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AGE OF THE CRETACEOUS MENEFEE FORMATION, GALLINA HOGBACK, RIO ARRIBA COUNTY, NEW MEXICO

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Abstract.—At the Gallina hogback on the eastern edge of the San Juan Basin, the Menefee Formation is ~180 m thick. It consists of trough crossbedded and thinly laminated sandstone beds, between which are mudstone, coal and coaly mudstone beds. Previous age interpretations of the Menefee have been based on the ammonite biostratigraphy of the underlying and overlying strata. An Ar/Ar age of 78.22±0.26 Ma of an ash bed high in the Menefee section indicates a middle Campanian age, but is not consistent with previously published radioisotopically-calibrated ammonite biostratigraphy. Also, we report a pollen assemblage collected from throughout the Menefee section at that Gallina hogback that indicates an age of late Santonian to early Campanian). We conclude that the the Menefee Formation at the Gallina hogback is best assigned an early Campanian age, about 81 Ma, but that uncertainty remains in assigning a precise age until the discrepancies between ammonite biostratigraphy, palynostratigraphy and radioisotopic dating are fully resolved.

INTRODUCTION

The Menefee Formation of northwestern New Mexico and southwestern Colorado is the middle, coal-bearing unit of the classic Mesaverde Group. It represents deposition during a Campanian regressive-transgressive cycle of deposition along the western margin of the Interior Seaway (R4-T5: Molenaar, 1983, fig. 4). The age of the Menefee Formation is usually constrained by the ammonite biostratigraphy of underlying and overlying marine strata. However, direct age dates from the Menefee Formation, itself, are sparse. Here, we report age data on the Menefee Formation at the Gallina hogback along the eastern edge of the San Juan Basin, New Mexico (Figs. 1-3). These are contradictory radioisotopic and palynological data, a conflict apparently but not certainly resolved by relying on the radioisotopically-dated ammonite biostratigraphy.

LITHOSTRATIGRAPHY

A homoclinal ~180 m thick section of the Menefee Formation was measured along the Gallina hogback (Figs. 1-3). Throughout the Gallina hogback the Menefee Formation conformably overlies the sandstone-dominated Point Lookout Sandstone and is unconformably overlain by the Cliff House Sandstone (Iacoboni, 2005).

At the Gallina hogback, the Menefee Formation is mostly sandstone beds that range in thickness from less than a meter to 23 m at the top of the section. Between these sandstones are beds of mudstone, coal and coaly mudstone. The mudstones and coaly mudstones are typically 3 m thick or less. The coal beds low in the section are 0.6 m or less, whereas higher in the section they are up to 1.6 m thick.

The thicker (5 m or more) sandstone beds are crossbedded, whereas the thinner beds are laminar, occasionally interlaminated with mudstones. Many of the sandstone beds are sideritic. The mudstones are usually gray to black. The coaly mudstones are typically brown and less than 3 m thick.

The Menefee Formation at the Gallina hogback can be divided into three units, two of which may correlate to the two Menefee members recognized elsewhere in the San Juan Basin (e.g., Molenaar, 1983). The lower unit (approximately units 10-30: Fig. 2; possibly correlative to the Cleary Coal Member) is coal-bearing and marks the regressional transition from shoreline to nonmarine conditions and includes lithofacies representative of a range of depositional conditions from storm-derived beach washover to quiet water lagoonal conditions, grading upward to swampy fluvial conditions. The middle unit (approximately units 32-82: Fig. 3; possibly correlative to the Allison Member) is mostly trough-crossbedded sandstone deposited under fluvial conditions. The upper coal member (approximately units 83-103: Fig. 2) at the Gallina hogback represents the transgressional approach of the shoreline. Sandstone units in this interval show evidence of deposition in an estuarine environment as fluvial channels were back flooded by the advancing sea. They are overlain by a transgressive lag at the base of the Cliff House Sandstone that was formed as the advancing beach reworked the upper Menefee Formation.

