# DISCUSSION

# MAGNETIC POLARITY ZONATION AND BIOSTRATIGRAPHY OF LATE CRETACEOUS AND PALEOCENE CONTINENTAL DEPOSITS, SAN JUAN BASIN, NEW MEXICO

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## INTRODUCTION

Lindsay, Butler, and Johnson (1981) have synthesized and further elaborated their earlier presentations (Butler and others, 1977; Lindsay, Jacobs, and Butler, 1978) of a magnetic polarity sequence for the Late Cretaceous-Paleocene continental sediments in the south-central San Juan Basin, N. Mex. Based on their correlation of the San Juan Basin polarity sequence with the polarity sequence in marine rocks at Gubbio, Italy (LaBrecque, Kent, and Cande, 1977), Lindsay, Butler, and Johnson (1981) conclude that the extinction of dinosaurs in the San Juan Basin did not coincide with the extinction of marine foraminifera that marks the Cretaceous-Tertiary boundary at Gubbio. We here challenge this conclusion by demonstrating that Lindsay, Butler, and Johnson's (1981) correlation of the San Juan Basin magnetic-polarity sequence with the Gubbio magnetic-polarity sequence contradicts all biostratigraphic evidence of the precise age of the San Juan Basin sediments. The contradiction is so great that we feel no reliable correlations based solely on their San Juan Basin magnetic polarity column are possible. Thus there is no reliable evidence to support Lindsay, Butler, and Johnson's (1981, p. 432) conclusion that "Late Cretaceous terrestrial and marine extinctions were diachronous."

## AGE OF THE FRUITLAND FORMATION

Lindsay, Butler, and Johnson's (1981) polarity sequence in the south-central San Juan Basin is anchored in the Fruitland Formation. According to Lindsay, Butler, and Johnson (1981) the Fruitland Formation corresponds to anomalies 30 and 31 and thus is of late Maastrichtian age. However, all biostratigraphic evidence indicates that the Fruitland Formation in the south-central San Juan Basin cannot be late Maastrichtian in age but must be older, almost certainly of late Campanian age.

The Fruitland Formation is a sequence of clastic deposits that prograded northeastward over the regressing strandline of an epeiric seaway (Fassett and Hinds, 1971, fig. 16). Delta plain and interdeltaic deposits of the Fruitland Formation intertongue extensively with the underlying marine Pictured Cliffs Sandstone which in turn grades into deeper marine deposits of the Lewis Shale (fig. 1; Fassett and Hinds, 1971, fig. 5, pl. 2). The relationships between these three formations is the classic regressive shoreline situation well described by Sears, Hunt, and Hendricks (1941, fig. 20), among others. In this situation the deltaic deposits are time equivalents of the marine deposits. In other words, ammonites living in the Lewis Shale sea were contemporaries of dinosaurs and mammals living in the deltaic swamps that became the Fruitland Formation. Thus ammonites in the Pictured Cliffs Sandstone and Lewis Shale provide an accurate means of determining the age of the Fruitland Formation, although the exact age of specific horizons in the Fruitland Formation based on correlation with ammonite zones will require more detailed stratigraphic information than is available at present.

Ammonites collected by Cobban, Landis, and Dane (1974) in the eastern San Juan Basin indicate that the Lewis Shale becomes younger to the north and east, well in accord with all evidence that the sea regressed from northwestern New Mexico to the north and east (Weimer, 1960; McGookey and others, 1972). Isopachs based on the Huerfanito bentonite in the Lewis Shale also demonstrate this change in age (Fassett and Hinds, 1971). The stratigraphically highest ammonites in the Lewis Shale on the eastern side of the San Juan Basin are in the *Baculites compressus* zone, a zone of late Campanian age (Obradovich and Cobban, 1975). Thus the Fruitland Formation *to the south and west* of that point *cannot be younger* than that zone (fig. 1). (This contrasts with Lindsay, Butler, and Johnson's (1981, p. 426) statement that "the lowermost Fruitland Formation overlying the Pictured Cliffs Sandstone cannot be *older* than the *Baculites compressus* faunal zone.") The presence of *Didymoceras cheyennense* in the Pictured Cliffs Sandstone in the northern San Juan Basin (Cobban, 1973) also supports the suggestion that the Fruitland Formation in the south-central San Juan Basin is at least as old as late Campanian.

