DATA BASE AND REVIEW OF PALEOFAUNAS AND FLORAS OF THE FRUITLAND FORMATION, LATE CRETACEOUS, SAN JUAN BASIN, NEW MEXICO, WITH INTERPRETIVE OBSERVATIONS AND AGE RELATIONSHIPS

by

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INTRODUCTION

This open-file report is the first part of a three-part series of reports that will treat the paleobiology of the uppermost Cretaceous-lowermost Tertiary faunas and floras of the San Juan Basin, northwestern New Mexico. This first part deals with the Fruitland Formation; part II will treat the Kirtland and Ojo Alamo Formations and part III will treat the Nacimiento Formation.

This series of reports will have several objectives: firstly, an effort is made to pull together in one place, the extant data available for each of the floras and faunas. Secondly, it is hoped that this data will provide a reasonable base and framework to which additional data can be added and fitted - most of the available literature is diffuse or inadequate. Thirdly, this series of reports will point the way towards needed data in order to adequately characterize each of the biotas involved and thus provide a standard size sample on which land use and coal-mitigation paleontological efforts can be based.

GENERAL GEOLOGY

The San Juan Basin of northwestern New Mexico and southwestern Colorado is an asymmetric structural depression that contains Precambrian, Cambrian, Devonian, Mississippian, Pennsylvanian, Permian, Triassic, Jurassic, Upper Cretaceous, Tertiary, and Quaternary deposits (see Kelley, 1951). A well drilled by El Paso Natural Gas Company in the SE¼ sec. 7, T. 29 N., R. 5 W., New Mexico principal meridian, penetrated Precambrian rocks at 14,030 feet (Fassett and Hinds, 1971, p. 4). Upper Cretaceous rocks in the San Juan Basin consist of intertonguing marine and nonmarine deposits representing a series of basinal transgressions and regressions. The final regressive episode, marking the last withdrawal of the Late Cretaceous epeiric sea from the region is marked by the Pictured Cliffs Sandstone.

The Pictured Cliffs Sandstone is overlain by the Fruitland Formation and the Kirtland Formation, of undoubted Late Cretaceous age. The Ojo Alamo Formation overlies the Kirtland. Evidence is being developed (Wolberg, in prep.) that most or all of the Ojo Alamo (sensu Brown, 1910) is Cretaceous in age and that the Ojo Alamo restricted (sensu Baltz, Ash, and Anderson, 1966) is a concept that cannot be substantiated.

The Nacimiento Formation overlies the Ojo Alamo Sandstone and is clearly Paleocene in age. To the north, the Kirtland Formation is overlain by the Animas Formation, the age relationships of which are in doubt.

The Fruitland Formation contains a rich and varied abundance of vertebrate, invertebrate, and botanical remains. Great coal reserves are also contained within the Fruitland Formation. Fassett and Hinds (1971, p. 67) estimated that approximately 200 billion tons of coal is contained in the

Fruitland Formation between its outcrop and greatest depth of more than 4,000 feet. In addition, in numerous areas of the San Juan Basin, partly natural and partly man (over grazing) induced erosion, acting on exposures of the Fruitland and overlying deposits produces characteristic and prominent badlands topography considered by some valuable for scenic and recreational enjoyment. Thus, the elements of a typical clash of economic, scientific, and scenic values are in place in the San Juan Basin (see Wolberg and Kottlowski, 1980 for additional discussion). It seems apparent that a more comprehensive understanding of each of the various elements involved in this conflict of views would serve to more reasonably reach an appropriate solution. A fuller understanding of the paleontology of the Fruitland Formation would place the potential scientific values of the region in proper context. Similarly, a better understanding of Fruitland paleontology would help resolve a number of misstatements in the literature and has a direct bearing on the age of the Formation and the likely ages of overlying units, the Kirtland Formation and the Ojo Alamo Sandstone.

THE FRUITLAND FORMATION

The Fruitland Formation was named by Bauer (1916) for a series of deposits that conformably overlie the Pictured Cliffs sandstone and consist of sandstone, shale, and coal and are of brackish to freshwater origin. The name is taken from the village of Fruitland, on the San Juan River, in San Juan County, New Mexico, which lies on outcrops of the formation.

Fassett and Hinds (1971, p. 8) discuss the lower contact of the Fruitland with the Pictured Cliffs Sandstone. On electric logs, this contact is placed at the top of the massive sandstone below the lowermost coal except where the Fruitland and Pictured Cliffs intertongue. In exposed sections, the contact is placed at the top of the highest Ophiomorpha major-bearing sandstone.

The upper contact of the Fruitland with the Kirtland Formation is not easily established. In general, petroleum geologists place the contact at the top of the highest coal or carbonaceous shale. Reeside (1924, p. 20) utilized the highest sandstone as the top of the Fruitland, while Dane (1936, p. 113) used the top of the highest brown sandstone. Barnes (1953) used an upper boundary definition that included all thick persistent coals and all prominent sandstones within the Fruitland. Powell (1972, p. 16) places the contact at "..the highest persistent fine-grained white sandstone bed which occurs above the highest bituminous coal bed and below the thick shales of the Kirtland Shale." Where the fine-grained white sandstones are lacking, the boundary is placed at the top of the highest coal bed. Elsewhere, where sandstones and/or coals are absent, the Fruitland and

Kirtland are mapped together as Kirtland-Fruitland undivided.

The Fruitland Formation is of variable thickness with an average thickness of 300-350 feet although thicknesses may range from 0 to a maximum of 500 feet. In the eastern part of the Basin the Fruitland thins to 0 feet, partly due to erosion and partly due to a stratigraphic rise of the underlying Pictured Cliffs Sandstone (Fassett and Hinds, 1971, p. 23). In general, the Fruitland thickens from the southeast to the northwest by as much as 150 feet.

The Fruitland is present in exposure on the north, west and south sides of the San Juan Basin. It is absent in two areas on the east side where the Pictured Cliffs is also absent as is the Kirtland Formation. In these areas, the Ojo Alamo Sandstone overlies the Lewis Shale. Cobban (1973) suggested that, "the uppermost part of the Lewis Shale and the lowermost part of the Pictured Cliffs Sandstone probably lies in the zone of Didymoceras cheyennense (Meek and Hayden) (p. 150)." However, he cautiously notes that although D. cheyennense has been found in the upper part of the Lewis Shale near Chimney Rock, only incomplete or fragmentary remains of a Didymoceras were found in the Pictured Cliffs Sandstone near Barker Dome. The Barker Dome material may represent D. cheyennense. The importance of this occurrence is the suggestion of an age for the lower part of the Pictured Cliffs that is older than the zone of Baculites compressus Say. Didymoceras is almost unknown from this zone.

This does not date the Fruitland Formation beyond the fact that it must be younger than the zone of D. cheyennense. The fact that B. compressus was not found at Barker Dome only dates that portion of the Pictured Cliffs. Clearly, other evidence would seem to indicate a Maestrichtian age for the Fruitland Formation and equivalent marine rocks for the later portion of the Fruitland are lacking to date. Additional study of higher portions of the Pictured Cliffs are needed. The Fruitland evidence indicates that higher ammonite zones should be found.

FRUITLAND LITHOLOGY

The Fruitland Formation is of exceedingly variable lithology. Fruitland deposits consist of interbedded sandstone, silts, coals, "clinker" beds and thin limestones with an abundance of brackish water mollusks such as Ostrea. The brackish water limestone beds appear to be confined to the lowest portions of the Fruitland. Coals dominate the lower part of the formation as do sandstones, while siltstones and shales are more common in the upper parts of the formation. The lithologic units are at best discontinuous and of limited areal extent. Coal beds offer the greatest areal continuity and, at least locally, serve as useful horizon markers. This utility may well be expanded with additional detailed mapping of prominent coal units similar to the work that has been done in the Powder River and Williston Basins of Montana and North Dakota (Sloan, 1969; Wolberg, 1978).

FRUITLAND MEGAFLORISTICS

Much work remains to be done on the paleobotany of the Fruitland, indeed the entire uppermost Cretaceous-lowermost Tertiary of the San Juan Basin. Needed studies include collection and analysis of megabotanical material especially leaves and wood; additional and detailed palynological studies within an exceedingly fine stratigraphic "mesh" and detailed paleoecologic studies within a framework of modern concepts. Much has been made of prevailing paleoclimates and environments on the basis of leaf-margins and form (Sloan, 1969; Axelrod and Bailey, 1969; Wolfe, 1971), but this idea has been severely questioned or at least reinterpreted (Wolfe, 1979). A dynamic and perhaps architectural analyses of Fruitland floras and forests can be undertaken with concerted detailed studies much on the model of Halle, Oldeman, and Tomlinson (1978).

The basic megabotanical study related to the Fruitland flora still remains Knowlton (1916) and Knowlton's list has been frequently repeated by later authors. The table below is taken from Knowlton. Comparison is also made to the Vermejo Formation of the Raton Basin (Knowlton, 1917). A good deal of similarity between the floras appears evident. However, a cautionary note is in order; the floras are not sufficiently well known to make this comparison useful for more than very general conclusions to be drawn.