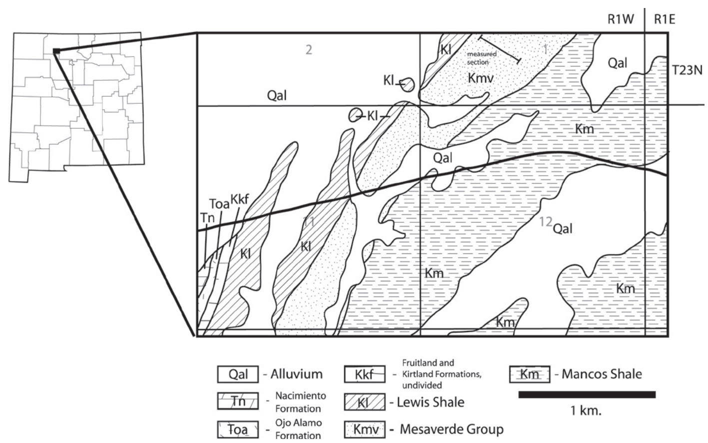

FIGURE 1. Geological map of part of the Gallina hogback in northern New Mexico, showing the location of the measured section and dated ash bed in the Menefee Formation.

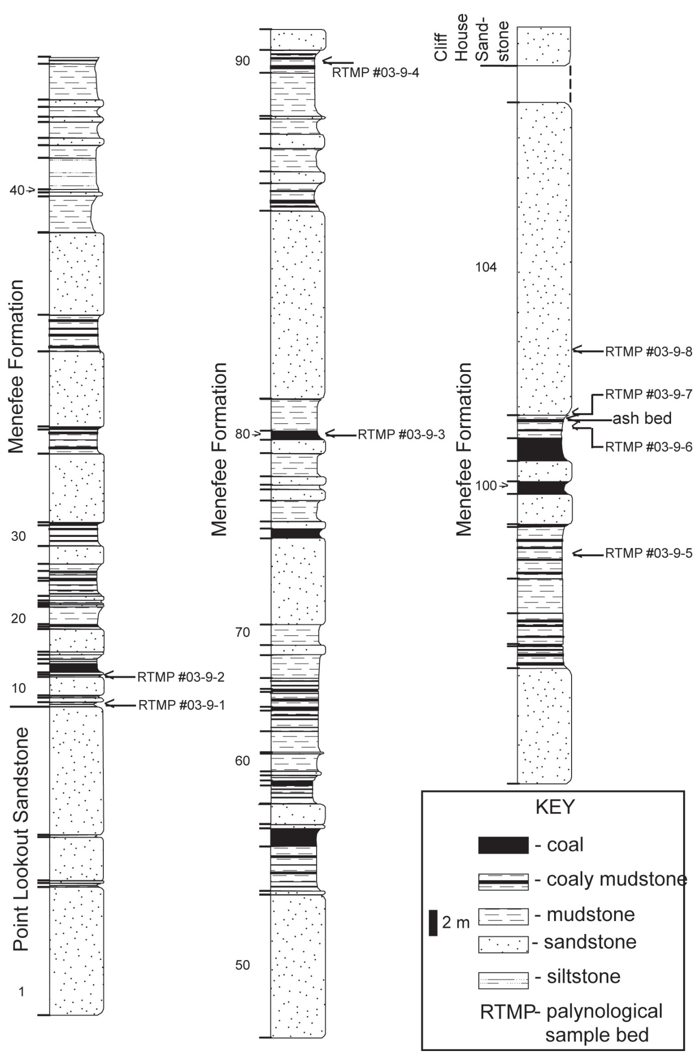

FIGURE 2. Measured stratigraphic section of the Menefee Formation at the Gallina hogback. Note selected unit numbers on left of column. Section measured by B. Brister, J. Amarante, W. Peabody and T. H. McElvain, Jr.

RADIOISOTOPIC DATE

In the upper part of the Menefee Formation at the Gallina hogback, we collected three tonstein samples and two bentonite samples. One of these, a single bentonite sample from the upper part of the Menefee Formation at the Jaquez Mine, was selected as the most promising, and a fine-grained, <60 mesh sanidine separate was prepared. The separate was analyzed as a sequence of multigrain bulk samples using the laser fusion method (Peters, 2001). The age data are displayed on a probability distribution diagram (Deino and Potts, 1992) (Fig. 4).

A weighted mean age of 78.22 ± 0.26 Ma is assigned to 24 of the 28 analyses of the Jaquez Mine bentonite (Fig. 4). These 24 analyses yield a Gaussian distribution with an acceptable MSWD of 1.1. The remaining four analyses yield ages ranging from 81.24 to 83.26 Ma.

The weighted mean age calculated from 24 of the 28 analyses of the Jaquez Mine sanidine (78.22±0.26 Ma) was interpreted as the eruption age of this sample (Peters, 2001; Amarante et al., 2002). We note that there is minor xenocrystic contamination of the sample, but that only four analyses seem to be affected.

