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Sedimentology of the Cutoff Formation (Permian), western Guadalupe Mountains, west Texas

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Abstract

The Cutoff Formation (middle Permian) of the western escarpment of the Guadalupe Mountains was formed by alternating erosion and deposition over a drowned shelf margin. The underlying carbonate bank (Victorio Peak Formation–Bone Spring Limestone) was abruptly terminated by erosion of the shelf edge, which formed a 2-mile-wide scarp with a relief of 900–1000 ft. The fine-grained Cutoff strata mantled this unconformity. Along this scarp, post-Cutoff erosion locally removed Cutoff strata so that it occurs today in three discontinuous areas: shelf, shelf margin, and basin. Within this section, five lithostratigraphic units, consisting of alternating intervals of lime mudstone and shale, can be traced from the shelf edge to the basin. Recognition of these five units appears to resolve the uncertainty of correlating the Cutoff Formation into the basin area. Within these units, variations in the sedimentary structures, color, and fauna of the lime mudstones record anoxic basin conditions.

The upper and lower contacts of the Cutoff Formation are unconformities, and an intraformational unconformity separates upper and lower units of the Cutoff Formation. For all three unconformity surfaces maximum truncation of underlying beds is along the shelf margin. Steep, spoon-shaped "half-channels" are enigmatic features along the unconformities that truncate at least 300 ft of strata along the shelf margin. Oriented parallel to the shelf edge, much of the margin relief is formed by these surfaces. Within the Cutoff Formation are numerous, less persistent surfaces ranging from broad (180–300 ft wide), flat-sided scours to narrow (less than 100 ft wide), steep-sided channels. The primary channel fills are intraclastic rudstone, megabreccia, and lutites. Clast lithologies indicate that the source was both underlying units and lithified Cutoff strata. The depositional geometries of the lutite beds and the interrelationship of channel fillings and erosion surfaces indicate that a model of a density-stratified basin with both bottom currents and interflows can be applied to deposition of Cutoff strata.

Previous faunal collections from the Cutoff Formation are largely allochthonous, reworked material. Fusulinids collected during this study from the upper Cutoff Formation are of Guadalupian age. The intraformational unconformity within the formation appears to be the first easily recognized, chronostratigraphic horizon below the reported Guadalupian fusulinids.

Introduction

The Cutoff Formation is a well-exposed drape of middle Permian basin-style facies that overlies the carbonate bank deposits of the Victorio Peak Formation. This facies records an 11–14 mi shelfward shift of basin sediments. At the Cutoff shelf-to-basin transition, the shelf margin is a paleoslope with a relief of 900–1,000 ft. This study concentrates on the facies at the shelf margin that contain a record of alternating deposition and submarine erosion.

The study area is located along the west escarpment of the Guadalupe Mountains, extending from the New Mexico–Texas border to the hills south of El Capitan (Fig. 1). The escarpment results from Cenozoic block faulting and exposes a little-disturbed, natural cross section oriented nearly perpendicular to the Permian shelf margin of the Delaware Basin.

Stratigraphy

Previous work by King (1942, 1948), Newell et al. (1953), and Boyd (1958) established the basic stratigraphic relationships (Fig. 2) of the Permian section. King (1948) established the Cutoff as a member of the Bone Spring Limestone, designating the type section at Cutoff Mountain (along the Texas–New Mexico border). Later, he changed the stratigraphic rank to formation, renaming the unit Cutoff Shale (King, 1965). In this report, the Cutoff Shale is redefined as the Cutoff Formation based on lithologic content. In the Guadalupe Mountains, the Cutoff strata consist of both limestone (60–70%) and shale (30–40%). Cutoff or Cutoff-age strata also occur in the northeastern Guadalupe Mountains (Hayes, 1959), Sierra Diablo Plateau (King, 1965), Wylie Mountains (Hay-Roe, 1957), and Apache Mountains (Wood, 1968).

Correlation of Cutoff strata from shelf to basin has long been problematical (Wilde and Todd, 1968) because post-Cutoff erosion has removed Cutoff strata locally along the shelf margin. Preserved strata occur in three distinct areas, as defined by the pre-Cutoff shelf profile (Fig. 3): 1) a flat shelf (0–1° dip), 2) a steeply dipping shelf margin (5–20° dip), and 3) a low relief basin that flattens out to a low angle (1–5° dip). Submarine erosion and shelfward retreat of the underlying Victorio Peak Formation and Bone Spring Limestone (Pray, 1971; Harms and Pray, 1974) formed this shelf profile with a relief of 900–1,000 ft (McDaniel and Pray, 1967).

King (1948) recognized upper and lower Cutoff units (informal names) at the shelf margin exposures based on lithologic variation and intervening unconformity surface. This report extends this informal division into shelf and basin areas (Figs. 3 and 4). The lower Cutoff Formation is black lime mudstone with abundant chert. The upper Cutoff Formation is predominantly black to medium gray lime mudstone and shale. Both units are bounded above and below by widespread unconformities.

As recognized by King (1948), the lower unit is best exposed in the shelf margin area as a large channel fill in south Shumard Canyon (King, 1948, pl. 12B). At the Cutoff Mountain type section (233 ft thick) only the lower 11 ft are assigned to the lower Cutoff Formation. This lower unit pinches out to the south, probably due to (erosional?) truncation along its upper surface. In the basin area, the lower Cutoff Formation appears 0.25 mi south of Bone Canyon, and reaches a maximum thickness (102 ft) an additional 0.25 mi south, just north of its disappearance into the subsurface. The overlying upper Cutoff strata make up the bulk of the formation and occur widely in basin, shelf margin, and shelf areas.

