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GATUNA FORMATION (LATE CENOZOIC), PECOS VALLEY, NEW MEXICO AND TRANS-PECOS TEXAS

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INTRODUCTION

The Gatuna Formation was identified and named in 1938 by Lang from exposures in Gatuna Canyon (fig. 1, Gc) and SW ½ sec. 35, T. 19 S., R. 30 E. along Nimenium Ridge, Eddy County, New Mexico. Lang described the unit as "an assemblage of rocks of various kinds that were laid down in the Pecos Valley in *post-High Plains time* and apparently after the completion of the maximum cycle of erosion in this valley." He did not describe a type section. The dominant lithology is fine red sand and silt largely derived from nearby Late Permian and Triassic rocks. Although sand is dominant, the Gatuna section locally contains mudstone, conglomerate, limestone, gray shale or very locally, gypsum. The most typical color is reddish orange, but gray, yellow, black or purple occur locally. Lang (1938) reported as much as 90 m in Cedar Canyon (fig. 1, Cc), T. 24 S., R. 29 E., and I (1971) described a section nearby at Pierce Canyon Crossing (fig. 1, Pc) of the Pecos River dipping 35 to 50 degrees, with neither top nor bottom exposed, also about 90 m thick. The section there is dominantly friable reddish-brown or tan-brown siltstone, sandstone and claystone. Several 0.3 m-thick, pebbly conglomerate or conglomeratic sandstone beds occur in the sandstone, a character which clearly sets them apart from the associated Permian beds. Vine (1963) measured three sections in close proximity along the north bluff of Pierce Canyon (sec. 22-24, T. 24 S., R. 29 E.) which range from 11 to 24 m thick. The individual sections bear little resemblance to one another as to the sequence of sandstone and siltstone, and the eastern section contains blocks and small fragments derived from underlying Permian rocks. Bachman (1976) measured and designated a reference section about 17 m thick just north of Gatuna Canyon (SW ¼ SW ¼ section 36, T. 19 S., R. 30 E.). Bachman (1976) concluded that the presence locally of Ogallala-like caliche fragments in the Gatuna indicates a post-Ogallala (Pleistocene) age. One of the more significant descriptions of early Pecos Valley fill is that of Maley and Huffington (1953) for the area around Pecos, Texas and northward into adjoining New Mexico. They suggested that the deeper parts of the thick fill would likely be Tertiary in age.

During recent field review of the Gatuna Canyon outcrops by several geologists, a 10-cm long fish was found in laminated shale in the upper part of the exposure near the center of sec. 1, T. 20 S., R. 30 E. (John Hawley and J. P. Bradbury, verbal communications, 1980). The fish has been identified as threadfin shad, *Dorosoma petenense* (Gunther) by Robert R. Miller.

OCCURRENCE AND STRATIGRAPHY

Figure 1 shows most of the presently known outcropping beds of the Gatuna Formation. Prior to this work no Gatuna beds had been mapped north of T. 6 S. along the Pecos River basin. One of the largest and most significant exposures of Gatuna is in the Cottonwood Creek area northwest of Artesia. Gatuna deposits also are present in the Buffalo Valley area east of Hagerman. Other areas of Gatuna are shown on the 1976 Geologic Atlas of Texas, Clovis and Pecos Sheets. Most of the new occurrences of Gatuna previously had been mapped as "older alluvium" scattered through much of the Fort Sumner sheet (Kelley, 1972). The expanse and volume of these northern occurrences just about triple previously known Gatuna exposures in the southern Pecos Valley (fig. 1).

In Texas Gatuna outcrops are sparsely distributed from Red Bluff Lake (fig. 1, RB), just south of the New Mexico line, to as far east as 120 km downriver from Pecos. Many of these occurrences are exposed in low bluffs in the Pecos River floodplain. Other larger exposures are many kilometers away from the river, such as south of Orla along Fourmile Draw. This outcrop band extends up the draw for 15 km to an altitude of 182 m above the floodplain (Barnes, 1976). High outcrops also occur 50 km west of Pecos near Toyah and 25 km south of Pecos.

