**Sequence stratigraphic framework of the upper San Andres Formation and equivalent basinal strata in the Brokeoff Mountains, Otero County, New Mexico**

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Abstract

The upper San Andres Formation, upper Cutoff Formation and Cherry Canyon Tongue (Permian, Guadalupian) in the southern Brokeoff Mountains comprise two mixed siliciclastic-carbonate, intermediate-order (high-frequency) sequences on the basis of observed seismic-scale stratigraphic geometries, integrated with detailed facies and high-order cycle stacking pattern analysis. These sequences are correlative to the two upper San Andres high-frequency sequences (G12 and G13) of Kerans et al. (this volume) and can be traced throughout the Brokeoff Mountains and along the Algerita Escarpment. Each sequence contains a largely basinally restricted, siliciclastic-dominated lowstand to transgressive systems tract, the updip part of which can be correlated to one or more sandstone-based carbonate cycles on its respective platform. The transgressive systems tracts are downlapped along the slope by clinoformal carbonate and mixed carbonate-siliciclastic strata of their overlying progradational highstand systems tracts. The G12 lowstand to transgressive systems tract onlaps the slope of the underlying G4 highstand and is provisionally correlated to the uppermost Brushy Canyon Formation on the basis of its stratigraphic position in the basin, i.e., within meters of the top of the Cutoff Formation, because its basal platform facies tracts are offset approximately 8 km basinward relative to similar facies tracts in the underlying sequence and due to the presence of a widespread karst profile that underlies the unit on the platform. The G12 highstand systems tract is composed of sigmoidal carbonate clinoform cycles that can be traced from the peritidal ramp crest facies tract to the subtidal toe-of-slope facies tract. These cycles prograded the platform margin about 0.5 km. The sequence boundary at the top of G12 is marked by minor erosional scour and stratal truncation along the outer shelf and slope. The G13 lowstand to transgressive systems tract onlaps the G12 highstand slope. It is definitively correlated to the lower two-thirds of the Cherry Canyon Tongue and provisionally correlated to the uppermost Brushy Canyon Formation. The G13 highstand is capped by a sequence boundary with minor erosion and stratal toplap along the outer 1-2 km of the platform and local karst development further landward. Paleocaverns and grikes within the karst profile extend downward as much as 30 m below the sequence boundary, which suggests a minimum relative sea level fall of similar magnitude.

INTRODUCTION

The broad stratigraphic relationships of lower Guadalupian platform and basin strata in the Guadalupe Mountains region have long been known (King, 1948; Boyd, 1958; Hayes, 1964; Wilde and Todd, 1968), but detailed correlation of these units has proved more difficult due to complex facies changes and the loss of critical marker beds in the platform to basin transition (Figs. 1, 2). Two stratigraphic problems in this region are the precise correlation of two basinal sandstone-dominated units, the Brushy Canyon Formation and the Cherry Canyon Tongue, with the carbonate-dominated, platformal San Andres Formation. The general paucity of sandstone within San Andres platform carbonates led several workers to conclude that the San Andres platform was an emergent area of siliciclastic sediment bypass during deposition of the basinal sandstone units (King, 1948; Sarg and Lehmann, 1986). However, the relative abundance of fusulinids and other carbonate allochthons in the Brushy Canyon and Cherry Canyon Tongue seems to indicate the presence of some permanently or episodically flooded platform area that is coeval with deposition of these units (Wilde and Todd, 1968; Rossen, 1985; Wilde, 1986; New, 1988). If one accepts that each of these basinal units is represented by single or multiple closely spaced bypass surfaces on the platform, the challenge is to locate these surfaces.

