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New Mexico Geology, v. 15, n. 2 pp. 25-32, 44, Print ISSN: 0196-948X, Online ISSN: 2837-6420.
https://doi.org/10.58799/NMG-v15n2.25

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New Mexico GEOLOGY
• Science and Service
ISSN 0196-948X
Volume 15, No. 2, May 1993

Reinterpretation of bioherms as submarine channels, San Andres Formation and Cherry Canyon Tongue (upper Leonardian and lower Guadalupian, Permian), Brokeoff and Guadalupe Mountains, southeastern New Mexico

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Abstract

The San Andres Formation and Cherry Canyon Tongue (upper Leonardian and lower Guadalupian, Permian) of southeastern New Mexico (Otero and Eddy Counties) include submarine-slope deposits and contain carbonate bodies previously interpreted as organic bioherms. Examination of these bodies in outcrop yields significant observations and permits a reinterpretation of their origin. Six lithofacies are recognized: massive carbonate mudstone, cherty carbonate mudstone, fusulinid packstone, skeletal packstone, skeletal siltstone, and unfossiliferous siltstone. The most important stratigraphic features are channelforms filled with low-angle inclined beds of skeletal packstone, fusulinid packstone, and skeletal siltstone. These lithofacies contain the only significant faunas, consisting of brachiopods, bryozoans, horn corals, crinoids, pelecypods, and fusulinids. The tabular accumulations of loose fossils are interpreted taphonomically as shell heaps of allochthonous skeletal material. The massive carbonate-mudstone lithofacies does not contain evidence of in situ biologic activity nor exhibit mound-shaped geometry and therefore does not represent bioherm cores. Thus, the channelforms are interpreted as broad, shallow submarine scours and channels filled by lateral and vertical aggradation of skeletal debris that was transported downslope from the bank edge by bottom currents. The massive carbonate-mudstone units are reinterpreted as part of the interchannel slope highs (possibly channel levees), part of the channel fill, or initial mantling deposits.

Introduction

The Permian rocks of the Permian Basin region (west Texas and southeastern New Mexico), especially the Glass Mountains, contain abundant sponge–bryozoan–brachiopod bioherms (Newell et al., 1953; Bain, 1967; Cooper and Grant, 1972). In the San Andres Formation and Cherry Canyon Tongue exposed in the Guadalupe Mountains, Boyd (1958) and Hayes (1964) reported several organic bioherms. Boyd described them as consisting of a core surrounded by flank beds. The cores were described as being sparsely fossiliferous, massive carbonate mud (now dolomitized) with sponges and lyttoniid brachiopods. The flank beds were described as consisting of skeletal-rich carbonate beds that dip away from the core edge; these layers reportedly contain abundant lyttoniid brachiopods. These features thus appear to be poorly preserved analogs of the sponge–bryozoan–brachiopod bioherms described by Bain (1967) and Cooper and Grant (1972) from the Glass Mountains. Consequently, they would be important because they would provide evidence of similar depositional settings on opposite sides of the Delaware Basin and would provide additional information pertaining to the paleoecology of lyttoniids, especially the niches filled by these brachiopods in reef building and dwelling. However, carbonate lenses in the Bone Spring and Getaway Limestones (both slope and basin deposits exposed in the Guadalupe Mountains) that previously were interpreted as bioherms (Newell et al., 1953), now are considered allochthonous blocks of bank and biohermal sediment derived from the shelf edge and transported into slope or basin environments (Pray and Stehli, 1962; Harris and Wiggins, 1985; Cuffey, 1987). Furthermore, Jacka et al. (1985) recognized large-scale channeling in the San Andres Formation and Cherry Canyon Tongue of the transition belt and interpreted those units as slope, fan, and submarine-canyon deposits, thus similar to the depositional setting of the Bone Spring Formation. Therefore, the interpretation of the San Andres Formation carbonate bodies as bioherms seemed suspect. The purpose of this research was to reevaluate the origin of these carbonate bodies in light of more recent sedimentologic interpretations of the area.

Stratigraphy

The Brokeoff and central Guadalupe Mountains of southeastern New Mexico, specifically western Eddy and eastern Otero Counties (Figs. 1, 2), expose a thick sequence of Permian carbonate and terrigenous rocks (Fig. 3; Boyd, 1958; Hayes, 1964). The upper Leonardian (Roadian) and lower Guadalupian (Wordian) San Andres Formation and Cherry Canyon Tongue (Figs. 3, 4; Cooper and Grant, 1972; Sarg and Lehmann, 1986; Wilde, 1986; Ross, 1987) were deposited along the northwestern margin of the Delaware Basin. In this region depositional strike trends southwest to northeast, parallel to the basin margin (Boyd, 1958). Here, Boyd (1958) recognized three primary facies belts: the

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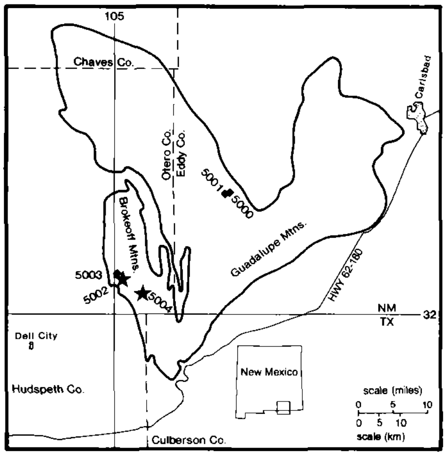


FIGURE 1—Brokeoff and Guadalupe Mountains with outcrops of San Andres Formation and Cherry Canyon Tongue studied; large stars = principal outcrops, small diamonds = subsidiary outcrops.

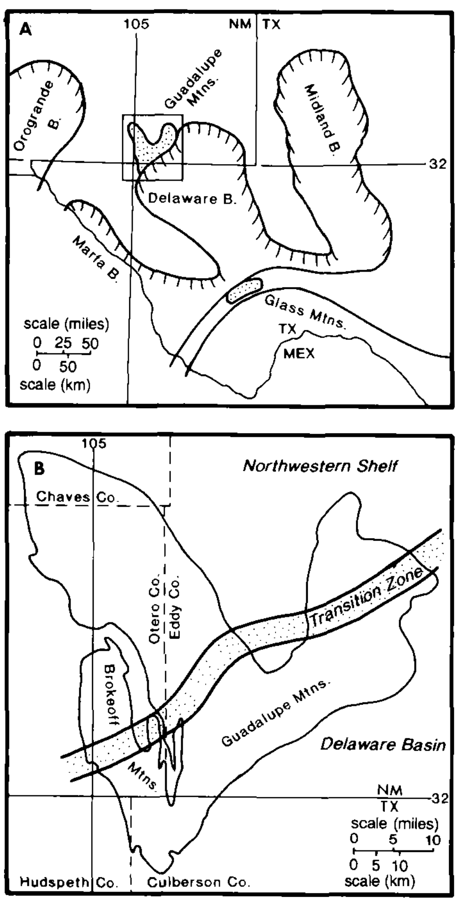


FIGURE 2—**A**, Permian depositional features of west Texas and southeastern New Mexico; **B**, facies belts along the northwestern margin of the Delaware Basin. Modified from Boyd (1958) and Cooper and Grant (1972).