The best leaf floras are present in the relatively commonly occurring "clinker" deposits associated with

Fruitland coals. These deposits, as well as non-clinker, fine-grained sediments should be sampled in a concerted effort.

Fossil wood is relatively common in the Fruitland, but generally as isolated occurrences. In the Split-lip Flats area, relatively near the old Ojo Alamo Trading Post, an interesting "fossil forest" (more accurately a fossil stump-field) is exposed. Numerous *in situ* stumps and occasional large logs occur and would form the basis for a useful wood study. The distribution of the observable stumps will be mapped.

Table 1. Megaflora identified by Knowlton (1916)

Family Schiziaceae

    * *Anemia hesperia* Knowlton

    Anemia sp.

Family Pinaceae

    *̲ *Sequoia rechenbachi* (Geinitz)

    *̲ *S. obovata*? Knowlton

    *̲ *Geinitzia formosa* Heer

Family Pontederiaceae

    Heteranthera cretacea Knowlton

Family Pontederiaceae

    Heteranthera cretacea Knowlton

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* genus present in Vermejo of Raton Basin

*̲ species present in Vermejo of Raton Basin

Table 1. continued

Family Palmaceae

* *Sabal* montana? Knowlton

Sabal sp.

Family Myricaceae

* *Myrica* *torreyi* Lesquereux

Family Salicaceae

* *Salix* *baueri* Knowlton

Salix sp. a.

Family Facaceae

* *Quercus* *baueri* Knowlton

Family Moraceae

Ficus *baueri* Knowlton

* *Ficus* *curta*? Knowlton

Ficus *praetrinervis* Knowlton

* *Ficus* *leei* Knowlton

Ficus *praelatifolia* Knowlton

Ficus sp.

* *Ficus* *rhamnoides* Knowlton

Ficus *squarrosa*? Knowlton

Ficus sp. cf. *F*. *wardii* Knowlton

* *Ficus* *eucalyptifolia*? Knowlton

Table 1. continued

Family Lauraceae

Laurus baueri Knowlton

* L. coloradensis Knowlton

Family Nymphaeaceae

Nelumbo sp.

Family Sterculeaceae

* Pterospermites undulatus Knowlton

P. neomexicanus Knowlton

Family Grossulariaceae

Ribes neomexicana Knowlton

Incertae sedes

Carpites baueri Knowlton

* Phyllites petiolatus Knowlton

Phyllites neomexicanus Knowlton

Fruitland Palynology

Zavada (1976) studied 16 samples of coals and shales collected from Fruitland Formation exposures in the San Juan Basin for palynomorph content. The samples yielded 152 species of spores and pollen belonging to 97 genera. These included 52 genera and 72 species of pteridophytes, 16 genera and 19 species of gymnosperms, 29 genera and 61 species of angiosperms.

Zavada compared his results to previous studies of Campanian, Maestrichtian and Paleocene microfloras of the western interior of North America. He found that only four species known to occur in the Campanian were found in the Fruitland samples. However, fully 35 species restricted to Maestrichtian microfloras occur in the Fruitland. 10 species elsewhere restricted to the Paleocene are found in the Fruitland assemblage. On the basis of these comparisons, Zavada assigned a Maestrichtian age to the Fruitland Formation.

Zavada's study represents the most detailed palynological analysis of the Fruitland Formation completed to date. Zavada notes that Tschudy (1971) (in Fassett and Hinds, 1971, pp. 19-23 and Tschudy, 1973) listed 81 genera and 37 species from the Fruitland. Of the 152 species listed by Zavada, only 12 species and 24 genera are common to all three floras. Zavada attributes this low correlation to the fact that Tschudy did not figure any of the specimens he recovered, did not provide a systematic treatment of the materials and only about half of Tschudy's palynomorphs were identified to species level.

Table 2. Palynomorphs Identified by Zavada (1976)

Division BRYOPHYTA
    Class MUSCI
        Order SPHAGNALES
            Family SPHAGNACEAE
                Cingutriletes clavus (Balme)
                Stereisporites stereoides (Potonié and Venitz)
                S. antiquasporites (Wilson and Webster)
                Zlivisporis novomexicanum (Anderson)

Division LYCOPHYTA
        Order LYCOPODIALES
            Family LYCOPEDIACEAE
                Hamulatisporis hamulatis Krutzsch
                Foveosporites canalis Stanley
                Inundatisporis vermiculisporites (Rouse)
                Lycopodiacidites arcuatus Hedlund
                Lycopodiumsporites austroclavatidites (Cookson)

        Order SELAGINELLALES
            Family SELAGINELLACEAE
                Acanthotriletes varispinosus Pocock
                Ceratosporites pocockii Srivastava
                Cingulatisporites dakotaensis Stanley

Table 2. continued

C. scabratus Couper

C. tavaredensis Groot and Groot

Echinatisporis longechinus Krutzsch

Foveasporis fovearis Krutzsch

Division ARTHOROPHYTA

Order CALANITALES

Family CALANITACEAE

Calamospora mesozoica Couper

Division OSNUMDACIDITES

Order OSMUNDALES

Family OSMUNDACEAE

Osmundacidites wellmanii Couper

Order FILICALES

Family SCHIZAEACEAE

Appendicisporites dentimarginatus Brenner

A. distocarinatus Dettmann

Cicatricosisporites cf. *C. crassiterminatus* Hedlund

C. dorogensis Potonié and Gelletich

C. hughesii Dettmann

Lygodiosporites verrucosus Srivastara

Trilobosporites purverulentus (Verbitskaya)

Triplanosporites sinuosus Pflug

Gleicheniidites apilobatus Brenner

Table 2. continued

G. circinidites (Cookson)

G. concavisporites (Rouse)

G. senonicus Ross

Family HYMENOPHYLLACEAE

Biretisporites deltoidus (Rouse)

Family DICKSONIZCEAE-CYATHEACEAE

Alsophilidites kerguelensis Cookson

Concavissimisporites punctatus (Del-Court and Sprumont)

C. variverrucatus (Couper)

Cyathidites australis Couper

C. minor Couper

C. subtilis Couper

Family MATONIACEAE

Matonisporites equiexinus Couper

M. impensus Hedlund

M. sp. cf. M. ornamentalis (Cookson)

M. phlebopteroides Couper

Order SALVINIALES

Family SALVINIACEAE

Azolla cretacea Stanley

Azollopsis coccoides Hall

Parazolla heterotricha Hall

Table 2. continued

SPORAE INCERTAE SEDIS

Balmeisporites longirimosus Kondinskaya

B. major (Norton)

B. sp. cf. *B. rigidus* Bergad

Chomotriletes fragilis Pocock

Cirratriradites teter Norris

Concavisporites praeobtusangulus Krutzsch

C. subgranulosus Couper

Foraminisporis undulatus Leffingwell

Foveotriletes balteus Partridge

Granulatisporites arenaster Paden and Felix

Laevigatosporites gracilus Wilson and Webster

L. irroratus Hedlund

L. ovatus Wilson and Webster

Lygodiumsporites exiguus Paden and Felix

Microfoveolatosporis tuemmlitzensis Krutzsch

Nevesisporites sp. cf. *N. radiatus* Chlonova

Perotriletes cubensis Anderson

Peromonolites granulatus Norton and Hall

Polycingulatisporites densatus (DeJersey)

Polypodiisporites favus Potanié

Punctatosporites ellipsoideus Pflug

P. reginensis Anderson

Reticuloidosporites dentatus Pflug

Schizosporis majusculus Hedlund

S. parvus Cookson and Dettmann

Table 2. continued

Stenozonotriletes stellatus Chlonova

Sporopollis laqueaeformis Weyland and Greifield

Trochicola scollardiana Srivastava

Undulatisporites undulapolus Brenner

Division CYCADOPHYTA

Order CYCADALES

Family CYCADACEAE

Cycadopites scabratus Stanley

Division CONIFEROPHYTA

Order CONIFERALES

Family PINACEAE

Laricoidites magnus (Potonié)

Alisporites grandis (Cookson)

Abietineae pollenites sp.

Gabonisporis bacaricumulus Srivastava

Tsugapollenites crispa Zaklinskaja

Family TAXODIACEAE

Taxodiaceaepollenites hiatus (Potonié)

Family ARAUCARIACEAE

Araucariacidites australis Cookson

Family PODOCARPACEAE

Podocarpites otagoensis Couper

P. radiatus Brenner

Ephedripites constaliferous Brenner

E. ovatus (Pierce)

Table 2. continued

Family GYMNOSPERMAE INCERTAE SEDIS

Circulina Parva Brenner

Classopollis obidosensis Groot and Groot

Exesipollenites tumulus Balme

Eucommiidites debillis Groot and Groot

E. troedssonii Erdtman

Inaperturopollenites limbatus Balme

Division ANTHOPHYTA

Class DICOTYLEDONEAE

Order URTICALES

Family ULMACEAE

Ulmipollenites Sp.

Order JUGLANDALES

Family JUGLANDACEAE

Momipites circularis Norton

M. coryloides Wodehouse

M. tenuipolus Anderson

M. triradiatus Nichols

Order FAGALES

Family FAGACEAE

Psilatricolporites prolatus Pierce

Family BETULACEAE

Alnipollenites trina (Stanley)

Alnipollenites n. sp.