On the Obradovich (1993) numerical timescale for the Cretaceous (also see the Gradstein et al., 2004 timescale), 78 Ma is a middle Campanian age, approximately equivalent to the *Baculites gilberti* ammonite zone (Fig. 5; Obradovich, 1993; Nicholls, 1994, fig. 2). In the palynostratigraphic zonation of Nicholls (1994), this age is in the lower part of the *Aquillapollenites quadrilobus* interval zone (Fig. 5).

PALYNOSTRATIGRAPHY

We collected eight samples of carbonaceous mudstone through the entire Menefee Formation section at the Gallina hogback for palynological analysis (Fig. 2). Six of the samples yielded diverse and well-preserved palynomorphs (Table 1).

The palynomorph assemblages suggest an age of late Santonian to earliest Campanian. However, this is based on carrying

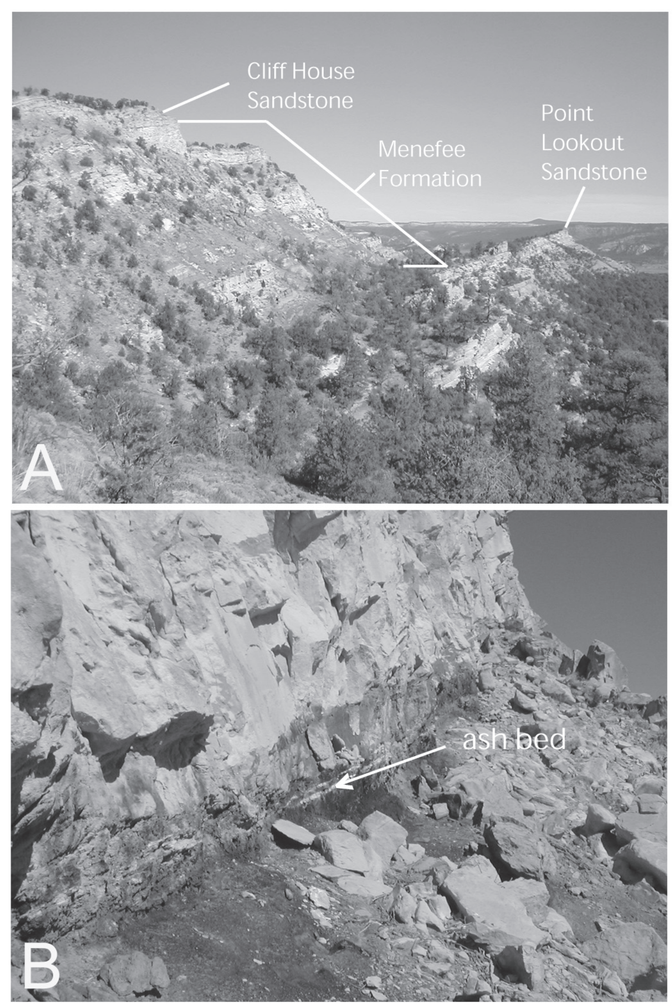

FIGURE 3. Outcrops of the Menefee Formation at the Gallina hogback. A, Overview of Point Lookout Sandstone, Menefee Formation, and Cliff House Sandstone. B, Close up of dated ash-bed in the upper part of the Menefee Formation.

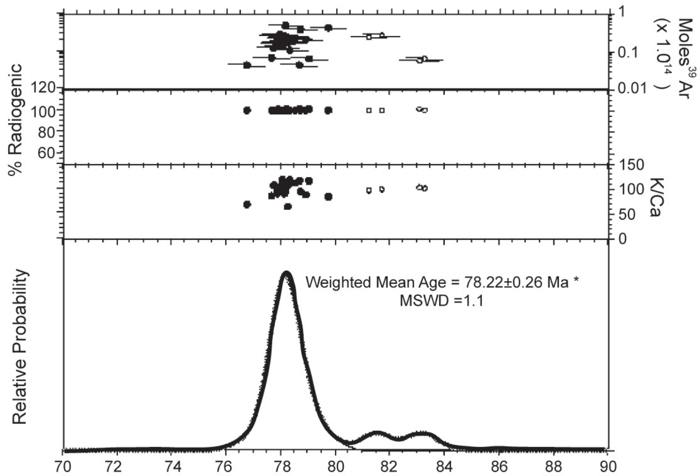

FIGURE 4. Radioisotopic age analysis of the Jaquez Mine bentonite sample. From Peters (2001).

