The Green River Formation of the west-central United States: Flood or post-Flood?

Michael J. Oard and John H. Whitmore

Many creationists believe the Genesis Flood was responsible for the bulk of sedimentary rocks and fossils. However, disagreements often arise in trying to determine where the Flood/post-Flood boundary should be placed in the stratigraphic record. This forum is a friendly exchange between two young-earth creationists who hold differing views on the origin of the Green River Formation (GRF). The authors have examined the rocks in the field together. Mike Oard will defend the thesis that the GRF was deposited in the Flood and John Whitmore will defend the thesis that it is a post-Flood lacustrine (lake) deposit. This paper outlines the geological setting of the GRF.

The Green River Formation (GRF) outcrops extensively in basins within the central Rocky Mountains, west-central United States. It is not a continuous formation, but consists of lithologically similar strata that occupy four major, separate basins exposed in south-west Wyoming and adjacent areas of north-east Utah and north-west Colorado (figure 1*). These basins, and their adjacent mountain ranges, formed (along with many other basins) during the Laramide orogeny in the late Cretaceous and early Tertiary within the uniformitarian paradigm.[1] The GRF has gained notoriety because it contains well-preserved fossils (especially fish), rich oil shale reserves, and economically important minerals such as trona ($Na_3HCO_3CO_3 \cdot 2H_2O$). Nearly every type of sedimentary lithology can be found in the GRF. Coarser sedimentary rocks (conglomerates and sandstones) typically are found around the perimeters, and finer sedimentary rocks (mudstones, laminated micrites and shales) are found near the centres of the basins. Various carbonate lithologies and/or cements are common, basin-wide. Currently, over 1,800 literature citations can be found on the GRF.[2]

The largest of the Green River basins is the Greater Green River Basin (once thought to have been occupied by 'Lake Gosiute'), which covers 51,000 km^2 and averages over 600 m in thickness.[3] It is subdivided into four major sub-basins (Green River, Washakie, Sand Wash and Great Divide). The north-south trending Rock Springs Uplift roughly divides the Greater Green River Basin in half, separating Green River Basin from the other three sub-basins. The Greater Green River Basin is bounded on all sides by various uplifts, including the Wind River Mountains to the north and the Uinta Mountains to the south. Stratigraphically, the basin has been subdivided into numerous members and 'tongues'. Many of the units are not continuous across the breadth of the basin, but are local units, often confined to sub-basins. There are three main formations in the basin. The lowest is the Wasatch Formation, which is coarser grained and considered fluvial. In the Greater Green River Basin, the Wasatch underlies the GRF, but it also occurs around the edges of the basin, where it laterally intertongues with the GRF. Overlying the GRF are the Bridger and Washakie Formations. They consist mostly of volcanoclastic sediments and are thought to have been deposited in fluvial and lacustrine settings.

Fossil Basin (figure 2) is a small (1,500 km^2), but well-studied basin immediately west of the Greater Green River Basin, and it contains more than 120 m of GRF sediments[4] It is cut off from the Green River Basin to the east by Oyster Ridge, a west-dipping, north-south trending, thrust-faulted ridge. Until recently, no strata had been correlated from Fossil Basin to the Green River Basin. However, it is now believed the two basins may have been connected for a short time during the later stages of Fossil Basin and the early stages of the Green River Basin.[5] Fossil Basin has long been recognized for its exceptionally preserved fauna and flora. Fossil specimens include fish (figure 3), birds, bats, snakes, turtles, crocodiles, sting rays, insects and many types of plants.[6]

The stratigraphy of Fossil Basin is in the process of revision and has recently been divided into three formal members: Road Hollow (lower), Fossil Butte (middle) and Angelo (upper).[7] The section is well exposed at Fossil Butte National Monument, near Kemmerer, Wyoming (figure 4). As in the Greater Green River Basin, the GRF has a complex intertonguing relationship with the Wasatch Formation, which lies stratigraphically below and laterally surrounds the Fossil Basin sediments (figure 5). Good stratigraphic control exists within the basin because of numerous tuff beds that can be traced throughout various changing facies.[4]

The Uinta and Piceance Creek Basins occur south of the Uinta Mountains in Utah and Colorado. They have many similarities to Fossil Basin and the Greater Green River

* Figures are numbered continuously through all the articles in this forum.

