Big Bend National Park, Its geologic history and historical interpretation

Abstract

The area in west Texas known as Big Bend National Park has undergone many changes throughout its existence. From the geologic forces that shaped its landscape to the political and economic forces that shaped its destiny. This paper will deal with certain areas exposed in the area as well as the people who have spent their careers and even lives trying to understand and then explain the area.

Introduction

As study for the Structural Geology course in the Earth and Space Science Department of Lamar University a semester-long research project was assigned as a means of tying in all the information covered during lab and lecture as well as preparing the students for field camp, of which two weeks will be spent inside of the Big Bend National Park and the geologic structure will be mapped and studied and structural as well as other interpretation will be made. The parameters of this paper would allow for a nearly inexhaustible search for everything geologically related to the formation and alteration of the area known as Big Bend. However I will be focusing on The San Vicente and Ernst Members, the Allocricoceras hazzardi Zone, and brief tectonics and structure with specific examples of the Hot Springs and Nine Point Draw Areas.

Previous Work

There have been innumerable papers and articles written about the Big Bend National Park Area. To go through each and every one is not in the scope of this paper. However the major advances and paradigm shifting papers are worth noting and authors cited throughout should also be mentioned. The list used in this paper includes Frush and Eicher, paleoenvironments, 1975. P.B King’s Outline of structural development of Trans-Pecos Texas, 1935 and his 1937 Geology of the Marathon Region, Texas are included. R. A. Maxwell’s work will be broadly examined. All this previous work will be tied in with Jim and Margaret Stevens’ work as well as that of Roger and D. A. Cooper.

An Early Coastline

The Big Bend region of Texas was once part of a southern coastline of a body of water known as the Western Interior Seaway. Throughout much of the late Cretaceous time period (99.6 to 65.5 MYA (Cooper et. all )) the area was at a junction between the southern Western Interior Seaway and the westernmost part of the Tethys Ocean system including the Gulf of Mexico and the proto-Caribbean. (Cooper and Cooper ) Given this depositional environment
that covered the Big Bend area geologist can trace a history of the area in the sediments and the rock layers and interpret Oceanic Anoxic Events, as well as numerous cyclothems of transgressions and regressions. Also the alert paleontologist can, with aid of fossils collected in the park, give a relatively accurate interpretation of how the climate during the late Cretaceous time period was evolving. Two of the most important fossils found are the * Allocroiceras hazzardi*, which has its own stratigraphic layer and is used as a time and formation boundary which will be discussed in detail later. There are also numerous accounts of *Inoceramids* help verify the interpretation of a warm water climate, as well as dissolved oxygen content of the area.

In their *Overview of the Big Bend Region During the Late Cretaceous* Roger and Dee Ann Cooper indicate that regional paleogeographic components durin the Late Cretaceous include a relatively stable platform/shelf environment in the east that included most of Texas, the subsiding Chihuahua Trough immediately to the west in Mexico and further west the Cordillera Island Arc System. The platform area was inundate and covered by a series of global as well as regional transgressions and regressions. The maximum transgression occurred in the Albanian (Early Cretaceous), early Turonian (Late Cretaceous), and early Coniacian (Late Cretaceous) to late Santonian (Late Cretaceous). (Cooper and Cooper)

**The Ernst Member and a Phantom Conglomerate**

The Ernst member of the Boquillas Formation is a widely exosed sequence f rhythmically bedded pelagic carbonate and Shale of Cenomanian-Turonian (C-T) age (Sanders 1988). There are five informal units that record a generally deepening upward sequence. Richard Sanders in his unpublished masters thesis documents that the basal unit consists of hummcky cross stratified foraminiferal echinoderm grainstone deposited disconformably on the Buda Limestone. This unit, he continues, contain breccias, chaotic bedding, and slump folds associated with debris flows which formed within a storm wave base. The black shale layer unit records the gradual encroachment of deeper basinal waters onto the Cohuila Platform. The lower limestone unit, upper shale unit, and cyclic limestone/shale unit consist of varying proportions of foraminiferal wackestone-packstone alternation with clcareoud shale which wa deposited on an open marine carbonate platform, well below storm wave base. Fish bonephosphate pebble conglomerate record periods of nondeposition, while intensely bioturbated beds indicate rare periods of oxygenation of a normally anoxic ocean bottom. This series of transgressions and regressions and deposition interpretation agrees with the Cooper’s interpretation.

