name is taken from the town of Judkins, situated on the same highway a few miles away (Text Fig. 1).

Along the highway for 11 miles northeast of Monahans the formation is largely concealed by younger sands. Beyond the outcrop area of the younger sands, however, the Judkins is exposed at the surface at many points along the highway between the towns of Barstow and Judkins. The areal extent of the formation is thus large, although its boundaries remain to be mapped.

Lithology.—At the type locality the Judkins consists of massive sand with which small particles of silt and clay are admixed. The color is a shade of reddish-brown which approximates "india spice" in the color dictionary of Maerz and Paul.[2] In fresh exposures the sand is sufficiently indurated so as to stand at steep angles, which are considerably greater than the angle of repose for uncemented material of the same texture (Plate I, Fig. 3). When excavated with a pick it breaks into small clods which are easily reduced to their component grains under gentle pressure between the fingers.

In hand specimen the sand appears to be well sorted, an observation verified by the mechanical analysis in Table 1. The sample analyzed had a sorting coefficient of slightly more than 1.4. At least 99 per cent of this sample consisted of rounded and frosted grains of quartz. Most grains are clear, but some are partly covered with patches of reddish or yellowish material, probably hematite or limonite.

Fine silt and clay particles adhere to the larger grains, lending a certain amount of cohesiveness to the mass. Even the smallest particles that can be resolved under the microscope seem to be mostly quartz dust. Most of the finer grains have a yellowish cast, and it is probably to colored flakes of microscopic and submicroscopic size that the reddish-brown color of the sand body is due.

Samples collected at localities northeast and southwest of the type area for the Judkins conform essentially to the description given above.

Thickness and relationship to older rocks.—At the type locality the Judkins has a maximum exposed thickness of six feet. The base, however, is not exposed, and the contact with the overlying deposits is along an erosional surface, so that

[2] Maerz, A. and Paul, M. R.: A dictionary of color, 1930.

the original thickness of the formation at this locality cannot be determined.

Between Barstow and Monahans the older sands rest in different places on rocks of Triassic, Cretaceous, and older Quaternary age. Where the basal contact could be observed, it was found that the Judkins forms a superficial layer of a few feet in thickness and distributed alike over minor elevations and depressions in the underlying rock.

Physiographic expression.—Where exposed at the surface the sands of the Judkins commonly occur as low, smoothly contoured mounds, many of which are covered with a scattering of scrub mesquite and other plants. Such mounds may be seen along the highway 1.7 miles east of Barstow, at which locality they stand as much as four feet above the general level. Mesquite and other plants anchor the mounds, lending a deceptive irregularity to their otherwise smooth sandy surfaces. Many of the mounds are irregular in plan, but a considerable number tend to be circular or elliptical, those with well defined long axes aligned between 10 and 30 degrees east of north. The simplified and rounded contours of these sand mounds suggest that they represent old dunes which, fixed for a considerable time by vegetation, have acquired simple contours by mass wasting. According to a recent classification of dunes proposed by Dr. H. T. U. Smith, these dunes are in the mature stage of an eluvial phase.[3]

Origin.—There can be little doubt that the Judkins was deposited by the wind. This is indicated by the excellent sorting of the sands, and the manner in which they are distributed without regard for minor elevations and depressions in the underlying bedrock, as well as by the modified dune forms retained in some places. Nowhere in the Judkins was there observed any material so coarse that it could not have been transported by the wind.

Monahans Formation.

Type locality and exposures.—The type locality for the Monahans is the same as that for the Judkins. The younger sands are exposed at the surface along the highway for approximately 11 miles northeast of the town of Monahans. Distribution of the Monahans within the areas observed by the

[3] Smith, H. T. U.: The sand dune cycle in western Kansas: MS; Abstract in Geol. Soc. America Bull., 50, 1934-1935, 1939.

writers is the same as that shown for "Quaternary dune sands" on the 1937 edition of the state geological map (*See* dotted pattern in Text Fig. 1). Thus it is possible that the state map shows the approximate distribution of the Monahans on the southern High Plains, but verification of this must await further study in the field.