Seismic-scale outcrops in the southern Brokeoff Mountains (Fig. 1) provide some key insights into the correlation of the Cherry Canyon Tongue and Brushy Canyon Formation with the upper San Andres Formation. The Brokeoff Mountains area is one of only two localities (Last Chance Canyon is the other) where the proximal onlap of these units can be examined and where their precise correlation to the San Andres platform can be determined. The Brokeoff Mountains section is further distinguished by its location between the Algerita Escarpment and the Western Escarpment, with nearly continuous outcrop exposure between these areas (Fig. 1). This paper first discusses the development of various sequence stratigraphic correlation frameworks for the San Andres Formation and equivalent units, to provide some background to the present study and to establish the relationship between lithostratigraphic (formation) names and sequence names. Next, the facies tracts and stratigraphic relationships of the upper San Andres Formation, Cherry Canyon Tongue and upper Cutoff Formation in the study area are described and interpreted within the sequence stratigraphic framework of Kerans et al. (1992 and this volume).
and its basinal equivalents, based on correlation of the well-studied (1986) proposed a bipartite subdivision of the San Andres Formation sequence, depositional sequence, which includes the Brushy Canyon Formation (see also Gardner, 1992). This sequence contains the Brushy Canyon Formation, uppermost Cutoff Formation, Cherry Canyon Tongue and upper San Andres Formations of King (1948) and Boyd (1958) (Fig. 2). The uppermost two intermediate-order sequences of the upper San Andres low-order sequence, termed GI2 and GI3 (previously G 11 and G12; Kerans et al., 1992) (Fig. 2), are the subject of this report.

This new subdivision of low-order sequences has greater genetic significance than previous schemes, because it better reflects the long-term fluctuation in accommodation and carbonate/siliciclastic sediment supply evident in the transgressive-regressive stacking pattern of intermediate-order sequences. The low-order sequence boundary that separates the sequences, which corresponds to the top of the G4 intermediate-order sequence of Kerans et al. (1992 and this volume), is marked by the most laterally extensive karst profile and the greatest basinward shift of the ramp crest facies tract. It is easily mapped along the outer 10-15 km of the platform and in the basin and forms a prominent reflection on seismic record sections (C. Kerans and W. M. Fitchen, unpubl. 1992).

STUDY AREA

The study area lies in the southern Brokeoff Mountains within the Panther Canyon 7.5 minute quadrangle, Otero County, New Mexico (Figs. 1, 3). The San Andres Formation, Cherry Canyon Tongue and Cutoff Formation are exposed along fault-bounded strike ridges and in canyon walls at an elevation of 4500 to 5000 ft. Pleistocene to Recent, northwest-trending faults associated with regional uplift are pervasive in the area and can hinder attempts at lateral tracing of units, but certain markers (sandstone beds, exposure/erosion and flooding surfaces) can be followed locally across fault zones. Key exposures within individual faulted blocks are located in the lower reaches of West Dog Canyon and along Cutoff Ridge (Figs. 3, 4).

The Brokeoff Mountains were originally mapped by Boyd (1958), who recognized three broad phases or zones within the San Andres Formation and coeval units (Fig. 4). These three phases trend northeast-southwest across the study area (Fig. 4). Boyd's shelf phase is composed of undifferentiated thick-bedded dolostones of the San Andres Formation; Boyd mistakenly mapped the upper San Andres Formation as the Grayburg Formation within his shelf phase, as pointed out by Wilde (1986). In the study area, this phase contains platform facies of the GI2 and GI3 sequences. Boyd's transition phase comprises a stratigraphically complex zone about 2-3 km in width that separates the shelf and basin phases. Boyd mapped the upper San Andres Formation, Cherry Canyon Tongue and Cutoff Formation separately within this...
zone. This phase contains an upward-shallowing succession of basinal to platform facies. Boyd's basin phase consists of the Cutoff Formation, which he correlated with the lower part of the San Andres Formation and the Cherry Canyon Tongue, which he thought spanned the San Andres/Grayburg boundary. This phase consists of an upward-shallowing succession of basinal to outer platform facies.

**FACIES TRACTS**

The G12 and G13 platforms can be described as distally steepened ramps (*sensu* Read, 1985) with approximately 65-100 m of relief between the platform top and the toe-of-slope, as measured from a detailed cross section (Fig. 5). Their paleotopographic profile is characterized by primary ramp margin dips of 5°-18°, which are intermediate in magnitude between that of the more gently sloping (<1°-5°) ramp margins of the lower San Andres sequence and the steep slopes (35°—near 90°) of Goat Seep and Capitan rimmed shelves (Kerans et al., 1992).