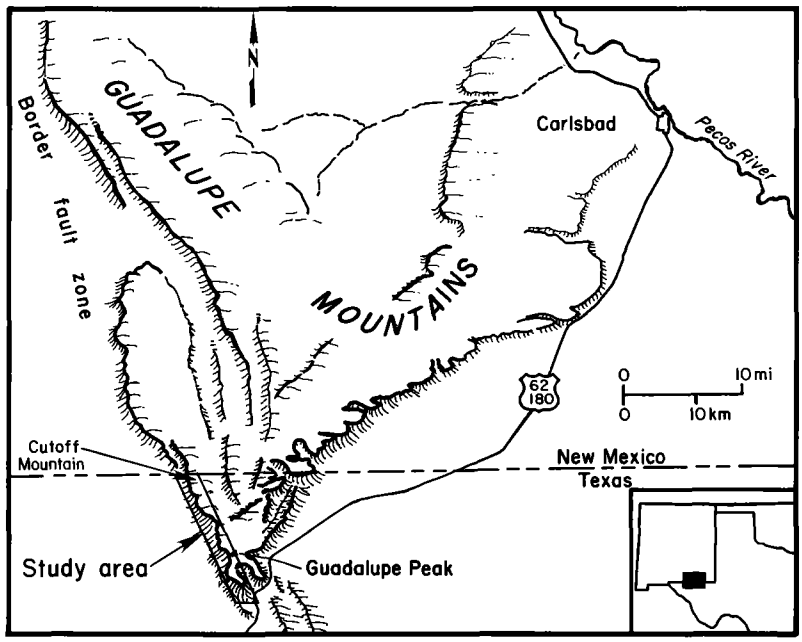

FIGURE 1—Location of the study area, western Guadalupe Mountains. Modified from Babcock (1977) and King (1948).

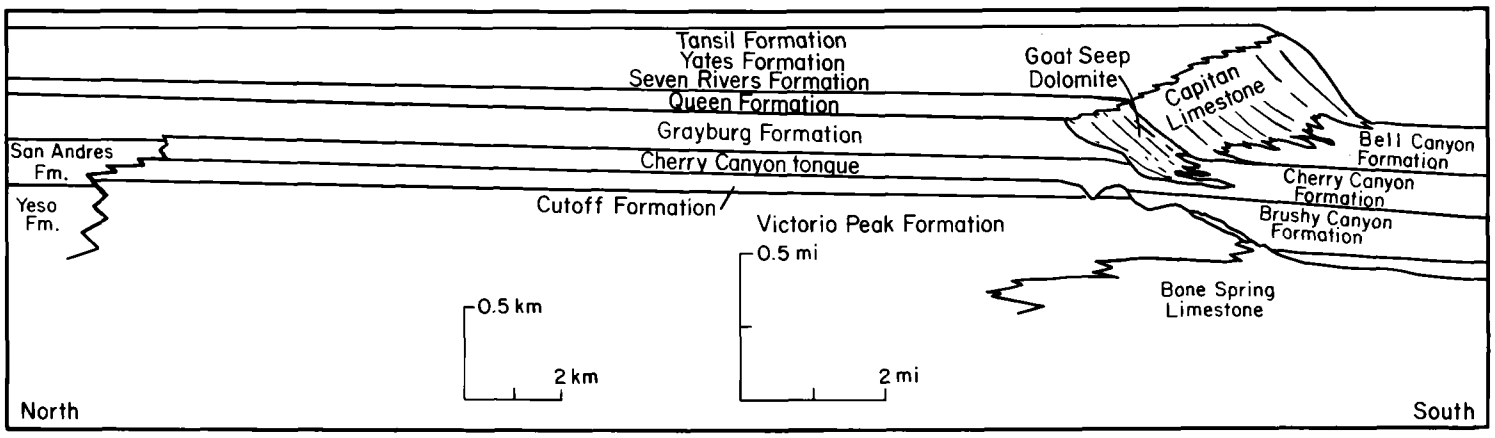

FIGURE 2—Stratigraphic cross section of the Guadalupe Mountains at the end of Guadalupian time. Vertical exaggeration = 4×; modified from Boyd (1958).

Rock types

Two major rock associations make up the Cutoff strata: 1) lime mudstone and shale (lutites) that comprise 95%+ of the strata exposed, and 2) coarser-grained lithologies that occur locally along the shelf margin and adjacent basin edge. Carbonate rock texture terminology follows Embry and Klovan's (1971) modification of Dunham's (1962) scheme. Bedding terminology is that of Ingram (1954).

Lutites

The lutites are suspension deposits that drape over pre-existing bottom topography. Slight bedding thickness variations indicate only minor current activity during deposition. Grain size of the lime mudstone ranges from fine silt to coarse clay. In places, calcareous sponge spicules (0.025 mm in diameter) are recognizable, but generally grain origin is indeterminant. Siliciclastic material is predominantly clay with minor quartz silt. Six lutite lithologies were recognized:

1. Black, cherty lime mudstone is medium bedded and contains abundant black chert (5–15%), which occurs in thin (about 2 inches thick) seams in nearly every bed. Typically, this lithology is thinly laminated, but laminations are faint or absent in the shelf area.
2. Thinly laminated, lime mudstone is dark gray and medium bedded with shaly partings and a very sparse brachiopod fauna.
3. Faintly laminated to nonlaminated lime mudstone is dark gray and medium bedded with shaly partings. Laminations are faint or absent. A very sparse brachiopod fauna occurs.
4. Medium-gray lime mudstone is medium bedded and nonlaminated. It contains scattered skeletals, predominantly brachiopods and echinoderms.
5. Medium-gray lime wackestone occurs as thin (about 1–2 inches thick) skeletal-rich layers within the medium-gray lime mudstone at the type section. These layers have sharp bases and irregular tops, and are interpreted as storm deposits.
6. Interbedded lime mudstone and siliceous shale are both dark brown to dark gray to black, unfossiliferous, thinly laminated, and fissile. The lime mudstone is commonly argillaceous. The shale is slightly calcareous and contains elliptical, football-sized concretions. Both lithologies are interbedded vertically and grade into each other laterally. In places, a few thin to very thin beds of unfossiliferous, thinly laminated siltstone occur.

