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BIOSTRATIGRAPHIC AND ISOTOPIC AGE OF THE HUERFANITO BENTONITE BED OF THE UPPER CRETACEOUS LEWIS SHALE AT AN OUTCROP NEAR REGINA, NEW MEXICO

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Abstract—The Huerfanito Bentonite Bed of the Upper Cretaceous Lewis Shale has been a useful stratigraphic marker bed throughout the subsurface of the San Juan Basin in New Mexico and Colorado. This bed was defined strictly as a subsurface unit because it was not known to crop out in the basin. The recent discovery of an exposure of the Huerfanito Bed at a road cut near the town of Regina, New Mexico, has provided the first opportunity to directly observe and sample this important bed. This work confirms the original assumption that the Huerfanito is an altered volcanic ash bed. It is about 9 in. thick at the Regina site, is in the uppermost part of the *Baculites scotti* Western Interior ammonite zone, and it has a radiometric age of 75.76 ± 0.34 Ma.

INTRODUCTION

The Huerfanito Bentonite Bed was defined in the subsurface of the San Juan Basin by Fassett and Hinds (1971, p. 6). The bed is in the upper part of the Late Cretaceous (Campanian) Lewis Shale and exhibits unique characteristics on geophysical logs. The Huerfanito Bed was named for the Huerfanito Unit 60 well (SW¼ SW¼ sec. 4, T26N, R9W, NMPM) and a type geophysical log from this well was shown by Fassett and Hinds (1971, fig. 2) to display the log characteristics of the bed. At the time the Huerfanito was defined it was not known to crop out anywhere in the basin and it had never been cored in any of the thousands of oil and gas wells that

had been drilled through it. Consequently no sample of the bed had ever been obtained to confirm its lithology or to possibly obtain a radiometric age for the bed. Because of its presence throughout the subsurface of the San Juan Basin, it was assumed that the bed had originated as a large, geologically instantaneous, volcanic ash fall into the Western Interior Seaway during late Campanian time. This marker bed is thus an isochron and has been widely used in numerous publications as a time-stratigraphic datum on geologic cross sections that portray the stratigraphy of Late Cretaceous rocks in the San Juan Basin.

Even though the Huerfanito Bed could not be found on the outcrop in the San Juan Basin, its stratigraphic position within the Lewis Shale, relative to