The area of the Ernst that Sanders is located and is a boundary of the Boquillas formation. This lower boundary was named by Maxwell et al. (1967) for exposures located at Ernst Tinaja, approximately 7.5 miles (12.6 km) north of the Hot Springs. The San Vicente was also named by Maxwell er al. for the exposures around the old village of San Vicente,
approximately 2 miles south of Hot Springs. Maxwell et al. (1967) defined the Ernst Member as ranging from the Buda-Boquillas contact to the top of the “Coilopoceras” marker bed, “246 feet (75m) above. Maxwell et al. (1967) reported that the Ernst is overlain unconformably by the San Vicente with a conglomerate layer separating the two members. However I [Sanders] was not able to locate a conglomerate layer at the top of the Ernst Member. Powell (1965) reported that he was unable to locate a conglomerate bed at the top of the Ernst Member either.

At Hot Springs, Ernst Tinja, and Well Creek there is a calcarenite composed of coarse-grained Inoceramus prisms located 5 m above the top of the Buda Limestone. This unit ranges in thickness from 2 cm at Hot Springs to 4 cm at Ernt Tinaja and Well Creek. Given this deposits unique lithology Sanders (1988) calls it a stratigraphically important marker bed. Sedimentologically, inoceramites are thought to form by storm action, braking up Inoceramus shell material, winnowing out the finer sediment, and leaving behind a nearly pure carbonate san (Hattin, 1975, 1986) (Sanders, 1988). If this is the case, then the presence of the inoceramites indicates that this area was in shallower water that could be disturbed and then re-deposited by storm waves.

The Allo Zone and Biostratigraphy

About 330 feet above the base of the Ernst is a 3-foot ledge of brown siliceous flagstone with shale partings, containing numerous Allocriceras hazzardi, which forms a low cuesta that can be trace for long distances. The Allocriceras is associated with Scapites sp., Scipinoceras cf. S. gracilis, and an unidentigie discoidal ammonite. The Allocriceras was observed by Udden (1907a, p. 43) and by Adkins (1933, p. 451). (Maxwell et al. 1967).

This Allocriceras hazzardi Zone (“AHZ” or “Allo Zone”) has been used as a boundary between the Ernst and the San Vicente, the top of the Allo Zone is used to denote the end of the Ernst and the beginning of the San Vicinte.

The ammonites of the Ernst were studied by W.S Adkins and R.T. Hazzard. Inoceramus labiatus is common and ranges throughout the formation. At least one or more additional species of that genus, one of the large, are also present. Ostrea congesta is commonly attached to many of the Inoceramus shells. Echinoids, probably Hemiaster Sp., are common in some beds and Durania sp. is sparsely distributed through the formation. Several cephalopods, including Eutrephoceras sp. and Baculites sp., as well as sharks teeth and fish bones, are recognized. The diagnostic ammonites establish at least a partial correlation between the Ernst Member and the Eagle Ford beds in other parts of Texas. Huffman (1960) studied the microfauna of the Ernst Member and reported 7 families, 13 genera, and 22 species of foraminifera. (Maxwell et al. 1967).
The following megascopic fossils were identified from the Ernst Member in the Park (taken from Maxwell et al. 1967):

*Allocrioceras hazzardi* Young, 1963

*Scipinoceras* cf. *S. gracilis* (Shumard, 1860)

*Inoceramus labiatus* Schlotheim, 1813.

*Ostrea congesta* Conrad, 1843

*Coilopoceras* sp.

*Eutrephoceras* sp.

*Baculites* sp.

*Durania* sp.

*Scaphites* sp.

*Inoceramus* sp.

*Hemiaster* sp.

**The San Vicente Member**

The Upper Cretaceous San Vicente Member of the Boquillas Formation consist of four intervals of predominately limestone layers that are separated by thee carbonate mud intervals. The San Vicente ranges in age from early Coniacian to possibly early Campanian based on invertebrate fossil fauna. It is the approximate lateral equivalent of the Austin Group of Central Texas (Cooper and Cooper).