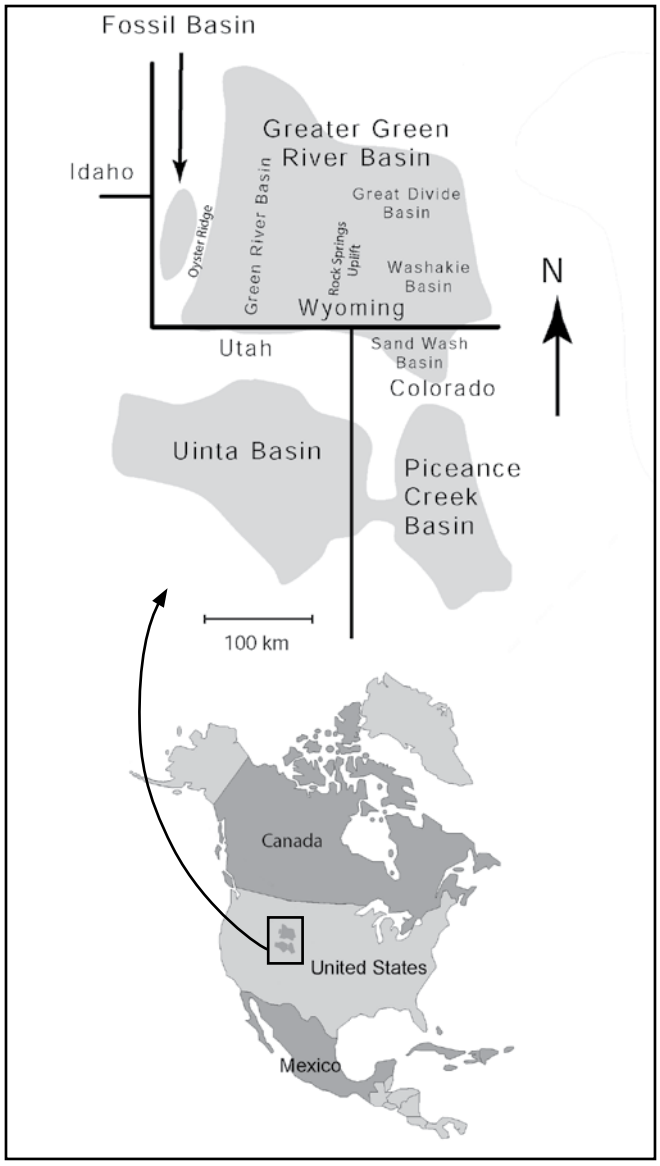

Figure 1. The basins of the Green River Formation in Wyoming, Utah and Colorado, USA (after Buchheim and Eugster).[4]

Basin. However, this forum will primarily address Fossil Basin and the Greater Green River Basin.

The creationist challenge

Evidence from the GRF has been used to strongly challenge creationists on biblical Earth history.[8,9] It has been argued, based on the number of so-called varves (figure 6) in the GRF, that it took between 5 and 8 million years to be deposited.[10] A varve, by definition, is 'a sedimentary laminae or sequence of laminae deposited in a body of still water within one year's time'.[11] Note that by definition a 'varve' is a sedimentary layer that is an *annual* event. The terminology has been used (and misused) to describe the finely laminated sediments of many different types of lakes. Because the finely laminated sediments of the GRF