Coarser rock types

Coarser-grained lithologies (coarser than lutites) occur either in lens-shaped channel or sheet-like bodies associated with truncation surfaces. These lithologies are limited to shelf margin and basin areas, but are distributed vertically throughout the Cutoff strata.

These rocks are all grain-supported and ungraded with either mud-filled or mud-free intergranular spaces. The megabreccias and most intraclastic rudstones are poorly sorted with a mud matrix. The skeletal rudstones, quartz sandstones, and some intraclastic rudstones are well sorted and mud-free. The grain-supported textures, erosive bases, and channel morphologies all suggest that these rocks are deposits from turbulent flows. In the megabreccias at the base of the Cutoff section along the shelf margin, the clasts are derived from the underlying Victorio Peak Formation and Bone Spring Limestone. Higher in the section, the principal clast source shifts to the lutites of the Cutoff Formation, ☞

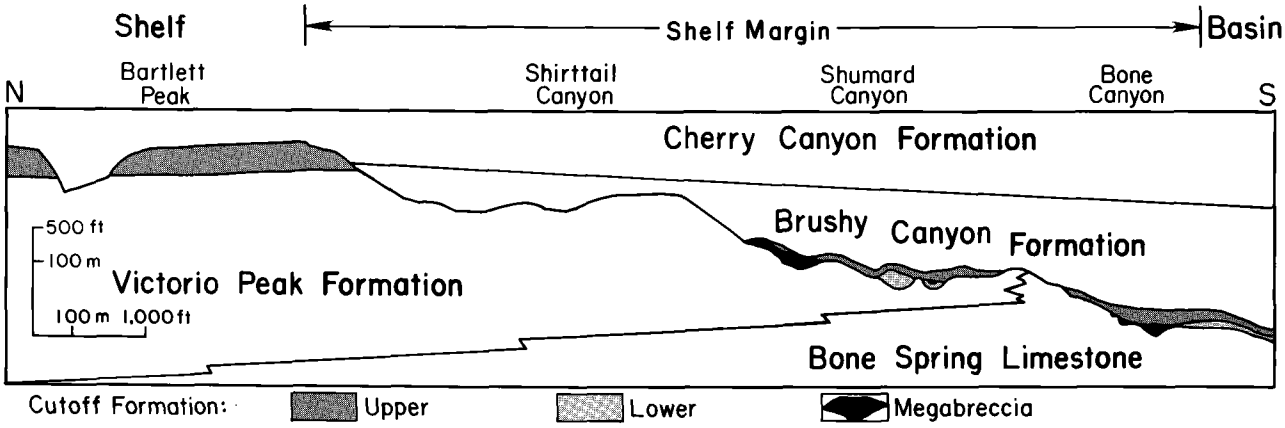

FIGURE 3—Detailed cross section of the Cutoff shelf-to-basin transition area. Section is oriented north–south through the study area (Fig. 1). Vertical exaggeration = 2×.

