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# MOSTLY DINOSAURS: A REVIEW OF THE VERTEBRATES OF THE POTOMAC GROUP (APTIAN ARUNDEL FORMATION), USA

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**ABSTRACT**: The vertebrate fossils of the Potomac Group (Aptian Arundel Formation), USA are diverse but fragmentary. There may be evidence for as many taxa as 12 dinosaurs, two pterosaurs, two crocodilians, four turtles, and two fish. As yet, no definitive evidence of mammals, birds, snakes, lizards or amphibians has been found, though undoubtedly all were present. In recent years, a significant and extensive track fauna has been discovered. The environment in which these animals lived, and the fossils were preserved, was perhaps not unlike the Mississippi delta region, "Bayou Country" of today, with the exception that the flora was of a generally earlier Mesozoic type largely devoid of angiosperms. Evidence is presented supporting the idea that fossil preservation occured in oxbow swamps.

## EARLY WORK

Early workers in the Potomac Group (Aptian Arundel Formation), USA, such as Marsh (1888), Ward (1888, 1897), Fontaine (1889), Bibbins (1895), Clark and Bibbins (1897) and Clark et al. (1911) recognized the terrestrial nonmarine character of the sediments. It is this feature of the deposits which make them unique in the Cretaceous of eastern North America. Other dinosaur faunas from the eastern North American Cretaceous are reported from isolated specimens carried into marine units from the land areas to the west.

While only Marsh (1888) insisted on a Late Jurassic age for the Potomac Group, all other workers, especially the paleobotanists, recognized them as Early Cretaceous age. Doyle (1992) places the Arundel Formation wholely within the latest Aptian. This age also adds to the Potomac Group's unique status in North America, as it provides a link between the much better known dinosaur faunas of the Late Jurassic and the Late Cretaceous. These early workers also recognized the probable links between the Potomac Group biota and those of Europe (Ward, 1888, 1897). This subject is largely beyond the scope of this review and will not be considered here.

Martin and Brett-Surman (1992) produced a comparative list of "dinosaur fauna of the Arundel Formation" reproduced here (Table 1). To this can be added a second list from other workers (Table 2). All of these lists are basically derived from reanalysis of the material collected by Hatcher and Bibbins in the late 1800s, with nothing new added.

## PRESENT WORK

Since 1989, when I began finding new vertebrate fossils in the Potomac Group, there has been an explosion of discoveries by many workers—at least doubling the known vertebrate fauna. All the new specimens not still held in private hands are in the collection of the National Museum of Natural History, Smithsonian Institution, or in a small "Muirkirk Study Collection," also at the Smithsonian. A printout from early January 1998 lists more than 200 entries, mostly dinosaurs, representing a far greater number of individual bones, teeth and fragments. With the exception of a partial femur of a large sauropod (*?Astrodon*) and a veterbral centrum of a large theropod ("Capitalsaurus") found in Washington, DC, all the other specimens come from the Potomac beds in Maryland. Note, however, that some tracks have been reported from Virginia (Weems and Bachman, 1997).

TABLE 1. Dinosaur Fauna of the Arundel Formation

| Listed by Marsh, 1888 | Listed by Lull, 1911 | Listed by Gilmore, 1921 | Listed by Ostrom, 1970 | Listed by authors, 1992 |
|---|---|---|---|---|
| **Theropoda** | **Theropoda** | **Theropoda** | **Theropoda** | **Theropoda** |
| *Allosaurus medius* | *Allosaurus medius* | *?Dryptosaurus medius* | large theropod 1 | large theropod |
| *Coelurus gracilis* | *Creosaurus potens* | *?Dryptosaurus potens* | large theropod 2 (?) | small theropod |
| | *Coelurus gracilis* | *Coelurus gracilis* | small theropod | |
| | | *Ornithomimus affinis* | ornithomimid | |
| **Sauropoda** | **Sauropoda** | **Sauropoda** | **Sauropoda** | **Sauropoda** |
| *Pleurocoelus nanus* | *Pleurocoelus nanus* | *Astrodon nanus* | sauropod 1 | sauropod 1 |
| *Pleurocoelus altus* | *Pleurocoelus altus* | *Astrodon altus* | sauropod 2 (?) | sauropod 2 (?) |
| | *Astrodon johnstoni* | *Astrodon johnstoni* | | |
| | **Ornithopoda** | | | **Ornithopoda** |
| | *Dryosaurus grandis* | | | *?Tenontosaurus* |
| | | | | ornithopod indet. |
| **Stegosauria** | **Stegosauria** | **Ankylosauria** | **Ankylosauria** | **Ankylosauria** |
| *Priconodon crassus* | *Priconodon crassus* | *Priconodon crassus* | ankylosaurid | nodosaurid |