Lithology.—At the type locality the Monahans consists of massive, loose sand of gray to light golden color.[4] Mechanical analyses of two samples are listed in Table 1. Sample Y was collected from one of the roadside dunes at the type locality; Z was taken four miles east of Sand Hills at a point about four miles south of the highway. Both samples are well sorted (sorting coefficient approximately 1.3) and both consist almost entirely of colorless grains of quartz. In minute pits and hollows of some of the grains are preserved thin coverings of reddish or yellowish materials believed to be hematite or limonite. Fine clay particles are absent, a fact that serves to distinguish these sands from the older deposits of the Judkins.

TABLE 1.

Mechanical analyses of sand samples. (X from the type locality of the Judkins; Y and Z from the Monahans near Sand Hills.)

	X	Y	Z
>.500 mm.	0.00	0.00	0.00
.500 to .250 mm.	27.18	42.89	5.24
.250 to .149 mm.	41.04	53.54	77.79
.149 to .062 mm.	23.10	3.36	15.44
<.062 mm.	8.11	0.08	1.50
	99.43 gms.	99.87 gms.	99.97 gms.

Thickness and relationship to Judkins formation.—It is difficult to give significant figures for the thickness of a deposit that occurs in dunes, even where the dunes are as closely spaced as they are around Sand Hills. The situation is complicated in the case of the Monahans sands by the fact that they overlie an irregular terrain, so that the maximum height of a dune does not necessarily approximate the maximum thickness of the sands. The maximum observed thickness of the sands was six feet, but it is probable that the sand is 30 or more feet thick in places.

At the type locality the contact between the two bodies of sand is well displayed (Plate 1, Figs. 2, 3). The incoherent

[4] For colors of representative samples see Pl. 13, B-8 and Pl. 11, F-7 in the dictionary of color of Maerz and Paul: *Op. cit.*

sands of the Monahans can be swept cleanly away from above the more compact sands belonging to the Judkins. When the surface of contact is thus exposed, artificially or by the wind, that surface is found to be irregular. In places the Judkins crops out as hummocky inliers whose sides are so steep that they could not possibly represent depositional surfaces. It must be concluded, therefore, that after the Judkins was deposited and had attained something like its present state of induration, the depositional surfaces were modified by erosion before the dunes of the Monahans covered them. The implications of this will be mentioned in the topic on the history of the Sand Hills area.

Physiographic expression.—The Monahans sands form conspicuous dunes up to 25 feet in height. As shown in Plate I, Fig. 1, the dune ridges are closely spaced, so that the sand body forms a continuous blanket except where it has been excavated along railways and highways. In many places the dunes are covered by small bushes and bunches of smaller plants. Elsewhere the surfaces are bare, and the upper portion of the sand blanket is free to drift before the wind. It might be argued that the film of reworked sand should be separated stratigraphically, on the ground of age difference, from the parent sands in the dunes. Practically, however, it is impossible to separate the superficial mobile sands from the underlying more stable dune sands. For this reason the writers include the reworked as well as the parent sands in the Monahans formation.

The dune forms of this area are complex, and any fundamental pattern that they may exhibit is not apparent from the ground.

Origin.—It follows from the foregoing description that the Monahans sands are of aeolian origin. Their sources are not known, but it is likely that at least some of the golden colored deposits near the base of the Monahans have been reworked from the underlying Judkins.

QUATERNARY HISTORY OF THE SAND HILLS AREA.

The earliest Quaternary event of which there is record in the sections observed around Sand Hills is the accumulation of the Judkins sands. These are aeolian deposits which, in some of the areas described, still retain modified dune forms beneath coverings of vegetation. At some time after the sands were

deposited, but before they were eroded during the Judkins-Monahans interval, these sands attained a slight degree of induration. Examination of sands at the type locality shows that this induration is due to fine silt and clay particles, which partly fill interstices between the larger grains, and adhere to them as well as to each other. Particles of comparable fineness are largely lacking in the younger sands of the Monahans, and it is regarded as highly unlikely that they were originally deposited by the wind in the interstices of the Judkins sands. More likely the clay and fine silt in the older sands are illuvial, having been carried down from higher source horizons by descending subsurface waters. The source of the finer materials is thus problematical, but it may well have been situated in soil zones which developed near the surface of the older dune deposits after they had become anchored by vegetation. The processes of disintegration and decomposition operating in such soil zones over a period of time would produce a supply of fine particles, and meteoric waters sinking into the porous sand would transfer these particles to lower levels. Soil zones such as may have existed near the top of the Judkins in the Sand Hills area evidently were destroyed during the interval of erosion recorded in the disconformity between the Judkins and Monahans formations.