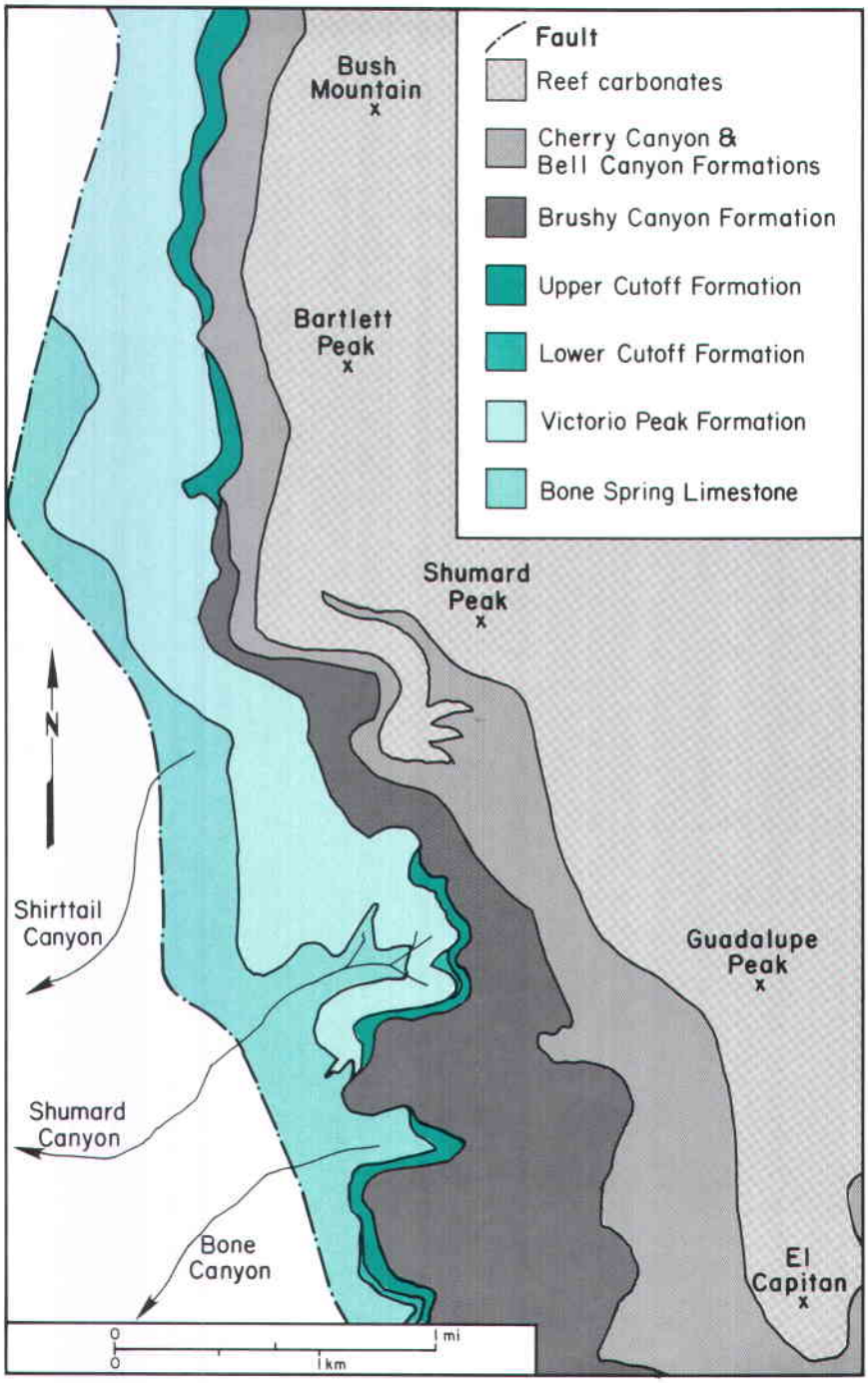

FIGURE 4—Geologic map of the shelf margin area.

indicating erosion of the shelf edge and/or upper shelf margin. The occurrence of the coarse-grained lithologies will be discussed below. Four types of coarser-grained rock types occur:

1. Intraclastic rudstone is predominantly composed of rock fragments coarser than sand size but less than 1 meter in diameter. Clasts are in grain-support, generally with lime mud as a pore filling, but two mud-free examples were found with spar cement. Fifteen examples were identified, one with (reworked?) fusulinids.
2. Megabreccia is texturally similar to intraclastic rudstone, but clasts of rock fragments greater than 1 meter across are a conspicuous component (Cook et al., 1972). Clasts greater than 2–3 cm across are in grain-support, with finer clasts and lime mud as a pore filling. Five examples were recognized, all associated with major unconformity surfaces.
3. Skeletal rudstone consists of well-sorted skeletal fragments coarser than sand size. Mud is absent and calcite spar or chalcedony cement fill pore spaces. Two examples are known.
4. Quartz sandstone is tan, thinly laminated, thickly bedded, and fine grained. It occurs only as a channel fill at the base of the lower Cutoff strata in the shelf margin.

Lutite distribution and interpretation

Vertical succession and lateral variations

The lutites occur in a vertical succession of five correlation units, each recognizable within the Cutoff Formation from shelf edge to basin. Recognition of this succession provides a stratigraphic framework within the Cutoff Formation that appears to resolve the shelf-to-basin correlation (Fig. 5). The five-fold succession is:

upper Cutoff	Unit 5: Medium-bedded lime mudstone Unit 4: Interbedded lime mudstone–shale Unit 3: Medium-bedded lime mudstone Unit 2: Interbedded lime mudstone–shale
lower Cutoff	Unit 1: Black, cherty lime mudstone

Within the lime mudstone units (1, 3, and 5), four consistent lithologic relations occur (Fig. 5): 1) black, cherty lime mudstone is restricted to unit 1 (lower Cutoff Formation); 2) well-laminated lime mudstone occurs basinward and grades laterally into poorly laminated lime mudstone in the shelf margin (units 3 and 5) or shelf (unit 1) area; 3) lime mudstone in basin and shelf margin areas is dark gray to black, but grades laterally and vertically into medium-gray limestone on the shelf; 4) fossils are rare in shelf margin and basin lutites, but occur widely in low abundance in the medium-gray shelf limestone.

Within the interbedded lime mudstone–shale (units 2 and 4) no persistent variations are discernible, probably due to the diagenesis of these clay-rich rocks. Table 1 shows the correspondence of these five units to the stratigraphic terminology of previous workers.

Anoxic model

An anoxic basin model (Byers, 1977) best describes the variations of lamination quality, rock color, and fossil content that occur in the Cutoff limestones. Oxygen concentration, as a function of water depth, affects biologic activity and the resulting sediment texture, thus dividing the basin profile and sedimentary facies into three depth zones (Table 2): aerobic, dysaerobic, and anaerobic.

In the Cutoff limestones (Fig. 5) each of these three depositional environments are recognizable by the sediment structures (laminated or bioturbated), color (dark gray or black due to organic content), and the presence or absence of shelled fauna. The basinal dark gray to black, laminated lime mudstones represent the anaerobic zone. The dark gray, faintly laminated to nonlaminated lime mudstones of the shelf margin are dys-