Betulaceoipollenites infrequens (Stanley)

Table 2. continued

Order CARYOPHYLLALES

Family CHENOPODIACEAE

Polyporina cribraria Srivastava

Order PROTEALES

Family PROTEACEAE

Proteacidites marginus Rouse

P. palisadus Couper

P. retusus Anderson

P. thalmanni Anderson

Order SANTALALES

Family SANTALACEAE

Aquilapollenites amygdaloides Srivastava

A. polaris Funkhouser

A. pyriformis Norton

A. senonicus (Mtchedlishvilli)

Aquilapollenites sp.

Aquilapollenites n. sp.

Fibulapollis scabratus B. Tschudy

Family BALANOPHORACEAE

Thomsonipollis magnificus Kurtzsch

Order CELASTRALES

Family AQUIFOLIACEAE

Ilexpollenites anguloclavatus

Table 2. continued

Order SAPINDALES

Family SAPINDACEAE

Cupaniedites reticularis Cookson and Pike

Family HIPPOCASTANACEAE

Aesculiidites circumstriatus (Fairchild)

Family ANACARDIACEAE

Rhoipites cryptoporus Srivastava

R. globosus Stanley

Order SCROPHULARIALES

Family OLEASEAE

Fraxinopollenites variabilis Stanley

Class MONOCOTYLEDONEAE

Order ARECALES

Family PALMAE

Palmaepollenites tranquillus Potonié

Order LILIALES

Family LILIACEAE

Liliacidites complexus (Stanley)

L. dividuus (Pierce)

ANGIOSPERMAE INCERTAE SEDIS

Chlonovaia sibiricus (Chlonova)

Kurtzipites annulatus Norton

Nudopollis terminalis (Pflug and Thomson)

Quadrapollenites vagus Stover

Table 2. continued

Simpsonipollis mullensis (Simpson)
Sindorapollis granulatus Tschudy
Tetracolpites pulcher Srivastava
Tricolpites albiensis Kemp
T. foveolatus Norton
T. pannosus Dettmann and Playford
T. psilascabratus Norton
Tricolpites sp. = Sp.C of Anderson
Tricolporites leuros Partridge
T. rhomboides Anderson
Tricolpopollenites anguloluminosus (Anderson)
T. hians (Stanley)
T. sinuosus Norton
T. microreticulatus Norton
Tricolporopollenites aliquantulus Hedlund
T. confossus Newman
T. kruschii (Potonié)
T. microreticulatus Pflug
T. pseudocingulum (Potonié)
T. spackmani Brenner
Triporopollenites bituitus (Potonié)
T. pseudocanalis Paden-Phillips
T. scabroporus Newman
"Pollen Type A"

Table 3. Fruitland Palynomorphs Restricted to the Campanian from Zavada (1976)

Fibulapollis scabratus
Sindorapollis granulatus
Punctatosporites reginensis
Inaperturopollenites limbatus

Table 4. Fruitland Palynomorphs Restricted to the Maestrichtian (from Zavada, 1976).

Azollopsis coccoides (=*Azolla sagittifera*)
Aquilapollenites polaris
A. pyriformis
Acanthotriletes varispinosus
Cypanicidites reticularis
Ceratosporites pococki
Cingutriletes clavus
Concavissimisporites variverrucatus
Cicatricosisporites dorogensis
Cingulatisporites scabratus
Deltoidospora halli
Ephedripites ovatus
Faveosporites canalis
Gabonisporis bacaricumulus
Gleicheniidites concavisporites
Inundatisporites vermiculisporites
Ilexpollenites spp. (= *Pistillipollenites*)

Table 4. continued

Kurtzipites annulatus
Liliacidites dividuus
Lygodiosporites verrucosus
Matonisporites equiexinus
Momipites croyloides

Nevesisporites radiatus
Perotriletes cubensis
Polyporina cribraria
Peromonolites granulatus
Podocarpidites olagoensis
Polycingulatisporites densatus
Styx minor (= *Balmaesporites longirimosus*)
Styx major (= *B. major*)

Tricolpopollenites sp. (Type C)
Trochocola scollardiana
Tricolpopollenites microreticulatus
Tricolporopollenites confossus
Rhoipites globosus
Undulatisporites undulapolus

Table 5. Fruitland Palynomorphs restricted to Paleocene Microfloras (from Zavada, 1976)

Alnipollenites Trina

Betulaceoipollenites infrequens

Foveasporis triangulus

Foveosporis cyclicus

Fraxinoipollenites variabilis

Momipites tenuipolus

Pinus semicirculus (= *Abietineaepollenites*)

Tricolpites anguloluminosus

T. psilascabratus

Tricolpopollenites prolatus

FRUITLAND MOLLUSKS

Adequate studies of the Fruitland mollusks are lacking. Much nomenclatural revision should modify the faunal list included below. Similarly, previous work has not related fossil mollusk occurrences to a detailed stratigraphy. A lack of stratigraphic precision makes it difficult to draw inferences from the described forms regarding biostratigraphy, paleoecology or relationships to molluscan faunas elsewhere. Work in progress and planned by Wolberg in cooperation with Hartman should resolve some of the difficulties. Particular attention will be paid to the stratigraphic distribution of molluscan assemblages. It is apparent, however, on the basis of available data, that at least two distinct molluscan "biofacies" can be detected: a dominantly brackish-water biofacies and a dominantly freshwater biofacies. The lower limestone beds of the Fruitland are at times almost coquinoid carbonates with abundant remains of _Ostrea_ sp., and clearly represent brackish-water conditions. Higher in the Fruitland section, freshwater forms appear to be dominant and are generally restricted to shales and claystones. The higher occurrences may represent a greater distance to influences of the Picture Cliffs seaway.

As a logical extension of these investigations, an examination of brackish-water deposits for potential foraminiferans would be worthwhile. As yet, no documentation is available for the presence of forams in the Fruitland.

Such documentation should be forthcoming and would be most worthwhile. Russell (1975, p. 151) notes the presence of *Proparreysia holmesiana* (White) in the Fruitland and *Proparreysia pyramidatoides* (Whitfield) in the Kirtland. These bivalves are typically Lancian forms. It has yet to be demonstrated that *P. holmesiana* and *P. pyramidatoides* both occur in the Fruitland or in the Kirtland; the separate occurrences may be anomalous. Nevertheless the occurrences of these forms is significant.

Table 6. FRUITLAND

Nonmarine Invertebrates

(from Stanton, 1916; Russell, 1975)

Ostrea glabra Meek and Hayden
Anomia gryphorhynchus Meek
Anomia gryphaeiformis Stanton
Modiola laticostata (White)
Unio holmesianus White (= *Proparreysia holmesiana* (White))
Unio amarillensis Stanton
Unio gardneri Stanton
Unio reesidei Stanton
Unio brachyopisthus White (= *Plesielliptio brachyopisthus* (White)
Unio neomexicanus Stanton
Unio brimhallensis Stanton
Unio sp. cf. *U. primaevus White*
Corbicula cytheriformes (Meek and Hayden)

Table 6. continued

Corbula chacoensis Stanton

Panopaea simulatrix Whiteaves?

Teredina neomexicana Stanton

Neritina baveri Stanton

Neritina (*Velatella*) sp.

Campeloma amarillensis Stanton

Tulotoma thompsoni White

Melania insculpta Meek?

Goniobasis? *subtortuosa* Meek and Hayden

Physa reesidei Stanton

Physa sp.

Planorbis (*Bathyomphalus*) *chacoensis* Stanton

Fruitland Vertebrate Faunas

A great deal of attention has been given to Fruitland vertebrate faunas. Yet surprisingly little actual comprehensive analysis of the variety and distribution of vertebrate faunal components is available for review that postdate the early studies of Gilmore (1916, 1919); Osborn (1923); or Ostrom (1963) and in part Gaffney (1972); Clemens (1973). Most recent work has been concerned primarily with determining faunal content (Powell, 1972, 1973; Armstrong-Ziegler, 1978; Wolberg and LeMone, 1980).

Vertebrate material is relatively common in the Fruitland Formation in a wide variety of lithologic types. Wolberg has recovered vertebrate material in sandstones, clays and shales, siltstones and even some material associated with coals. Vertebrate material associated with coals is the least abundant and least well preserved of the types of occurrences noted. The best preserved material appears to be associated with sandstones.

Turtles are very abundant in the Fruitland Formation but form the least understood faunal element. Turtle systematics was for long in need of extensive revision and it is probable that most of the reported taxa are suspect. It is suggested that all previous classification schemes for turtles be discarded and the ideas of Gaffney (1972) for baenids and Gaffney (1975) for higher categories be utilized for future badly needed analyses of Fruitland (and higher) turtle taxa.

Table 7. Gaffney's (1972) Classification of Baenoidea of North America.