T. 23 N., R. 1 W.

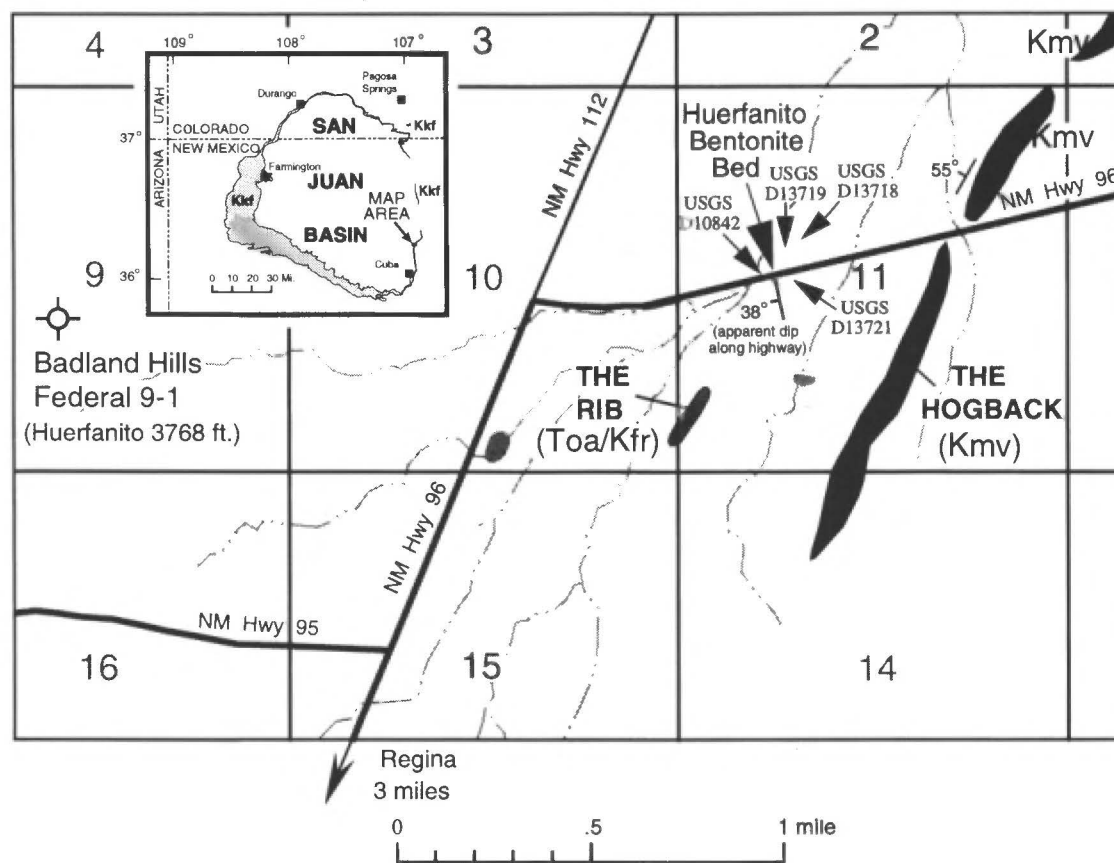


FIGURE 1. Map of the Regina fossil site showing the locations of the Huerfanito Bentonite Bed, USGS fossil collection sites, and the location of the Cotton Petroleum Badland Hills Federal 9-1 drill hole. The Hogback Monocline in the northeast part of the map is held up by the Mesaverde Group (Kmv); the Mesaverde Group consists of the Point Lookout Sandstone, Menefee Formation and Cliff House Sandstone (Fig. 2). The Rib, southwest of the Regina site, is formed by the Tertiary Ojo Alamo Sandstone (Toa) and the Cretaceous Fruitland Formation (Kfr). The inset map of the San Juan Basin shows the location of the Regina site map area in the southeast part of the basin and the distribution of the Kirtland Shale and Fruitland Formation, undivided (Kkf).

the overlying Pictured Cliffs Sandstone and underlying Cliff House Sandstone, was well known in the subsurface, and thus, the approximate position of the Huerfanito at the outcrop could be projected with a high degree of confidence. Fassett (1987) summarized all known information regarding published ammonite-fossil collection sites from the upper part of the Lewis Shale at several localities around the periphery of the basin and estimated the boundary levels of the six upper Lewis Shale Western Interior ammonite zones (*Baculites scotti* to *B. compressus*) relative to the Huerfanito Bed (published ammonite-collection data for the San Juan Basin were from Cobban, 1973, and Cobban et al., 1974). Because radiometric ages had been determined for altered volcanic ash beds in many of the Western Interior ammonite zones at various localities throughout the Western Interior (Obradovich and Cobban, 1975), it was possible, by projection, to estimate the ages of the strata laterally equivalent to the six upper Lewis Shale Western Interior ammonite zones. Fassett (1987) suggested that the Huerfanito Bentonite Bed was in the upper part of the *B. scotti* zone and had an age in excess of 73.9 Ma.

In 1992, USGS geologists Bill Cobban and K Molenaar, en route from Denver, Colorado to Gallup, New Mexico, to conduct field work, made a short detour outside of Cuba, NM, to spend an hour at an old ammonite collection site of Cobban's about 4 mi north of the small town of Regina, New Mexico (Fig. 1). They arrived at the site, in a light rain, near sundown and had very little time to search for ammonites, but while there, Molenaar discovered an altered volcanic ash bed and collected a sample of it. They spent that night in Cuba and the next day traveled on to Gallup. Upon his return to Denver, Molenaar submitted the ash-bed sample to John Obradovich for a radiometric age determination, describing the sample as probably coming from the Huerfanito Bentonite Bed. The ash yielded an initial age of 75.89 ± 0.72 Ma (Obradovich, 1993). The ash was subsequently redated in 1995 (Table 1) at 75.76 ± 0.34 Ma.

THIS STUDY

Geologic setting of Regina site

The Regina fossil site is located at a road cut in the Lewis Shale about 16 mi north of Cuba, N.M. (Fig. 1). The road cut is along NM Highway 96 about 0.7 mi east of the point where NM-96 makes a right-angle turn to the east at its intersection with NM-112 (Fig. 1). The road cut is low, about 15 ft high on the north side of the road, and the Lewis is covered in this cut, for the most part, by a thin veneer of black to gray soil. On the south side of the highway, the road cut is much higher and steeper and is covered by a thicker layer of soil. Fossil collection efforts were concentrated in the road cut on the north side of the highway. Several calcite-concretion zones are visible through the soil cover in this road cut. This zone of concretions has made the Lewis Shale more resistant to erosion in this area, creating a prominent, but relatively low, northeast-trending topographic ridge (see Regina USGS 7.5' topographic quadrangle map). The large, prominent hogback about 0.7 mi east of the Regina site is held up by the Mesaverde Group (Fig. 1). The feature labeled The Rib on Figure 1 (southwest of the Regina site) is held up by the steeply dipping Tertiary Ojo Alamo Sand-