Northwestern shelf, transition belt, and Delaware Basin (Fig. 2). Stratigraphic relationships are complex but elucidated by careful lithostratigraphy, sequence stratigraphy, and biostratigraphy. Stratigraphic details have been described by Boyd (1958), Hayes (1959, 1964), Fekete et al. (1986), Sarg (1986), Sarg and Lehmann (1986), Wilde (1986), and Pray (1988a); only a summary of the critical interval is provided here.

In the interval considered, Sarg and Lehmann (1986) recognized two major sequences. The lower and middle parts of the San Andres Formation comprise the lower sequence (Fig. 4). On the Northwestern shelf they consist of evenly and horizontally bedded cherty carbonates that were deposited on a carbonate platform and bank margin (Sarg and Lehmann, 1986). To the southeast this facies is replaced by cherty carbonates exhibiting large-scale intraformational truncation surfaces and channeling, strata interpreted as part of the slope into the Delaware Basin (Jacka et al., 1985; Sarg and Lehmann, 1986). Farther to the southeast the lower and middle San Andres Formation grades into the carbonate muds and terrigenous rocks of the Cutoff Formation (Fig. 4), deposited at the toe of slope and on the basin floor (Boyd, 1958; Wilde, 1986). The tops of these units are truncated by a major unconformity (Hayes, 1959, 1964), interpreted as a sequence boundary by Sarg and Lehmann (1986).

The basal part of the upper sequence is the Brushy Canyon Formation, which is restricted to the basin and equivalent to the unconformity on the shelf (Fig. 4; Wilde, 1986). Subsequent onlapping resulted in renewed deposition in the transition belt and on the Northwestern shelf, where noncherty carbonates of the upper San Andres Formation were deposited (Fig. 4). Sarg (1986) interpreted this facies as carbonate-platform and bank deposits. To the southeast in the transition belt, the carbonates interfinger laterally with sandstones of the upper Cherry Canyon Tongue (Fig. 4; Hayes, 1959, 1964; Sarg, 1986; Sonnenfeld, 1990). The upper Cherry Canyon Tongue consists of interbedded sandstones and carbonates with large-scale intraformational truncation surfaces and channeling and is interpreted as slope deposits (Jacka et al., 1985). Basinward these beds grade into sandstones of the lower Cherry Canyon Formation (Fig. 4), interpreted as toe-of-slope, distal-fan, and basin sediments by Jacka et al. (1985).

The Grayburg Formation, which consists of interbedded dolomites and sandstones, overlies both the upper San Andres and Cherry Canyon Tongue (Fig. 4). Sarg and Lehmann (1986) interpreted the Grayburg as a carbonate bank that prograded basinward over the Cherry Canyon Tongue. On the Northwestern shelf, the upper San Andres–Grayburg contact is unconformable (Hayes, 1959, 1964), but in the transition belt the basal Grayburg interfingers with the uppermost Cherry Canyon Tongue (Fekete et al., 1986; Pray, 1988a).

Methods

To determine the origin of the San Andres carbonate bodies, the two examples considered most likely to be bioherms, based on Boyd's (1958) descriptions, were studied in detail. These are in West Dog Canyon (locality 5002) and Cork Draw (locality 5004; Fig. 1, Table 1). Several nonbiohermal outcrops also were studied for comparison (Fig. 1, Table 1). First, outcrop-scale field observation permitted recognition of important geometric relations of the beds and hence large-scale sedimentary features. Second, macroscopic field observation of fresh and weathered rock surfaces permitted recognition of six lithofacies. Their attributes and distribution within the outcrops were recorded. Third, the fossil content and their mode of occurrence within each lithofacies were recorded. These data were integrated to provide a more reasonable interpretation of the strata under consideration.

New Mexico GEOLOGY

• **Science and Service**

ISSN 0196-948X

Volume 15, No. 2, May 1993

Editor: Carol A. Hjellming

Published quarterly by
New Mexico Bureau of Mines and
Mineral Resources
a division of New Mexico Institute of
Mining & Technology

Subscriptions: Issued quarterly, February, May, August, November; subscription price $6.00/calendar year.

Editorial matter: Articles submitted for publication should be in the editor's hands a minimum of five (5) months before date of publication (February, May, August, or November) and should be no longer than 20 typewritten, double-spaced pages. All scientific papers will be reviewed by at least two people in the appropriate field of study. Address inquiries to Carol A. Hjellming, Editor of *New Mexico Geology*, New Mexico Bureau of Mines & Mineral Resources, Socorro, NM 87801-4796.

Circulation: 1,600

Printer: University of New Mexico Printing Services

TABLE 1—Outcrops examined for this research.

Outcrop no.	Location
5000	south side of Last Chance Canyon, opposite mouth of Wilson Canyon, NE¼ SW¼ sec. 33 T23S R22E, Red Bluff Draw 1:24,000–scale topographic map, Eddy County
5001	north side of Last Chance Canyon, opposite mouth of White Oaks Canyon, SE¼SE¼ sec. 32 T23S R22E, Red Bluff Draw 1:24,000–scale topographic map, Eddy County
5002	base of west side of West Dog Canyon, SW¼NW¼ sec. 2 T26S R19E, Panther Canyon 1:24,000–scale topographic map, Otero County
5003	middle of west side of West Dog Canyon, opposite mouth of Panther Canyon, NE¼SW¼ sec. 34 T25S R19E, Panther Canyon 1:24,000–scale topographic map, Otero County
5004	south side of Cork Draw, SE¼NW ¼ sec. 17 T26S R20E, Panther Canyon 1:24,000–scale topographic map, Otero County