Three broad facies tracts are recognized within these platforms (Fig. 5). The *ramp crest facies tract* consists of relatively horizontal strata composed of four general facies, which include fenestral peloid-pisolite packstone, burrowed to crossbedded ooid-peloid packstone to grainstone, burrowed peloid-dasyycladacean algae wackestone to packstone and burrowed to crossbedded fine-grained quartz sandstone. These facies represent shallow subtidal to supratidal environments of deposition on the topographically highest part of the platform.

The *ramp margin facies tract* consists of gently to steeply dipping strata composed of five general facies, which include burrowed peloid-skeletal packstone to grainstone (outer ramp), fusulinid-peloid wackestone to packstone (upper slope), bryozoan-sponge-crenoid packstone to bafflestone (upper slope), echinoid-rich spiculo-brachiopod wackestone to mudstone (mid-to lower slope) and massive bioturbated quartz sandstone (outer ramp to lower slope). These facies represent shallow to deeper subtidal environments of deposition along the outer ramp, ramp margin and slope.

The *toe-of-slope/basin facies tract* consists of gently basinward dipping strata composed of allochthonous peloid, skeletal and ooid grainstone to packstone, carbonate breccia to megabreccia, parallel-laminated-to-ripple cross-laminated (Bouma B-C) or bioturbated quartz sandstone and carbonate mudstone. The former three facies contain allochthonous carbonate allochems from adjacent ramp crest and ramp margin facies tracts and exhibit textures and sedimentary structures indicative of transport by sediment gravity flow. This facies tract represents deep subtidal environments of deposition, but the presence of burrows in some of these facies indicate that the water column was aerobic to dysaerobic.

**UPPER SAN ANDRES SEQUENCES**

**Introduction**

Two intermediate-order or high-frequency sequences (G 12 and G 13; Fig. 2) are defined within the upper San Andres/Cherry Canyon Tongue/uppermost Cutoff Formation interval in the study area, based on data from seven measured sections, mapping of genetic units on photomosaics and correlation to sequences of Kerans et al. (1991) on the Algerita Escarpment. Exposures of the initial platform margins of both sequences permit the delineation and mapping of sequence boundaries, maximum flooding surfaces and systems tracts from ramp crest to toe-of-slope/basin facies tracts (Fig. 5).

Sequence boundaries are defined by the following criteria: stratal onlap, truncation and karst along the surface; stratal toplap below the surface on the platform; a basinward shift of facies tracts on the platform.
relative to the underlying sequence; the occurrence of quartz sandstone
above the surface along the platform and slope; and carbonate breccias
with quartz sandstone matrix lying on the surface at the toe-of-slope
(Mitchum et al., 1977; Sarg, 1988). Maximum marine-flooding surfaces
are recognized by stratal downlap above the surface along the slope, a
landward shift in facies tracts across the surface along the platform and
upper slope and a change from mixed siliciclastic-carbonate cycles to
carbonate cycles on the platform. As a result of the progradational
character and low accommodation potential of upper San Andres se-
quencies (relative to the older intermediate-order sequences of the lower
San Andres), sequence boundaries are well expressed in all depositional
settings, whereas maximum-flooding surfaces are best expressed where
downlap is evident or where sandstones occur on the platform (Kerans
et al., 1992).

