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A Quantitative Assessment of the Genesis Flood Rock Record: Colorado as a Pilot Study

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Abstract

The Noahic Flood deposited and emplaced a significant amount of sedimentary and volcanic rock on the continents. Much of it remains despite appreciable Recessional Stage erosion. How much? We answer using a method in Colorado as a pilot for many other locations. The principle is simple: creating grids of the basal and upper diluvial boundaries, then subtracting the lower from the upper. In Colorado, we chose the top of the Precambrian crystalline surface as our basal boundary and digitized a Colorado Geological Survey map into a Geographic Information System (GIS). NOAA's ETOPO1 Digital Elevation Model (DEM) of surface topography was selected as the upper boundary. Small volumes of Precambrian sedimentary and metasedimentary rocks and most of the San Juan and Thirty-Nine Mile volcanic fields were not included in the final calculation, and minor postdiluvial sediments were ignored. The total Flood rock record in Colorado totals more than one-half million cubic kilometers, predominantly in six sedimentary basins. Our method allows recalculation for revised or alternate boundaries.

Key Words: Colorado, GIS, basement, Precambrian, sediment volume

Introduction

Other than Creation, the Genesis Flood is the greatest geological event of Biblical Earth history. Like Creation, it is dismissed by secular man. Since secularists value science, creationists use those methods to challenge that dominant worldview. For example, they point out that strata are commonly laterally extensive (Snelling, 2009) and show little or no erosion between and within layers (Oard, 2004; Roth, 2009). The Tapeats Sandstone and its equivalents, predominantly overlying igneous and metamorphic basement rocks, cover half of North America (Snelling, 2009; Clarey, 2020). Sedimentological studies (Austin, 1994; Barnhart 2012a, 2012b; Snelling, 2021) show how little time was needed for their deposition. Secular scientists claim the horizontal strata in

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the Grand Canyon required over 250 million years. But they show little erosion, and since erosion is considered, on average, very fast on a million-year timescale, extensive erosional surfaces should have developed with numerous canyons and valleys in those strata. None are observed, posing problems for uniformitarians and their time scale, while confirming the diluvial paradigm.

A needed step in advancing understanding of deposition and erosion in the rock record, especially at larger scales, includes quantifying the volume and distribution of the rock record of the Deluge. Geologists have approximated volumes by mapping the extent and thickness of strata and doing rough calculations (e.g., Ronov, 1983). Modern mapping software allows more accurate calculation, though there is always uncertainty in mapping.

A global flood suggests a benefit in knowing the global volume and distribution of the diluvial record. It would help constrain estimates of the amount of sediment deposited on the continents by the peak of the Flood and track regional to mega-regional erosion and deposition patterns of the Recessional Stage (Walker, 1994). It would point to provenance and suggest volumes eroded from antediluvian crust. It is a prerequisite for examining the sedimentary cycle of erosion, transport, and deposition of sedimentary rocks and for quantitative large-scale hydrodynamic studies. A quantitative understanding of the Deluge would aid creation scientists in understanding various geologic phenomena and answering uniformitarian challenges.

Large scale regional maps are likewise beneficial, as demonstrated by Clarey (2020). Mapping upper and lower diluvial boundaries suggests areas needing more study. One such category is Precambrian basins. Are they remnants of the antediluvian crust or features of the early Flood? Mapping helps determine consistency in such determinations, and detailed large-scale maps (e.g., Albert et al, 2016) are rare.

The many specific Earth Science questions beg for a unified understanding that might flow from a comprehensive understanding of the diluvial rock record. Mapping and calculating the total diluvial record in any one location is a necessary step in contributing to a comprehensive Flood model. Current diluvial models suffer from a lack of systematic, quantitative geologic data. Some researchers are working to correct that shortcoming (Baumgardner, 2018; Clarey, 2020), but much remains to be done.

Part of this work has been done by the GlobSed project, which estimated the volume and distribution of sediments in the oceans (Straume et al, 2019). Based on their work, we made a preliminary estimate of the volume of sediment eroded off the continents during the Recessive Stage. It represented an average of 1900 m from today's continental land area (Reed et al., 2022; Oard et al., 2023). A natural follow-up project is to determine the volume of sediments remaining on the continents. Clarey (2023) is doing so for Flood megasequences. Our project envisions examining total diluvial volume and distribution. In addition to volumetric analyses, we provide reasonably detailed maps of the lower and upper diluvial boundaries. We present Colorado as an example because it requires only two surfaces and because the upper boundary is essentially the equivalent of its DEM.