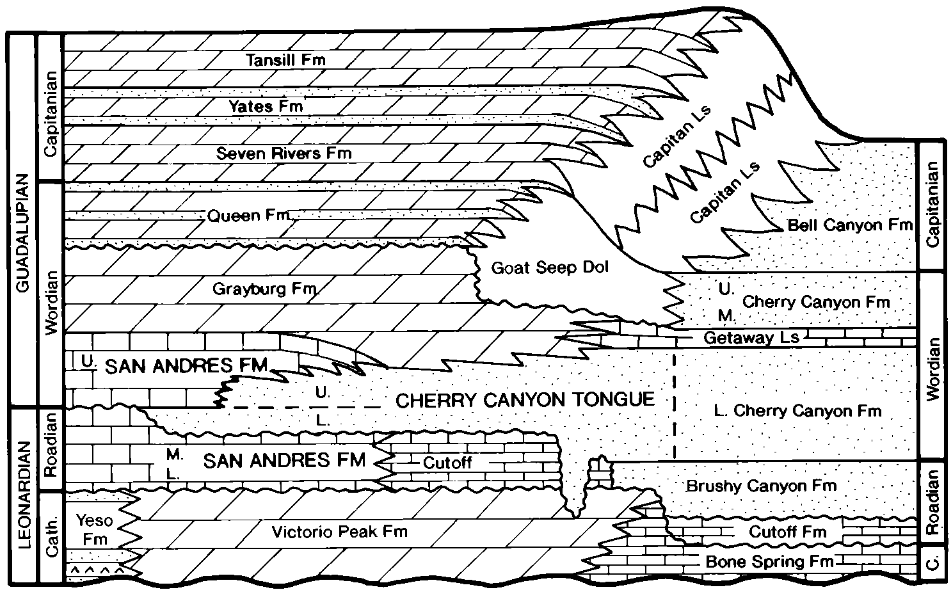


FIGURE 3—Permian stratigraphy of the Brokeoff and Guadalupe Mountains; abbreviations are C. and Cath. = Cathedralian. Based on King (1948), Fekete et al. (1986), Sarg and Lehmann (1986), Pray (1988a), Rossen and Sarg (1988), Sarg et al. (1988).

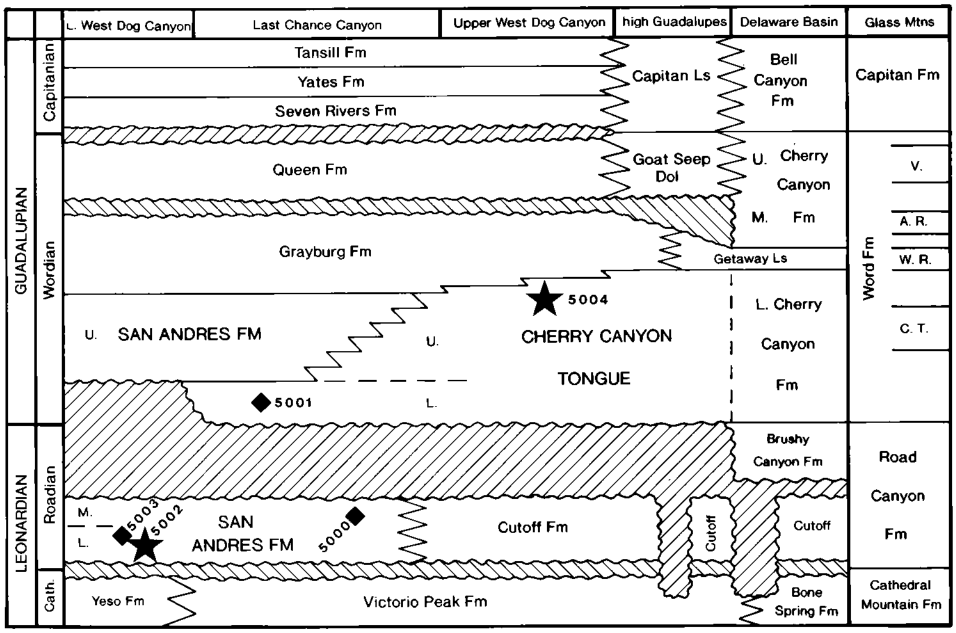


FIGURE 4—Correlation chart of upper Leonardian (Roadian) and lower Guadalupian (Wordian) stratigraphic units; modified from Cooper and Grant (1972), Fekete et al. (1986), Sarg and Lehmann (1986), Ross (1987), Pray (1988a), and Rossen and Sarg (1988). Stratigraphic position of outcrops examined based on Darton and Reeside (1926), Boyd (1958), Hayes (1964), and Sarg (1986). Abbreviations are Cath. = Cathedralian, C. T. = China Tank Member, W. R. = Willis Ranch Member, A. R. = Appell Ranch Member, V. = Vidrio Member.

Lithofacies

At the West Dog Canyon and Cork Draw outcrops six lithofacies are recognized in the lower San Andres Formation and Cherry Canyon Tongue. They are: 1) massive carbonate mudstone, 2) cherty carbonate mudstone, 3) fusulinid packstone, 4) skeletal packstone, 5) skeletal siltstone, and 6) unfossiliferous siltstone.

The massive carbonate-mudstone lithofacies (Fig. 5A) consists of medium-gray, massive carbonate mudstone with rare chert nodules. It contains very few sponges, crinoids, and lyttoniids. Medium-gray, tabular and evenly bedded, cherty carbonate mudstone constitutes the cherty carbonate-mudstone lithofacies (Fig. 5B). Large-scale intraformational truncation surfaces are present throughout this lithofacies. The fusulinid-packstone lithofacies consists of medium-gray carbonate mud replete with fusulinids (Fig. 5G). It exhibits tabular bedding that is commonly inclined at low angles (5°–15°).

Fossil-rich and skeletal-rich, medium-gray carbonate mud constitutes the skeletal-packstone lithofacies (Fig. 5C, D). This lithofacies is tabular bedded, but normally the beds exhibit low-angle inclination (5°–15°). The skeletal-siltstone lithofacies consists of abundantly fossiliferous, tan, medium-bedded to shaly-bedded quartz siltstone (Fig. 5F, H). Tabular bed geometry and low-angle inclination also characterize this lithofacies.

The unfossiliferous-siltstone lithofacies consists of unfossiliferous, thick-bedded to shaly-bedded, tan and green siltstone (Fig. 5E). This lithofacies contains broad, shallow channels that resemble the intraformational truncation surfaces of the cherty carbonate-mudstone lithofacies.