Jim and Margaret Stevens began their study of the San Vicente in 1995 in an area where the rocks are exposed across the Sunken Block. Their overview states that the San Vicente Member, Boquillas Formation, involves a set of rocks that owe their preservation to a low topographic position within the Sunken Block of Udden (1907). The Ernst Member (previously discussed in this paper) and the San Vicente Member, Boquillas Formation, and the overlying Pen, Aguja, and Javelina Formations from a superposed latest Cretaceous/earliest Tertiary, transgressive/regressive sequence, that ended in completely nonmarine later Maastrichtian (fluvial, lacustrine, deposition), that is not preserved elsewhere in the Texas-Coahuila-Chihuahua region. The Stevens became interested in the Boquillas Formation because if a desire to know more about the pre-Eocene deformation of the basement rocks (see Stevens
and Stevens, 2003) that underlie Tertiary continental sediments outside of the ‘Tornillo Basin’ (Wilson, 1972; Stevens and Stevens, 1989), and because the 250-300 meter thick formation had not been studied for approximately 40 years, and not in much detail before that. (Stevens and Stevens).

In 1995 the Stevens investigated the Sunken Block. During their field work they noted that in addition to the intervals (more calcareous intervals: SV:MCI-1; SV:1-2 Shale; SV:MCI-2; SV:2-3 Shale; SV:MCI-3; SV:3-4 Shale; and SV:MCI-4) [see appendix A] described elsewhere, and in spire of lithologic changed that involve increasing or decreasing percentages of calcareous or argillaceous material, and color changes due to increases of limonite, they found six roughly isochronous beds that can be traced widely (including Cladoceramus undulatoplicatus beds). And three that are found regionally, that form the basis for their suggested correlations. Two of the three, the Allocriceras hazzardi Zone (conformably underlying the San Vicente), and the uppermost part of MCI-2 are probably isochronous, and were deposited on surfaces of little or no topographic relief. The third, the File Flat member, describd as a lentil by Moon (1953), appears to be coextensive with MCI-2, forms the lower two thirds of the 2-3 Shale regionally, the range zone of Magaiceramus subquadratus complicates), and directly overlies MCI-2. There is not, at present, a means to be sure that the upper contact of this unit is better than approximately isochronous. (Stevens and Stevens).

Tectonics and Structure

Hot Springs Area:

According to Cooper et all, the Hot Springs area is an excellent example of the Gulfian Boquillas formation in Big Ben National Park. In this area about 40 cm stratigraphically above the contact there is an ammonite zone (Cooper et al. 2008). The ammonites are poorly preserved but have been located more intact, described and identified, mostly by W.A Cobben. The index tax table in the appendix is a compiled list (see table for authors) of index ammonites, inoceramids for the region as well as the Western interior Seaway.

The Cenomamian/Turonian Stage Boundary is known worldwide as coincideing with Oceanic Anoxic event 2 (Cooper et al 2008). Observations by field researchers (in this case Roger Cooper) suggest that the lower part of the Ernst Member was deposited in a shallow water environment relatively close to shore. Sandy Clay layers will react differently to tectonic forces than the more resistant limestone that over- or underlies it. There is a fine example of this in the Appendix illustrations as well.

Nine Point Draw Area:

Personal experience has led Roger Cooper (Cooper et all) to conclude that there are as many geologic interpretations of this particular area as there are geologist who have attempted to map any part of the area. His ongoing work is the first that takes into account the Members
[of the Boquillas Formation] (Ernst and San Vicente) and other identified subunits of the members. The *Allocrioceras hazzardi* Zone is present and can be seen partway up a cuesta immediately to the west of a campsite frequented by field trip attendants. As in the hot Springs area the *A. hazzardi* Zone in the Nine Point draw area consists of 4 indurated layers separated by 3 carbonate mud layers. (Cooper et al, 2008).

Near the area called Dog Canyon, the Santa Elena, Del Rio, and Buda formations as well as the lowermost Ernst Member are folded into an overturned asymmetrical fold. The overturned upper limb is dipping approximately 65 degrees to the northeast and is subparallel to a high angle reverse fault that also dips to the northeast. The Ernst member in the lower limb generally strikes north0northeast and dips gently into the northwest and has been affected by the northwest striking high angle faults. Recent earthquakes have loosened outcrops in some areas. A rock scar can be seen in the Santa Elena Formation forming an abrupt escarpment near a campsite used on field trips. This scar is the result of a 6.5 magnitude earthquake known as the Alpine earthquake on April 14, 1995. (Cooper et al, 2008). This type of activity will continue to alter the landscape and allow the Big Bend area to continue to resist attempts to map it completely.

**Stereonet Results**

Three areas were given as projects to map with stereonets. In this case the strike and dips were already included and it was simply a matter of plotting them on a stereonet and finding the plane to pole measurements. These areas mapped were the contact of the Ernst and San Vicente contact, the *Allocrioceras hazzardi* Zone, and the Buda and the Ernst contact. The results are included as the final three pages of the Appendix. Given the match up on the three stereonets, it is apparent that the folding, tectonicv activity, and tilting affected all three areas at the same time. There poles and planes cluster in such a way to give the appearance of a shallow dip of just 10 degrees throughout the whole of the area where the contacts were mapped.