In Texas the Gatuna locally overlies Permian, Triassic and Cretaceous beds and is overlain by Pleistocene to Holocene alluvium. The Pecos Sheet legend suggests that the lacustrine Tahoka Formation (Pleistocene) is older than the Gatuna, but the two are nowhere in contact at the surface. About 15 km northeast of Pecos the Tahoka is about 10 to 15 m above the floodplain; about 4 km south of Pecos the Tahoka along Toya Creek is at a similar altitude above the floodplain. On the Llano Estacado the Tahoka overlies the Ogallala Formation (Upper Miocene-Pliocene). On the other hand, the nearby Gatuna is at the floodplain and clearly covered by its deposits. Maley and Huffington (1953) have demonstrated old alluvium to be more than 540 m thick and have shown that at least the deeper part was likely Tertiary. Inasmuch as the bluffs at the floodplain around Pecos are of Gatuna, it is also almost certain that all the subsurface alluvium above a nominal floodplain thickness, are Gatuna; in addition, the Tahoka is not known to be collapsed or disturbed as is common for Gatuna beds. Tahoka-Gatuna age relations are not completely resolved, but they suggest that the Gatuna is older than the Tahoka. The critical relationship between Gatuna and Ogallala cannot be determined from stratigraphic relationships in Texas.

The New Mexico occurrences of the Gatuna are described in two parts, those of the lower Pecos valley and those of the upper valley. The Gatuna outcrops around Carlsbad and southward near Loving and Malaga are the original areas recognized and described by early workers. In this area the Gatuna is as much as 100 m above the Pecos floodplain on the east and only about 30 m on the west. Its base is on Permian or Triassic rocks in a number of exposures, but for the most part it is buried by floodplain, terrace, caliche or aeolian deposits. At Pierce Crossing some 90 m of Gatuna are exposed in the limbs of a basin along the river bottom (Kelley, 1971). A thickness of about 40 m is exposed in nearby bluffs along Pierce Canyon. Elsewhere in this area the exposed thicknesses are generally less than 40 m. The Pierce Crossing downwarp strongly suggests dissolution of the underlying Permian evaporites. Similar relations occur elsewhere, as near the pro-