Geology is done over a wide range of scales. We work at the state level for several reasons and use Colorado as a pilot study to showcase the procedure. The state scale is reasonably accurate for regional projects (e.g., Albert et al., 2016), yet points to local phenomena requiring more study by diluvialists. The states provide the best source of easily-found public data, since most state geological surveys provide maps made by local experts, some seismic and well data, and bulletins, books, and reports of investigations going back many decades. They are also a window into the more detailed local work in basins or provinces. Furthermore, most state surveys are responsive to questions or requests for help. In our experience, they have proven the most reliable doorway to needed data. In short, this scale best balances detail and practicability.

Volumetric analysis can be narrowed or expanded. In addition to the entire state, we can perform such analyses for any area that can be defined by a planar boundary on a map. For Colorado, we include the volumes of its sedimentary basins to illustrate this ability. An isopach map of the two boundaries shows the distribution of the diluvial record. While individual states may reveal little immediately helpful information for regional questions, a growing compilation of such data from multiple states will. It will also guarantee the reliability of such data to at least a state level, while highlighting specific areas of uncertainty.

Analyses require gridded surfaces of the lower and upper diluvial boundaries. The location and nature of the lower boundary (Austin, 1994; Austin and Snelling, 1994; Hunter, 2000; Wise and Snelling, 2005; Froede and Oard, 2007; Oard and Froede, 2008; Dickens, 2018; Hunter, 2022) and upper boundary (Austin, 1994; Whitmore and Garner, 2008; Whitmore and Wise, 2008, Snelling, 2009; Ross, 2012; Whitmore, 2013; Brand and Chadwick, 2016; Oard, 2016; 2017a, 2017b; 2018; 2019; Clarey, 2017; 2020; Clarey and Davis, 2019) have been robustly debated. Although debates about the boundaries and details of the Genesis Flood will continue, we hope to at least constrain them with reliable maps and comparative volumetric analyses.

Colorado illustrates the procedures and pitfalls in such a process. It has relatively few complications compared to other states. Those complications include exposed basement rocks, (which by definition yield no diluvial rock volume), large volcanic fields which are less well understood, examples of assessing local strata for inclusion or exclusion from the diluvial rock record, and the limits imposed by balancing detail and scale. Refinement of our method is ongoing and open to other researchers.

Previous Work

Reed et al. (2022) estimated the diluvial volume and distribution of sediment in the oceans based on the work of Straume et al. (2019), from the GlobSed project (c.f., Divins, 2003; Whittaker et al., 2013). Based on their latest analysis, which refined the depth of sediment in deep troughs and better defined it in less accessible areas like the Antarctic continental margin, their estimate of total marine sediment volume increased 30% over that of Whittaker et al. (2013) and represents current knowledge. The greatest thicknesses of marine sediment are located on continental margins, which average 3,044 m (Straume et al., 2019), with some coast-parallel troughs and basins containing more than 15,000 m of sediment. For example, sediments in the Baltimore Canyon, offshore of the eastern United States, exceed 18,000 m (Poulsen et al., 1998). Grids of their data are available.

We reasoned that since most marine sediment is terrigenous, it was likely eroded from the continents during the Recessive Stage of the Deluge. We conservatively estimated that continental margin sediment volumes and approximately half the deep-sea volume was deposited by this runoff (Oard et al., 2023), resulting in a volume averaging about 1900 m over today's continental surface area. Adding this volume, with no correction for compaction or chemical loss, to that existing today on the continents allows an estimate of continental sediment volume at the peak of the Genesis Flood. Although some verses of Genesis 6 and 7 suggest the Flood peaked at Day 40, other verses indicate it more likely peaked at Day 150 (Johnson and Clarey, 2021). This timing is the conclusion of most scholars who have studied the verses (Boyd and Snelling, 2014).