stone underlain by about 100 ft of Cretaceous Fruitland Formation. At The Rib, the Pictured Cliffs Sandstone is absent and the Fruitland rests directly on the Lewis Shale. A stratigraphic section for this area (Fig. 2) is interpreted from the geophysical log of the Cotton Petroleum Badland Hills Federal 9-1 drill hole located in the NE¼ SW¼ sec. 9, T23N, R1W (Fig. 1). This drill hole is 1.9 mi west of the Regina site (Fig. 1) and the Huerfanito Bed is at a depth of 3768 ft in this hole (Fig. 2).

The dip of the Mesaverde Group rocks on the Mesaverde Hogback is 55° to the northwest (Fig. 1). The apparent dip of the Lewis Shale along the highway at the Regina site is 38° to the southwest. This apparent dip appears to be consistent along the highway and was used to measure the stratigraphic levels of the ammonite collection sites above and below the Huerfanito Bentonite Bed outcrop along NM-96. The Huerfanito outcrop is relatively inconspicuous but is marked by a large, elongate, calcite-concretion block (about 2 ft in diameter), the base of which is in the Huerfanito. The Huerfanito is about in the middle of the Lewis road cut (Fig. 3); it is about 9 in. thick and has been replaced by calcium carbonate. A small sample of this bed was dissolved in hydrochloric acid and found to contain sanidine crystals similar to those in the Huerfanito above the calcite block where the ash bed is not replaced by calcium carbonate. The ash bed is yellow-brown in color. The original sample collected by Molenaar was from the clayey part of the bed.

Fossil localities and fossil identification

Our Lewis Shale fossil collections were made at four localities at the Regina site; one locality was stratigraphically above and the other three stratigraphically below the Huerfanito Bed. USGS fossil locality D10842 is on the north side of NM-96 and is in gray and brown limestone concretions at the westernmost end of the Lewis Shale road cut a few feet above the road level (Fig. 1). A deep gully is just west and north of this locality. The stratigraphic position of this collection site is 121 ft above the Huerfanito Bentonite Bed (Fig. 2). Fossils identified from this collection include *Pteria linguaformis* (Evans and Shumard), *Inoceramus sublaevis* Hall and Meek, and *Didymoceras nebrascense* (Meek and Hayden). Locality D13719 is a few hundred feet north of the NM-96 road cut along the northeast-trending ridge held up by the zone of limestone concretions. The stratigraphic level of this locality is about 25 ft below the Huerfanito Bed. *Ichthyosarcodites coraloidea* (Hall and Meek) was identified at this locality. This fossil has no precise age significance but it belongs to an extinct group of aberrant bivalves known as rudists. Specimens are rare in the Western Interior. For a description and illustration of the type specimen of *I. coraloidea*, see Hall and Meek (1856, p. 380, pl. 1, fig. 3a-f).

USGS fossil locality D13718 is in gray- to orange-weathering limestone concretions about 2–3 ft beneath large, closely spaced, orange-weathering, septarian limestone concretions. This site is 105 ft stratigraphically below the Huerfanito Bentonite Bed (Fig. 2). Fossils identified from this collection include *Nucula* sp., *Pteria linguaformis* (Evans and Shumard), *Placentoceras* sp., *Didymoceras binodosum* (Kennedy and Cobban), and *Baculites scotti* Cobban. USGS locality D13721 (south of NM-96) is in

TABLE 1. Analytical data for $^{40}\text{Ar}/^{39}\text{Ar}$ age determinations for sanidine crystals from a sample of the Huerfanito Bentonite Bed collected by C.M. Molenaar in 1992 at the Regina fossil site (Fig. 1).