TABLE 2. Dinosaur Fauna of the Potomac Group (Arundel Formation)

| listed by Vokes, 1949 | listed by Gallup, 1988 | listed by Kranz, 1989 |
|---|---|---|
| **Theropoda** | **Theropoda** | **Theropoda** |
| *?Coelurus gracilis* | *Dryptosaurus* | *"Coelurus gracilis"* |
| *?Dryptosaurus medius* | coelurid(s) | *"Dryptosaurus medius"* |
| *?Dryptosaurus potens* | | *"Dryptosaurus potens"* |
| *Ornithomimus affinis affinis* | | *Archeornithomimus* |
| **Sauropoda** | **Sauropoda** | **Sauropoda** |
| *Astrodonaltus* | *Pleurocoelus* or *Astrodon* | *Astrodon altus* |
| *Astrodon johnsytoni* | *Tenontosaurus* | *Astrodonjohnstoni* |
| *Astrodon nanus* | | *Astrodon nanus* |
| | | *"Tenontosaurus* sp." |
| **Ankylosauria** | **Ankylosauria** | **Ankylosauria** |
| *Priconodon crassus* | *Priconodon* | *Priconodon crassus* |

## The Vertebrates of the Potomac Group

### Dinosaurs

It has been accepted by all previous reviewers that there exist in the Potomac Group fauna elements from large carnivores, small carnivores, sauropods, and something, based on teeth, which seems likely to be a nodosaur. As to number of genera and names there is no general agreement. Moreover, there are other elements of the dinosaur fauna that are disputed as to their very existence in the fauna. Among the disputed material is a fragmentary tooth (USNM #244564) which has been called *Tenontosaurus* (Galton and Jensen, 1979). Various bones, including some which were described by Lull (1911) as *Dryosaurus grandis*, were later assigned by Gilmore (1921) to *Ornithomimus affinis* and still later called *Archeomithomimus affinis* by Russell (1972). A recently discovered ornithipod-like tooth (USNM #337984) (Kranz, 1996) and a similar as yet uncatalogued one have been variously called a dryosaur or an early ceratopsian, possibly even a neoceratopsian (Zhiming Dong, pers. comm., 1998). If it is a ceratopsian, it would be the only one known from eastern North America and perhaps the oldest known ceratopsian. (This tooth is discussed in more detail by Chinnery et al., this volume.)

### Other Vertebrates

Only one genus of turtle, *Glyptops caelatus* (Hay, 1908), is described from the Potomac Group. Evidence for three other genera, one similar to *Naomichelys*, has been found by the author in recent years (see Kranz, this volume). Crocodilian teeth, bones and armor are abundant, but as yet no significant systematic work has been done on them. A shark tooth was found in 1894 (USNM #010294), and recent finds by workers like Tom Lipka and Mike Styer have turned up more teeth and spines that suggest that the shark was a freshwater hybodont. A tooth plate (Acc. #404827), still uncatalogued in the Muirkirk Study Collection, found by Bob Wiest, appears to have come from the lungfish *?Ceratodus*.

There is abundant, yet largely unreported, trace fossil evidence from various unidentified localities in the Potomac Group found by Ray Stanford of Berwyn Heights, Maryland. Most of Ray's finds have occured during the last three years. The tracks and traces occur in ironstone crusts which were presumed to have formed around freshwater ponds and seeps. Among the tracks are prints that can be presumed to belong to all the known body fossils as well as many others. Most interesting of the others, are tracks of a large pterosaur, and what may be feather impressions indicating a bird or a feathered dinosaur.