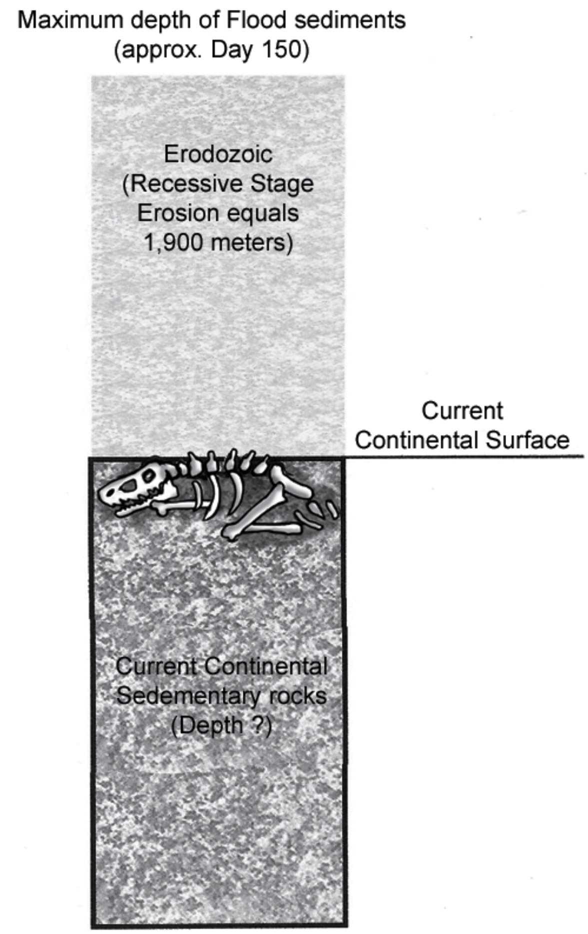

Figure 1. A block diagram representing the sediments and sedimentary rocks at Day 150 made up of an average thickness of ~1,900 m of sediment eroded during the Recessive Stage plus the current volume of sedimentary rocks presently on the continents, which is unknown (Oard et al., 2023; drawn by Melanie Richard).

How Much Sediment Remains on the Continents?

In Figure 1, we do not include a numerical volume or average thickness of current continental sedimentary rocks because such estimates are poorly constrained. Previous continental volumes and average thicknesses have been estimated by some researchers but are rendered less certain by coarse grids, incomplete data, and coarse calculations (Blatt and Jones, 1975; Ronov, 1983).

If the GlobSed grids are accurate, then ocean sediment thickness to the shorelines is currently well-constrained. Quantifying the total diluvial volume thus requires better numbers for the continents. Work done at appropriate scales should provide more accurate numbers and a better understanding of uncertainty. There are also several specific challenges. Older estimates, such as those by Blatt and Jones (1975) or Ronov (1983) and newer estimates, such as those by Clarey and Werner, (2023), include some offshore continental margin sediments, throwing off the estimate of the strictly terrestrial sediment volume. Second, amounts of Precambrian sedimentary and volcanic rocks included in a continental volume on the continents vary between researchers. This is because of poor outcrop exposures, difficulty in correlation without fossils, and metamorphism that altered many Precambrian sediments.

Addressing Challenges

In determining the amount of truly diluvial sediments in Colorado, we need to deal with Precambrian sedimentary and metasedimentary rocks, volcanic rocks, and postdiluvial sediments. Precambrian sedimentary rocks need to be assessed, because creation scientists need to know whether Precambrian sedimentary rocks are antediluvial, diluvial, or both, and much remains to be determined. One reason we chose Colorado to showcase our method was the low volume of these rocks; the mapped Precambrian surface is primarily crystalline basement and thus readily used as the lower diluvial boundary.

Volcanic and volcaniclastic rocks and volcanic ash beds, especially within sedimentary rocks, were included as diluvial products. The exceptions were two large volcanic fields, the San Juan and Thirty-Nine Mile Volcanic Fields. These were not excluded because of their diluvial status, but because we are mainly mapping sedimentary rocks and a lack of data precludes accurate mapping of their lower surface. Volcanic rocks overlying or interbedded with sedimentary rocks were included as a part of the diluvial record. Colorado sedimentary basins may contain significant volumes of such rocks. This differentiation may be more problematic in other states but appeared less so in Colorado. Typically, such questions are assessed on a case-by-case basis.