Systems tracts are defined by their enclosing surfaces and by the
stacking pattern of their component high-order cycles with respect to
facies proportions, depositional geometries and the nature of their bounding
surfaces (Van Wagoner et al., 1988; Goldhammer et al., 1991). Low-
stand systems tracts cannot be unambiguously defined in the area, as
it is difficult to differentiate potential lowstand strata from transgressive
strata that onlap the toe-of-slope and that correlate to widespread, high-
order siliciclastic-carbonate platform cycles (Figs. 5, 6). I propose that
much of the lowstand stratigraphic record of these sequences is confined to
more basinward positions, whereas on the platform the record is rep-
resented by a hiatus associated with subaerial exposure and siliciclastic
sediment bypass. Due to this difficulty in separating the two systems
tracts within the area of study, they will be discussed together in the
following sections. Highstand systems tracts are generally composed

of sets of sigmoid-progradational, upward-shoaling (asymmetric) car-
bonate cycles. Within the G 13 sequence, these high-order carbonate
cycles evolve into sigmoid- to oblique-progradational, mixed silici-
clastic-carbonate symmetric cycles that are microcosms of the inter-
mediate-order sequence (Sonnenfeld, 1991) (Fig. 5).

**G12 sequence**

The G 12 sequence (28-65 m thick) overlies the G4 sequence on the
platform (Figs. 5, 6). Along the Algerita Escarpment, the uppermost
several high-order cycles of the G4 sequence comprise a laterally ex-
tensive ooid-peloid grainstone complex that forms a conspicuous light-
colored bench above underlying darker-colored fusulinid-peloid pack-
stones and below thinner-bedded, more recessive peloid packstone and
mudstone strata of sequence G12. A regionally extensive karst profile
at the top of this grainstone complex marks the basal sequence boundary
of the upper San Andres low-order sequence (Kerans et al., 1992 and
this volume). This distinctive grainstone complex can be visually cor-
related across Big Dog Canyon to the Brokeoff Mountains, where it
bears a similar relationship to enclosing strata. This unit was traced
from Choisie Canyon (La Paloma Canyon 7.5 minute quadrangle) south
to Panther Canyon, within 1 km of the area described in this report,
in order to establish a correlation between the Algerita Escarpment and
Brokeoff Mountains sections. In the study area, the terminal platform
margin of sequence 04 is exposed on the west wall of West Dog Canyon,
SW1/4 sec. 2, T26S, R19E (Figs. 5-7); excellent exposures of these
sequences also occur on the east wall. Most of the relationships de-
scribed below refer to this locality.
The sequence boundary above the G4 platform slopes about 1° basinward and is broadly channelized with up to 2 m of local erosional relief. No macroscopic evidence of subaerial exposure was noted along this boundary within the area of study. The sequence boundary is overlain by a 2 to 4.5-m-thick, fine- to very fine-grained quartz sandstone bed that thins toward the platform interior (Figs. 5, 6); this thinning is interpreted as an onlap relationship. The sandstone bed contains dune-to ripple-scale trough cross-stratification that becomes increasingly obscured by burrows towards its top. Burrow types include Ophiomorpha, Diplocraterion, Rhizocorallium and possibly Muensteria, which is consistent with a shallow marine to tidal flat environment (Ekdale et al., 1984). Skeletal fragments, peloids and ooids are present toward the top of the bed and in a downdip direction. Updip, this bed is overlain by quartz-rich ooid grainstone with a thick fenestral packstone cap. Down-dip, the bed is overlain by a thin ooid-peloid packstone capped by a burrowed horizon. This succession is interpreted as the lowstand to transgressive systems tract of the GI2 sequence (Figs. 5, 6). The maximum flooding surface that overlies this unit is characterized by erosion updip, where supratidal units are channelized by a 10-m-thick grainstone cycle containing intraclasts at its base and a burrowed horizon downdip, which is overlain by a 7-m-thick peloid-oooid packstone cycle containing abundant fusulinids at its base. These successions represent a basinward shift in facies tracts relative to uppermost G4 facies, which here are composed of peloid-skeletal packstone (updip) to fusulinid-peloid packstone (downdip) (Fig. 6). The lowstand to transgressive systems tract can be traced across the ramp margin and slope of the G4 highstand systems tract to the toe-of-slope, where it forms a 5 to 10-m-thick onlap wedge of carbonate-rich sandstone (Figs. 5-7). Sandstones and silt-stones equivalent to this unit are exposed at several other localities, including along the north and south walls of West Dog Canyon, N1/2 sec. 12, T26S, R19E and along the streambed on the south side of West Dog Canyon, SW 1/4 sec. 8, T26S, R20E.