## CURRENT STATUS OF TAXA

The continuing fragmentary nature of the Potomac Group vertebrate fossils still leaves workers with a host of taxonomic ambiguities. Despite this, I shall attempt to summarize the current status of the vertebrate fauna in Table 3, including recent evidence already mentioned above.

### Environment of Deposition

The vertebrate fossils of the Potomac Group have been

TABLE 3. Vertebrates of the Potomac Group

| General Taxa | Scientific Name | Type of Evidence |
|---|---|---|
| **Theropoda** | | |
| large carnivore | *"Capitalsaurus"* | vertebra |
| large carnivore | (possibly *"Capitalsaurus"*) | teeth and various isolated postcrania |
| medium sized carnivore | none | teeth and various isolated (some associated) postcrania |
| small carnivore | none | teeth |
| **Sauropoda** | | |
| Brachiosaur | *Astrodon johnstoni* | teeth, skull fragments, and isolated postcrania |
| **Ornithopoda** | | |
| large ornithopod | *?Tenontosaurus* | tooth |
| medium sized ornithopod | (possibly *Tenontosaurus)* | isolated postcrania |
| **Ankylosauria** | | |
| notosaur | *Priconodon crassus* | teeth |
| **Cerotopsia (?)** | | |
| neocerotopsian (?) | *"Magulodon muirkirkensis"* | teeth |
| **Pterosauria** | | |
| large pterosaur | none | tracks |
| **Birds(?)** | | |
| bird(?) | none | possible feather impressions |
| **Crocodilia** | | |
| crocodile | none | teeth, armor, and isolated postcrania |
| **Turtles** | | |
| large ?tortoise | none | articulated skeleton with skull |
| small pond turtle | *Glyptops caelatus* | shell |
| small pond turtle | *?Naomichelys* | shell fragments |
| **Amphibians** | | |
| frog (a) | none | tracks |
| **Fish** | | |
| shark (freshwater) | *?Hybodus* | teeth and spines |
| lungfish | *?Ceratodus* | toothplate |

Mammals, amphibians, snakes, and lizards are probably present but as yet there is no solid evidence for their existence.

regarded as restricted to what has been called the "Arundel Formation." It seems to me that from the beginning the reasoning that has led to this conclusion has been circular. It is always stated without much support geologically as far as I am aware, that when a dinosaur fossil is discovered in the Potomac Group, that it was found in the Arundel Formation. This is invariably based on the citation of previously published assertions that the dinosaur fossils are always found in the Arundel Formation, not necessarily the geology. Thus, it becomes virtually impossible for a dinosaur fossil found in the Potomac Group to come from any formation other than the "Arundel Formation."

### Does the "Arundel Formation" Really Exist?

The Arundel Formation was first defined by Clark and Bibbins (1897). It was loosely conceived as beds filling depressions in the irregular surface in the upper part of the Patuxent Formation. When Clark and Bibbins were writing, the "facies concept" had yet to be widely accepted in the United States (Teichert, 1958). Had they written after its general acceptance their description of the Potomac Group might have been different since they were both fine geologists and keen observers. In those days, however, formations were thought of as distinct and separate units stacked one on top of each other and separated from one another in time.

The "Arundel Formation" lithology was usually described as "blue charcoal clays with iron carbonate nodules." The Arundel was of significant lithologic interest because the iron nodules were the basis of an important, though then declining, iron