In summary, it may be postulated that after the Judkins sands were deposited as dunes, the dunes became fixed by vegetation and the sands weathered for a considerable period of time under climatic conditions more humid and favorable to plant growth than those locally prevailing at the time of sand accumulation.

At some time after the sands of the Judkins had attained the degree of induration already described, they were locally eroded and then covered over again by the younger body of sand belonging to the Monahans. Evidence for the erosional interval is found in the irregular surface of contact between the two bodies of sand. This surface, sections of which are well displayed at the type locality, is diversified by small, narrow, and fairly sharp ridges such as could have been produced only by the erosion of a fairly compact mass. However, the configuration of the surface of disconformity could not be established in detail sufficient to indicate what agency, whether wind or water, was more responsible for these ridges and their intervening depressions. Ridges and depressions alike were covered

Fig. 1. Dunes formed of sand belonging to the Monahans formation, near Sand Hills, Texas.

Fig. 2. Type locality of Judkins and Monahans formations, near Sand Hills, Texas.

Fig. 3. Small, steep-sided inliers of the Judkins, surrounded by unconsolidated gray sand of the Monahans, near Sand Hills, Texas.

over by a new blanket of sand when the Monahans dunes advanced across the eroded terrain.

Thus in the Sand Hills area there is direct evidence for two stages of dune building separated by an interval of erosion. There is indirect evidence, in the relatively high proportion of clay and fine silt in the older body of sand, to suggest that after the older dunes became fixed by vegetation, weathering in soil zones was effective in reducing some of the sand particles to clay and silt sizes.

TENTATIVE CORRELATION OF SANDS WITH QUATERNARY DEPOSITS IN OTHER AREAS.

Davis Mountain Area.

Quaternary alluvial deposits in the Davis Mountains, in which the town of Alpine (Text Fig. 1) is located, have been divided into three formations: the Neville, Calamity, and Kokernot, in order from oldest to youngest.[5] The three formations underlie broad, intramontane valley-flats and are separated from each other by disconformities. The three formations were deposited at different times by streams, and the surfaces of disconformity between the formations are surfaces of erosion produced when the same streams ceased depositing alluvium and eroded the valleys. The alternate channeling and alluviation of the valley flats is ascribed to climatic changes, the channeling having taken place under relatively arid conditions, and the alluviation under relatively humid conditions.

Evidence especially suggestive of past cycles of relative aridity in the Davis Mountains is afforded by dust found in caves, and by abundant wind-polished stones now losing their polish by exfoliation.[6] It is probable that a considerable portion of the cave dust was derived from the alluvial deposits of the valley flats; moreover, certain older deposits of reddish cave dust seem to have been derived from similarly red Neville alluvium and deposited during the arid cycle that followed Neville sedimentation. It is impossible to say when the wind-polished stones were abraded by the natural sand blast, but it

[5] Albritton, C. C., Jr. and Bryan, Kirk: Quaternary stratigraphy in the Davis Mountains, Trans-Pecos Texas: Geol. Soc. America Bull., 50, 1423-1474, 1939.

[6] *Op. cit.*, pp. 1456-1458.

Bryan, Kirk, and Albritton, C. C., Jr.: Wind-polished rocks in Trans-Pecos Texas (Abst.): Geol. Soc. America Bull., 50, 1902, 1939.

may be that they too bear record of the dusty Neville-Calamity erosional interval.