Class Reptilia

- Order Testudines
  - Suborder Cryptodira
    - Superfamily Baenoidea
      - Family Glyptopsidae
        - *Glyptops* March (U.J.)
      - Family Baenidae Cope
        - Subfamily Trinitichelinae
          - *Trinitichelys* Gaffney (K.)
        - Subfamily Hayemydinae
          - *Hayemys* Gaffmey (U.K.)
        - Subfamily Eubaeninae
          - *Plesiobaena* Gaffney (U.K.-Pal)
          - *Eubaena* Hay (U.K.)
          - *Stygiochelys* Gaffney & Hiatt (U.K.)
        - Subfamily Palatobaeninae
          - *Palatobaena* Gaffney (U.K.-Pal)
        - Subfamily Baeninae
          - *Baena* Leidy (Eocene)
          - *Chisternon* Leidy (Eocene)

Taxa within Baenidae but not referable to subfamily:

- *Compsemys* Leidy (K-Pal)
- *Neurankylus* Lambe (U.K.)
- *Boremys* Lambe (U.K.)
- *Thescelus* Hay (U.K.)

Table 8. Gaffney's (1975) Classification of Higher Categories of Turtles.

- Order Testudines Linnaeus
  - Suborder Proganochelydia Romer
    - Family Proganochelyidae (Triassic)
  - Suborder Casichelydia Gaffney
    - Infraorder Pleurodira Cope
      - Family Pelomedusidae (K-Rec.)
      - Family Chelidae (Eocene-Rec.)
    - Infraorder Cryptodira (Cope)
      - Parvaorder Paracryptodira Gaffney
        - Superfamily Baenoidea Williams
          - Family Glyptopsidae (Jur.)
          - Family Baenidae (K-Eoc.)
      - Parvaorder Eucryptodira Gaffney
        - Superfamily Trionychoidea Gray
          - Family Kinosternidae (Olig.-Rec.)
          - Family Dermatemydidae (K-Rec.)
          - Family Carettochelyidae (Eoc.-Rec.)
          - Family Trionychidae (K-Rec.)
        - Superfamily Chelonioidea Baur
          - Family Plesiochelyidae (Jur.)
          - Family Protostegidae (K)
          - Family Toxochelyidae (K-Eoc.)
          - Family Cermochelyidae (Eoc.-Rec.)
          - Family Cheloniidae (K-Rec.)

Superfamily Testudinoidea Baur

Family Chelydridae (Pal.-Rec.)

Family Emydidae (Pal.-Rec.)

Family Testudinidae (Eoc.-Rec.)

Gaffney's classifications are included below. Attempts have been made to rationalize reported occurrences of turtles in the Fruitland with Gaffney's scheme in the vertebrate faunal lists that follow.

Although turtles obviously formed an important part of Fruitland faunas, their apparent abundance may be misleading. Turtle bones are very dense and resistant. A single turtle cavapase and plastron will easily break into numerous smaller pieces that in turn break into still smaller resistant pieces. An accurate representation of turtle abundance is badly needed. The detailed plotting of turtle occurrences and abundances should provide interesting ecologic data and data related to depositional environments.

Table 9 represents Gaffney's (1972) view of the stratigraphic distribution of baenoid turtles.

Table 9. Stratigraphic Distribution of Baenoid Turtles (from Gaffney, 1972).

	Maestrichtian	
Skulls	Associated Skulls and Shells	Shells
Hayemys latifrons	*Plesiobaena antiqua*	*Thescelus insiliens*
Eubaena cephalica		
Stygiochelys estesi		*Neurankylus eximius*
Palatobaena bairdi		form genus "*Baena*"
		Compsemys victa
	Campanian	
	Plesiobaena antiqua	*Boremys pulchra*
		Thescelus insiliens
		Neurankylus eximius

To demonstrate the confusion and "over-description" of turtles the synonomies are taken from Gaffney (1972) and have a direct bearing on San Juan Basin faunas.

Table 10. Examples of Revisions

1. *Compsemys victta* Leidy
    - *C. parva* Hay 1910
    - *C. vafer* Hay 1910
    - *C. puercensis* Gilmore 1919
    - *C. torrejonensis* Gilmore 1919
2. *Neurankylus eximius* Lambe
    - *Charitemys capitans* Hay 1908
    - *Neurankylus baueri* Gilmore 1916
    - *Baena fluviatilis* Parks 1933
3. *Boremys pulchra* (Lambe 1906)
    - *Baena pulchra* Lambe 1906
    - *Boreymys albertensis* Gilmore 1919
    - *Boreymys grandis* Gilmore 1935
    - *Baena nodosa* Wiman 1933
4. *Thescelus insiliens* Hay 1908
    - *Thescelus rapiens* Hay 1908
    - *Thescelus hemispherica* Gilmore 1935
    - *Baena longicauda* Russell 1935

Gaffney (1972) notes that analyses of a sample of *Baena arenosa* from the Bridger Formation of Wyoming indicates that a great deal of variation occurs in terms of shell morphology. A sympatric species *Chisternon undatum* has a distinct skull morphology but a shell very similar to that of Baena. On the basis of shells only, it would be difficult to separate these taxa. In the Cretaceous, a similar situation can be demonstrated with shell morphologies that are as variable as in B. arenosa and C. undatum but very few associated skulls. Although it is likely that more than one species is present, reasonable separation of the taxa is only nominally possible.

As noted above, the vertebrates of the Fruitland are discussed by Gilmore (1916, 1919, and elsewhere); Osborn (1923) described Pentaceratops sternbergii and Wiman (1930, pp. 14-15) reported Pentaceratops? sp., collected by Charles Sternberg in New Mexico for the Paleontological Institute in Upsala, Sweden. The fragmentary material:

> "An der Sudseite von Alamo Wash, drei miles oberhalb Hunters Store wurden in den Fruitland Shales einige Ceratopsidenfragmente gefunden."

Sternberg's stratigraphy deserves a closer look but essentially appears reasonable and is primarily based upon Reeside's work in the San Juan Basin.

C.M. Sternberg (1949, p. 42) places Pentaceratops sternbergii in a position older than Lancian Triceratops but younger than Monoclonius, roughly Edmontonian in age as compared to a Judith River age for Monoclonius. This may well be valid for Alberta but not valid for New Mexico. As noted elsewhere, the Pentaceratops community is likely to have continued through the Cretaceous in New Mexico as a part of a southern, contemporaneous fauna. The presence of Monoclonius in New Mexiso is questioned by this author.

Ostrom (1963) described _Parasaurolophus_ _cyrtocristatuts_ from the Fruitland Formation. The specimen was collected in 1923 by C.H. Sternberg near Coal Creek, about eight miles southeast of Tsaya in McKinley County.

Powell (1972, 1973) synthesized much of the diffuse vertebrate data for the San Juan Basin. Table 11 is taken from Powell (1972). More recent work has modified his interpretations.

Table 11. Vertebrates of the Fruitland Formation

- Subclass Anapsida
  - Order Chelonia
    - _Neurankylus_ _baueri_ Gilmore
    - _Baena_ _nodosa_ Gilmore
    - _Adocus_ _bossi_ Gilmore
    - _Asperidites_ sp.
- Subclass Archosauria
  - Order Crocodilia
    - _Crocodylus_ sp.
    - _Brachampsa?_ sp.
  - Order Saurischia
    - Family Megalosauridae
      - _Deinodon?_ Sp.
  - Order Ornithischia
    - Family Hadrosauridae
      - _Parasaurolophus_ _cyrtocristatus_ Ostrom
    - Family Ceratopsidae
      - _Monoclonius_ sp.?
      - _Pentaceratops_ _sternbergii_ Osborn

It should be noted that Powell neglects to mention that Gilmore (1916) reports *Adocus? lineolatus* Cope and *Aspideretes austerus* Hay. *Neurankylus baueri* is in fact *Neurankylus eximius* of Gaffney (1972). Similarly *Baena nocosa* is perhaps better referred to as "form genus *Baena*."

Clemens, and a series of other researchers (R.E. Sloan, M.C. McKenna for example) have had a longstanding interest in San Juan Basin mammals. Clemens has long actively researched mammalian faunas of the Fruitland. Clemens (1967 written communication) in Fassett and Hinds (1971, p. 19) provided the following faunal list for mammals recoverd in Hunter Wash from the Fruitland Formation:

Table 12. (from Fassett and Hinds, 1971)

Multituberculata

- *Mesodma*, possibly *M. formosa*
- *Cimolodon*, two species, one resembling *C. nitidus*, the other including animals of smaller individual size.
- A new species with a low, eucosmodontidlike P_4.
- A new species with high, trenchant P^4_4 .

Marsupialia

- *Alphadon marshi* or a closely related species and at least one other, as yet undescribed species.
- *Pediomys* sp.

Eutheria

- *Gypsonictops* sp.

Table 12. continued

Cimolestes sp.

A therian mammal that cannot be referred to the Marsupiala or Eutheria on the available evidence.

Clemens (p. 19) also provides the following observations:

> "Comparison of this faunal unit with the Lance local fauna from the Late Cretaceous of eastern Wyoming points out some interesting differences. For example, Meniscoessus (a multituberculate) and Pediomys (a marsupial) have high relative abundances in the Lance local fauna. The former is unknown and the latter very rare in New Mexico. Our collections are now large enough to warrant suggesting that their absence or low frequency of occurrence are not a product of bias in collecting technique or small sample size. Whether these faunal differences reflect differences in age, ecology or combinations of these and other factors, remains to be determined."