Clemens (1973), following this line of reasoning, estimated that the Fruitland Formation in the Hunter Wash area, the area where Lindsay, Butler, and Johnson (1981) measured their polarity sequence in the Fruitland Formation, may be a time equivalent of the Campanian *Didymoceras nebrascense* zone but probably is slightly younger. He based this estimate on the assumption that isopachs of the distance between the Huerfanito bentonite bed and the Pictured Cliffs Sandstone are time lines

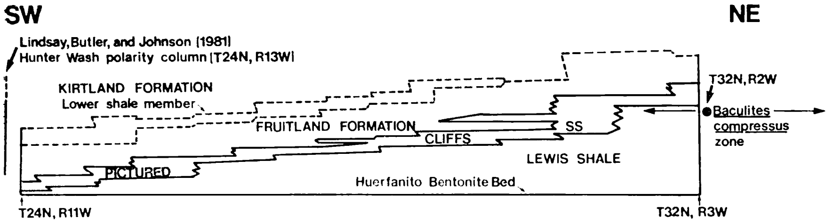

Fig. 1. Cross section (vertical axis=time) from the south-central San Juan Basin, N. Mex. to the northeastern San Juan Basin, Colo. showing the interval from the Huerfanito bentonite bed (datum) of the Lewis Shale to the Kirtland Shale (modified from Fassett and Hinds, 1971, pl. 2). The locations of the Hunter Wash polarity column (Lindsay, Butler, and Johnson, 1981, fig. 5) and fossil invertebrates of the *Baculites compressus* zone (Cobban, Landis, and Dane, 1974, figs. 1, 2) relative to the cross section are shown. Time transgression of the Lewis Shale–Pictured Cliffs Sandstone–Fruitland Formation indicates that the Fruitland Formation as far southwest of T32N, R2W as the point where Lindsay, Butler and Johnson measured their Hunter Wash section (T24N, R13W) is older than the late Campanian *Baculites compressus* zone.

(Fassett and Hinds, 1971). Whatever assumption of the rate of regression is used, the facies relationships of the Fruitland Formation, Pictured Cliffs Sandstone, and Lewis Shale coupled with the ammonite biostratigraphy clearly demonstrate that the Fruitland Formation in the Hunter Wash area is older than the *Baculites compressus* zone, perhaps as old as the *Didymoceras nebrascense* zone and thus of late Campanian age.

In fact, a much greater correlation than just the age of the Fruitland in the San Juan Basin is at stake here. The Fruitland Formation–Pictured Cliffs Sandstone–Lewis Shale regression in the San Juan Basin is part of a much larger paleogeographic story of Late Cretaceous transgressions and regressions in the Western Interior. Weimer (1960; also see McGookey and others, 1972) identified four major regressive-transgressive pulses in the Late Cretaceous seaway in western North America. The Lewis Shale–Pictured Cliffs Sandstone–Fruitland Formation sequence represents the penultimate regression of the sea, R3 of Weimer's terminology (fig. 2). If the Fruitland Formation is of late Maastrichtian age, then the age of the Pierre and Trinidad Formations in the Raton Basin in eastern New Mexico and of the Pierre and Fox Hills Formations in the Denver Basin must be revised. In fact, the entire Campanian and Maastrichtian paleogeographic history of the Western Interior seaway, which indicates that by late Maastrichtian time the Cretaceous seaway no longer was present in northwestern New Mexico (Weimer, 1960; McGookey and others, 1972; Williams and Stelck, 1975), must be reinterpreted. Until Lindsay, Butler, and Johnson present such a reinterpretation, we feel that the presently accepted paleogeographic history of the