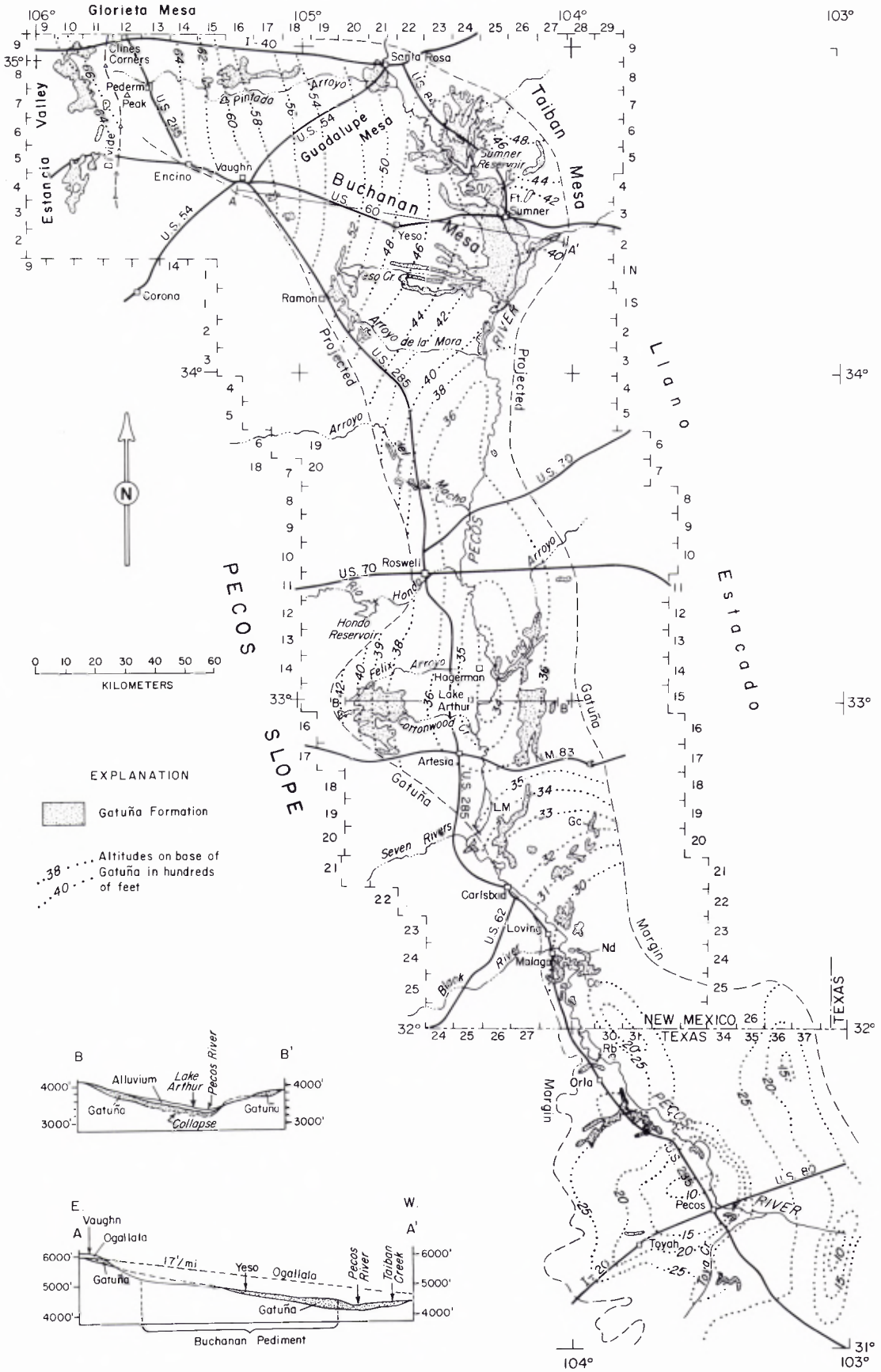


Figure 1. Outcrops, cross-sections and contours of elevation of base of Gatuna Formation, New Mexico and West Texas.

posed Brantly dam on the Pecos River about 20 km northwest of Carlsbad. Here drilling has penetrated Gatuna some 90 m thick, with its base about 65 m below the river level and surrounded by Permian rocks (Raymond N. Larsen, U.S. Bureau of Reclamation, verbal communication, 1980). The evidence does not suggest a downwarp but rather either dissolution collapse or washing of Gatuna sediment into cavernous openings. In the Malaga area Gatuna is exposed beneath cemented "quartzose conglomerate" (Bretz and Horberg, 1949; Reddy, 1961) in numerous small piercement and collapse structures. As in Texas the Gatuna is lower in the valley than is the Tahoka Formation.

Several large exposures of Gatuna exist in the Artesia to Hagerman area (fig. 1). The New Mexico State geologic map (Dane and Bachman, 1965) shows most of the Gatuna outcrops north to about Hagerman along Long Arroyo. On the other hand, one of the largest and most significant exposures of the Gatuna in the Cottonwood Creek area northwest of Artesia was mapped as the Permian Artesia Formation. This section is about 45 m thick. Nye (Fiedler and Nye, 1933) identified these beds as Permian Artesia (his "Pecos formation") and described them in some detail, including mention of fresh-water limestone beds. The beds in Cottonwood Creek consist of orange-red, fine- to medium-grained sandstone and reddish claystone. Besides limestone, there are lithic fragments of Artesia sandstone (Kelley, 1971). The Gatuna at Cottonwood Creek is nearly horizontal and laps onto Permian San Andres beds which dip a few degrees eastward.

During my studies in the late sixties I found in Buffalo Valley southeast of Hagerman other Gatuna beds (Kelley, 1971) that had been mapped as Permian Artesia, even though they lay variously on Artesia and Triassic units. Locally some chunks of Permian rocks are incorporated in red festooned aeolian beds of the Gatuna, features foreign to the Permian.

The widest part of the New Mexico Pecos Valley is from the Seven Rivers drainage on the south to about T. 9 S. on the north. The eastern edge is a line of generally abrupt bluffs followed rather closely by the Pecos River. The bluffs, which begin on the south at Lake McMillan, range from about 30 to 65 m in height. The valley is 25 to 40 km in width. The asymmetric nature of the valley, with the bluffs and river on the east side, appears to be caused by the greatly dominant tributaries of the Pecos slope on the west. Much of this valley is in the evaporitic facies of the Artesia Group that was deposited behind the Capitan reef. Widespread dissolution in these beds beneath the alluvium of the valley has increased thickness of the Holocene gravel fill and also quite likely the Gatuna beds just below. The nature of this possible development is shown in Figure 1, cross-section B-B'. There is no evidence that Gatuna reaches thicknesses and depths comparable to those in Texas.