information obtained to the north a considerable distance to the south, so there may be some inaccuracies inherent in this determination. The assemblages have elements that appear very similar to those seen in the Milk River Formation of southern Alberta, Canada (Braman, 2002) and to the Telegraph Creek and lower Eagle formations of Montana (Payenberg et al., 2002). The assemblages lack any of the indicators of the upper lower Campanian such as *Siberiapollis* and *Aquilapollenites*, which occur in the upper Eagle, Claggett and Pakowki formations to the north. The lack of these types of pollen suggests that the samples are older than those studied from the Tohatchi Formation, where they were noted (Lucas et al., 2003). The Menefee hogback assemblages are similar to those described by Tschudy (1976) and Jameossanaie (1987) from the Menefee Formation in the San Juan Basin to the Gallup area.

DISCUSSION

Regional age constraints for the Menefee Formation can be derived from the ammonite biostratigraphy of underlying and overlying marine strata (Fig. 5). In northwestern New Mexico, the R-4 regression is represented by the upper part of the Satan Tongue of the Mancos Shale, Point Lookout Sandstone, and the lower part of the Menefee Formation (Clearly Coal Member and homotaxial strata). The T-5 transgression is represented by the upper part of the Menefee Formation, Cliff House Sandstone and lower part of the Lewis Shale. Indeed, the turnaround point from R-4 to T-5 is approximated by the middle, sandstone-dominated part of the Menefee Formation.

Ammonite- and inoceramid-dominated invertebrate fossil assemblages of the Satan Tongue of the Mancos Shale range in age from late Santonian (~*Clioscaphites choteauensis* zone) to early Campanian (~youngest of *Scaphites hippocrepis* zones) (Reeside, 1927; Dane, 1948; Molenaar, 1983). Direct age control of the top of the Mancos Shale is not known at the Gallina hogback, but is known to the north in T26N, R1E (Dane, 1948) and to the south in T20N, R1W (locality 185 of Reeside, 1927). The Point Lookout Sandstone has a stratigraphic rise of nearly 400 m across the San Juan Basin, and parallels the generally younger-toward-the-northeast trend of the Satan Tongue. These age constraints indicate that the Menefee Formation at the Gallina hogback cannot be older than the base of the Campanian.

The oldest age of the Lewis Shale above the Cliff House Sandstone is early Campanian (~*Baculites obtusus* zone). Indeed, the *Baculites obtusus* zone is known from about 62 m above the Lewis Shale base at USGS locality D4534 in the SW1/4 NE sec. 11, T23N, R1W, less than 2 km southwest of the Gallina hogback section studied here (Cobban et al., 1974). This sets a minimum age for the Menefee Formation at the Gallina hogback. The Menefee Formation there thus encompasses part of early Campanian