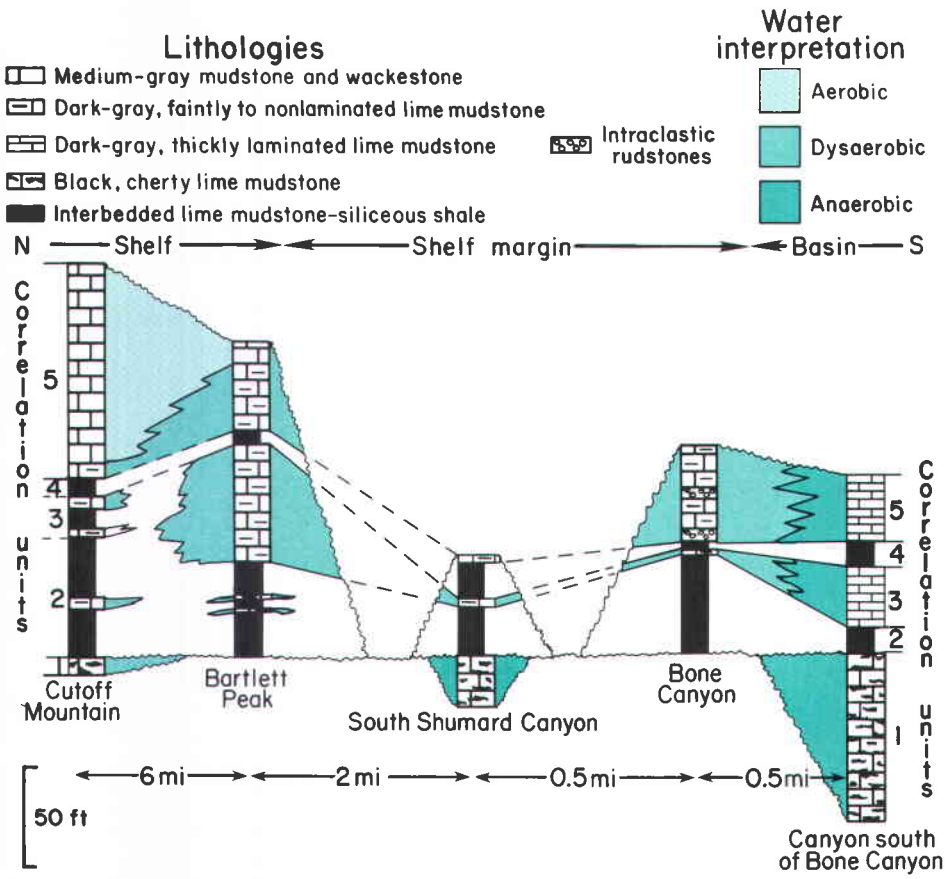

FIGURE 5—Distribution of lithologies and interpreted water zones. Correlation unit 1 = lower Cutoff Formation, and correlation units 2–5 = upper Cutoff Formation. Correlation of units is good across the problematic gap between the shelf margin and the basin. However, correlation across the shelf is uncertain, perhaps due to lack of section control. Detailed sections for these and additional sections are in Harris (1982).

aerobic in nature. The initial shelf sediments are also dysaerobic, but they grade upward and shoreward into medium-gray limestones of aerobic nature. These low-energy shelf deposits grade into the San Andres Formation (Boyd, 1958), probably a shallower water, higher energy shelf deposit, 11–14 mi north of the shelf margin (southern New Mexico).

Truncation surfaces

Truncation surfaces, which occur at many horizons throughout the Cutoff Formation, are concentrated at the shelf margin. Most surfaces laterally merge to form three widespread shelf-to-basin unconformities. These occur at the base and top of Cutoff strata (Pray, 1971) and between the lower and upper units of the Cutoff Formation.

Truncation surfaces occur in these forms: 1) channel cross sections with a relief ranging from a few inches to 150 ft, 2) spoon-shaped "half-channels" that truncate more than 300 ft of strata at the shelf edge (Pray et al., 1980), and 3) low-angle (1–5°) truncation of strata in shelf and basin areas over a distance of several miles. Examples of these surfaces are described below (see Figs. 3, 4, 6, and 7).

Shelf

The predominant truncation feature in the shelf area is low-angle truncation of strata along the three unconformity surfaces. The post-Cutoff surface runs parallel to the basal unconformity, and Cutoff strata are consistently 200–240 ft thick from the type section to the basin edge. The intraformational unconformity is undulatory near the type section, and it entirely truncates lower Cutoff strata near the shelf edge.

Two miles north of the shelf edge (near Bartlett Peak) a large channel cuts through 240 ft of Cutoff strata and 100 ft into the Victorio Peak Formation. Filled with Cherry Canyon Sandstone and two megabreccia sheets, it may have served as a feeder channel into the Delaware Basin for sand during post-Cutoff time (Harms, 1974).

Shelf margin

The truncation surfaces along the shelf margin vary widely in scale and type. The preserved Cutoff strata are bounded by marked angular unconformities and channel forms. The pre-Cutoff unconformity shapes the shelf margin by truncating 900–1,000 ft of the underlying Bone Spring Limestone and Victorio Peak Formation carbonate bank (McDaniel and Pray, 1967).

At the shelf margin, the upper Cutoff Formation is largely missing and limited to the more basinward portion of the shelf margin (Fig. 4), and the lower unit is restricted to a single channel fill (Fig. 6). This channel is predominantly filled with black, cherty lime mudstone with minor basal beds of intraclastic rudstone and quartz sandstone. The intraformational unconformity truncates this channel fill and is overlain by upper Cutoff strata (units 2, 3). The post-Cutoff unconformity cuts into the Cutoff Formation throughout the shelf margin area, in places completely removing the formation.

At the shelf edge, 150 ft of Cutoff strata and 150 ft of underlying Victorio Peak Formation are truncated by a half-channel. The initial Cutoff shelf edge was probably farther basinward than at present. The redeposited clasts that make up the megabreccia and intraclastic rudstone deposits record the shelfward retreat of this edge. At the northern (shelfward) extent of the preserved shelf margin, upper Cutoff strata overlie a second 300-ft-deep half-channel cut into the Victorio Peak Formation. Both half-channels are spoon-shaped, dip steeply (>20°) basinwards at their shelfward head, and strike parallel to the shelf edge. The origin of these surfaces and similar Guadalupian surfaces is not well understood (Pray et al., 1980). ☞

TABLE 1—Comparison of stratigraphic terminology for the basin area. Note that King (1948, pl. 9) mapped limestones at the base of the Brushy Canyon Formation that are Cutoff strata, as he suggested.

King (1948)	Newell et al. (1953)	This report
	Brushy Canyon Formation	Brushy Canyon Formation
Brushy Canyon Formation	Upper Bone Spring Limestone	Cutoff Formation: unit 5
	Cutoff Formation	Cutoff Formation: upper units 2–4; lower unit 1
Bone Spring Limestone	Middle Bone Spring Limestone	Bone Spring Limestone

TABLE 2—Anoxic model summary, after Byers (1977).