During mapping in the late sixties the northernmost Gatuna exposures found were those along Arroyo del Macho some 30 to 50 km north of Roswell (Kelley, 1971). These beds, which were formerly mapped as Permian Artesia, overlie San Andres beds. As the result of the Pecos slope work (Kelley, 1971), I became interested in trying to trace Late Permian stratigraphy into central New Mexico, where stratigraphic terminology was in puzzling variance with that of the Permian Basin. During this work (Kelley, 1972) much reddish sand and gravel, mostly lying beneath expansive pediments, was discovered in the Fort Sumner area (Kelley, 1972, Map 2, QTo). On the New Mexico State geologic map (Dane and Bachman, 1965) these beds had been mapped mostly as Triassic, even though Darton (1928a) had mapped much of the Gatuna-covered area as alluvium. During mapping I labelled the outcrops Gatuna, but because of the considerable distance from the Gatuna in the Carlsbad area, and because the main interest was in Permian stratigraphy, I chose not to make the Gatuna correlation and designation. However, during recent compilations of a new State geologic map I decided to approach the problem again and consider the whole Gatuna occurrence in relation to the origin of the Pecos valley.

The principal northern occurrences are:

1. beneath the Buchanan and Guadalupe Mesas west of the Pecos River,
2. north of Sumner Reservoir east of the Pecos River,
3. in the large collapse structure at Santa Rosa,
4. along Pintada Canyon in R. 15-18 E.,
5. in T. 2 S. to 2 N. just east of U.S. Highway 285 between Vaughn and Roswell, and
6. along the eastern flank of Estancia Valley in T. 3-9 N.

The total area of Gatuna beds in this northern area, either at or near the surface, is about 100 km^2; Gatuna lies on rocks from Late Permian to Precambrian in age.

The largest occurrences (1 and 2 above) center around Fort Sumner, and the town itself is mostly on Gatuna beds. This great area extends from along the Pecos River in T. 3 S. northward past Sumner Reservoir (fig. 1) through T. 7 N. West of the Pecos, beneath a high pediment forming the tops of Buchanan and Guadalupe Mesas, is preserved most of what may have been the original thickness of the Gatuna. Around the eastern end of Buchanan Mesa the thickness is as much as 120 m between the pediment surface on the west and exposures along the Pecos River resting on Triassic beds. East of the river younger erosion has greatly thinned the Gatuna down to exposures beneath a much lower southward-sloping pediment. However, there is an arcuate remnant of Gatuna exposed in T. 5 N., R. 27 E. east of the sloping pediment and near the base of Taiban Mesa at altitudes of 1400 to 1500 m. These exposures are 120 to 150 m above outcrops of Gatuna resting on Triassic rocks along the shores of Sumner Reservoir. For details of the Gatuna outcrops see Kelley (1972, map 2). An unusually good exposure of Gatuna occurs in a bluff along an arroyo 1.6 km north of Ft. Sumner and just east of U.S. Highway 84. It rests on Triassic strata and is capped by pediment gravel in an interval about 17 m thick. The section consists of reddish- brown to mauve fine-grained clayey sandstone, greenish-gray shale, gray thin-bedded sandstone, pebbly to cobbly gravel lenses and local patches of carbonaceous wood fragments. The gravel fragments are subrounded discoid pieces of sandstone, quartzite, gneiss and greenstone.

The gigantic Santa Rosa sink, 9.7 km in diameter, is filled with sand and gravel estimated to be 75 to 120 m in thickness. These beds may be entirely or in part Gatuna. However, it is likely that some of the upper part is post-Gatuna material as the solution and sinking is still progressing.

Another separate area of possible Gatuna beds lies mostly along the northern side of Pintada Arroyo (T. 8 N., R. 15-18 E.). The Gatuna of this area is generally less than 30 m thick and consists almost entirely of poorly bedded, reddish-brown, fine-grained clayey sandstone. It lies under a pediment which was once continuous with the Guadalupe pediment south of the canyon. The Gatuna lies mostly on Santa Rosa Sandstone (Kelley, 1972, map 1). Locally this Gatuna underlies a still higher pediment, the sediments at the surface of which have been mapped and correlated (Kelley, 1972) as Ogallala. This high surface is quite extensive southward to the Vaughn area. In general it is as much as 100 m higher than the Buchanan pediment (Kelley, 1972, p. 29, map 1).