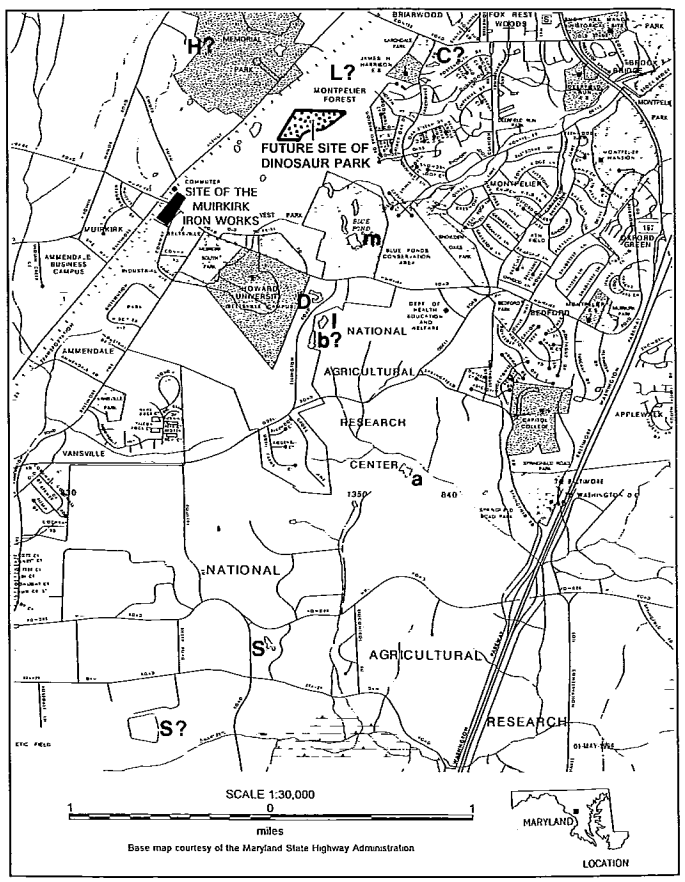


FIGURE 1. Muirkirk fossil region with ponds which fill old mine pits (note: bold letters mark some of the known fossil localities.

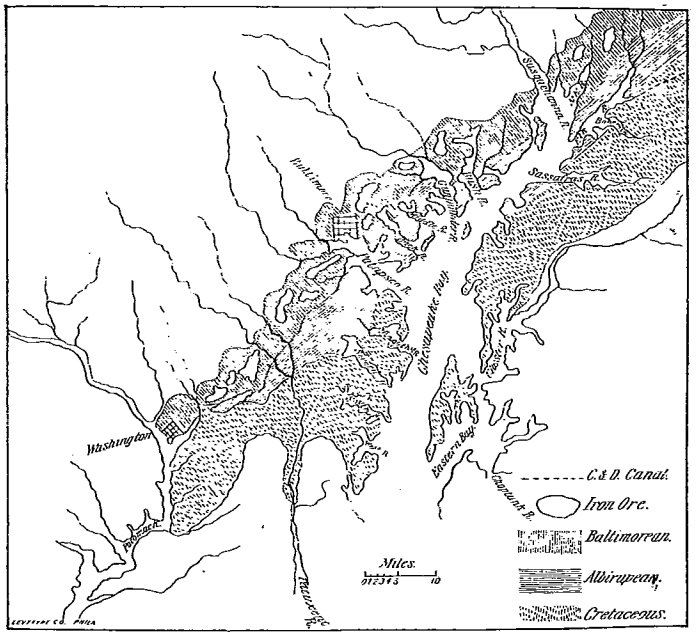


FIGURE 2. Map of Cretaceous formations of Maryland (Uhler, 1888). Modern equivalents: Cretaceous ~ Upper Cretaceous marine beds; Albirupean ~ Patapsco Formation; Baltimorean ~ Patuxent Formation; Iron Ore ~ Arundel Formation.

manufacturing industry in eastern Maryland and Virginia which had existed for about 200 years. There appears to be some field evidence to support the notion that these lithologies are concentrated near the upper part of the Patuxent Formation near its contact with the Patapsco Formation. Moreover, Harry Hansen (pers. comm., 1997) of the Maryland Geological Survey has expressed the view that in the subsurface of eastern Maryland the "Arundel Clays" are a much thicker, more continuous unit. If this is the case, it may be legitimate to regard the "Arundel Formation" as a real geologic formation.