	Aerobic	Dysaerobic	Anaerobic
Oxygen level	Abundant	Low	Absent
Benthic fauna	Shelled and soft-bodied	Soft bodied	Absent
Sediment texture	Bioturbated	Bioturbated	Laminated
Shelled fossils	Present	Absent	Absent
Organic content	Low	Variable	High
Color (generally)	Light	Medium	Dark

Channel forms are best exposed at the basinward edge of the shelf margin (Bone Canyon; Fig. 7). Two types of channels occur: 1) broad (180–600 ft) forms with flattened (<10°) sides predominantly filled with lutites and minor intraclastic rudstone lenses, and 2) narrow (<100ft), steep-sided (>10°) forms with megabreccia channel fillings. Most broad channels do not occur along major unconformity surfaces; however, some locally truncate stratigraphic units. In contrast, narrow megabreccia-filled channels (Pray and Stehli, 1963; the "patch reefs" of Newell et al., 1953) are limited to the unconformity surfaces. This variety of channel shape and filling is duplicated in the more poorly exposed strata in the basin area. It also occurs on a smaller scale of channels a few inches deep.

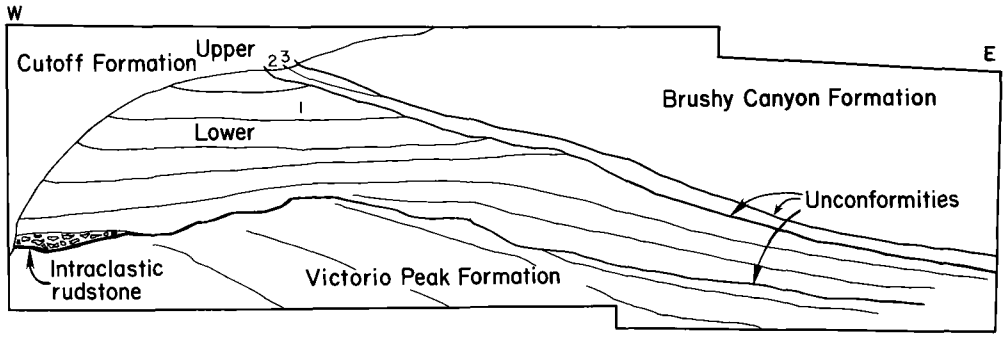

FIGURE 6—Sketch of the north wall of South Shumard Canyon at the middle of the shelf margin looking north (shelfward). Large channel scour filled with lower Cutoff Formation (unit 1) is unconformably overlain by upper Cutoff Formation (units 2–3). Intraclastic rudstone fill at the base of the lower Cutoff strata is underlain by 3–5 ft of quartz sandstone (not visible in this view). The Cutoff section through the channel fill is 150 ft thick. Drawn from field sketches and photographs.

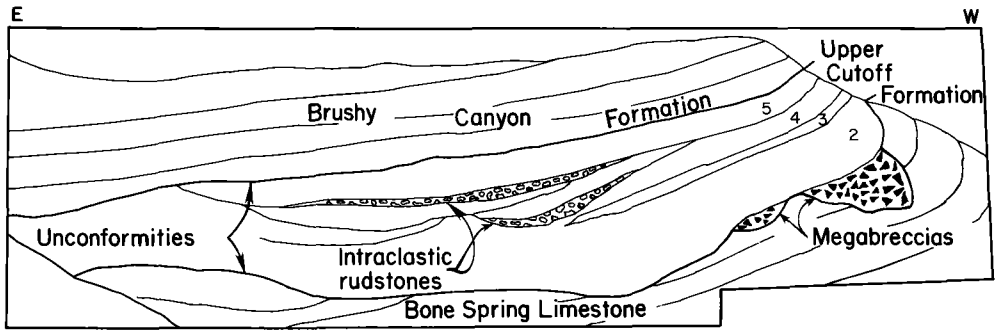

FIGURE 7—Sketch of the south wall of Bone Canyon at the base of the shelf margin looking south (basinward). The lower Cutoff Formation is missing, and two megabreccia lenses occur at the base of the upper Cutoff section. Two of the broad channel features contain an intraclastic rudstone as the initial basal fill. The Cutoff section in the middle of the canyon wall is 122 ft thick. Drawn from field sketches and photographs.

Basin

In the basin area, Cutoff units thicken uniformly away from the shelf margin due to both stratigraphic thickening and decreasing truncation along unconformity surfaces. The lower Cutoff Formation appears 0.25 mi south of Bone Canyon. It increases in thickness from its truncated feather edge to 102 ft (beneath the intraformational unconformity) over a distance of 0.25 mi, and disappears southward into the subsurface. The upper Cutoff Formation thickens basinward from 122 ft, in the south wall of Bone Canyon, to 283 ft over a distance of 1.1 mi to the south (sec. 17 of King, 1948). This expanded upper Cutoff section can be traced to the south where it forms the low black hills south and southwest of El Capitan, which King (1948) and Newell et al., (1953) considered Bone Spring Limestone.

Small, poorly exposed channels with a relief of up to 2–3 ft occur in low abundance within the basinal Cutoff strata. These are inferred to be similar in their geometry to the well-exposed channels in the shelf margin area.

Formation of truncation surfaces

Cutoff truncation surfaces are believed to be of subaqueous origin because of 1) the lack of features typical of vadose, subaerial, or shallow marine environments; 2) the typically basinal nature of the Cutoff strata; and 3) the similarity of these surfaces to features in the overlying deep-water deposits of the Delaware Mountain Group (Harms and Pray, 1974).