The GI2 highstand systems tract thickens from 19 m on the platform to about 55 m at its terminal platform margin. On the platform, it is composed of at least two subtidal-dominated ramp crest cycles. These grade basinward into ramp margin facies that downlap the maximum.
The G13 sequence (30-152 m thick) overlies the G12 highstand on the platform (Figs. 5, 6) and is in turn overlain by the Grayburg Formation (G14 and G15 sequences of Kerans et al., this volume). The sequence boundary at the base of the G13 sequence is relatively conformable and marked by low-relief, channel-form scour scarps along the outer several hundred meters of the G12 platform. No evidence of subaerial exposure was noted along this surface in the area, although Kerans et al. (1991) documented karst features along the correlative surface on the Algerita Escarpment. At the platform margin the sequence boundary truncates biothermal strata, as discussed previously (Figs. 5, 6, 8). At the toe-of-slope (SE\(^1/4\) SE\(^1/4\) sec. 1, T26S, R19E), the sequence boundary occurs at the base of a 7 to 13-m-thick, 400-m-wide (parallel to depositional dip) carbonate breccia to megabreccia whose matrix contains fine-grained quartz sand. The unconformity is a relatively horizontal surface (as viewed from the southwest) that truncates approximately 10 m of underlying G12 highstand strata, here composed of gently southeast-dipping allodapic peloid grainstone interbedded with spiculitic mudstone. Farther basinward, the sequence boundary is a relatively conformable surface that separates distal slope mudstones of the G12 highstand (uppermost Cutoff Formation) from fine- to very fine-grained sandstones of the GI 3 lowstand to transgressive systems tract (lower Cherry Canyon Tongue) (Fig. 5).

The downlap (maximum-flooding) surface within the Cherry Canyon Tongue, first recognized by New (1988), can be traced landward along Cutoff Ridge and within West Dog Canyon into Boyd’s (1958) transition phase. This surface represents the upper boundary of the G13 lowstand to transgressive systems tract along the slope. Just basinward of the terminal G12 highstand margin, the lowstand to transgressive systems tract is composed of interbedded fine- to very fine-grained sandstones and minor siltstones with interbedded allodapic ooid and skeletal grainstones and carbonate breccia/megabreccia that onlap the sequence boundary or overlying autochthonous slope strata (Figs. 5, 6, 8). Sandstone strata contain cut-and-fill structures with low-angle slaley laminations and rare channels filled with massive (slumped or liquified?) sandstone. Alloelastic grainstones are parallel-laminated to trough cross-stratified. Carbonate breccias are massive to crudely bedded; bedding is accentuated by the presence of contorted sandstone lenses and stringers at (and above) bed contacts. In this proximal setting the unit is 25-30 m thick; 65-70% of this thickness consists of carbonate strata.
Carbonate strata thin and wedge out basinward within 3 to 4 km of the toe-of-slope. Sandstone strata expand basinward to a maximum thickness of 70 to 80 m, as measured by New (1988) on Cutoff Ridge. Although no allodapic carbonates were noted in the lower Cherry Canyon Tongue along Cutoff Ridge, channelized carbonate breccias and associated grainstones occur in the unit at the basin margin on the Western Escarpment, about 20 km basinward of the platform margin (New, 1988).

The uppermost sandstone of the lowstand to transgressive systems tract at the toe-of-slope can be traced several tens of meters landward into the ramp margin facies tract, beyond which it is obscured by recent colluvium (Figs. 5, 6, 8). This sandstone bed is inferred to correlate to the uppermost of three sandstone beds on the ramp crest, which is exposed about 0.5 km to the north (landward). On the ramp crest, the lowstand to transgressive systems tract as defined consists of 3-4 sandstone-based carbonate cycles (Fig. 6). The systems tract thins landward (north-northeast) from 22 m to 12 m across the outer 0.8 km of the platform, possibly due to onlap against the sequence boundary. Ramp crest sandstones are typically very fine- to fine-grained (in contrast to dominantly very fine-grained slope sandstones) and contain ripple to megaripple cross-stratification. Fusulinids are present in some beds. Carbonate facies that cap these cycles consist of ooid-peloid packstone/grainstone and fenestral packstone in the seaward part of the ramp crest and peloid wackestone to ooid-peloid grainstone in the more landward part of the ramp crest. The maximum-flooding surface is tentatively placed at the top of the uppermost sandstone-based carbonate cycle (Figs. 5, 6). In the seaward part of the ramp crest, the surface is marked by minor erosion and is overlain by an ooid-peloid grainstone bed containing abundant fusulinids. The abundance of fusulinids in this bed reflects maximum flooding of the ramp crest and a shelfward encroachment of the ramp margin (upper slope) facies tract.