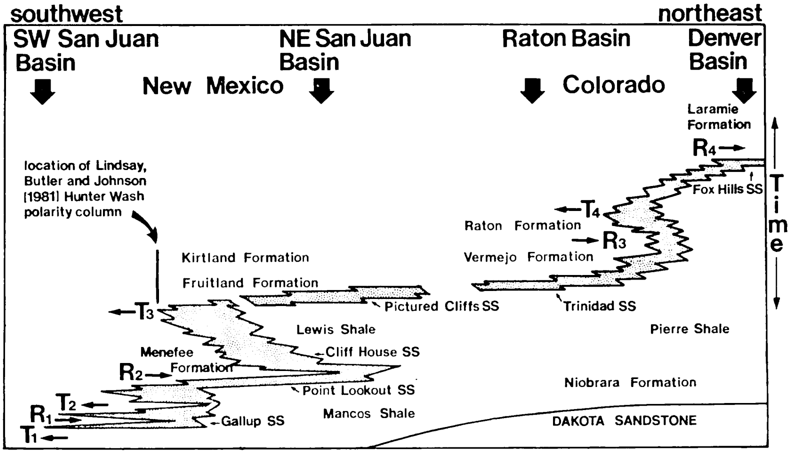

Fig. 2. Restored diagrammatic section in Upper Cretaceous rocks from the southwestern San Juan Basin, N. Mex. to the Denver Basin, Colo. (modified from Weimer, 1960, fig. 2 and McGookey and others, 1972, fig. 35). Ages of major transgressions (T) and regressions (R) are: T1 = Cenomanian-Turonian, R1 = late Turonian, T2 = Coniacian, R2 = early Campanian, T3 = early Campanian, R3 = late Campanian, T4 = latest Campanian-early Maastrichtian, R4 = Maastrichtian (McGookey and others, 1972, fig. 23).

seaway, based as it is on marine and terrestrial stratigraphy and biostratigraphy supported by radiometric dates, is correct. Therefore, the Fruitland Formation is late Campanian, not late Maastrichtian, in age.

Dinosaurs, fossil mammals, megafossil plants, nonmarine invertebrates, and pollen from the Fruitland Formation also indicate that it is not late Maastrichtian in age (Gilmore, 1916; Knowlton, 1916; Stanton, 1916; Clemens, 1973; Powell, 1973; Tschudy, 1973; Lucas and Rigby, 1979). Lindsay, Butler, and Johnson (1981, p. 422) claim that the Fruitland Formation fossil mammals "must be close to the Edmontonian-Lancian transition" because the genera *Mesodma, Alphadon, Pediomys, Gypsonictops,* and *Cimolestes* are found in the late Maastrichtian Lance Formation of Wyoming. However, all these genera, except *Cimolestes,* are found also in the Judithian (Late Campanian) Judith River Formation in Montana (Sahni, 1972), as are *Cimexomys* and *Cimolodon* which also occur in the Fruitland Formation. These genera thus are of little use in determining whether the Fruitland Formation is Judithian or Lancian in age.

## AGE OF THE KIRTLAND FORMATION

Biostratigraphic and stratigraphic evidence indicates that the Kirtland Formation is mostly of late Campanian age though it probably, in its upper part, is as young as early Maastrichtian (fig. 1; for example, Gilmore, 1916, 1935; Knowlton, 1916; Stanton, 1916; Baltz, Ash, and Anderson, 1966; Powell, 1973; Tschudy, 1973). However, Lindsay, Butler, and Johnson (1981) presented an early Paleocene-late Maastrichtian radiometric date of 64.6 ± 3.0 m. y. from the middle part (Farmington Sandstone Member) of the Kirtland Formation. This date is based on fission track analysis of zircons separated from "an ash deposit that was altered, and possibly reworked" (Lindsay, Butler, and Johnson, 1981, p. 401). It is possible that this anomalously young date may be the result of track fading due to thermal alteration of the ash bed. Lindsay, Butler, and Johnson (1981) did not investigate this possibility nor did they resolve the discrepancy between their radiometric date and the biostratigraphic evidence. Their correlation of the upper part of the Kirtland Formation with the latest Maastrichtian and earliest Paleocene part of the Gubbio section is based solely on this date, and we urge them to reconcile their age determination with the biostratigraphic evidence based on dinosaurs, mammals, plants, and invertebrates as well as the stratigraphic evidence (fig. 1). Again, this calls for a reinterpretation on their part of much of the biostratigraphy and stratigraphy of the Late Cretaceous of the Western Interior.