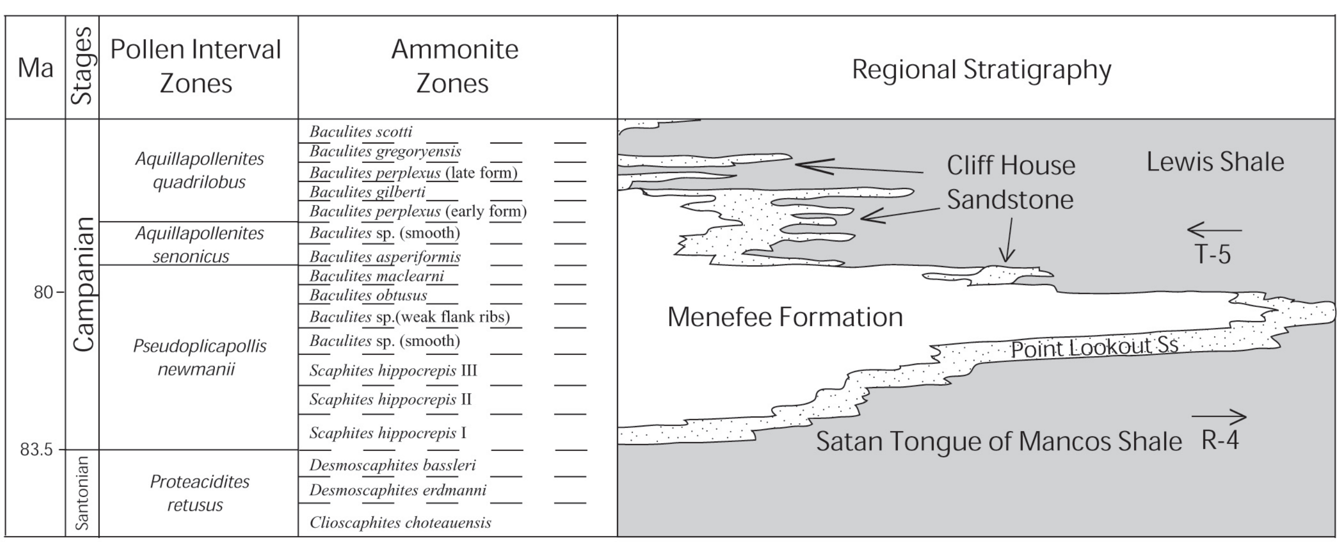

FIGURE 5. Regional stratigraphic and age relationships of the Menefee Formation (modified from Molenaar, 1983).

time and can be dated using the Obradovich (1993) radioisotopic calibration of the ammonite biostratigraphy as about 81 Ma.

The radioisotopic age of the ash bed near the top of the Menefee Formation is not consistent with the radioisotopically-calibrated ammonite data. Thus, 78 Ma is a middle Campanian age approximated by the *Baculites gilberti* ammonite zone. This is an age for the upper part of the Menefee Formation at the Gallina hogback too young to be consistent with the radioisotopically-calibrated regional ammonite biostratigraphy. However, note that the radioisotopic control of the middle Campanian ammonite zones (see Obradovich, 1993, fig. 2) is sparse and interpolate between ~ 80 Ma and ~ 75 Ma ages. This opens up the possibility that more radioisotopic ages in the middle Campanian may modify the numerical age estimates of the ammonite zones in this time interval.

The three dating methods (ammonites, radioisotopic date and palynostratigraphy) thus do not fully agree on the age of the Menefee Formation at the Gallina hogback. If the radioisotopic age is correct, then much radioisoptic-age control of the regional ammonite biostratigraphy must be off by about 3 million years. The palynostratigraphy much more closely agrees with the ammonite biostratigraphy. On face value, the pollen suggests a late Santonian or early Campanian age and thus supports the ammonite-based age.

Particularly important here is the possibility that there is a transgressive unconformity at the base of the Cliff House Sandstone, and this might mean the Menefee is much older than the *Baculites obtusus* zone, which is the first ammonite record above that unconformity. Another possibility, however, is that the ammonite control provided by USGS locality D4534 (*Baculites obtusus* zone in the lower Lewis Shale at the Gallina hogback) is not definitive, as it is based on specimens only identified as *B.* cf. *B. obtusus* (Cobban et al., 1974, p. 279).

Therefore, at the Gallina hogback, the ammonites suggest the Menefee Formation is early Campanian, and the palynostratigraphy is consistent with that. The numerical age of ~78 Ma, however, is much younger than the biostratigraphy indicates. Obviously, the best interpretation of the isotopic data (Fig. 4) is that they support a 78 Ma eruption age. Thus, at present an early Campanian age for the Menefee Formation at the Gallina hogback is well supported by biostratigraphy but inconsistent with the radioisotopic age of ~ 78 Ma. More work is needed to resolve this inconsistency.

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TABLE 1. Distribution of palynomorphs and some other microfossils in the Menefee Formation at the Gallina hogback.