Clemens (1973) provided an update of the Hunter Wash local fauna (Table 13).

Table 13. (from Clemens, 1973)

- Order Multiturberculata
  - Suborder Ptilodontoidea
    - Family Ectypodontidae
      - *Mesodma* sp. The P_4 resembles that of *M. primaevus*...but is larger
      - *Cimexomys*, cf. *C. judithae*
    - Family Ptildontidae
      - cf. *Kimbetohia campi*
    - Family Cimolodontidae
      - *Cimlodon* sp. At least one species resembling *C. nitidus* and the other including animals of smaller individual size.
  - Suborder Taeniolabidoidea
    - Family Eucosmodontidae
      - A new genus and species

- Order Marsupialia
  - Superfamily Didelphoidea
    - Family Didelphidae
      - *Alphadon* cf. *marshi*. Teeth of this species are approximately intermediate between *A. marshi* and *A. wilsoni*.
      - *Alphadon?* new species
    - Family Pediomyidae
      - *Pediomys* cf. *cooki*

Table 13. continued

Order Insectivora

Family Leptictidae

Gypsonictops sp. Two species are present.

Family Palaeorcytidae

cf. *Cimolestes* sp. Smaller than *C. incisus*

Eutherian of uncertain ordinal affinities. Clemens (1973, p. 165) notes that the Hunter Wash collections were obtained from the upper 40 feet of the Fruitland Formation and the lower 55 feet of the Kirtland Shale. It is probably younger than the zone of *Didymoceras nebrascense*. However, documentation by Lindsay, and others (1978) indicates that the Hunter Wash faunas are from the Fruitland Formation.

Although, predominantly a listing, the work of Armstrong-Zieglar (1978) is very significant. Many lower vertebrate forms are reported from the Fruitland for the first time. Unfortunately, difficulties exist with respect to locality data reported by Armstrong-Zieglar. However, it is possible to compare her Fruitland fauna to comparable Judith River faunas (Sahni, 1972), Lance faunas (Estes, 1964) and Hell Creek faunas (Estes and others, 1969).

Table 14. (from Armstrong-Zieglar, 1978)

Chondrichthyes

Selachii

Hybodontidae

Table 14. continued

x*_Lonchidion selachos_ Estes

Insuridae

Isurus (_Oxyrhina_) sp.

Orectolobidae

*_Squatirhina americana_ Estes

Squatirhina sp.

Batoidea

Pristidae

x*_Ischyrhiza avonicola_ Estes

Dasyatidae

Ⅹx*_Myledaphus bipartitus_ Cope

Osteichthyes

Acipenseriformes

Acipenseridae

x* _Acipenser eruciferus_ (Cope)

Polyodontidae

x_Paleopsephurus wilsoni_ MacAlpin

O. Amiiformes

Amiidae

Ⅹx*_Amia fragosa_ (Jordan)

---

x species in Hell Creek of Estes et al, 1969
x̲ genus in Hell Creek of Estes et al, 1969

Ⅹ species in Judith River of Sahni (1972)

Ⅹ̲ genus in Judith River of Sahni (1972)

* species in Lance of Wyoming (Estes, 1964)
*̲ genus in Lance of Wyoming (Estes, 1964)

\# species of Estes (1969)

Table 14. continued

- O. Lepisosteiformes
  - Lepisosteidae
    - ⧖x**Lepisosteus occidentalis* (Leidy)
- O. Elopiformes
  - F. Phyllodontidae
    - ⧖x#*Paralbula casei* Estes
- Perciformes
  - Sciaenidae
    - **Platacodon nanus* Marsh

Amphibia

- Anura
  - Discoglossidae
    - x*Scotiophryne pustulosa* Estes
  - Pelobatidae
    - x? ?*Eopelobates* sp.
- Urodela
  - Prosirenidae
    - ⧖x**Prodesmodon ?copei* P. copei Estes at Lance
  - Batrachosaurordidae
    - ⧖x**Opisthotriton kayi* Auffenberg
  - ?Urodela
    - x*Cuttysarkus mcnallyi* Estes

Reptilia

- Testudinata
  - Dermatemyididae
    - x*Adocus* sp.
    - x*Compsemys sp.

Table 14. continued

Ⅹ?* ?*Basilemys* sp.

Trionychidae

Ⅹx*Trionyx* sp.

Sauria

Teiidae

Ⅹx**Leptochamops denticulatus* (Gilmore)

Ⅹx**Chamops segnis* Marsh

Anguidae

Gen. et. sp. indet.

*cf. *Gerrhonotus* sp.

Serpentes

Aniliidae

x**Coniophis cosgriffi* s.sp.

Crocodilia

Crocodylidae

Ⅹx**Leidyosuchus* sp.

?*Thoracosaurus* sp.

Ⅹx**Brachychampsa* sp.

Saurischia

Coeluridae

x**Paronychodon lacustris* Cope

?Coeluridae

Unidentified genus and species

?Dromaeosauridae

Table 14. continued

- Deinodontidae
  - $\overline{\underline{X}}$*Deinodon horridus*
- Ornithischia
  - ?Pachydephalosauridae
  - Hadrosauridae
    - $\overline{\underline{X}}$*Kritosaurus navajovius*
  - Ceratopsidae
    - *Pentaceratops sternbergii* Osborn
    - ?*Monoclonius* sp. Gilmore

Mammalia

- Multituberculata
  - Ectypodontidae
    - $\overline{\underline{X}}$?*Mesodma* sp.
    - ? new multituberculate(s)
  - Ptilodontidae
    - ? *Essonodon* sp.
  - Cimolodontidae
    - $\overline{\underline{X}}$*Cimolodon* sp. n. sp.
  - Eucosmodontidae
    - new genus and species
  - Marsupilia
    - Didelphidae
      - $\overline{\underline{X}}$*Alphadon* cf. *marshi*
      - ?*Peradectes* sp.

Table 14. continued

Revised list in Mesozoic Mammals, p. 43

- Order Multituberculata
  - Neoplagiaulacidae
    - *Mesodma*? sp.
      - new genus? and new species?
  - Cimolodontidae
    - *Cimolodon* sp.
  - Eucosmodontidae
    - new genus and species
- Family *incertae sedis*
  - *Essonodon*? sp.
- Order Marsupialia
  - Didelphidae
    - *Alphadon* cf. *marshi*
    - cf. *Peradectes* sp.

The turtle nomenclature of Armstrong-Zieglar is in need of revision. *P. casei* was first described by Estes (1969) from the Maestrichtian of New Jersey (Navesink Marl) but is also known from the Campanian Old Man Formation of Canada and the London Clay Ypresian (Early Eocene) of England.

Amia fragosa (Jordan) was originally described as *Kindleia fragosa* until revised by Boreske (1974). Fox (1975) and Estes (1964) have also reported anilliids. A series of larger trunk vertebrae recovered by Wolberg from the vicinity of Bisti Trading Post, may represent *Amia* cf. *uintaensis*. These specimens agree well with Boreske's (1974, p. 64) description. They appear larger and more robust than vertebrae in *A. kindeila*.

Wolberg and LeMone (1980) reported a Fruitland vertebrate fauna from the vicinity of the old Bisti Trading Post. This fauna however is unlocated stratigraphically in the Fruitland; work is in progress to more accurately delimit the stratigraphy of the collecting areas. However, this fauna records the presence of *Champsosaurus* for the first time as well as *Gorgosaurus*. The latter referral should probably read ?*Gorgosaurus*. This fauna is recorded in table 15. The turtles listed should be revised.

Table 15. Fruitland Fauna from near Bisti (from Wolberg and LeMone, 1980)

Class Chondrichthyes
  Subcalss Holocephali
    Order Chimaeriformes
      Suborder Chimaeroidei
        Family Chimaeridae
          Myledaphus sp.

Class Osteichthyes
  Subclass Actinopterygii
    Infraclass Holostei
      Order Semionotiformes

Table 15. continued

Suborder Lepisostoidei
  Family Lepisosteidae
    Lepisosteus sp. A

Order Ammiformes
  Suborder Amioidei
    Family Ammiidae
      Amia sp.

Class Reptilia
  Subclass Anapsida
    Order Chelonia
      Suborder Amphichelydia
        Superfamily Baenoides
          Family Baenidae
            Baenia sp. A

      Suborder Cryptodira
        Superfamily Testudinoides
          Family Dermatemydidae
            Adocus sp.

        Superfamily Trionychoidea
          Family Trionychidae
            Trionyx sp. cf. *T. vorax*
            Trionyx sp. cf. *T. austerus*

Table 15. continued

Subclass Lepidosauria
  Order Eosuchia
    Suborder Choristodera
      Family Champsosauridae
        Champsosaurus sp.

Subclass Archosauria
  Order Crocodilia
    Suborder Eusuchia
      Family Crocodylidae
        Crocodylus sp.
        Brachychampsa sp.

  Order Saurischia
    Suborder Theropoda
      Infraorder Carnosauria
        Family Tyrannosauridae
          Gorgosaurus sp.