Ash bed name and J value	Irradiation number	Mineral analysis	Run. number	40Ar/39Ar	37Ar/39Ar	36Ar/39Ar	K/Ca	%40Ar*	40Ar*/39Ark	Age (Ma)	1 sigma
Huerfanito Bed	JD021-4	Sanidine	95Z0514	5.94189	0.006248	0.000045	78.42	99.63	5.92029	75.74	0.25
<i>Baculites scotti</i> J=0.007243		single Xl	95Z0515	5.95008	0.006189	0.000129	79.17	99.22	5.90369	75.54	0.28
			95Z0516	5.99998	0.006300	0.000216	77.78	98.79	5.9279	75.84	0.32
			95Z0517	5.97914	0.005509	0.000055	88.94	99.58	5.95435	76.17	0.29
			95Z0518	5.93312	0.006025	0.000081	81.33	99.45	5.90085	75.50	0.26
Unweighted mean and error of the mean at the 95% confidence level including the error in J										75.76	0.34

$^{40}\text{Ar}^*$ in table = radiogenic argon

Ca and K corrections and decay constants

$$(^{36}\text{Ar}/^{37}\text{Ar})_{\text{Ca}} = 2.69 \pm 0.24 \times 10^{-4}$$

$$(^{39}\text{Ar}/^{37}\text{Ar})_{\text{Ca}} = 6.79 \pm 0.051 \times 10^{-4}$$

$$(^{40}\text{Ar}/^{39}\text{Ar})_{\text{K}} = 9.1 \pm 5.4 \times 10^{-3}$$

$$I_1 + I_2 = 0.581 \times 10^{-10} \text{ yr}^{-1}$$

$$I_3 = 4.962 \times 10^{-10} \text{ yr}^{-1}$$

$$^{40}\text{K}/\text{K} = 1.167 \times 10^{-4} \text{ atom/atom}$$

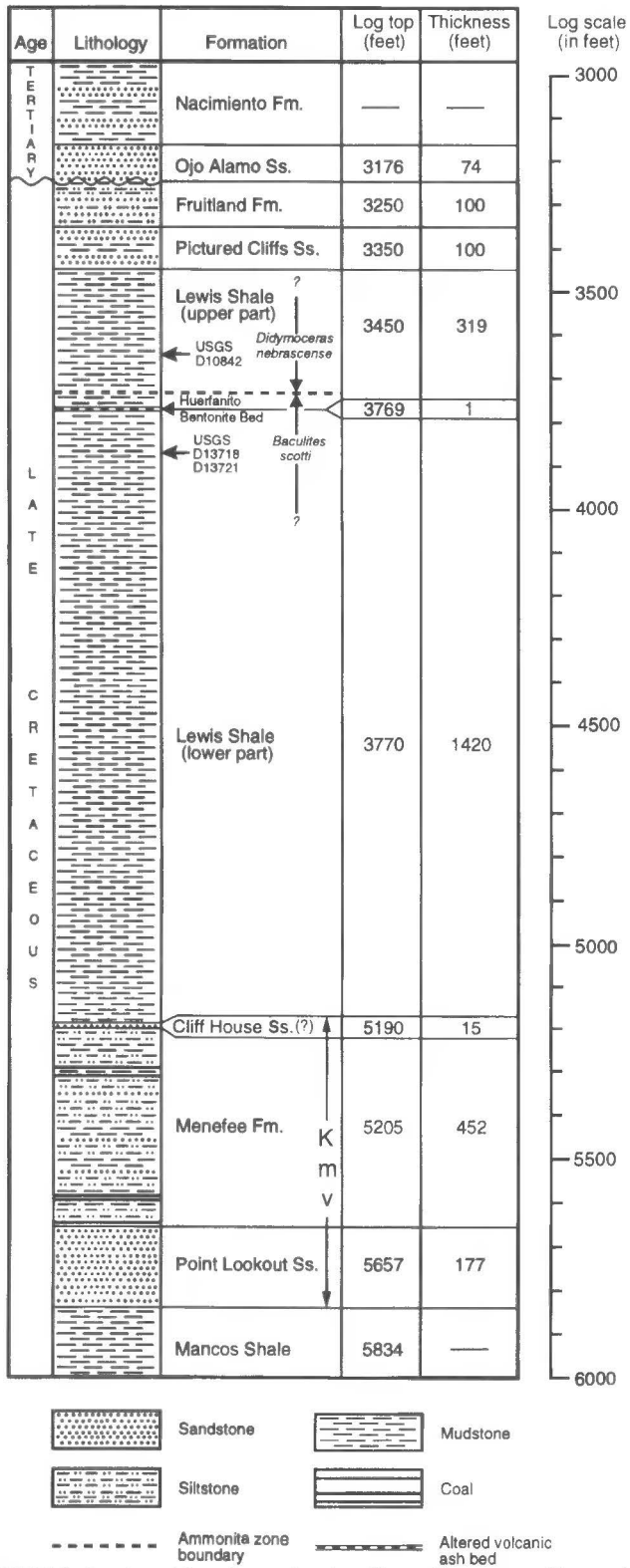


FIGURE 2. Stratigraphic column showing Upper Cretaceous (Campanian) rocks in the vicinity of the Regina fossil site. Formation boundaries shown are interpreted from the geophysical logs of the Badland Hills Federal 9-1 drill hole (Fig. 1). Kmv refers to the Mesaverde Group. The Cliff House Sandstone is shown queried because the sandstone on the geophysical log at this level may be a fluvial sandstone in the Menefee rather than the shoreface marine Cliff House. The projected stratigraphic positions of the Regina area USGS fossil collection sites are shown; D10842 at 121 ft above the Huerfanito Bed and D13718 and D13721 at 105 ft below the Huerfanito. The estimated position of the *D. nebrascense/B. scotti* boundary, 35 ft above the Huerfanito Bed is also shown.



FIGURE 3. Huerfanito Bentonite Bed at the Regina fossil site. Photograph taken looking north at road cut in the Lewis Shale on NM-96. Large limestone concretion in center of photograph is in the Huerfanito Bed. Huerfanito is uncovered in lower part of photograph (at arrow point). Note hammer for scale.

limestone concretions just beneath the bed of orange-weathering, septarian limestone concretions noted at locality D13718, and thus is at the same stratigraphic level—105 ft below the Huerfanito Bed—as locality D13718. Fossils from this locality include *Inoceramus convexus* Hall and Meek and *Baculites scotti* Cobban.