Taxon	Section Unit 7 (RTMP #03-9-1)	Section Unit 11 (RTMP #03-9-2)	Section Unit 80 (RTMP #03-9-3)	Section Unit 90 (RTMP #03-9-4)	Section Unit 97 (RTMP #03-9-5)	Section Unit 103 (RTMP #03-9-5)	Base of Unit 104 (RTMP #03-9-6)	5 m. above base of Unit 104 (RTMP #03-9-7)
Accuratipollis lactiflumis Braman 2002					X			
Appendicisporites undosus Hedlund 1966						X		
Appendicisporites sp. C of Braman 2002			X					
Arecipites tenuiexinous Leffingwell 1971			X					
Baculatisporites comaumensis (Cookson) Potonié 1956					X			
Biretisporites deltoidus (Rouse) Dettmann 1963					X	X		
Brevimonosulcites corrugatus Yu & Zhang 1987				X	X	X		X
Callialasporites dampieri (Balme) Dev 1961			X		X	X		X
Camarozonosporites ambigens (Fradkina) Playford 1971			X		X	X	X	
Camarozonosporites sp.						X		
Cicatricosisporites cuneiformis Pocock 1964			X		X			X
Cingutriletes sp.						X		
Circulina parva Brenner 1963					X	X		
Circumflexipollis tilioides Chlonova 1961								X
Concavissimisporites punctatus (Delcourt & Sprumont) Brenner 1963								X
Cyathidites australis Couper 1953					X			
Cyathidites minor Couper 1953			X	X	X	X		
Deltoidospora diaphana Wilson & Webster 1946			X			X		
Enzonalasporites bojatus Braman 2002			X				X	
Foraminisporis semiscalaris (Paden Phillips & Felix) Braman 2002			X		X			
Foraminisporis undulatus Leffingwell 1971						X		
Foveogleicheniidites confossus (Hedlund) Burger *in* Norvick & Burger 1976				X				
Fraxinoipollenites sp.							X	
Gabonisporis labryinthus Srivastava 1972			X		X			
Gleicheniidites delicatus (Bolkhovitina) Pocock 1970					X	X	X	
Gleicheniidites senonicus Ross 1949			X		X	X	X	
Hamulatisporis hamulatisi Krutzsch 1959			X	X				
Hazaria sheopiarii Srivastava 1971				X				
Heliosporites kemensis (Chlonova) Srivastava 1972								X
Inaperturotetradites scabratus Tschudy 1973			X	X				
Indeterminate algae	X	X						
Klukisporites sp.						X		X
Kuprianipollis sp.						X		
Kuylisporites scutatus Newman 1965						X		
Laevigatosporites haardti (Potonié & Venitz) Thomson & Pflug 1953			X	X	X	X	X	
Leptolepidites crepitus Braman 2002				X				
Liliacidites sp.				X				
Monosulcites riparius Braman 2002						X		
Palaeoisoetes subengelmannii (Elsik) Nichols 2002					X			
Penetetrapites inconspicuus Sweet 1986					X			
Periretisyncolporites chinookensis Braman 2002						X		
Pityosporites constrictus Singh 1964								X
Plicapollis retusus Tschudy 1975			X			X		
Podocarpidites canadensis Pocock 1962			X					
Polycingulatisporites reduncus (Bolkhovitina) Playford & Dettmann 1965								X
Pristinuspollenites microsaccus (Couper) Tschudy 1973								X
Proteacidites thalmanni Anderson 1960			X	X	X	X	X	
Quadripollis krempii Drugg 1967								X
Reticuloidosporites pseudomurii Elsik 1968					X	X	X	
Ruffordiaspora australiensis (Cookson) Dettmann & Clifford 1992)			X					
Schizosporis parvus Cookson & Dettmann 1959	X							
Selaginella simplex Krasnova 1961			X		X	X		
Sequoiapollenites paleocenicus Stanley 1965					X			
Sestrosporites pseudoalveolatus (Couper) Dettmann 1963			X			X	X	
Stenozonotriletes dedaleorimosus Fradkina 1967								
Stereisporites antiquasporites (Wilson & Webster) Dettmann 1963					X	X		
Stereisporites cingulatus Krutzsch 1963			X		X	X	X	
Taxodiaceaepollenites hiatus (Potonié) Kremp 1949					X	X		
Taxodiaceaepollenites vacuipites (Wodehouse) Wingate 1980								X
Triporopollenites sp. C of Braman 2002				X	X	X		
Weylandipollis sp.								
Zlivisporis reticulatus (Pocock) Pacltová & Simoncsics 1970			X					
Zlivisporis simplex (Cookson & Dettmann) Braman 2002				X				


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PLATE 16: PHOTOGRAPHIC STRATIGRAPHY OF THE CHAMA BASIN CRETACEOUS AND CENOZOIC STRATIGRAPHY

PLATE 16. Cretaceous and Cenozoic stratigraphy in the Chama Basin. A, Cretaceous stratigraphy at the hogback west of Gallina, New Mexico. Lower gold cliffs are the Point Lookout Sandstone, the slopes are formed by the Menefee Formation and the cuesta is capped by the Cliff House Sandstone. B, View of Cerro Pedernal, looking southwest. Low, flat country in the foreground is the Upper Triassic Poleo Formation (Chinle Group). Occasionally visible gold cliffs are the Jurassic Entrada Sandstone, which is overlain by the Summerville-Bluff-Morrison formations. The flanks of Cerro Pedernal are the Oligo-Miocene Abiquiu Formation, and this striking landmark is capped by the Late Miocene Lobato basalt flow.