  Order Ornithischia
    Suborder Ornithopoda
      Family Hadrosauridae
        cf. *Kritosaurus*

    Suborder Ankylosauria
      Family Nodosauridae
        Euoplocephalus sp.

Table 15. continued

Class Mammalia

    Order Multituberculata

      Suborder Ptilodontoidea

        Family Ectypodontidae

          Mesodma sp.

        Family Cimolodontidae

          cf. *Cimolodon*

    Order Insectivora

      Family Leptictidae

        cf. *Gypsonictops*

The Fruitland fauna is thus better known, in some respects, than expected at least in terms of potential diversity. However, this is almost entirely on the basis of isolated studies that only report isolated occurrences. No definitive treatment or synthesis of the Fruitland exists. No coherent stratigraphic framework for the placement of these isolated faunas exists. For comparison, Sahni's (1972) Judith River fauna is shown below in Table 16.

Table 16. Judith River Fauna (after Sahni 1972)

Class Elasmobranchii

    Order Rajiformes

      Family Dasyatidae

        Alyledaphus bipartitus Cope

Table 16. continued

Class Osteichthyes
Order Amiiformes
Family Amiidae
Kindleia fragosa Jordan
Order Aspidorhynchiformes
Family Aspidorhynchidae
Belonostomus longirostris (Lambe)
Order Lepisosteiformes
Family Lepisosteidae
Lepisosteus occidentalis (Leidy)
Order Elopiformes
Family Albulidae
?*Paralbula* sp.

Infraclass Teleostei, indet
Class Amphibia
Order Salientia
Family Discoglossidae
Family Pelobatidae
Order Urodela
Family Scapherpetonidae
Scapherpeton tectum Cope
Lisserpeton bairdi Estes
Family Sirenidae
Habrosaurus dilatus Gilmore
Family Plethodontidae
Prodesmodon copei Estes

Table 16. continued

Family ?Plethodontidae
Opisthotriton Kayi Auffenberg

Class Reptilia
Order Testudines
Family Dermatemydidae
Basilemys sp.
Family Trionychidae
Trionyx sp.
Family ?Baenidae
Order Eosuchia
Family Champsosauridae
Champsosaurus sp.
Order Crocodilia
Suborder ?Sebecosuchia
Suborder Eusuchia
Family Crocodylidae
Subfamily Crocodylinae
Leidoyosuchus canadensis Lambe
Subfamily Alligatorinae
Brachychampsa montana Gilmore
Order Sauria
Family Teiidae
Chamops segnis Marsh
Leptochampos denticulatus (Gilmore)
Family Anguidae
Peltosaurus piger Gilmore

Table 16. continued

- Family Xenosauridae
  - *Exostinus lancensis* Gilmore
- Family ?Xenosauridae
  - cf. *Exostinus* sp.
- Family Parasaniwidae
  - *Parasaniwa wyomingensis* Gilmore
  - *Paraderma bogerti* Estes

Order Saurischia

- Family Deinodontidae
  - *Deinodon horridus* Leidy
  - *Dromaeosaurus albertensis* Matthew and Brown
  - *Troodon formosus* Leidy
  - *Paronychodon lacustris* Cope

Order Ornithischia

- Family Hadrosauridae
  - Subfamily Hadrosaurinae
    - *Kritosaurus* cf. *K. breviceps* (Marsh)
  - Subfamily Lambeosaurinae
    - *Procheneosaurus altidens* (Lambe)
- Family Pachycephalosauridae
  - ?*Stegoceras* validus Lambe
- Family Hypsilophodontidae
  - *Thescelosaurus* cf. *T. neglectus* Gilmore
- Family Ceratopsidae
  - Genera and sp. indet.
- Family Nodosauridae
  - *Palaeoscincus costatus* Leidy
  - *Edmontonia longiceps* Sternberg

Table 16. continued

Class Mammalia
  Infraclass Allotheria
    Order Multituberculata
      Family Ectypodontidae
        Cimexomys judithae Sahni
        Cimexomys magnus Sahni
        Mesodma primaevus (Lambe)
      Family Cimolomyidae
        Cimolomys clarki Sahni
        Meniscoessus major (Russell)
      Family Cimolodontidae
        Cimolodon sp.
  Infraclass Metatheria
    Order Marsupicarnivora
      Family Didelphidae
        Alphadon praesagus (Russell)
        Alphadon halleyi Sahni
        Alphadon cf. *A. rhaister* Clemens
      Family Pediomyidae
        Pediomys clemensi Sahni
      Family Stagodontidae
        Boreodon matutinus Lambe
  Infraclass Eutheria
    Order Insectivora
      Family Leptictidae
        Subfamily Gypsonictopsinae
          Gypsonictops lewisi Sahni

The Judith River Formation has been dated at 75±2 my. It interfingers with the Pierre Shale to the east and is Campanian in age. Judith River deposits are fluvial, channel sandstones, silts and mudstones with occasional beds of lignite and coal, especially at the top of the formation.

The Judith River fauna was confined to the lowland, coastal regions between the rising Cordilleras some 400-500 miles to the west and the Pierre Sea, about 100 miles to the east. The area was covered by a multistoried tropical rain forest similar to that found at the present time on the eastern coast of Costa Rica.

Three Judith River communities are recognized by Sahni:

1. Stream and Stream Bank
2. Megaterrestrial
3. Microterrestrial

The stream and stream bank community was proximal to depositional areas and represented by a diversity of fish, amphibians, crocodiles and champsosaurs, snails and clams.

The Megaterrestrial community consists of large herbivorous and carnivorous dinosaurs. Dinosaur egg shell fragments are relatively common. The microterrestrial community consisted of mammals (herbivores and omnivores) and carnivorous reptilian forms.

Sahni was able to offer a detailed stratigraphic distribution, depositional environments, relative proportions of faunal components for the Judith River faunas. This provided a coherent model of community structure and paleoenvironments. This has yet to be done for the Fruitland Formation.

Table 17 below is a first effort to provide such an overall model of at least the faunal elements of the Fruitland as they are presently understood. It is very incomplete and the reported occurrences are just that: reports of the presence of certain taxa. No statements regarding abundance can yet be made.

Table 17.

STREAM AND STREAM BANK COMMUNITY

CARNIVORES	*Leidyosuchus* sp.	*Brachychampsa* sp.
	?*Thoracosaurus* sp.	*Champsosaurus* sp.
	Lenchidion selachos	*Isurus* (*Oxyrhina*) sp.
	Squatirhina americana	*Squatirhina* sp.
	Ischyrhiza avonicola	*Myledaphus bipartitus*
	Acipenser eruciferus	*Paleopsephurus wilsoni*
	Leprsosteus occidentalis	*Paralbula casei*
	Platacodon nanus	*Scotiophryne pustulosa*
	?*Eopelobates* sp.	*Prodesmodon* ?*copei*
	Opisthotriton kayi	*Cuttysarkus mcnallyi*
OMNIVORES	*Amia fragosa*	*Neurankylus eximius*
		"*Baena*" *nodosa*
		Basilemys
		Trionyx
		Aspideretes
		Adocus
		Adocus? lineolatus
HERBIVORES	Bivalves & Gastropoda	

Table 17. continued

	MEGATERRESTRIAL COMMUNITY (forest floor, Understory)	ARBOREAL COMMUNITY (Microterrestrial)
CARNIVORES	*Dernodon horridus*	*Leptochamops denticulatus*
	dromaeosaurid	*Chamops segnis*
	Paronychodon lacustris	*Gerrhonotus*
	gorgosaur?	*Coniophis cosgriffi*
		Gypsonictops sp.
		Gypsonictops hypoconus
		Cimolestes sp.
OMNIVORES		*Alphadon* cf. *A. marshi*
		cf. *Peradectes*
		Pediomys cf. *P. cooki*
HERBIVORES	?*Monoclonius* sp.	*Mesodma* sp.
	Pentaceratops sternbergii	*Cimolodon* sp.
	Kritosaurus mavajovius	Eucosmodontid
	Parasaurolophus cyrtocristatus	*Essonodon*
	Euoplocephalus sp.	*Cimexomys* sp.
		cf. *Kimbetohia campi*

Age and Paleoecology of the Fruitland Formation

Much has been made of the archaic nature of Fruitland-Kirtland megaterrestrial communities. Comparisons of Fruitland-Kirtland to other megafaunas have stressed similarities to Campanian-age faunas of Montana and Canada rather than Maestrichtian-age faunas of Montana and Canada. The error inherent in this logic has been a general neglect of radiometric and paleomagnetic data and a stress on general faunal composition as a chronostratigraphic datum rather than biogeographic inference.