**Conclusions**

Conclusions on laboratory work on an area not actually visited can be somewhat sketchy. It is my opinion that although none of the field information was verified in person that it was given as accurate. I have found that certain areas have been affected separately from others by folding or faulting events. Given the sedimentary makeup of the rocks that create the Big Bend National Park, with its alternating bands of varying resistance, it is little wonder that there are so many interpretations to the geological history of the park and the area as a whole. Whether conclusions drawn are correct or not this activity has better prepared me to undertake a field mapping and research project that will be part of field camp in July and August 2009.
Hot Springs, Big Bend National Park, Texas.

Allocococeras hazzardi Zone at Torrillo Creek.

(Photograph taken from Cooper et al., 2008)
SV:MCI-4 Thin limestone layers and carbonate mud/shale intervals with a total thickness of ±125 feet (7.6m).

SV:3-4 Shale Dominantly carbonate mud/shale with rare thin massive limestone beds up to 10 cm thick with a total thickness of ±75 feet (22.9m). Fauna: Large bowl-shaped inoceramids 1 to 1.5 m in diameter (underidentified as of 10/15/97).

SV:MCI-3 Massive limestone layers (40%) and interlayered carbonate mud/shale intervals (60%) with a total thickness of 25 to 30 feet (7.6 to 9.1m). Index Fauna: Cladoceramus undulatoplanus and Sphenoceras sp.

SV:3 Shale Dominantly carbonate mud/shale with occasional thin massive limestone beds up to 10 cm thick with a total thickness of ±90 feet (27.4m). Fauna: Protecanites boureoutianus (d’Orbigny, 1850)

SV:MCI-2 Massive limestone layers (60%) and interlayered carbonate mud/shale intervals (40%) with a total thickness of 40 to 50 feet (12.2 to 15.2m). Index Fauna: Magadoceras complicatus, Platyceramus platius

SV:2-3 Shale Carbonate mud/shale with rare thin massive limestone beds up to 5 cm thick with a total thickness of ±50 feet (15.2m). Index Fauna: Platyceramus platius (in upper 1/3 to 1/2 of unit)

SV:2 Shale Carbonate mud/shale with rare thin massive limestone beds up to 5 cm thick with a total thickness of ±50 feet (15.2m). Index Fauna: Platyceramus platius (in upper 1/3 to 1/2 of unit)

SV:MCI-1 Massive limestone layers 0.5 to 5 cm thick (85%) and interlayered cm scale laminated carbonate mud/shale intervals (15%) with a total thickness of ±80 feet (24.4m).

SV:1-2 Shale Carbonate mud/shale with rare thin massive limestone beds up to 5 cm thick with a total thickness of ±50 feet (15.2m). Index Fauna: Crennoceras deforms erectus, C. crassus crassus Allocococeras hazaridi Zone (±4.2 feet/1.3m thick)

SV:1 Shale Carbonate mud/shale with rare thin massive limestone beds up to 5 cm thick with a total thickness of ±50 feet (15.2m). Index Fauna: Crennoceras deformis erectus

Upper Ernšt-Predominantly carbonate mud/shale intervals (0.5-2cm thick) that alternate with thin massive limestone layers (≤20cm thick). Limestone beds increase in thickness upward through unit and proportion of limestone beds to mud/shale intervals increases from 10/90 to 30/70 upward.

Index Fauna: C. walterdorferi; M. scutipina; M. incertus; I. dakotensis; E. Periplocus

Middle Ernšt-Indurated limestone layers (5-20cm thick) that alternate with thin intervals (±5-15cm) of carbonate mud/shale. Proportion of limestone layers to mud/shale intervals decreases upward from 70/30 to 40/60.

Index Fauna: I. howelli; P. pyattii; C. woolgarit; M. pueblensis

Lower Ernšt-Massive limestone layers (5-20cm thick) that alternate with reddish to yellowish weathering carbonate mud/shale intervals that form couplets ±0.5-1.5m thick. Limestone layers have undulatory tops and bases indicative of current activity and shallow water deposition. Proportion of limestone layers to mud/shale intervals is approximately 40/60. Large meter-scale wavelength oscillation ripple marks with internal cross-bedding occur locally near the top of the unit.