Discussion

Identification of Huerfanito Bentonite Bed

An important question about the Regina site is: how can we be sure that the altered volcanic ash bed that crops out here and sampled by Molenaar is really the Huerfanito Bentonite Bed?

The Huerfanito Bed has been identified on the geophysical log of the Badland Hills Federal 9-1 drill hole located just 1.9 mi west of the Regina site (Fig. 1). In addition, the Huerfanito has been correlated widely from the Federal 9-1 hole to many other drill holes. The distance from the Huerfanito Bed to the top of the Mesaverde Group in the 9-1 drill hole is 1420 ft (Fig. 2). The horizontal distance from the top of the Mesaverde Group to the Huerfanito Bentonite Bed along NM-96 is 2380 ft. Multiplying this horizontal distance along NM-96 (2380 ft) times the sine of 38° (0.6157) equals 1465 ft. This thickness is 45 ft less than the thickness of the interval of 1420 ft in the Federal 9-1 drill hole (Fig. 2); however, this thickness difference could easily be accounted for by only a slight variation of the dip of the Lewis strata over the nearly half-mile distance from the Huerfanito outcrop to the top of the Mesaverde Group outcrop or by a change in thickness of this interval between the Federal 9-1 hole and the Regina site outcrop. Also, the absence of other altered ash beds at the Regina site road cut leaves little doubt that the ash bed discovered here by Molenaar is indeed the widespread Huerfanito Bentonite Bed.

Another piece of evidence lends support to the identification of the Huerfanito Bed at the Regina locality. An altered volcanic ash bed from a

coal bed in the Fruitland Formation in the southwest part of the San Juan Basin (a few miles south of the Bisti Badlands) was analyzed by Obradovich and found to have a radiometric age of 75.56 ± 0.41 Ma (Fassett and Steiner, this volume). These authors state: "The Huerfanito Bentonite Bed is projected to lie 95 feet below the DEP (Dog Eye Pond) ash bed (Figs. 1, 4) in the southwest part of the San Juan Basin. The age of ash DEP is 75.56 ± 0.41 Ma. At a rate of deposition for the interval between the DEP ash and ash 2 [a stratigraphically higher dated ash bed] of 106 m/ma., the extrapolated age of the Huerfanito is 75.83 Ma." The virtually identical ages of the Huerfanito at Dog Eye Pond (projected) and at the Regina site (measured) of 75.83 Ma and 75.76 Ma, respectively, provide independent supporting evidence that the ash bed cropping out at the Regina site is the Huerfanito Bentonite Bed.