A third problem area is the volume of postdiluvial sediments. In this case, Colorado exhibits much surficial erosion (see below), suggesting the late stages of the Flood. If so, then remaining rocks, other than small volumes associated with modern watersheds, would be diluvial in origin, and are counted as such in this study. We believe postdiluvial sediments and Ice Age erosion is sufficiently small compared to the total amount of diluvial rocks that both can be ignored. In either case, both would most likely represent reworking of diluvial sediments. Others may believe that some of this volume was a result of postdiluvial catastrophism. That is why we present a *method*; other researchers can use it to calculate alternate volumes by mapping their boundary and recalculating. However, in Colorado, we believe the evidence strongly argues against a different boundary.

An advantage of our method is that it allows anyone interested in different lower or upper diluvial boundaries to map them, and then re-calculate an alternative volume and compare the results. As a side note, we believe that transparency, replication, and cooperation are hallmarks of scientific work and that special care is needed in forensic natural history. We thus invite any creation scientist who desires to refine or expand our work to request our grids and shape files from the lead author.

Colorado: A Template

Recognizing these challenges, we present a quantitative method for collecting data, mapping the surfaces, and calculating the volume of diluvial rocks for Colorado that can be applied elsewhere. To determine the volume of diluvial rocks for a given area, first define that area, in this case, the area within the state boundary of Colorado. Volumes can be derived by anything defined by a two-dimensional surface outline, such as sedimentary basins or geologic provinces.

The second step is to define and map the lower and upper diluvial boundaries, including decisions to simplify as needed. For Colorado, in addition to the postdiluvial rocks, we chose to ignore small volumes of Precambrian sedimentary and metasedimentary rocks in: (1) the eastward extension of the Uinta Mountains into northwest Colorado, and (2) the Needles Mountains in the southwest San Juan Mountains (Tweto, 1977). The Precambrian rocks in the Uinta Mountains of Colorado are quartzite and sandstone, up to 7.3 km thick (Tweto, 1977), but occurring only in an area of roughly 600 km^2 (Dehler et al., 2005, 2010). Though thick, their area is 0.2% that of the state. The occurrences in the Needles Mountains are smaller still, predominantly metasedimentary rocks that occur in an arc about 14 km by 2 km, with thicknesses reaching about 2,600 m (Barker, 1969). Both are very small compared to the volume of Phanerozoic sedimentary rocks in Colorado, so both are ignored in this initial iteration. Given maps of their bases, they could easily be added to the existing grids. Whether these Precambrian sedimentary or metasedimentary rocks are antediluvial or products of the Genesis Flood is a question not addressed here.

Therefore, we assume that the lower diluvial boundary corresponds to the unconformity at the top of the Precambrian, which for most of the state is the top of crystalline basement. This leads to two immediate issues. Besides deep sedimentary basins, Colorado has regions of uplifted and exposed crystalline basement, where the lower grid penetrates the upper grid. These areas must be accurately delineated so that they can be excluded from any calculation.

Our upper diluvial boundary assumes no significant postdiluvial catastrophes. Thus, our boundary corresponds to the top of the Tertiary in traditional nomenclature (Oard et al., 2023). For practical purposes, that is the DEM of the ground surface. The major evidence supporting this choice is the significant erosion exhibited across Colorado, indicating action during the Recessive Stage of the Noahic Flood (Walker, 1994). According to McMillan et al. (2006) and based on erosional remnants and eroded anticlines, about 550–600 m was eroded in northwest and north central Colorado, 900–1,500 m in the Rocky Mountain sedimentary basins of central and south-central Colorado, and 180 m from southeast Colorado. Based on the extent of the Ogallala Formation (Ogallala Group in Nebraska), resistant rocks from the central and southern Rocky Mountains were transported and deposited in a broad sheet extending from southern South Dakota to West Texas. Sand and gravel are often found on tops of interstream divides in West and Central Texas, up to 300 m above the adjacent streams and rivers (Byrd, 1971). However, even these deposits were significantly eroded after deposition, especially east of the Rocky Mountain front, which includes much of eastern Colorado. The present area of the Ogallala Formation is around 768,000 km^2 (Frye et al, 1956), while the inferred maximum area was around 1.5 million km^2 (Heller et al., 2003). This supports the erosional estimates cited above.