The occurrence of channel forms along truncation surfaces, the coarse clasts in the channel fills, and the similarity of features from top to base of the shelf margin and over a range of scales imply that the surfaces are, at least in part, erosional in origin. The enigmatic "half-channels" truncate more than 300 ft of shelf edge strata, and shape the shelf margin profile (Fig. 3). They may be the result of large-scale slumps or gravity-slide features, as recorded along modern carbonate margins (for examples, see Mullins, 1986). However, the erosional features and lack of any fault scarp or notable slump features (only two small slump-fold features occur in the basin) indicate significant modification of any such features.

Depositional model

The depositional style of the Cutoff strata and the associated erosion surfaces are well described by the density current model proposed by Harms (1974) and Harms and Pray (1974) for the basinal sands and silts of the overlying Brushy Canyon Formation. In contrast, the Cutoff strata reflect similar processes in a carbonate anoxic basin setting.

Lutites, carried in suspension by interflows over density stratified basin waters, alternate with erosional features and traction deposits deposited by denser bottom-hugging currents, as presented by Harms (1974). Graded beds, indicative of turbidity flows and deep-sea fan geometries, are absent. In contrast to the siliciclastic Brushy Canyon Formation, the Cutoff rocks are predominantly carbonates. The greater predominance of lutites is probably due to the lack of sand-sized particles (which are limited to the shallow-shelf equivalent, San Andres Formation); thus, bottom currents are recorded largely by erosion surfaces. The anoxic basin conditions recorded in the lime mudstone units indicate that a stable, stratified water column existed throughout Cutoff deposition. This setting is ideal for separation of density interflows and bottomflows, but the cause of the scouring episodes is unclear.

Megabreccias and intraclastic rudstones are numerous, probably because of the availability of lithified carbonate clasts. Initially, the retreating edge of the Victorio Peak bank served as the major source of clasts. As the Cutoff Formation blanketed the 900–1,000 ft paleoscarp, the main clast source shifted to lithified Cutoff strata of the upper shelf margin and shelf edge. The coarse deposits always overlie erosional features, and are concentrated at the shelf margin along the shelf-to-basin unconformities. Erosion and deposition alternated along the shelf margin, producing the complex of truncation surfaces (and missing section) that make direct physical correlation impossible.

Fossil collections and age relations

The position of the boundary between the Guadalupian and Leonardian stages is uncertain, largely because of previous uncertainties over the correlation and age of the Cutoff Formation (Wilde and Todd, 1968).

Cutoff fauna is difficult to interpret because the fauna is very sparse, almost all fossils are allochthonous, and shelf-to-basin correlation problems resulted in attribution

of key fauna collections to incorrect stratigraphic units. Based on their sample locations (for a detailed list of sample locations see Cooper and Grant, 1972–1977), many of the Bone Spring Limestone fauna collections of King (1948) and Newell et al. (1953) were from the basinal upper Cutoff Formation (the lime mudstone hills south and southwest of El Capitan). Because these collections were from the Bone Spring Limestone (the Cutoff was a member of the Bone Spring Limestone according to workers in the 1940's and 1950's), the fauna was assigned to the Leonardian. However, these collections were probably from small channel fills within the Cutoff Formation of this report. This fauna is allochthonous and includes material reworked from the Victorio Peak Formation, Bone Spring Limestone, and parts of the Cutoff Formation, similar to the fauna of the megabreccia lenses in Bone Canyon (Wilde and Todd, 1968). Garner Wilde (pers. comm. 1986) identified fusulinids from the upper Cutoff Formation (a small channel fill at the base of correlation unit 5 in the basin) as Guadalupian in age. Previously, Guadalupian fusulinids were recognized by Hollingworth and Williams (Boyd, 1958, p. 60) and Wilde (Wilde and Todd, 1968) from Cutoff strata to the north.

Brachiopods are the most abundant macrofauna in the Cutoff Formation, but other groups reported or observed are ammonites, nautiloids, pelecypods, gastropods, bryozoa, crinoids, fusulinids, corals, conularids (*Conularia*) and dasycladacean algae. Boyd (1958) provided a detailed fauna listing for the New Mexico exposures, and Cooper and Grant (1972–1977) summarized the brachiopod occurrences.

Trace fossils are rare. At the basin edge, flattened horizontal burrows occur in the upper Cutoff Formation. Bioturbation is inferred to be intensive in the sediments of the shelf margin, but individual traces are not apparent.

The age of the upper Cutoff Formation is Guadalupian, on the basis of the reported fusulinid occurrences. The age of the lower Cutoff Formation is uncertain because it contains a largely allochthonous fauna, and no datable fusulinids are reported. For convenience, I suggest the stage boundary be taken at the unconformity surface between lower and upper Cutoff Formation. This is the first widespread surface below Guadalupian fauna that is both easily recognizable lithologically and nearly a chronostratigraphic surface (almost everywhere overlain by Cutoff correlation unit 2).

Conclusions

The Cutoff Formation is a drape of fine-grained basinal sediments over a shelf margin, representing an 11–14 mi shift of this lithofacies into a shelf setting. The predominant lithologies are lutites, deposited in an anoxic basin with rocks recording aerobic, dysaerobic, and anaerobic environments. Within these strata, a vertical succession of five correlatable units is recognized, facilitating lithostratigraphic correlation of shelf-to-basin strata.

Erosional features (channels, half-channels) are concentrated at the shelf margin. Many of these features combine to form three major shelf-to-basin unconformities that truncate pre-Cutoff and Cutoff strata, with the maximum removal being at the shelf margin. The truncation surfaces, inferred to be submarine in origin, shape the shelf-to-basin profile.

These Cutoff lithologies and the erosion surfaces appear to be formed in a density-stratified basin with density flows scouring the shelf margin and carrying fine material out into the basin. This is a carbonate version of Harms' (1974) model for the Delaware Mountain Group.

The two informal units of King (1948), upper and lower, can be traced from shelf to basin within the Cutoff Formation. The distinction is based on lithologic differences and the intraformational unconformity.