Outcrop descriptions

The West Dog Canyon outcrop (locality 5002; Fig. 6) is approximately 600 ft wide (from northwest to southeast) and exposes approximately 60 ft of strata. The lowest beds exposed are cherty carbonate mudstones that exhibit broad concave-up (listric) geometry. At least 40 ft of relief exists between the sides and center of this channelform; the total depth of the channelform cannot be determined because its extremities extend beyond the limits of the outcrop. The channelform contains low-angle inclined beds of skeletal packstone, fusulinid packstone, and cherty carbonate mudstone. These beds dip toward the south or southeast and appear to be foresets filling the channelform. They ☞

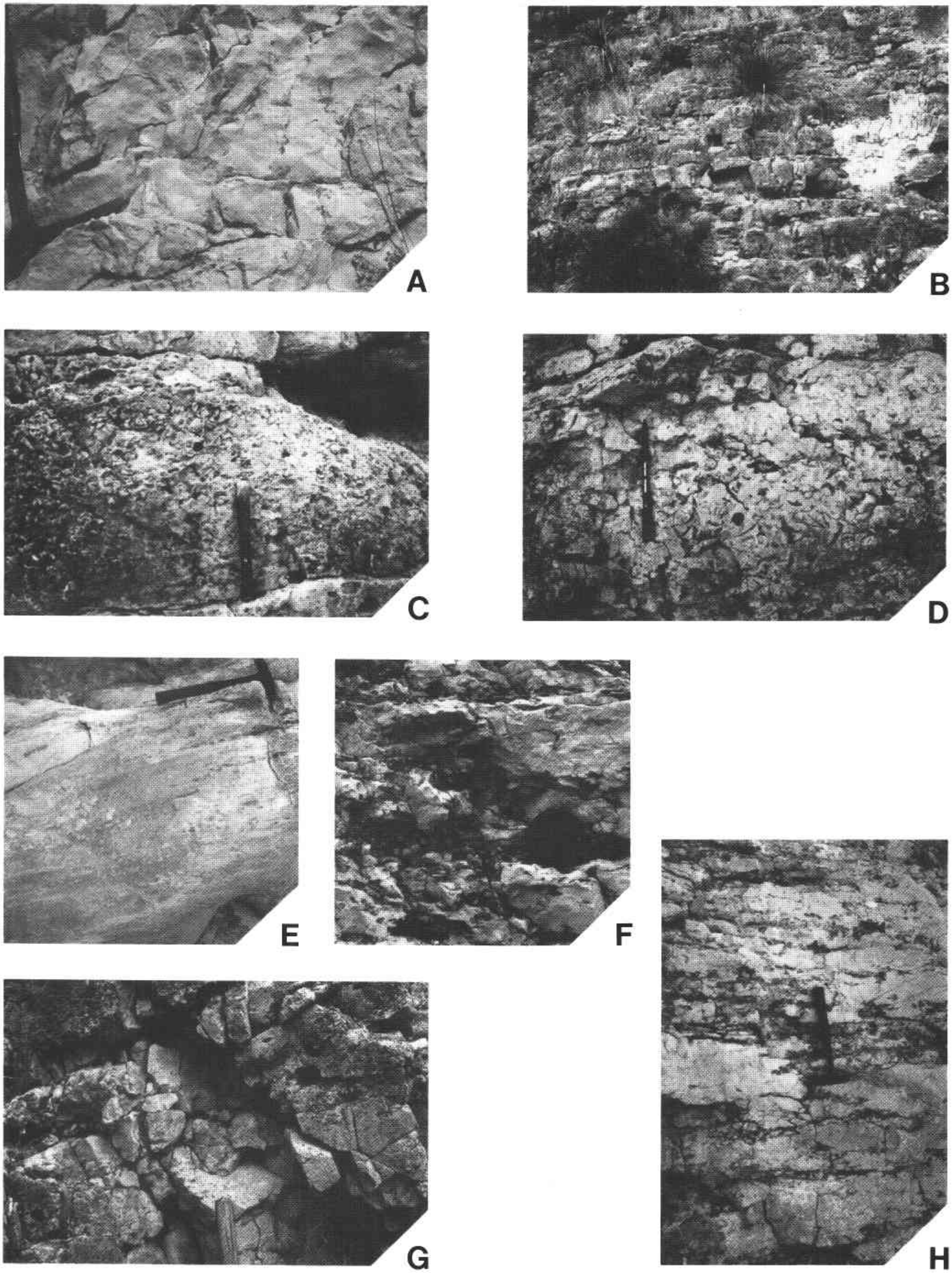
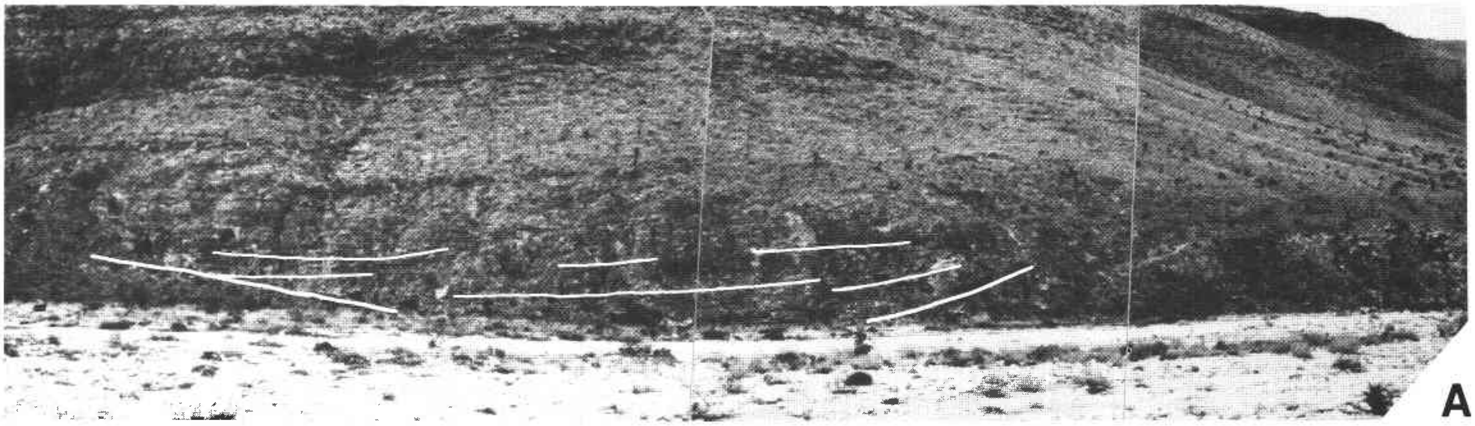


FIGURE 5—Outcrop appearance of lithofacies recognized within the lower San Andres Formation and Cherry Canyon Tongue; **A**, massive carbonate mudstone (locality 5004); **B**, cherty carbonate mudstone (locality 5002); **C**, skeletal packstone (locality 5002); **D**, skeletal packstone with lyttoniid brachiopods (locality 5002); **E**, unfossiliferous siltstone (locality 5004); **F**, skeletal siltstone with lyttoniid brachiopods (locality 5004); **G**, fusulinid packstone (locality 5002); **H**, skeletal siltstone (locality 5004).