As Sloan (1969) noted some years ago, Late Cretaceous megaterrestrial communities evidence a good deal of regional and temporal variation. North American megaterrestrial communities range in age from the Campanian through the Maestrichtian and that include the Judithian, Edmontonian, and Lancian Stages (Russell, 1964, 1975). The term Lancian was first used by Dorf (1942). Late Cretaceous North American megaterrestrial communities consist of two main "biofacies." The older of these is a community known from the Judith River Formation of Montana (Sahni, 1972) and the Oldman Formation of Alberta (Russell, 1964). Folinsbee, and others, (1965) dated the overlying Bearpaw Shale as 70-73 m.y. and the typical Judithian vertebrate fauna must be approximately 74-75 m.y. (Russell, 1975, p. 148). This community is also known from the Fruitland and Kirtland and the lower part of the North Horn Formation of Utah from latest Campanian through

Maestrichtian. The community is dominated by longfrilled, fenestrate ceratopsians, crested duckbilled dinosaurs, ankylosaurs and some flatheaded duckbilled dinosaurs.

The only North American sauropod, Alamosaurus, known from the Late Cretaceous occurs in this community. The northern-most occurrence of Alamosaurus is in the type Lance of Wyoming (Sloan, 1969) and it is not known to occur earlier than the Maestrichtian. Sloan suspects that the genus migrated into western North America from Europe via the northern Tethyian shore or by crossing Tethys from South America.

The above described more southern "biofacies" represents an older southern community that persists through time, basically intact with periodic additions or deletions (e.g., Alamosaurus in the Maestrichtian.

The second megaterrestrial community is dominated by flat-headed duckbilled dinosaurs and the ceratopsian Arrhinoceratops or its descendant Triceratops. This community probably originated from the Judith River-Oldman community but continues through time and to the north of the late phases of the older community. This later, more northern community is well known from the upper Edmonton of Alberta, the Hell Creek of Montana and the Dakotas and the Lance of northern Wyoming.

By and during Maestrichtian time, the southern border of Wyoming appears to form a boundary between the southern Alamosaurus-Pentaceratops-Parasaurolophus community and the northern Triceratops-Anatosaurus dominated community.

Apart from the megaterrestrial community, the Fruitland fauna contains another "biocomponent," the stream and stream bank community. The Fruitland stream and stream bank community is very similar to stream and stream bank communities ranging in age from Campanian to latest Maestrichtian (Armstrong-Ziegler, 1978; Sahni, 1972; Estes, 1969). Wolberg and LeMone (1980) note the occurrence of Champsosaurus in the Fruitland as well. The stream and stream bank community represents a slowly evolving biota that remains stable through time and persists well into the early Tertiary. It would appear that whatever ecological constraints existed, primarily affected the megaterrestrial and micro-terrestrial communities rather than the stream and stream-bank community. The latter remains especially uniform from New Mexico to Canada.

Stability in the Stream and Stream Bank community does not imply compositional uniformity. Estes and Berberian (1970) demonstrated the sensitivity of detailed quantitative and qualitative analyses for separating faunas inhabiting a swamp-forest-small watercourse environment from one nearer the deeper waters of major rivers that probably issued from the lowland swamps. Such analyses has yet to be done for the Late Cretaceous of New Mexico.

In Knowlton (1916) Anemia hesperia is compared to living species that include Anemia wrightii Baker, Anemia cicutaria Kunze, and Anemia cuneata Kunze. These species are all natives of Cuba and are found growing in crevices in rocks along shaded rivers. The genus Heteranthera is small and comprises nine species, two of which occur in tropical Africa, the others in the Americas. Three species are known in the United States. They are herbs that grow in mud or shallow water. Heteranthera has creeping, ascending or floating stema and petioled leaves. H. cretacea seems most similar in form to Heteranthera limosa (Swartz), the smaller mud plantain, which currently is known from Virginia to Kentucky and Missouri, south to Florida and Louisiana and into tropical America.

Stodola (1967, p. 260-63) illustrates H. limosa and discusses other species of Heteranthera as well. Heteranthera appears to prefer muddy bottoms or at least sand with clay and neutral to alkaline waters (pH 7-8). Although water temperatures down to 50°F are tolerated by H. dubia and probably H. limosa as well, warmer waters (65°-86°F) are preferred by other species.

The presence of a ceratopsian at Elephant Butte Reservoir will have major bearing on the validity of northern and southern megaterrestrial communities. If the ceratopsian is actually Pentaceratops, the model may be, but is not necessarily valid. If the ceratopsian is Triceratops, the model is most likely wrong, and the available San Juan data will have to be reviewed. On the basis of available biostratigraphic data, paleomagnetic data, phylogenetic data, paleoecologic data, Triceratops probably does not occur at Elephant Butte.

Russell, 1964 as noted above recognized the Lancian, Edmontonian and Judithian stages and there associated faunas. He found that certain mollusks are characteristic of each stage. Table 18 lists these. Note that _Proparreysia holmesiana_ is known from the Fruitland Formation.

Table 18. (after Russell, 1964) Upper Cretaceous Stages and Characteristics Mollusks

Lancian State (Upper Maestrichtian)

Quadrula cylindricoides
Proparreysia barnumi
Proparreysia holmesiana

Edmontonian (Part of Maestrichtian)

Fusconaia? stantoni
Sphaerium heskethense
Viviparus westoni
Lioplacodes sanctamariensis

Judithian (Part of Campanian)

Plesielliptio abbreviatus
Rhabdotophorus senectus
Lioplacodes vetula
Goniobasis sublaevis

Lindsay, Jacobs, and Butler (1978) place the Hunter Wash fauna in magnetic anomaly 31, in the Fruitland Formation. This is the Hunter Wash local fauna of Clemens (1973) as noted in Butler, Lindsay, and Jacobs (1977). Reasonable correlation of the magnetostratigraphic record between anomalies 32 and 31 exist between the San Juan Basin and Red Deer Valley, Alberta (Lerbekmo, Evans, and Baadsgaard, 1979), and to the revised Cenozoic polarity time scale of Tarling and Mitchell (1978). The Fruitland Formation appears to encompass anomaly 31 and the lower portion of anomaly 30. La Breque, Kent, and Condie (1977) and Kent (1977) indicate that anomalies 30 and 31 should include the span of time from 65.5 m.y. to 67.5 m.y. Anomaly 31 may represent just or slightly less than one million years; perhaps as little as 750,000 years (see Kent, 1977, p. 770). In any event, it does not appear likely that major interruptions in sedimentation of any appreciable duration occurs within this magnetostratigraphic interval.

Direction of Continued Studies

Certain directions for continued studies of the Fruitland Formation emerge from this data compilation and limited interpretation. There are obvious gaps in our knowledge of Fruitland geology, faunas and floras, although a surprisingly broad data base exists on which to base additional work. There is a clear need for more detailed stratigraphic study of the Fruitland, including a better definition of the formation's lower and upper boundaries, mapping of available exposures and detailed attention to lithologies. Study of the depositional environments available in the Fruitland should be undertaken as should the detailed mapping of coal beds; individual coal seams may offer the best horizon markers in the Fruitland Formation.

A detailed collecting program for plant fossils should be carried out, both leaf and wood studies and palynology. Zavada'a research is very provocative and verification of his results is needed. Knowlton's early marcobotanical studies should be expanded and brought up to date. No published study of Fruitland fossil wood exists and an excellent opportunity is available in the "fossil forest" area.

Vertebrate studies are almost all old or diffuse, but better data is available than was expected. Almost all extent studies pay very little attention to a coherent stratigraphic framework. Future vertebrate work must be keyed to an excellent stratigraphic concept of the Fruitland-prominent "marker-coals" may serve as the needed hook for this work. Vertebrate work should concentrate on the distribution and abundance of taxa through the formation rather than on isolated occurrences. Increased emphasis should be placed on the acquisition of microvertebrate materials for study.

Invertebrate studies are badly needed. The taxonomy of published taxa has been badly distorted in comparison to present understanding. Hartman's planned work will go far in establishing a reasonable understanding of the Fruitland mollusks.

It is suggested that Fruitland studies (and Kirtland as well) now have a testable model or hypothesis that should guide future work. The Fruitland fauna (and probably flora) may be the southern expression of a Late Cretaceous community separable but parallel to a more northern community. Little or no difference is seen between stream and stream bank communities from Canada to New Mexico. Differences are apparent, however, between the megaterrestrial communities. Differences are also apparent between the microterrestrial communities. Some isolating mechanism must have been responsible for these differences.

With this model, it should be possible to predict and test the following. Earlier faunas should have been similar between areas. Differences should first appear low in the Fruitland and become progressively greater higher in the Fruitland and well into the Kirtland and Ojo Alamo (The age of the Ojo Alamo will be discussed in a later report, but it is most likely Cretaceous.). More southern faunal elements besides Alamosaurus should be present. Additional differences should be detectable in the microterrestrial fauna.

References

Armstrong-Ziegler, J.G., 1978. An anilid snake and associated vertebrates from the Campanian of New Mexico. Journal of Paleontology, v. 52, no. 2, pp. 480-483

Axelrod, D.I. and H.P. Bailey, 1969, Paleotemperature analysis of Tertiary floras. Palaeogeography, Palaeoclimatology, palaeoecology. v. 6. pp. 163-195

Baltz, E.H. 1967. Stratigraphy and regional tectonic implications of part of Upper Cretaceous and Tertiary rocks, east-central San Juan Basin, New Mexico. U.S. Geological Survey Professional Paper 552. 101 p.