Another area of probable Gatuna occurs along U.S. Highway 285 0.5 to 10 km southeastward from Vaughn. The Gatuna, as above, lies beneath the Buchanan pediment and unconformably on Permian San Andres and Artesia beds. These patches are as much as 30 m thick. Farther south near U.S. Highway 285 in T. 2 S. to T. 2 N., between the upper reaches of Arroyo Yeso and Arroyo de la Mora, considerable Gatuna is exposed lying on beds ranging from Permian San Andres to Triassic Santa Rosa. Locally in the southeastern part of T. 1 N., R. 20 E. the Gatuna is 100 to 125 m thick beneath the Buchanan calichified pediment. The Gatuna here consists of rather indurated sandstone and gravel. The sediments are mostly light gray. The gravel consists of subrounded sedimentary and volcanic rock fragments. The western edges of these outcrops (T. 4 N., R. 17 E.) also lie 50 to 100 m below Ogallala gravels, again suggesting a lower stratigraphic position.

The last of the northern Gatuna occurrences are those along the eastern flank of Estancia Valley and outside the Pecos drainage area. They are on the western flank of the Pedernal Hills and extend north and south in several patches from T. 4 N. to T. 9 N. The outcrops have been previously mapped (Dane and Bachman, 1965) as either Permian Yeso Formation or bolson deposits. The likely Gatuna beds rest on Yeso, San Andres and Precambrian rocks and might be just as easily correlated with the upper part of the Pliocene Santa Fe Formation as with Gatuna.

CONFIGURATION OF GATUNA

Figure 1 shows contours drawn on elevations (in feet) of the base of Gatuna outcrops. Along the present course of the Pecos River from near Santa Rosa, New Mexico, to about 130 km east of Pecos, Texas, the projected altitudes on the base of the Gatuna range from about 4900 to 1500 ft (1500-450 m). The base of Gatuna is either near or greatly lower than the Pecos River in Texas. Between Carlsbad and the Texas State line, the base of the Gatuna Formation is mostly above the river, although it is below river at Pierce Canyon Crossing and locally elsewhere, probably owing to solution collapse. In the area between Loving and Carlsbad outcrops of Capitan reef limestones appear to have caused a considerable constriction in the ancient Gatuna valley. In the Artesia–Hagerman area outcrops of Gatuna are either at or slightly below river at the mouth of Long Arroyo or considerably above east of the river between the Seven Rivers tributary and Long Arroyo. As shown in Figure 1, section B-B', the base of Gatuna in the Cottonwood Creek area is above the river, but may be considerably below the wide alluvial terraces in the Artesia area.

North of Roswell present topographic relationships and meager Gatuna exposures indicate that the Gatuna valley was narrow. In the Fort Sumner area the base of the Gatuna ranges from below the river to several tens of feet above the river. Northward toward Santa Rosa the base is considerably above the river as though rising out of the ancient valley on its eastern side.

The total configuration of the reconstructed Gatuna base is puzzling. Considerable differences in local thickness of the Gatuna Formation are due to 1) abrupt onlapping of the Gatuna valley sides, 2) younger terrace or pediment cutting, and 3) considerable solution slumping during and following Gatuna deposition.

Another feature of the reconstructed surface shown by Figure 1 is its asymmetrical form, in which the western side is higher all the way from west of Pecos, Texas to the Santa Rosa–Fort Sumner area, where it is especially evident. No Gatuna is known north of Santa Rosa along the course of the Pecos River. Thus, the ancient valley, which became somewhat aggraded with Gatuna sands and gravels, swung westward toward sources in either the Pedernal Hills, southern Glorieta Mesa or beyond. Gatuna-equivalent deposits in Estancia Valley most likely came from the Pedernal Hills, and they may never have had continuity across the hills with the Gatuna proper of the Pecos drainage. It is likely that both the Gatuna and younger Ogallala have been slightly tilted eastward in latest Pliocene or early Pleistocene time. The slope on the Ogallala from near Vaughn to the Llano Estacado is about 10 m/km, which is slightly greater than the 8 m/km slopes projected similarly north and south of the Capitan Mountains (Kelley, 1971). Similar tilting was postulated for the Guadalupe Mountains by Bretz and Horberg (1949). It is probable that the slope of the contoured surface on the Gatuna east of Fort Sumner, which is about 24 m/km, is mostly erosional but may reflect a lesser element of Quaternary tilting.