## AGE OF THE NACIMIENTO FORMATION

Lindsay, Butler, and Johnson (1981, fig. 15) used their radiometric date from the Kirtland Formation to correlate anomaly $\gamma +$ in their San Juan Basin magnetic polarity sequence with anomaly 29 in the Gubbio sequence. They thus correlated the Puercan (early Paleocene) mammal fauna of the Nacimiento Formation with anomaly 28 in the Gubbio sequence; the Torrejonian (middle Paleocene) mammal faunas of the Nacimiento Formation are correlated with anomalies 27 and 26 in the Gubbio sequence (Lindsay, Butler, and Johnson, 1981, fig. 16). However, in an earlier paper, Butler, Lindsay, and Gingerich (1980, fig. 1) correlated a Tiffanian (late Paleocene) mammal fauna in the Bighorn Basin (Wyoming) with anomaly 26 in the Gubbio sequence. Evidently, Lindsay, Butler, and Johnson (1981) consider the Tiffanian mammals in the Bighorn Basin to be temporal equivalents of the Torrejonian ("*Pantolambda* zone") mammals of the San Juan Basin. This correlation is impossible biostratigraphically (Wood and others, 1941), particularly when one considers that a well known Torrejonian fauna (Rock Bench Quarry), one that shares many taxa with the San Juan Basin Torrejonian, is present in the Bighorn Basin stratigraphically below the Tiffanian interval correlated with anomaly 26 by Butler, Lindsay, and Gingerich (1980). Furthermore, anomaly 26 at Gubbio corresponds to the *Globoratalia pseudomenardii* foraminiferal zone (Alvarez and others, 1977), a correlative of the Thanetian (late Paleocene) mammal faunas in France (for example, Berggren and others, 1978). The Thanetian mammal faunas have been correlated with the Tiffanian-Clarkforkian (latest Paleocene) land mammal "ages" in western North America (for example, Gingerich and Rose, 1977; Savage and Russell, 1977). Clearly anomaly 26 cannot be correlated with the late Torrejonian of the San Juan Basin. The late Torrejonian must be correlated with an older anomaly, and thus Lindsay, Butler, and Johnson's (1981) correlation of the upper part of their San Juan Basin magnetic polarity sequence must be revised.

### REVISED MAGNETIC POLARITY SEQUENCE

In accordance with the biostratigraphic evidence presented above, we revise the correlation of the San Juan Basin magnetic polarity sequence of Lindsay, Butler, and Johnson (1981) with the magnetic polarity sequence at Gubbio (fig. 3). We discount the brief reversal in the upper part of the Fruitland Formation and correlate the $\alpha +$ interval with anomaly 33, a long normal interval of late Campanian age at Gubbio. Nevertheless, we are uncertain of the precise correlation of interval $\gamma +$. It may correspond to the short normal interval between anomalies 32 and 33 or may represent anomaly 32. Our present correlation of the lower part of the San Juan Basin magnetic polarity sequence is based on recognition of a major unconformity that may represent much of Maastrichtian time at the base of the Ojo Alamo Sandstone (*sensu* Baltz, Ash, and Anderson, 1966). Lucas and Rigby (1979) have reviewed the documentation of the stratigraphic magnitude and temporal significance of this unconformity. This unconformity may, however, not be the final solution to the discrepancy between the paleomagnetic and biostratigraphic correlations. The possibility that additional unconformities exist in the Kirtland Formation (particularly in association with the Farmington Sandstone Member) should be further investigated by detailed rock-stratigraphic and biostratigraphic studies.