My work in recent years has suggested a somewhat different interpretation. Brenner (1963) and others (i.e. Doyle and Hickey, 1976; Doyle and Robbins, 1977; Robbins, 1991) have suggested that the palynomorphs of the so-called "Arundel Formation" are indistinguishable from the presumed underlying Patuxent Formation, but are quite distinct from those of the overlying Patapsco Formation.

Field observations by the author suggest that "Arundel"-type clays occur as elongate, discontinuous bodies. This is further supported by the shapes of the ponds which now fill the abandoned iron pits, which are also elongate and separated by substantial distances (Fig. 1). Most early geologic maps of Maryland's Cretaceous beds depict the "Arundel" or "iron-ore clays" as elongated isolated bodies contained completely within the more extensive Patuxent Formations (e.g., Fig. 2). The later misconceptions of the "Arundel" as a formation of separate character, and lying as a separate time unit between the Patuxent and Patapsco formations, can be attributed to the paradigm associated with the word "formation" as used by American geologists in the late 19th and early 20th centuries. Soil auger borings taken in December 1991 have shown elongate deposits near Muirkirk, Maryland to have U- or V-shaped profiles. Some of the bodies are more than half a mile long, while others are much shorter. Some of the longer bodies seem to show curvature

in plan view. The bodies vary in width from approximately 25 to 50 feet and depths (thicknesses) of 10 to 30 feet. However, Clark and Bibbins (1897) report thicknesses exceeding 100 ft. The geomorphic features appear to suggest the so-called "Arundel Formation" is actually abandoned stream and river channels that were later filled with clay, dead animals and plants during periods of flooding.

The notion that the "Arundel Formation" actually is oxbow swamp deposits is further supported by geologic work on the Potomac Group in general. Glaser (1969) and others have described the environment of the Potomac Group as a broad, flat, low-lying, sub-tropical coastal plain which spread out at the foot of the Appalachian Mountains on the shores of the then expanded Atlantic Ocean. The area, except for the more primitive vegetation and different animal life, might resemble the environment of southern Louisiana today.

Samples of clay and its content reveal further evidence in support of the flooded oxbow hypothesis. The contents of the deposits appear to be almost exclusively clay and silt with large amounts of tree (probably cypress-like) lignite and substantial amounts of autocthonous iron carbonates and occasionally abundant vertebrate remains (Table 4).

Evidence for the contemporaneous nature of the iron deposits is the fact that footprints are common in some of the ironstones in the deposits. The lack of coarse sediment and abundance of lignites suggest that the materials of the deposits floated in during periods of flooding from the main channels some distance away. One would also expect to find carcasses of drowned animals in the deposits. Two recent finds by me (Kranz, 1996) of a large turtle and a therapod show some articulation and association and may represent some of these drowned individuals.

I believe based on the above evidence that the "Arundel Formation" lithologies represent flood deposits in oxbow swamps and as such do not necessarily constitute a true formation, but instead may occur throughout the Potomac Group, even if they may be more abundant in the upper part of the Patuxent Formation. I expect further study will resolve the questions regarding the contemperoneity of the deposits of the so-called "Arundel Formation."

I had initially believed that the iron ores in some way were responsible for the preservation of the dinosaur fossils of the Potomac Group. I am now of the opinion that they are only a nuisance, albeit they were responsible for the discovery of the dinosaur bones in the first place, as it was the ores that were being sought by the miners, and not the bones. It appears that it is the fine-grained nature of the clay that is responsible for both. The clays, in acting as an aquaclude—an excluder of water—prevented both the dissolution of the bones and the movement of ground water, thereby creating the swampy conditions in which the iron carbonates formed.

Table 4. "Arundel Clay" Particle Size Analysis % by Weight

| Log No. | Coarse Sand | Fine Sand | Silt | Clay |
|---|---|---|---|---|
| P-3 | 4 | 6 | 41 | 49 |
| P-4 | 3 | 13 | 35 | 49 |
| P-5 | 3 | 6 | 45 | 46 |

Ironstone and Lignite not included
State Highway Administration of Maryland
Soils and Foundations Division;
Contract: P-987-851-312; Date 12/31/91

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