DISCUSSION AND CONCLUSIONS

As quoted at the beginning of this paper, Lang (1938) saw the Gatuna as an aggradational unit which partly filled the Pecos Valley in post-High Plains time after maximum erosion of the valley. In 1949 Bretz and Horberg concluded that:

> "An ancestral Pecos depression, probably formed jointly by warping and solution collapse, existed in pre-Ogallala time and that the present depression (valley), enlarged by retreat of the Llano (Estacado) scarp and modified by later deformation and solution-subsidence, is in part a resurrected feature. It follows that the 'Reef escarpment' (Capitan reef), which forms the southeast margin of the Guadalupe Range, has been exhumed at least twice: first by stripping of weak Permian fore-reef deposits and later by removal of the Ogallala fill."

The Gatuna Formation has been difficult to date or fix stratigraphically because it was not known to lie in contact with the Ogallala. However, Kelley (1971) and Reeves (1972) suggested a pre-Ogallala or a "post-basal gravel part of the Ogallala" (Reeves, 1972) on the Llano Estacado; this may be a Gatuna equivalent.

If identification of Gatuna sediments in the northern part of the Pecos Valley is accepted, then there is the possibility of relating the section to outcrops of Ogallala west of the Pecos River. Darton (1928b) pointed out "outliers" of the Ogallala west and northwest of Fort Sumner and around the Pedernal Hills, much of which turned out to be a pediment (Kelley, 1972, maps 1 and 2), the surface of which forms the tops of Buchanan and Guadalupe Mesas. Bretz and Horberg (1949) showed several other Ogallala occurrences west of the Pecos in the northern area. As pointed out above, there are several localities where the Gatuna lies beneath the correlated western Ogallala occurrences. If these correlations of Gatuna are accepted, then the Gatuna is older than the Ogallala.

Some geologists (J. Frye, personal communication, 1980) believe that the Buchanan pediments are correlatives of the Ogallala surface east of the Pecos. East of Fort Sumner and Santa Rosa the Ogallala surface slopes southeastward in its northwestern part and southward at its southern edge on Taiban Mesa. Buchanan Mesa slopes mostly eastward. If the northern Ogallala surface east of Santa Rosa is projected to Buchanan Mesa it is 100 to 130 m too high. If one accepts this improbable correlation then the underlying northern Gatuna would obviously be older.

As early as 1926 Meinzer and others identified a "quartzose conglomerate" in the Carlsbad region which may also be a part of the problem. This unit occurs as valley fill and terraces, and it is commonly indurated or more disturbed than are widespread younger

terrace deposits. Bretz and Horberg (1949), after much study and analysis of the distribution of the quartzose conglomerate, concluded that it was a product of pre-Ogallala warping, dissolution-collapse, erosion and aggradation in an ancestral Pecos Valley. Inasmuch as the quartzose conglomerate lies in many places on the Gatuna the latter would also be pre-Ogallala. The caliche clasts in the Gatuna described by Bachman (1976) are not conclusive of derivation from the Ogallala, because in a pre-Ogallala valley there would have been earlier caliche sources, such as in the Permian Rustler Formation.

Identification of Ogallala west of Fort Sumner and Santa Rosa on the west side of the Pecos River is strongly supported by the considerable development of indurated caliche beds up to 10 m thick. This surface is distinctly above the Buchanan pediment. The Buchanan pediment must have been graded to a Pecos Valley base as it projects below the Ogallala occurrences of the Llano Estacado (fig. 1). The erosion of the wide Buchanan surface must have required considerable time, and a large volume of Gatuna appears to have been removed by transport down the Pecos Valley. If this happened then it may be that the lower Pecos Valley Gatuna, including that of the type area and its included caliche clasts, is younger than the upper Pecos Valley Gatuna. Thus, the lower Pecos Valley Gatuna could be reworked upper valley Gatuna, a product of a normal down-river process. This possibility does not rule out older as well as younger Gatuna in the lower valley area. The great thicknesses of alluvium in the Toya basin near Pecos below outcropping Gatuna beds, as described by Maley and Huffington (1953), weigh greatly toward a Tertiary age for the Gatuna. Problems still remain to be unravelled in the fascinating history of the development of the Pecos Valley.

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Plains lovegrass plant and spikelet, *Eragrostis intermedia*.