Albritton and Bryan have presented evidence which strongly suggests that the climatic changes that caused the streams of the Davis Mountains to aggrade and degrade their valleys alternately were not local but regional.[7] Accordingly the area of the southern High Plains, about 75 miles northeast of the Davis Mountains, might be expected to afford some confirmation or denial of this hypothesis.

It would seem that the sands of the southern High Plains accumulated during times when the source areas were largely lacking a protective cover of vegetation—hence probably when they were subjected to relatively arid climatic conditions.[8] The two bodies of sand around Sand Hills may, therefore, have been deposited during two of the arid cycles recorded by disconformities in the Quaternary alluvium of the Davis Mountains.

More specifically, the older body of reddish-brown sand may have been deposited during the interval of erosion following deposition of the Neville formation and preceding deposition of the Calamity in the Davis Mountains. The reddish cave dust of the Davis Mountains which is likewise believed to belong to this erosional stage, is of the same color as the older dune sand. The red color of both the cave dust and the older dune sands may thus record the deflation of mantles which had previously acquired this color through long weathering under humid conditions. Preservation of red color in the dust and dune deposits may reflect the fact that the sand and silt were not transported far from the source areas, and hence did not entirely lose by attrition the thin films of iron coloring compounds.

In like manner it is possible that at least the older portions of the Monahans record the relatively arid erosional stage that followed deposition of the Calamity formation in the Davis Mountains. It is unlikely that any considerable part of this great body of dune sands could have accumulated since the deposition of the youngest alluvial fill in the Davis Mountains. This fill—the Kokernot—is quite recent, and was in process of

[7] Albritton and Bryan: *Op. cit.*, pp. 1466-1471.

[8] The location of source areas for the sands is not known, although the sandy valley of the Pecos River, lying to the west and south, would seem to be the nearest adequate source of supply.

deposition during the interval 1100-1400 A.D.[9] with deposition continuing up to 1890 ± A.D.[10]

If the relative areas on the High Plains covered by the two bodies of dune sand may be taken as an index to the duration of the arid stages in the course of which they supposedly accumulated, one again finds circumstantial evidence for the correlation above suggested. There is reason for the belief that the Neville-Calamity interval of erosion was of greater duration than the Calamity-Kokernot interval; in fact, the disconformity between the Neville and Calamity is thought to be a major gap in the Quaternary alluvial history of the Davis Mountain area.[11] Thus the widely distributed Judkins sands are more likely to correspond to this long erosional interval rather than to the shorter post-Calamity interval, during which the less widely distributed Monahans sands are supposed to have accumulated.

The Quaternary alluvium of the Davis Mountains and the Quaternary dune sands of the southern High Plains may thus provide supplementary chronologies. The alluvium may record the sedimentary history for the relatively humid climatic intervals of the late Quaternary, whereas the dune sand may record a similar history for the arid intervals. The correlations tentatively proposed in this section are summarized in Table 2.

Other Areas on the Southern High Plains.

Subsequent to the writers' work in the Sand Hills area, there has appeared a paper by Melton containing a well illustrated account of dune patterns on the southern High Plains as revealed by aerial photographs.[12] From his analysis of intersecting dune patterns, Melton proposed a tentative Quaternary chronology in which three sets of dune deposits of different ages are recognized. These were designated as Series I, II, and III, in order from youngest to oldest.

At present it is impossible to do more than suggest a correlation of the sands described in this paper with the broader classification proposed by Melton. It would seem likely, how-

[9] Age determination based on archaeological evidence supplied by J. C. Kelley in a personal communication dated June 4, 1939.

[10] Bryan, Kirk; personal communication, June 4, 1940.

[11] Albritton and Bryan: *Op. cit.*, p. 1465.

[12] Melton, F. A.: A tentative classification of sand dunes; its application to dune history in the southern High Plains: Jour. Geol., 48, 113-174, 1940.

ever, that the Judkins is part of Series III, which Melton estimated to have been formed more than 15,000 years ago. In this connection it should be noted that Albritton and Bryan have suggested, by entirely different means of age estimation, that the Neville formation in the Davis Mountains may be as old as 25,000 years.[13] Granting this determination, and accepting the suggestion already advanced to the effect that the Judkins was deposited during the erosional interval that followed deposition of the Neville, the Judkins is less than 25,000 years old. Thus a fraction of the Judkins may be of the order of 15,000 years in age, Melton's estimate for the age of Series III. Similarly, the older part of the Monahans may belong to Melton's Series II.