Index Fauna: I. pictus; I. ginerensis; I. prefrugilis; I. rutherfordi; I. arvanus

Other Fauna: M. flavus; ?Hamites simplex; Pseudocococeras angulatense; A. annulatum; Caleyoceans sp.; Ostracoolit; Turritites acutus; T. aranoceras sellardi; Moremanoceras braevoense; Euhystrichoceras adkinsi

(Table Taken from Cooper et. all 2008)

<table>
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<tr>
<th>STAGE AND SUBSTAGE</th>
<th>AGE INTERVAL</th>
<th>AMMONITE</th>
<th>TAKEN FROM</th>
<th>CONTRACTED</th>
<th>PROXIMAL</th>
<th>AMMONITE</th>
<th>COMBINATION</th>
<th>SOUTHWEST HIGH MEXICO 1000 PECS TOTAL</th>
</tr>
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<tr>
<td>Cambrian (Ortho)</td>
<td>585 ± 1.7</td>
<td>Subulina</td>
<td>Cooper et al. 2008</td>
<td>105.0 ± 1.7</td>
<td>105.0 ± 1.7</td>
<td>Subulina</td>
<td>Cooper et al. 2008</td>
<td>105.0 ± 1.7</td>
</tr>
<tr>
<td>Ordovician (Pettina)</td>
<td>585 ± 1.7</td>
<td>Subulina</td>
<td>Cooper et al. 2008</td>
<td>105.0 ± 1.7</td>
<td>105.0 ± 1.7</td>
<td>Subulina</td>
<td>Cooper et al. 2008</td>
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<tr>
<td>Silurian (Oleniense)</td>
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<td>Subulina</td>
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<td>105.0 ± 1.7</td>
<td>Subulina</td>
<td>Cooper et al. 2008</td>
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<tr>
<td>Devonian (Emsian)</td>
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<td>Permian (Guadalupian)</td>
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<td>105.0 ± 1.7</td>
<td>Subulina</td>
<td>Cooper et al. 2008</td>
<td>105.0 ± 1.7</td>
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</tbody>
</table>

(Table Taken from Cooper et al. 2008)
Late Cretaceous Boquillas Formation showing the lowermost part of the San Vicente Member and the uppermost part of the Ernst Member including the *Allocricoceras hazzardi* Zone at the Hot Springs, Big Bend National Park, Texas with Terlingua Creek in the foreground. The Turonian-Coniacian Stage Boundary (±89.3 My ago) is located immediately below the *Allocricoceras hazzardi* Zone.
(Photo Taken from Cooper et al. 2008)

PL 10 Looking north along Javelina Creek, McKinney Spring quadrangle
indicating disharmonic folding of SV:MCI-1 and SV:MCI-2 and thinning of SV:1-2 Shale (SV = San Vicente member of Boguilla Formation)
Geology of the Boquillas Formation, Hot Springs Area, Rio Grande Village and San Vicente Quadrangles, Texas
by Roger W. Cooper, December 29, 2007

Upper part of San Vicente member modified from unpublished geologic maps by J.B. and M.S. Stevens, and D.A. Cooper, 1997.

EXPLANATION

**CRETACEOUS**

**Boquillas Formation**

- **SV** San Vicente Member with identified subunits; SV/MCI-1, SV/MCI-2, SV/MCI-3, and SV/MCI-4
- **E** Ernst Member with *Allococeras hazzardi* (Allo) Zone (red line) defining the top of the Ernst Member. Green line labeled MTM identifies Middle Turonian limestone layer containing *I. howelli* and *P. hyatti*.
- **Geologic contact between units or subunits**
- **Strike (102) and dip (32) of bedding. In this example, 102/32 is N78°W32°SW**
- **Fault showing relative movement; U=Upthrown side; D=Dowthrown side. Nature, attitude, and type of fault identified where determined. Dashed where covered or inferred; question marked (?) where not known.**

Scale = 1:24,000

Figure 37. Geology of the Boquillas Formation, Hot Springs area, Rio Grande Village and San Vicente Quadrangles, Texas.
(Map Taken from Cooper et. al 2008, Stereonet measured section outlined.)
(Map Taken from Cooper et. al 2008, Stereonet Measured area outlined.)
San Vicente Stereonet. Measurements taken by author from map handout.
The Allo Zone Stereonet. Measurements taken by author from map handout.
Buda Ernst Contact Stereonet. Measurements taken by author from map handout.
Works Cited