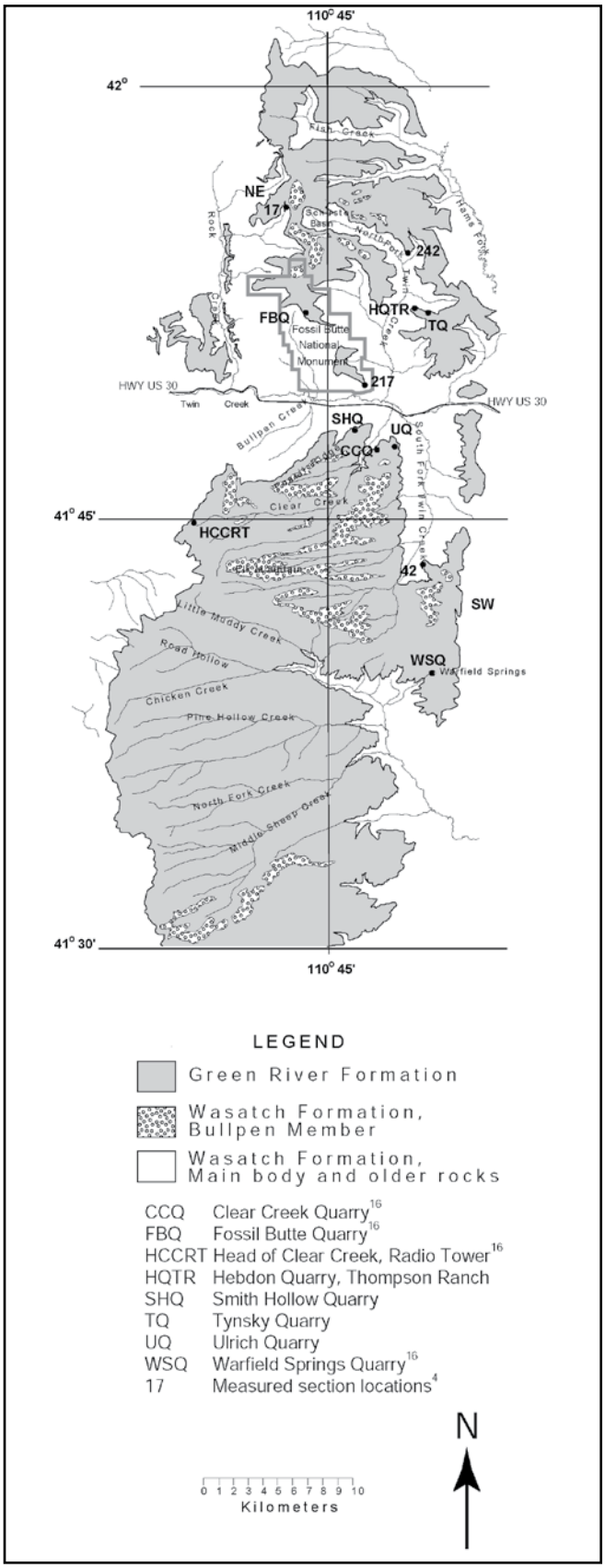

Figure 2. Outcrop map of the Green River Formation, Fossil Basin (after Buchheim and Eugster).[4]

Figure 3. Fossil fish from Fossil Basin, Wyoming. Fish occur through much of the section and are occasionally found in large numbers, as in this slab on display at Fossil Butte National Monument. Many types of fish have been found, but the most abundant are the herring-like fish: Diplomystus and Knightia.

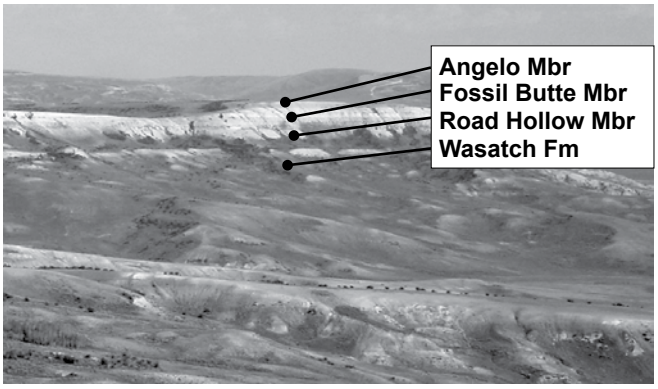

Figure 4. The Wasatch Formation and the Road Hollow, Fossil Butte and Angelo Members of the Green River Formation as exposed near Fossil Butte National Monument, near Kemmerer, Wyoming. The visitors' centre is not visible at this scale, but is located in the lower right corner of the photograph.

Figure 6. The finely laminated micrites and oil shales found in the centre of many of the Green River basins have been interpreted as 'varves' by many authors. In other words, each pair of laminations, or 'varve', is interpreted to have been deposited over one year. A coprolite occurs in the centre of the photograph. Note how the laminations are draped over the top of it. The cut slab is from the Smith Hollow Quarry. The penny is about 19 mm in diameter.