Platform sandstones of the G13 lowstand to transgressive systems tract occur within 25 to 47 m of the top of the San Andres Formation in the study area. This stratigraphic position is similar to that of the Lovington sandstones, which comprise a regionally persistent subsurface marker on the Northwest Shelf (Meisner, 1972). Correlations discussed herein equate the Lovington sandstones to the lower Cherry Canyon Tongue of New (1988).

The G13 highstand systems tract concordantly overlies the maximum-flooding surface across the ramp crest and downlaps this surface along the slope (Figs. 5-8). The highstand is subdivided into early and late phases on the basis of variable cycle geometries, progradation/aggradation ratios and facies content. The early highstand consists of sigmoid-progradational cycles that aggraded the ramp crest 25 m and prograded the ramp margin about 1 km (Fig. 5). On the ramp crest, the highstand is composed of thin, relatively horizontal peritidal carbonate cycles (Fig. 6). These cycles grade seaward and topographically downward into clinoformal ramp margin cycles that downlap the lowstand to transgressive systems tract along the slope (Figs. 5, 6, 8). Aggradation of platform strata, coupled with basinward thinning of equivalent slope strata, resulted in an increase in the relief of the ramp crest above the distal slope during the early highstand. The relief on the maximum-flooding surface is about 65 m, whereas the youngest part of the early highstand platform has a relief of about 100 m (Fig. 5).

The late phase of the highstand systems tract is composed of mixed carbonate-siliciclastic cycles with sigmoid- to oblique-progradational geometries. These cycles developed subsequent to the full aggradation of the ramp crest and thus offlap with little net aggradation (Fig. 5). Late highstand cycles contain a (high-order) lowstand to transgressive wedge at their base that is composed of bioturbated, very fine-grained sandstone. This wedge onlaps the slope and outer ramp. This wedge grades upward into a (high-order) highstand unit composed of ramp margin carbonate facies that contain abundant quartz sand. Cycles are occasionally capped by high-order subaerial exposure surfaces that merge with the intermediate-order sequence boundary, or are truncated directly by the intermediate-order (upper G13) sequence boundary (Sonnefeld, 1991; Fitchen, 1992). The occurrence of sandstones in these late highstand cycles is inferred to be the result of low accommodation on the platform, which allowed sandstones to bypass the emergent ramp crest and be delivered directly to the ramp margin during high-order relative lowstand to transgressive phases. During high-order relative highstand phases, sandstones were limited to the shorezone and were reworked basinward during the subsequent relative lowstand. The relief of these clinoform cycles decreases from about 100 m to as little as 65 m during the development of the late highstand. This decrease may be the result of an intermediate-order relative fall of sea level, which is reflected in a basinward-sloping toplap surface and in the progressive development of oblique-progradational cycles, coupled with aggradation of the toe-of-slope and basin by sandstone wedges of high-order cycles (Sonnefeld, 1991; Fitchen, 1992).
The sequence boundary at the top of the G13 highstand systems tract is concordant with uppermost early highstand strata. A karst profile is developed in early highstand strata below the sequence boundary in the NW 1/4 SE 1/4 SE 1/4 sec. 1, T26S, R19E. This profile consists of solution-widened fractures (grikes) and a southeast(?)-dipping paleocavern that appears to parallel clinoform bedding. Grikes and paleocaverns are filled predominantly by fine- to medium-grained sandstones similar to overlying transgressive sandstones of the Grayburg Formation (Premier sandstone of Meissner, 1972) together with rotated, angular breccia blocks of host dolostone. The base of the deepest paleocavern lies 30 m below the sequence boundary. This suggests that the sequence boundary and its associated karst formed during a relative sea level fall of at least 30 m. This does not account for sediment compaction or the apparent topographic fall of the sequence boundary towards the terminal platform margin, which would suggest a fall of greater amplitude.