Thickness of the Huerfanito Bentonite Bed

Fassett and Hinds (1971, p. 6) estimated that the Huerfanito Bentonite Bed was 12 ft thick on the geophysical log of the Huerfanito Unit 60 well. This estimate was based on measuring the distance between the inflection points for the Huerfanito on the conductivity log for this well. In the years following publication of that report measurements of altered volcanic ash beds from Late Cretaceous rocks at numerous sites in the San Juan Basin have shown that the *maximum* thickness of these ash beds is 1.5 to 2 ft (Fassett and Steiner, this volume). In addition, experience gained by comparing geophysical log responses to drill core from the same drill hole shows that a relatively thin bed (1 ft or less) of contrasting physical characteristics will often exhibit a greatly exaggerated log response, in terms of thickness of the bed. Consequently, the discovery that the outcropping Huerfanito Bed at the Regina site measured only 9 in. thick came as no great surprise. It is important, however, to here formally correct the greatly exaggerated thickness of 12 ft for the Huerfanito Bed reported by Fassett and Hinds (1971). The Huerfanito may well be thicker than 9 in. in the subsurface of the San Juan Basin, but its maximum thickness there is probably no greater than the maximum thickness of altered ash beds in outcrops in the San Juan Basin of from 1.5 to 2 ft.

Fassett (1987) estimated that the boundary between the *Didymoceras nebrascense* and the *Baculites scotti* ammonite zones was located 200 ft above the Huerfanito Bentonite Bed in the San Juan Basin. That determination was based on collections of ammonites at several localities around the periphery of the basin as reported in Cobban (1973) and Cobban et al. (1974). Table 2 shows that the stratigraphic position of the *B. scotti* zone is 50 ft below the base of the Huerfanito Bed at USGS locality D4796 at the Barker Dome area. The *B. scotti* collections at the Regina site are 105 ft below the Huerfanito; thus these collections do not help to narrow the interval containing the *D. nebrascense/B. scotti* boundary. The *D. nebrascense* collection at the Regina site is 121 ft above the Huerfanito compared to the previous nearest position of this ammonite at 260 ft above the Huerfanito at the Barker Dome site. Thus, the new ammonite data from the Regina site narrow the possible position of the *D. nebrascense/B. scotti* boundary to between 50 ft below the Huerfanito and 121 ft above the Huerfanito. Assuming the boundary is halfway between these positions, we estimate that the *D. nebrascense/B. scotti* boundary is 35 ft above the top of the Huerfanito Bed. The occurrence of *Didymoceras binodosum* at

the D13718 fossil locality in association with *B. scotti* supports the placement of the *D. nebrascense/B. scotti* boundary well above the Huerfanito because this ammonite indicates a position in the middle of the *B. scotti* ammonite zone. This placement of the ammonite zone boundary confirms that the Huerfanito Bed is in the uppermost part of the *B. scotti* Western Interior ammonite zone as reported by Fassett (1987) and Fassett and Steiner (this volume).

Conclusion

A more accurate biostratigraphic placement of the Huerfanito Bentonite Bed in the uppermost part of the *Baculites scotti* zone helps to more precisely interpret the stratigraphy of Upper Cretaceous rocks in the San Juan Basin. This more exact placement of the Huerfanito will now make it easier to find and identify the Huerfanito at other localities in the Western Interior where the stratigraphic position of the *D. nebrascense/B. scotti* ammonite zone boundary has been located. Because the Huerfanito is present across the entire San Juan Basin there is good reason to think that this important San Juan Basin marker bed may also be present in other Western Interior basins. In addition, the precise age of the Huerfanito of 75.76 ± 0.34 Ma, virtually at the *D. nebrascense/B. scotti* Western Interior ammonite zone boundary, essentially dates that zone boundary. This knowledge now allows the projection of this age to other parts of the Western Interior where the biostratigraphic boundary is well documented but the radiometric age of the rocks containing the boundary has not been determined.

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TABLE 2. Localities and stratigraphic positions, relative to the Huerfanito Bentonite Bed, of known *Didymoceras nebrascense* and *Baculites scotti* fossil collections in the San Juan Basin, New Mexico (adapted from table 2 of Fassett, 1987); numbers in bold from Regina fossil site.

Western Interior ammonite zone	U.S. Geological Survey fossil locality number	Distance above (+) or below (–) Huerfanito Bentonite Bed (feet)
<i>Didymoceras nebrascense</i>	D4834 ¹	+400
	D4797 ²	+260
	D10842³	+121
<i>Baculites scotti</i>	D4796 ²	– 50
	D13718³	– 105
	D13721³	– 105

¹Llaves locality (Cobban and others, 1974; Fassett, 1987)

²Barker Dome locality (Cobban, 1973; Fassett, 1987)

³Regina locality (this report)