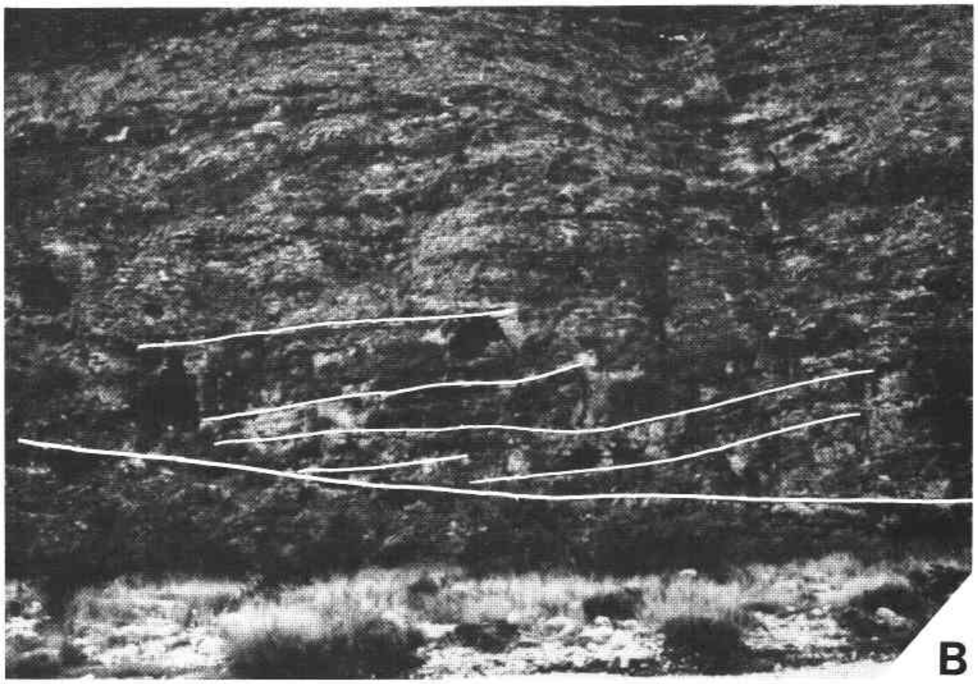


FIGURE 6—West Dog Canyon outcrop (locality 5002); **A,** photomosaic of the entire outcrop, view to the southwest; **B,** southeast part of outcrop exhibiting differential dips at the base of the channelform (beds dip northward in lowest part of exposure, beds dip southward in remainder of exposure); on overlay thick line indicates base of channelform, thin lines indicate bedding planes.

thus resemble epsilon crossbeds described from fluvial systems. A body of the massive carbonate-mudstone lithofacies approximately 100 ft wide and 40 ft thick abuts against the northwestern side of the channelform. Only a few crinoid-stem fragments and questionable sponges were observed in this unit, and no evidence of an organic frame exists. The northwestern extent of this unit could not be determined because it is covered by colluvium. The massive carbonate-mudstone body appears to be separated from the channelform by an intraformational truncation surface. Flat-lying cherty carbonate mudstones overlie the channelform.

At the Cork Draw outcrop (locality 5004; Fig. 7) the lower approximately 100 ft of exposed bedrock consists of the unfossiliferous-siltstone lithofacies. A thin (10 ft) resistant layer of massive carbonate mudstone, which grades laterally into unfossiliferous siltstone, delineates and occupies the base of the channelform. This unit contains scattered sponge gravel and a few lyttoniids. As much as 30 ft of low-angle inclined beds of the skeletal-packstone lithofacies fills the lower part of the channelform. On the east side of the exposure these beds dip toward the west, whereas on the west side they dip toward the east. On the west side, however, this part of the channelform fill is much thinner (10 ft), resulting in a shift of the center from east to west. As much as 60 ft of low-angle inclined and listric beds of cherty carbonate mudstone fills the remainder of the east side of the channelform. This lithofacies grades laterally into an equal thickness of massive carbonate mudstone on the west side of the channelform. Flat-lying carbonates of the Grayburg Formation overlie the whole exposure.

Paleontology

At the West Dog Canyon and Cork Draw outcrops, fossils are abundant in the skeletal-packstone, skeletal-siltstone, and fusulinid-packstone lithofacies. Fossils are rare in the massive carbonate mudstone and absent in the cherty carbonate-mudstone and unfossiliferous-siltstone lithofacies. Table 2 lists the observed fauna.

Lyttoniid brachiopods numerically dominate faunas from the skeletal-packstone and skeletal-siltstone lithofacies (Cuffey, in press). In these lithofacies, fossils are concentrated in tabular beds commonly inclined at low angles (5°–15°). The beds are loose accumulations of shells not in living positions, and no organic framework is present. The orientation of the shells appears to be random, but lyttoniids typically are attached to each other in clusters of three or four individuals. Additionally, virtually all lyttoniid specimens are pedicle valves; brachial valves are extremely rare. Other than lyttoniids, few frame-building organisms are present.

The fusulinid-packstone lithofacies contains abundant fusulinids; other fossils are rare. The fusulinids may exhibit parallel orientation, but the vertical nature of the outcrops and the moldic preservation make this difficult to determine.

In the massive carbonate-mudstone lithofacies sponges, crinoids, and lyttoniids are rare, widely scattered, and not preserved in living positions. No evidence of an organic frame exists. Furthermore, no evidence of binding activity or sediment production by algae is observable in outcrop.

Further paleontologic evidence comes from examination of several other outcrops outside of the channelforms. At locality 5003, thin tabular layers of skeletal packstone are present within unfossiliferous cherty carbonate mudstone. Likewise, at locality 5001, thin tabular layers of skeletal siltstone are present within unfossiliferous siltstone. These skeletal siltstones contain fusulinids that exhibit parallel orientation.