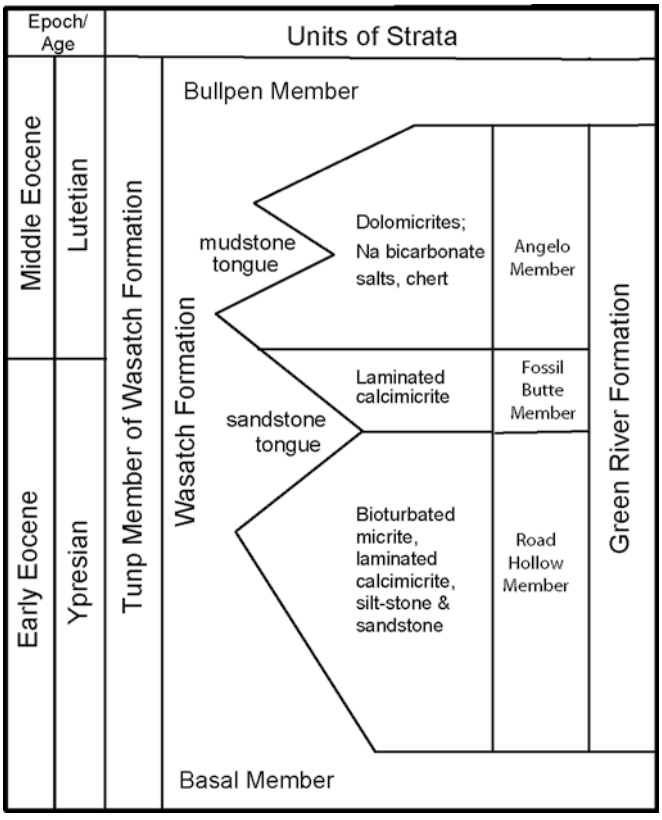

Figure 5. The stratigraphic relationship between the Wasatch Formation and the Road Hollow, Fossil Butte and Angelo Members of the Green River Formation in Fossil Basin, Wyoming. This figure was adapted and modified from Buchheim and Eugster.[4]

have been interpreted as 'varves', it is supposed that they formed over millions of years of geological time, blowing the Creation-Flood model timescale out of contention.

Creationist hypotheses

Whitcomb and Morris argued, in *The Genesis Flood*,[8] that the GRF and its related formations were deposited in the late Flood. Since that time a number of creationists have come to believe that the GRF was deposited in a large post-Flood lake.[12–14] They see evidence of a lacustrine ecology with rapid

deposition of lake laminae that are not true varves.[15] These creationists believe that the Flood/post-Flood boundary occurs in the vicinity of the Cretaceous/Tertiary boundary at many locations. Whitmore studied the GRF in Fossil Basin as part of his Ph.D. work at Loma Linda University.[16–18] He has also examined parts of all the other Green River basins and believes they are best interpreted as post-Flood lakes based on their paleontology, lithologic facies patterns, mineralogy and other features.

On the other hand, some other creationists have come to believe that the Flood/post-Flood boundary is generally in the late Cenozoic.[19–23] Oard has been doing extensive work in the geological subfield of geomorphology and sees strong evidence everywhere that the Flood/post-Flood boundary is in the late Cenozoic.[24–26] Since the GRF is dated as Eocene (early Tertiary within the uniformitarian geological column), he believes it very likely formed during the Flood. Oard has briefly examined the geomorphology of the Greater Green River, Uinta and Piceance Creek Basins a few times, which have reinforced his Flood leanings for the formation.

Forum on the Flood or post-Flood deposition of the Green River Formation

Together, in the summer of 2004, we examined the GRF. We primarily focused on Fossil and small parts of the Greater Green River Basin. We challenged each other with data from the field. Although neither one of us has changed his mind, we now have a better understanding of the other's interpretation. This friendly forum is a result of this exchange in the field. The purpose is to present observational data, along with interpretations, for both sides of the issue and to let the reader decide. At the same time, we will be presenting evidence why the uniformitarian interpretations are not correct. We believe that this exchange of information and deductions is a very informative way to communicate with the readers about the complex geology of the GRF, and to illustrate how that geology is interpreted within a biblical framework. It is our hope that the discussion that follows will more clearly elucidate the Flood/post-Flood boundary in other areas of the world.

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