Bauer, C.M. 1916. Stratigraphy of a part of the Chaco River Valley: U.S. Geological Survey Professional Paper. 98-P, pp. 271-278

Boreske, J.R., Jr. 1974. A review of the North American fossil amiid fishes. Bulletin Museum of Comparative Zoology. v. 146, no. 1, pp. 1-87

Brown, Barnum. 1910. The Cretaceous Ojo Alamo beds of New Mexico with description of the new dinosaur genus <u>Kritosaurua</u>. Bulletin of the American Museum of Natural

Butler, R.J., E.H. Lindsay, and L.L. Jacobs. 1977. Magnetostratigraphy of the Cretaceous-Tertiary boundary in the San Juan Basin, New Mexico. Nature, v. 267, no. 5609, pp. 318-323

Clemens, W.A. 1973. The roles of fossil vertebrates in interpretation of Late Cretaceous stratigraphy of the San Juan Basin, New Mexico. In Cretaceous and Tertiary rocks of the southern Colorado Plateau, J.E. Fassett (editor), pp. 154-167. Memoir of the Four Corners Geological Society

Cobban, W.A. 1973. Significant ammonite finds in uppermost Mancos Shale and overlying formations between Barker Dome, New Mexico, and Grand Junction, Colorado. pp. 148-153 of Four-Corners Geological Society guidebook

Dane, C.H. 1936. The La Ventana-Chacra Mesa coal field, pt. 3 of Geology and field resources of the southern part of the San Juan Basin, New Mexico: U.S. Geol. Survey Bull. 860-C, pp. 81-161

Dorf, E. 1942. Upper Cretaceous floras of the Rocky Mountain region. Carnegie Institute Washington. Publication 508, 168 p.

Estes, R. 1964. Fossil vertebrates from the Late Cretaceous Lance Formation, eastern Wyoming. Univ. Calif. Publ. Geol. Sci. v. 49, pp. 1-187.

Estes, R. 1969. Studies on fossil phyllodont fishes. Interrelationships and evolution in the Phyllodontidae (Albuloidei). Copeia, v. 5, no. 2, pp. 317-331

Estes, R., P. Berberian, and C. Meszoely. 1969. Lower vertebrates from the Late Cretaceous Hell Creek Formation, McCone County, Montana Museum of Comparative Zoology, Harvard University. Breviora. No. 337, 35 p.

Fassett, J. and J. Hinds. 1971. Geology and fuel resources of the Fruitland Formation and Kirtland Shale of the San Juan Basin, New Mexico and Colorado. U.S. Geol. Surv. Prof. Paper 676. 76 p.

Folinsbee, R.E., H. Baadsgaard, G.L. Cumming, J. Nascimbene, and M. Shafiqullah. 1965. Late Cretaceous radiometric dates from the Cypress Hills of western Canada. Alberta Society of Petroleum Geologists. 15th Annual Field Conference Guidebook, pt. 1, pp. 162-174

Fox, C.R. 1975. Fossil snakes from the upper Milk River Formation (Upper Cretaceous), Alberta. Canadian Journal of Earth Science. v. 12, pp. 1557-1563

Gafney, E.S. 1972. The systematics of the North American family Baenidae (Reptilia, Cryptodira). Bull. Amer. Mus. Nat. Hist. Vol. 147, Article 5, pp. 241-320

Gaffney, E.S. 1975. A phylogeny and classification of the higher categories of turtles. Bull. Amer. Mus. Nat. Hist. Vol. 155, Article 5, pp. 387-436

Gilmore, C.W. 1919 Reptilian faunas of the Torrejon, Puerco, and underlying Upper Cretaceous formations of San Juan County, New Mexico. U.S. Geol. Survey Professional Paper 119. 71 p.

Gilmore, C.W. 1916. Vertebrate faunas of the Ojo Alamo, Kirtland, and Fruitland formations: U.S. Geol. Survey Prof. Paper 98-Q, pp. 279-308

Halle, F., R.A.A. Oldeman, and P.B. Tomlinson. 1978. Tropical trees and forests. Springer-Verlag, N.Y. 441 p.

Kelley, V.C. 1951. Tectonics of the San Juan Basin. In: New Mexico Geological Society Guidebook of the south west sides of the San Juan Basin, New Mexico and Arizona, 2nd Field conference, 1951, pp. 124-131

Kent, D.V. 1977. An estimate of the duration of the faunal change at the Cretaceous-Tertiary boundary. Geology. v. 5, pp. 769-771

Knowlton, F.H. 1917. Fossil floras of the Vermejo and Raton Raton Formations of Colorado and New Mexico. United States Geological Survey Professional Paper 101, pp. 223-435

La Brecque, J.L., Kent, D.V., and Cande, S.C. 1977. Revised magnetic polarity time scale for Late Cretaceous and Cenozoic time. Geology v. 5, pp. 330-335

Lerbekmo, J.F., M.E. Evans, and H. Baadsgaard. 1979. Magnetostratigraphy, biostratigraphy, and geochronology of Cretaceous-Tertiary boundary sediments, Red Deer Valley. Nature. vol. 279, pp. 26-30

Lindsay, E.H., J.L. Jacobs, and R.F. Butler. 1978. Biostratigraphy and magnetostratigraphy of Paleocene terrestrial deposits, San Juan Basin, New Mexico. Geology, vol. 6, pp. 425-429

Osborn, H.F. 1923. A new genus and species of Ceratopsia from New Mexico, Pentaceratops sternbergii. American Museum Novitates, no. 93, 3 p.

Ostrom, J.H. 1963. Parasaurolophus cyrtocristatus, a crested hadrosaurian dinosaur from New Mexico. Fieldiana, Geology. Vol. 14, no. 8, pp. 143-169

Powell, J.S. 1972. The Gallego Sandstone (formerly Ojo Alamo Sandstone) of the San Juan Basin, New Mexico. Unpublished MS thesis. The University of Arizona. 131 p.

Powell, J.S. 1973. Paleontology and sedimentation models of the Kimbeto Member of the Ojo Alamo Sandstone. In: Cretaceous and Tertiary rocks of the southern Colorado Plateau, J.E. Fassett (editor), pp. 111-122. Memoir of the Four Corners Geological Society.

Russell, L.S. 1964. Cretaceous nonmarine faunas of northwestern North America. Royal Ontario Museum. Life Science Contribution 61. 24 pp.

Russell, L.S. 1975. Mammalian faunal succession in the Cretaceous System of western North America. In: The Cretaceous system of the western interior of North America Geological Association of Canada. Special Paper No. 13, pp. 137-161.

Sahni, (1972). The vertebrate fauna of the Judith River Formation, Montana. Bulletin of the American Museum of Natural History. Vol. 147 Article 6, pp. 321-412

Sloan, R.E. 1969. Cretaceous and Paleocene terrestrial communities of western North America. Proceedings of the North American Paleontological Convention. Part E, pp. 427-453

Stanton, T.W. 1916. Nonmarine Cretaceous invertebrates of the San Juan Basin. United States Geological Survey Professional Paper 98, pp. 309-327

Sternberg, C.M. 1949. The Edmonton fauna and description of a new Triceratops from the Upper Edmonton Member; Phylogeny of the Certopsidae. Annual Report of the National Museum of Canada for the Fiscal Year 1947-1948. Department of Mines and Resources, Bulletin No. 113; pp. 33-46

Stodola, J. 1967. Encyclopedia of Water Plants. T.F.H. Publications, Inc. Jersey City, NJ 368 p.

Tarling, D.H. and J.G. Mitchell. 1978. Revised Cenozoic polarity time scale. Geology. v. 6, pp. 133-136

Tschudy, R.H. 1973. The Gasbuggy core - a palynological appraisal. In: Cretaceous and Tertiary rocks of the southern Colorado Plateau, J.E. Fassett (editor), pp. 131-143. Memoir of the Four Corners Geological Society.

Wiman, C. 1930. Über Ceratopsia aus der Oberen Kreide in New Mexico. Nova Acta Regiae Societatis Scientiarum Upsaliensis. Serv. IV, Vol. 7, No. 2, pp. 1-19.

Wolberg, D.L. and F. Kottlowski. 1980. Dinosaurs, turtles, badlands, and coal in northwest New Mexico. Annual Report 1978-1979, NMBM&MR, pp. 68-74

Wolberg, D.L. 1978. The mammalian paleontology of the Late Paleocene (Tiffanian) Circle and Olive localities, McCone and Power River counties, Montana. Unpubl. Ph.D. Dissertation, 385 p.

Wolberg, D.L. and D. LeMone. 1980. Paleontology of Fruitland Formation near Bisti, San Juan Basin, New Mexico - A progress report. Annual Report 1978-1979, NMBM&MR, pp. 55-57.

Wolfe, J.A. 1971. Tertiary climatic fluctuations and methods of analysis of Tertiary floras. Palaeogeography, Palaeolimatology, Palaeoecology, v. 9, p. 27-57

Wolfe, J.A. 1979. Temperature parameters of humid to mesic forests of eastern Asia and relation to forests of other regions of the Northern Hemisphere and Australasia. United States Geological Survey Professional Paper 1106. 37 p.