Discussion and interpretation

Boyd (1958) interpreted both the West Dog Canyon and Cork Draw outcrops of ☞

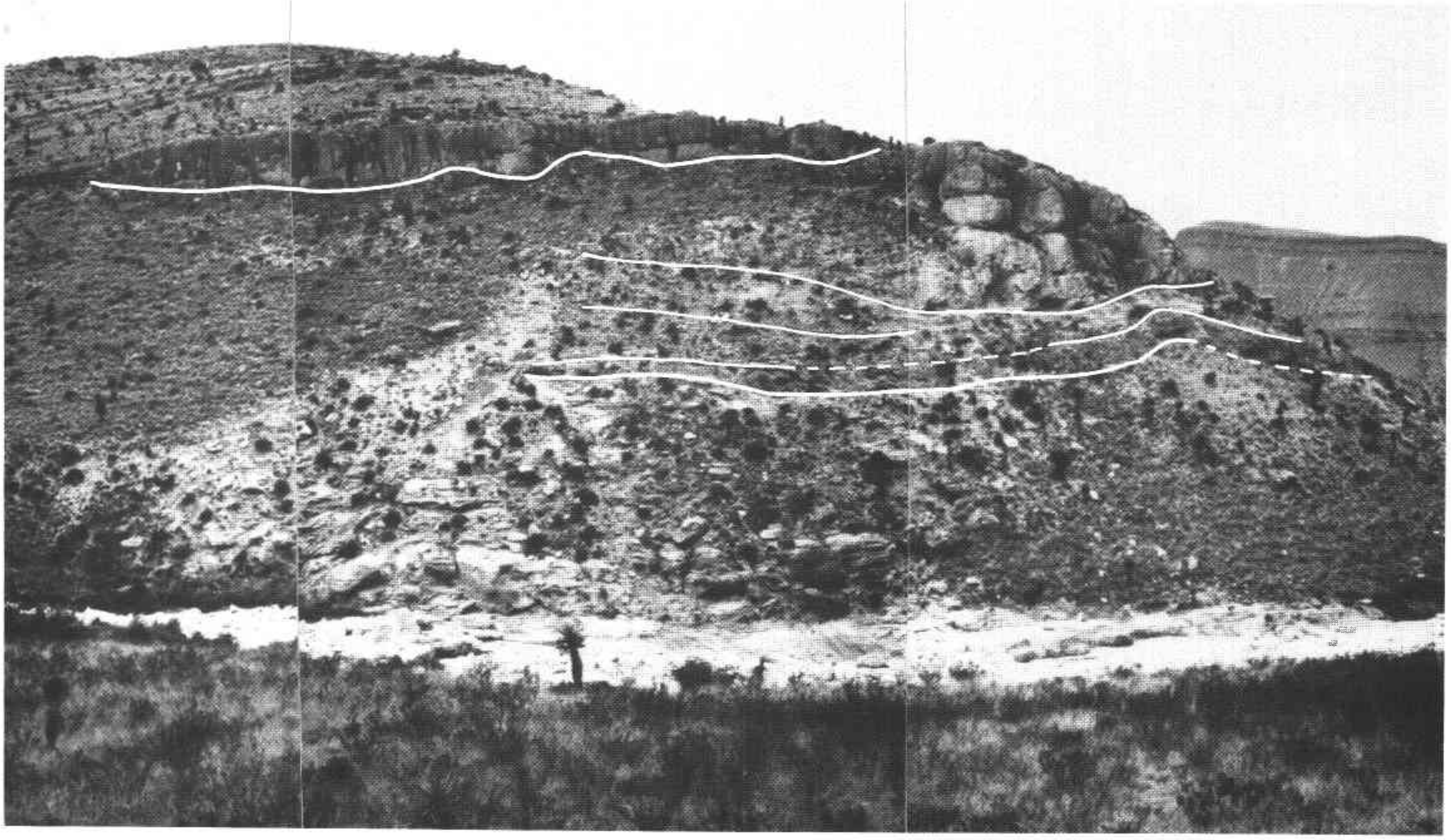


FIGURE 7—Cork Draw outcrop (locality 5004), view to the south; on overlay thick line indicates base of channelform, thin lines indicate bedding planes.

massive carbonate mudstone as bioherm cores. But, careful examination proves that these are essentially barren carbonate mudstone without any organic framework. Furthermore, neither feature exhibits mound-shaped geometry typical of bioherms (Heckel, 1974); instead, the top surfaces of the mudstone facies are planar. In contrast, all bioherms of the Glass Mountains contain abundant and prominent skeletal constituents and are mound shaped (Bain, 1967; Cooper and Grant, 1972). Moreover, in the Cork Draw outcrop the beds on the east side dip into the massive carbonate mudstone, inconsistent with a flank-bed interpretation. These facts strongly suggest that this lithofacies does not represent bioherm cores. Likewise, because no organic frame is present, they cannot be large boulders of reefal rock transported downslope as is the case with carbonate lenses in the Bone Spring Formation or Getaway Limestone (Pray and Stehli, 1962; Harris and Wiggins, 1985; Cuffey, 1987) and some lower Leonardian "bioherms" of the Glass Mountains (Rogers, 1978).

Based on the data presented here, the channelforms and their skeletal-packstone and skeletal-siltstone fills are concluded to be the most significant features of the study outcrops. The broad concave-up (listric) geometry of these features is very similar to that developed in submarine channels of the Brushy Canyon Formation (Harms, 1974). It is also similar to large-scale intraformational truncation surfaces described from carbonate slope deposits (Wilson, 1969; McIlreath and James, 1984; Mullins and Cook, 1986; Pray, 1988b). Specifically, Mullins and Cook (1986) noted that intraformational truncation is common in upper slope deposits. Additionally, the low-angle inclined bedding of the deposits filling the channelforms resembles foresets of epsilon crossbedding that are produced by vertical and lateral accretion in fluvial channels (Walker and Cant, 1984). Therefore, the exposures are interpreted as broad, shallow submarine channels or scours located near the submarine-canyon system (Fig. 8) described by Jacka et al. (1985) from the West Dog Canyon area.

In West Dog Canyon the massive carbonate-mudstone body at the northwest end of the exposure is interpreted as part of the interchannel slope that has not been incised. In part it may be levee deposits (Jacka et al., 1985), but no conclusive evidence for this was observed. In Cork Draw, the primary massive carbonate-mudstone body appears to be part of the side-channel fill. The change upsection from siltstone to carbonate channel fill is interpreted to be the result of shallowing as the Grayburg carbonate bank prograded basinward into the area. The 10 ft of massive carbonate mudstone at the base of the channel probably represents an initial channel-mantling deposit (Harms, 1974).