Another potential sediment source is glacial deposits of the Ice Age. In Colorado, glaciation was limited to mountainous areas and not significant enough to address. In some states, Ice Age glaciation resulted in postdiluvial deposition, typically 100 m or less of unconsolidated sediments. In those states, that volume estimate will have to be calculated separately from a diluvial one. However, Ice Age erosion occurred on both diluvial sedimentary rocks and crystalline basement, so some Ice Age sediments are reworked diluvial sediments.

Another complication arose from Colorado's numerous volcanic fields. For the most part, we include the small ones in the diluvial record. However, we excluded most of the large San Juan Volcanic Field. The primary reasons were we were mapping sedimentary rocks and the lack of available data to map its base. Low Bouguer gravity and seismic velocity anomalies indicate a large granitic batholith lies directly beneath it, with few intervening sedimentary rocks. Drenth et al. (2012) believe the volcanics were sourced from that batholith. Similarly, the basement beneath the Thirty-Nine Mile Volcanic Field is poorly constrained by data, with little sedimentary rock beneath it (Epis and Chapin, 1974). The pre-volcanic formation is called the Echo Park Alluvium and is crudely stratified and only partly consolidated. It fills small grabens in the Precambrian crystalline bedrock and varies in thickness; where found, it averages around 300 m in thickness. Both were excluded from this iteration.

Methods

The volumetric analysis is based on a straightforward differencing of gridded three-dimensional surfaces of the lower and upper diluvial boundaries using GIS software.

We created the basal diluvial grid from the Colorado Geological Survey map of the Precambrian surface (Hemborg, 1996, Figure 2). The Survey also published digital maps of bedrock geology (Green, 1992) based on Tweto's (1979) paper map, available through the USGS (https://pubs.usgs.gov/of/2005/1351/#CO). This geologic map provided accurate geo-registered polygons of exposed Precambrian rocks. It was simpler and probably more accurate than digitizing Hemborg's (1996) exposed Precambrian. Regions of the San Juan and Thirty-Nine volcanic fields were digitized from Hemborg (1996).

His map was supported by data from 197 wells, 174 of which reached the top of the Precambrian surface. His contours that were done in feet relative to sea level. Conversion to metric can be done in the GIS software, and volumetric calculations are output as cubic kilometers.

Figure 2 also shows major faults, well data, and oil and gas data. Well data are available through the Colorado Oil and Gas Conservation Commission. Wells to the Precambrian were obtained from the Colorado Geological Survey by the lead author in 2007. All of these data were digitized or imported into Blue Marble Geographics Global Mapper©. For this project, we are converting crucial layers to ESRI shape files for portability with other GIS programs. Global Mapper© can grid, map, and analyze data, but we created grids using Golden Software's mapping program, Surfer©, because it offers greater flexibility. We set the projection to WGS84 using the European Petroleum Survey Group (EPSG) code 4326. Our county and state boundaries were obtained from Natural Earth (https://www.naturalearthdata.com/).

Figure 3 shows our Precambrian surface. Figure 4 shows the same surface looking east. Until recently, most U.S. subsurface data were provided in feet, which is what we use. But the new software can accommodate both. Researchers are free to use as they choose.

The total area of Colorado is 269,601 km^2. The area outside the blanked regions measured 224,770 km^2, resulting in blanked pixels totaling 44,831 km^2. The area used in the calculations was thus 83.4% of the total surface area of the state. The total area for Colorado (and for other states for future papers) is from Wikipedia for ease of access and consistency.

Subtracting the basement grid from the NOAA ETOPO1 surface elevation grid returned a total volume of 521,391 km^3. The average thickness of the Flood-derived rock column would therefore be