In the upper part of the San Juan Basin magnetic polarity sequence we correlate interval $\iota +$, corresponding to the late Torrejonian mammal fauna, with anomaly 27, thus eliminating the contradiction with Butler, Lindsay, and Gingerich's (1980) Bighorn Basin sequence. The early Torrejonian fauna thus is correlated with the interval between anomalies 27 and 28 and with the upper part of anomaly 28. The Puercan fauna is a correlative of part of anomaly 29.

Consequently the Cretaceous-Tertiary boundary in the San Juan Basin magnetic polarity sequence is located below anomaly 29 as at Gubbio. This agrees with Lerbekmo, Evans, and Baadsgaard's (1979) paleomagnetic placement of the Cretaceous-Tertiary boundary in the Red Deer Valley, Alberta, the only other magnetic polarity sequence in continental sediments spanning the Cretaceous-Tertiary boundary in the

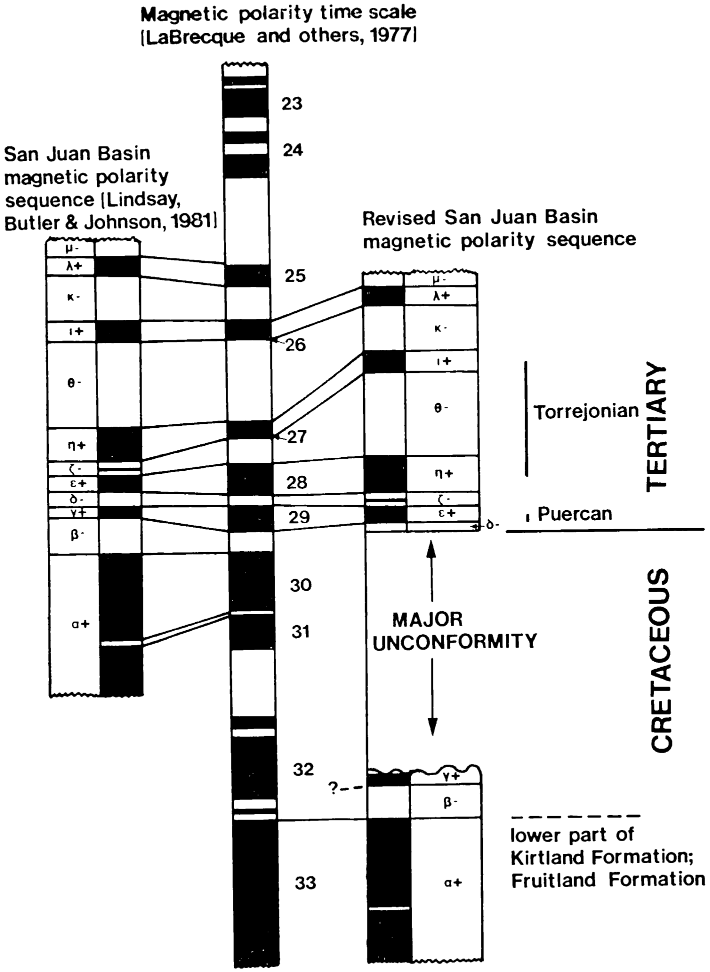

Fig. 3. Revised correlation of the San Juan Basin magnetic polarity sequence with the magnetic polarity time scale (LaBrecque, Kent, and Cande, 1977) compared with the correlation proposed by Lindsay, Butler, and Johnson (1981, figs. 15, 16).

Western Interior. The position of the Cretaceous-Tertiary boundary thus is virtually the same in continental sediments in Alberta and New Mexico and in marine sediments at Gubbio, undermining any argument based on magnetic polarity stratigraphy that the marine and terrestrial extinctions were diachronous.

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