Boyd (1958, pp. 53–55, fig. 6) discussed and illustrated what he termed "primary dips of uncertain origin" in the San Andres Formation and Cherry Canyon Tongue. Based on his discussion, we conclude that most of those features are channelforms and intraformational truncation surfaces produced by submarine channeling and scouring similar to that discussed here. Furthermore, Boyd (1958, pl. 4, fig. B) illustrated a channel at the top of the Cherry Canyon Tongue and exposed in Cork Draw near locality 5004. This is probably a good analog for the channel interpretation of locality 5004.

Based on the taphonomic observations presented here, the preserved faunas are interpreted as predominantly consisting of allochthonous skeletal material and are thus transported fossil assemblages (Fagerstrom, 1964). Thus, they are analogous to the shell heaps preserved in the Glass Mountains and described by Cooper and Grant (1972). Presumably, the organisms preserved in the channelforms originally inhabited, and were derived from, the bank margin, which Sarg and Lehmann (1986) reported to contain abundant skeletal material in this region. Furthermore, Sonnenfeld (1990) reported small sponge–brachiopod and bryozoan–crinoid bioherms at the bank margin in the upper San Andres Formation; these could have provided many of the specimens of sponges and lyttoniids. However, personal observation of the bank margin failed to verify the reported bioherms. Likewise, Sarg (1986) did not report these bioherms.

We suggest that the strata studied were deposited by the following sequence of

TABLE 2—List of fauna observed in the San Andres and Cherry Canyon deposits under consideration and relative abundances in each lithofacies; A = abundant, C = common, UC = uncommon, R = rare, — = absent (abundances estimated from field observations); **mcm** = massive carbonate mudstone, **skp** = skeletal packstone, **fup** = fusulinid packstone, **sks** = skeletal siltstone.

	Lithofacies			
Fossil group	**mcm**	**skp**	**fup**	**sks**
Foraminifera				
fusulinids indet.	—	R	A	—
Porifera				
calcisponges indet.	R	R	—	—
Cnidaria, Anthozoa				
solitary rugosans indet.	—	R	—	—
Bryozoa				
fenestrates indet.	—	R	—	—
trepostomes indet.	—	R	—	—
Brachiopoda				
derbyiids:				
Derbyia sp.	—	R	—	—
Meekella sp.	—	—	—	R
productids:				
Paucispinifera sp.	—	C	—	R
Kochiproductus sp.	—	—	—	R
lyttoniids:				
Collemataria sp.	—	A	—	A
Eolyttonia sp.	R	A	—	A
rhynchonellids:				
Torynechus sp.	—	—	—	R
spiriferids:				
Neospirifer sp.	—	R	—	UC
Reticulariina sp.	—	R	—	—
compositids:				
Composita sp.	—	C	—	C
Martinia sp.	—	—	—	R
retziids:				
Hustedia sp.	—	UC	—	—
Mollusca, Pelecypoda				
pectinids indet.	—	UC	—	R
Echinodermata, Crinozoa				
crinoids, stem fragments	R	UC	—	UC
Arthropoda, Trilobita				
Delaria sp.	—	R	—	—

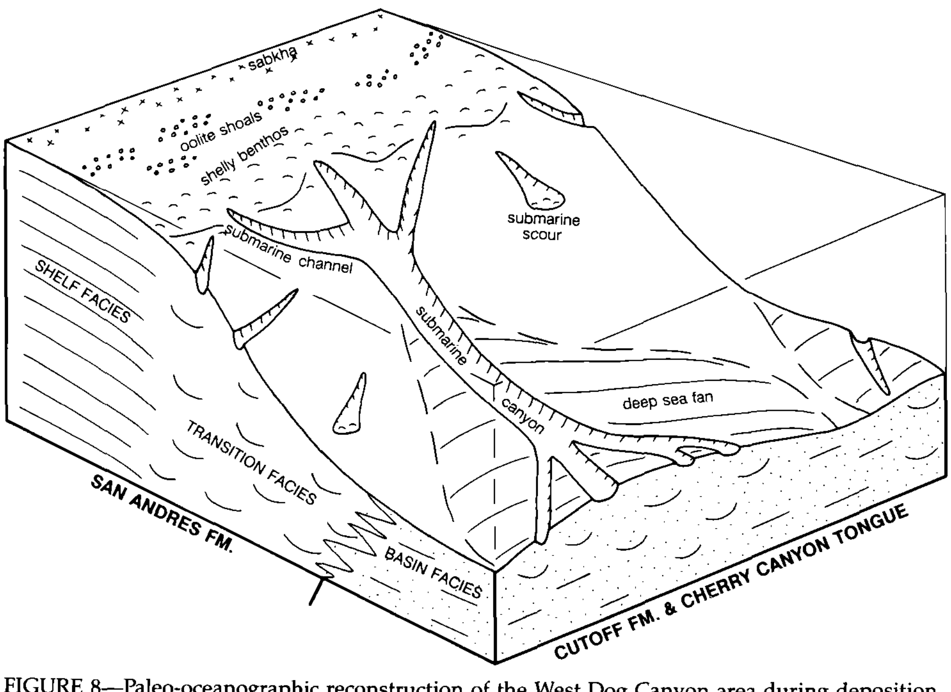


FIGURE 8—Paleo-oceanographic reconstruction of the West Dog Canyon area during deposition of the San Andres Formation and Cherry Canyon Tongue. Modified from Jacka et al. (1985).

events. Density currents periodically swept the area, scouring the bottom, hence producing broad, shallow channels and depressions (Harms, 1974). Some of these currents originated on the bank margin, were probably storm induced, and transported large volumes of skeletal material basinward into the channels. Initially, the channels were mantled by carbonate-mud deposits (either the cherty carbonate-mudstone or the massive carbonate-mudstone lithofacies) similar to the initial deposits in Brushy Canyon Formation channels (Harms, 1974). Subsequently, channel filling by lateral and vertical aggradation of skeletal-rich carbonate and/or terrigenous sediments produced the low-angle inclined beds of the skeletal-packstone, skeletal-siltstone, and fusulinid-packstone lithofacies. The currents responsible for the transportation also winnowed out the lighter, smaller, and delicate brachial valves of the lyttoniids. Some of the creatures may actually have inhabited the current-deposited shell heaps, as indicated by some specimens that are very well preserved.