Dunes of Series I, which includes the modern and active dunes, are not shown by Melton's map to occur in the areas described in this paper. However, Melton has emphasized that some of these younger dunes are very recent, having been formed within the past few hundred years.[14] Therefore it is probable that some of the younger sands in the Monahans are of the same age as some of the dunes included by Melton in Series I.

These correlations are entered tentatively in Table 2. It would be possible to expand this table to include comparisons with other areas in which the Quaternary chronology has been explored, but at present this procedure would involve pyramiding uncertainties without resolving any of the many individual problems of correlation. It should be emphasized that all of the correlations in Table 2 are provisional and at present unsupported by any paleontological or archeological evidence. The writers regard the table as little more than a summary of possibilities to be tested in the light of future investigations.

SUMMARY.

Quaternary sands in the vicinity of Sand Hills, on the southern High Plains of Texas, are divisible into two formations. Both formations are of aeolian origin, and, except where the two are superimposed, both occur in the form of dunes.

The older deposit, Judkins formation, is of reddish-brown

[13] Albritton and Bryan: *Op. cit.*, p. 1471.
[14] Melton: *Op. cit.*, p. 140.

TABLE 2.

Tentative Correlation of Quaternary Formations.

Davis Mountains*		Southern High Plains	
		General†	Sand Hills
Alluvial	Aeolian	Aeolian	Aeolian
		Series I	Monahans (Upper part)
Kokernot		*Inferred disconformity*	*Undetected break*
Disconformity		Series II	Monahans (Main body)
Calamity		*Inferred disconformity*	*Disconformity*
Disconformity	Older cave dust	Series III	Judkins
Neville		?	*Unconformity*

* Albritton and Bryan, 1939.
† Melton, 1940.

color, and consists of quartz sand with a relatively small but significant quantity of fine silt and clay. Where exposed at the surface, the older sands generally form mounds which are fixed by vegetation, and which have the rounded contours characteristics of dunes in their passive or eluvial stage of development.

The younger sands, or Monahans formation, are of gray or light golden color, consisting mostly of clear quartz sand with negligible quantities of fine silt and clay. These sands form dunes which are anchored by vegetation in many places but which are bare and mobile elsewhere. Of the two bodies of sand, the older is the more extensive within the areas observed.

Where the two bodies of sand are in contact, the surface of contact is one which in spite of the massive nature of the sands above and below it, is so irregular as to be classed as a disconformity and interpreted as recording a stage of erosion between two stages of sand accumulation.

The hypothesis is advanced that the two stages of maximum sand accumulation, represented by the major portions of the formations described, were during relatively arid times coincident with two stages of arroyo-cutting in the nearby Davis Mountains. Tentatively the Judkins is correlated in part with the reddish cave dust of the Davis Mountains, and with the

interval of erosion which intervened between deposition of the Quaternary Neville and Calamity formations. The major portion of the younger body of sand is tentatively correlated with the interval of erosion which followed deposition of the Calamity formation and preceded deposition of the Kokernot formation in the Davis Mountains.

Previous studies of the Quaternary in the Davis Mountains have indicated that the intervals of alluviation represented by the Neville, Calamity, and Kokernot formations were relatively humid times, whereas the intervening stages of erosion, evidence for which is found in the disconformities separating the three formations, were relatively arid times. It is thus possible that the alluvial deposits of the Davis Mountains and the aeolian deposits of the southern High Plains supplement each other—the disconformities in one sequence corresponding approximately to the sedimentary deposits of the other.

The correlations suggested in this paper remain to be tested in the light of archeological and paleontological investigations. That the end of such studies is important can hardly be denied, for it is only by the piecing together of Quaternary deposits of all origins—glacial, fluvial, and aeolian—that a complete chronology can be formulated and the history of man traced through the changing environments of late geologic time.

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