琥珀 (personal comm. 1992) noted several beds composed of ramp facies in the lower Grayburg-equivalent Cherry Canyon Tongue at Cutoff Mountain, which is about 0.5 km basinward of the terminal G13 highstand ramp margin. If one uses a stratigraphic datum in the Grayburg Formation to relate the Cutoff Ridge sections of New (1988) to Kerans’ Cutoff Mountain section, these peritidal beds appear to be about 60 m lower than the G13 margin, which suggests a minimum relative sea level fall of about 75 m(!). Further field work is required to support this hypothesis.

CONCLUSIONS

Two intermediate-order platform sequences can be defined in the upper San Andres, Cherry Canyon Tongue and uppermost Cutoff Formation in the Brokeoff Mountains on the basis of stratal geometries tied to facies distributions and high-order cycle stacking patterns. These sequences reflect mixed silicilastic-carbonate, reciprocal sedimentation of both intermediate-order and high-order cyclic scales. Reciprocal sedimentation and the development of high-order cycles is inferred to be the result of high-order (low amplitude?) fluctuations in relative sea level, or accommodation. The development of high-order cycles appears to be modulated by intermediate-order (high-amplitude) accommodation changes. Intermediate-order accommodation changes determine the stacking pattern of high-order cycles with respect to geometry and site of deposition, thickness and facies proportions, as indicated by the physical stratigraphy of upper San Andres intermediate-order sequences described here.

The G12 sequence contains a lowstand to transgressive sandstone wedge that occurs within the upper part of the Cutoff Formation and is clearly distinct from the Cherry Canyon Tongue in the study area. On the platform, this unit contains a basal sandstone that lies 60-80 m below the top of the San Andres. I propose that this wedge is correlative to the uppermost Brushy Canyon Formation of the Delaware Basin. The sequence boundary at the base of the G12 sequence is thus a hialtal surface across which most of the Brushy Canyon sandstones were bypassed to the basin.

The G13 sequence contains a lowstand to transgressive wedge that is correlative with the lower Cherry Canyon Tongue of New (1988) and to the upper-upper San Andres sequence lowstand and transgressive systems tracts of Sonnenfeld (1991). On the platform, this unit contains several sandstone beds, the lowermost of which lies 25-47 m below the top of the San Andres Formation. The stratigraphic position of these sandstones is similar to that of the Lovington sandstones; thus the Lovington sandstones and the sequence boundary upon which they rest appear to be equivalent to the lower Cherry Canyon Tongue.

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BROKEOFF MOUNTAINS SAN ANDRES


1907 guano mining in Bat Cave, later named Carlsbad Cavern. Photographer unknown. Courtesy of Southeastern New Mexico Historical Society of Carlsbad.
Cork Draw in southern Brokeoff Mountains. View is upstream, N65°E. The canyon is about 90-150 m deep. Cliffs and ridge consist of Grayburg Formation. Lower mostly covered slopes are upper San Andres Formation/Cherry Canyon tongue (Fitches, this volume). The gravelly flood plain is occupied by an unidentified silvery white shrub. Creosote bush (medium gray shrub) is confined mainly to the low alluvial terrace and small alluvial fans at base of canyon walls. The two small trees beyond the tall yucca in the left foreground may be desert willow. Scattered trees on ridgecrest in distance are pinion pine. Camera station is in SW 1/4 sec. 17, T26S, R20E, about 10.5 km southwest of El Paso Gap. Altitude is approximately 1516 m. W. Lambert photograph No. 851.109. November 16, 1985, 9:41 a.m. MST.