The Leonardian and lower Guadalupian of the Glass Mountains, on the opposite flank of the Permian Basin (Fig. 2), provide a partial analog for San Andres Formation and Cherry Canyon Tongue deposition and paleoecology. In the eastern part of the Glass Mountains carbonate deposits prevail, with bioherms and zootikepia growing on the margin of a carbonate bank (Bain, 1967; Cooper and Grant, 1972). This eastern facies was probably similar to the bank-margin facies of the San Andres Formation, although bioherms have not been positively identified in the San Andres. Westward, the eastern facies grades and thickens into a siliciclastic sequence having thin, interbedded carbonates (Cooper and Grant, 1972; Cys, 1987; Ross, 1987).

The carbonates in the Glass Mountains, most notably the China Tank, Willis Ranch, and Appel Ranch Limestone Members of the Word Formation, contain many shell heaps (Cooper and Grant, 1972). Allochthonous boulders of biohermal rock also are present in these deposits, particularly in the Skinner Ranch Formation (Rogers, 1978). Several authors (Cys, 1987; Ross, 1987; Rogers, 1978) interpreted these rocks as slope deposits. They are similar to the slope deposits of the San Andres Formation and Cherry Canyon Tongue, except for the absence of allochthonous blocks in the latter two units. It remains to be determined whether the Glass Mountains region contains the large-scale intraformational truncation surfaces and channeling that are common in the Guadalupe Mountains.

Comparison with other upper Paleozoic bioherms outside the Permian Basin does not reveal any analogs. Upper Paleozoic phylloid algal mounds (Toomey, 1991) contain readily visible phylloid-algae ☞

fronds. Similarly, Permian bioherms constructed by various organisms, including hydrozoans (Davies, 1971) and bryozoans (James, 1983), contain easily discernible macroscopic skeletal material. Neither are the West Dog Canyon and Cork Draw outcrops analogous to "Waulsortian mud mounds" of the Mississippian, which contain abundant skeletal material, predominantly fenestrate bryozoans and crinoid columnals (Pray, 1958; Cotter, 1965; Ausich and Meyer, 1990), readily visible in outcrop (Cuffey, pers. obs.).

Summary and conclusions

Examination of carbonate bodies, previously interpreted as bioherms, in the San Andres Formation and Cherry Canyon Tongue of the Brokeoff and Guadalupe Mountains yielded significant observations and permitted reinterpretation of their origin. The primary observations and conclusions reached are:

1) six lithofacies are present: massive carbonate mudstone, cherty carbonate mudstone, fusulinid packstone, skeletal packstone, skeletal siltstone, and unfossiliferous siltstone;

2) sedimentologically, stratigraphically, and geometrically, the most important features are channelforms mantled with cherty carbonate mudstone or massive carbonate mudstone and subsequently filled with low-angle inclined beds of skeletal packstone, fusulinid packstone, and skeletal siltstone that resemble epsilon crossbedding;

3) the skeletal-packstone and skeletal-siltstone lithofacies contain the only significant invertebrate faunas, which are preserved as tabular accumulations of loose skeletal material that are taphonomically interpreted as allochthonous shell heaps;

4) the massive carbonate-mudstone lithofacies does not contain evidence of in situ biologic activity nor mound-shaped geometry; therefore, units composed of this lithofacies are not bioherms;

5) the channelforms are interpreted as broad, shallow submarine scours and channels filled by lateral and vertical aggradation of skeletal debris, which was most likely transported downslope from the bank edge by bottom currents, probably storm generated;

6) the massive carbonate-mudstone units are reinterpreted as part of the interchannel slope (possibly channel levees in part), part of the channel fill, or channel-mantling deposits, not as organic bioherms.

ACKNOWLEDGMENTS—The authors thank the following people: Brant and Mary Logan of Dell City, Texas, for permission to collect at West Dog Canyon and for providing useful logistical information; Doug Stavinoha of Texas A & M University for his assistance in the field; and Dr. William Ausich of Ohio State University, Dr. David Brezinski of Maryland Geological Survey, Dr. Russell Clemons of Las Cruces, Drs. Frank Kottlowski and Jiri Zidek of New Mexico Bureau of Mines and Mineral Resources, Dr. Roger Cuffey of Pennsylvania State University, and Elizabeth Larson of University of Oklahoma for reviewing this manuscript.

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Upcoming geologic meetings

Conference title	Dates	Location	Contact for more information
Rocky Mountain Association of Geologists 1993 Fall field trip	Sept. 24 & 25, 1993	Cortez, CO Bus leaves Denver the 23rd; returns 26th	Dennis C. Irwin 220 Cimarron Way Boulder, CO 80303 (303) 494–3815
American Water Resources Association annual meeting	Aug. 29–Sept. 3	Tucson, AZ	Herbert B. Osborn 2341 S. Lazy A Place Tucson, AZ 85713 (602) 883–4517
Rocky Mountain Section, American Association of Petroleum Geologists meeting	Sept. 12–15	Tulsa, OK	AAPG Box 979 Tulsa, OK 74101 (918) 584–2555
Denver Gem and Mineral Show	Sept. 16–19	Denver, CO	P.O. Box 621444 Littleton, CO 80162 (303) 233–2516

New U.S.G.S. map products

The U.S. Geological Survey National Mapping Division recently released maps showing new and currently available map-related digital data for New Mexico. These digital products are used primarily to generate new maps using computers. Digital elevation models (DEMs) are made by sampling elevations shown on common topographic maps at regular intervals (Map A, 7 or 15 meters). These DEMs can be used to make computer-drawn shaded relief maps. Several kinds of information commonly are printed on top of basic topographic maps and are called overlays. These overlays in digital form are called digital line graphs (DLGs). The DLG overlays available for parts of New Mexico (Maps B, C, D) include political boundaries, the public land survey system (PLSS: township, range, section lines), culture (human-made features), transportation (roads), hydrography (streams and lakes), hypsography (topographic features), and vegetation (types of ground cover). Some digital orthophoto quadrangle products with a ground resolution of about one meter are also available. Readers interested in obtaining more information may contact Sam Bardelson, Albuquerque Mapping Support District Office, U.S. Geological Survey, P.O. Box 355583, Albuquerque, NM 87176, (505) 265-7796. Readers interested in other digital geographic information may contact Mike Inglis, Resource Geographic Information Systems' Clearinghouse, Technology Application Center, University of New Mexico, Albuquerque, NM 87131, (505) 277-3622.

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