Many of the previously reported Cutoff fauna are allochthonous, reworked from either the Bone Spring Limestone, Victorio Peak Formation, or the Cutoff Formation. Previous collections from "Leonardian-age" strata appear to be from the upper Cutoff Formation, from which Guadalupian-age fusulinids have been reported. Based on the fusulinids, the upper member is of Guadalupian age, but the age of the lower member is uncertain.

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References

Babcock, J. A., 1977, Calcareous algae, organic boundstones and the genesis of the upper Capitan Limestone (Permian, Guadalupian), Guadalupe Mountains, west Texas and New Mexico; *in* Hileman, M. E., and Mazzullo, S. J. (eds.), Upper Guadalupe facies, Permian reef complex, Guadalupe Mountains, New Mexico and west Texas: Society of Economic Paleontologists and Mineralogists, Permian Basin section, Guidebook to 1977 Field Conference, pp. 3–44.

Boyd, D. W., 1958, Permian sedimentary facies, central Guadalupe Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 49, 100 pp.

Byers, C. W., 1977, Biofacies patterns in euxinic basins—a general model; *in* Cook, H. E., and Enos, P. (eds.), Deep-water carbonate environments: Society of Economic Paleontologists and Mineralogists, Special Publication 25, pp. 5–18.

Cook, H. E., McDaniel, P. N., Mountjoy, E. W., and Pray, L. C., 1972, Allochthonous carbonate debris flows at Devonian bank ("reef") margins, Alberta, Canada: Canadian Petroleum Geologists, Bulletin, v. 20, pp. 439–497.

Cooper, G. A., and Grant, R. E., 1972–1977, Permian brachiopods of west Texas, I–VI: Smithsonian Contributions to Paleobiology, nos. 14, 15, 19, 21, 24, and 32, 3370 pp.

Dunham, R. J., 1962, Classification of carbonate rocks according to depositional texture; *in* Ham, W. E. (ed.), Classification of carbonate rocks: American Association of Petroleum Geologists, Memoir 1, pp. 104–121.

Embry, A. V., and Klovan, J. E., 1971, A Late Devonian reef tract on northeast Banks Island, Northwest Territories: Canadian Petroleum Geologists Bulletin, v. 19, pp. 730–781.

Harms, J. D., 1974, Brushy Canyon Formation, Texas—a deep-water density current deposit: Geological Society of America Bulletin, v. 85, pp. 1763–1784.

Harms, J. D., and Pray, L. C., 1974, Erosion and deposition along the mid-Permian intercratonic basin margin, Guadalupe Mountains, Texas (abs.); *in* Dott, R. H., and Shaver, R. H. (eds.), Modern and ancient geosynclinal sedimentation: Society of Economic Paleontologists and Mineralogists, Special Publication 19, p. 37.

Harris, M. T., 1982, Sedimentology of the Cutoff Formation (Permian), western Guadalupe Mountains, west Texas and New Mexico: Unpublished M.S. thesis, University of Wisconsin, Madison, 186 pp.

Hay-Roe, H., 1957, Geology of Wylie Mountains and vicinity, Culberson and Jeff Davis Counties, Texas: Bureau of Economic Geology, University of Texas (Austin), Geologic Quadrangle Map 21.

Hayes, P. T., 1959, San Andres Limestone and related Permian rocks in Last Chance Canyon and vicinity, southeastern New Mexico: American Association of Petroleum Geologists Bulletin, v. 43, pp. 2197–2213.

Ingram, R. L., 1954, Terminology for the thickness of stratification and parting units in sedimentary rocks: Geological Society of America Bulletin, v. 65, pp. 937–938.

King, P. B., 1942, Permian of west Texas and southeastern New Mexico: American Association of Petroleum Geologists Bulletin, v. 26, pp.535–763.

King, P. B., 1948, Geology of the southern Guadalupe Mountains, Texas: U.S. Geological Survey, Professional Paper 215, 183 pp.

King, P. B., 1965, Geology of the Sierra Diablo region, Texas: U.S. Geological Survey, Professional Paper 480, 185 pp.

McDaniel, P. N., and Pray, L. C., 1967, Bank to basin transition in Permian (Leonardian) carbonates, Guadalupe Mountains, Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 51, p. 474.

Mullins, H. T., 1986, Part 4—Periplatform carbonates; *in* Warme, J. E., and Shanley, K. W. (eds.), Carbonate depositional environments—modern and ancient: Colorado School of Mines Quarterly, v. 81, no. 2, 63 pp.

Newell, N. D., Rigby, J. K., Fisher, A. G., Whiteman, A. J., Hickox, J. R., and Bradley, J. S., 1953, The Permian reef complex of the Guadalupe Mountains region, Texas and New Mexico: Freeman & Co., San Francisco, 236 pp.

Pray, L. C., 1971, Submarine slope erosion along the Permian bank, west Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 55, p. 358.

Pray, L. C., Crawford, G. A., Harris, M. T., and Kirkby, K. C., 1980, Early Guadalupian (Permian) bank margin erosion surfaces, Guadalupe Mountains, Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 64, p. 768.

Pray, L. C., and Stehli, F. G., 1963, Allochthonous origin, Bone Spring "patch reefs," west Texas (abs.): Geological Society of America, Special Paper 73, pp. 218–219.

Wilde, G. L., and Todd, R. G., 1968, Guadalupian biostratigraphic relationships and sedimentation in the Apache Mountain region, west Texas; *in* Silver, B. A. (ed.), Guadalupian facies, Apache Mountains area, west Texas: Society of Economic Paleontologists and Mineralogists, Permian Basin section, Guidebook 68–11, pp. 10–31.

Wood, J. W., 1968, Geology of the Apache Mountains, Trans-Pecos Texas: Bureau of Economic Geology, University of Texas (Austin), Geologic Quadrangle Map 25, 32 pp. □