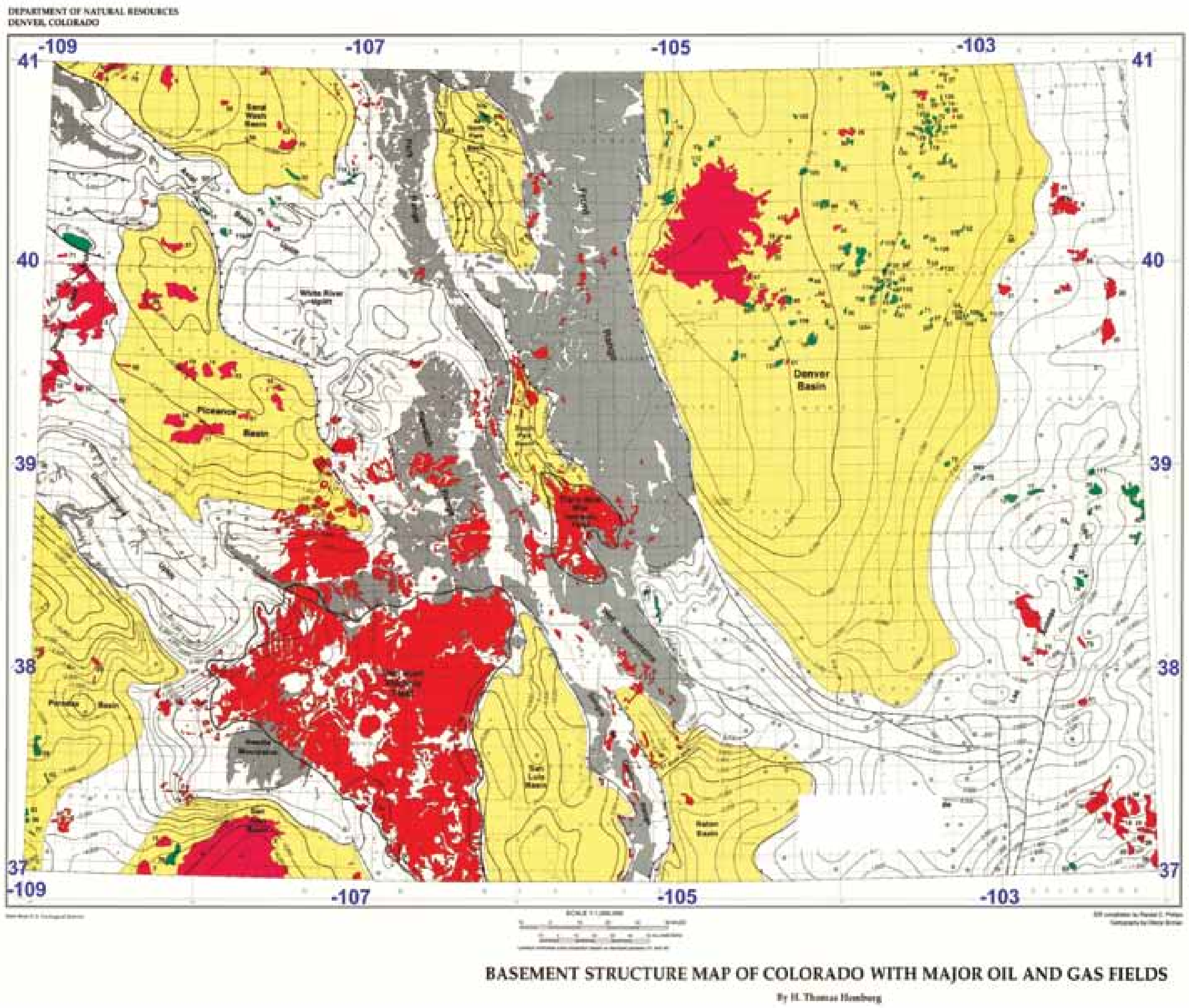

Figure 2. The Colorado Geological Survey map of the top of the Precambrian (Hemborg, 1996) was used to create a basal diluvial boundary grid. Contours are in feet relative to sea level, sedimentary basins in yellow, oil and gas fields in green, exposed Precambrian crystalline rocks in gray, and volcanic fields in red. The map also shows contours, faults, and well location (circles). His sedimentary basin boundaries allowed us to quantify volumes for each one. Hemborg's map is shown in a Lambert conformal conic projection (larger fonts showing the latitude-longitude grid were added); our GIS files were done in the WGS84 projection.

2,320 m (7,612 ft.) for the area calculated and 1,934 m (6,345 ft.) for the total area of the state, (including the blanked areas). Figure 5 shows the distribution of the resulting thickness of sedimentary rocks for Colorado in feet.

Results: Volumes and Average Thicknesses by Sedimentary Basin

Global Mapper© is capable of deriving the volume for any defined geographic area, using its analysis tool. We used this feature to provide areas, volumes, and average thicknesses for the sedimentary basins delineated by Hemborg (1996), shown in Figure 6. These included the North Park Basin, the South Park Basin, the Denver Basin, the Raton Basin, the San Luis Basin, the San Juan Basin, the

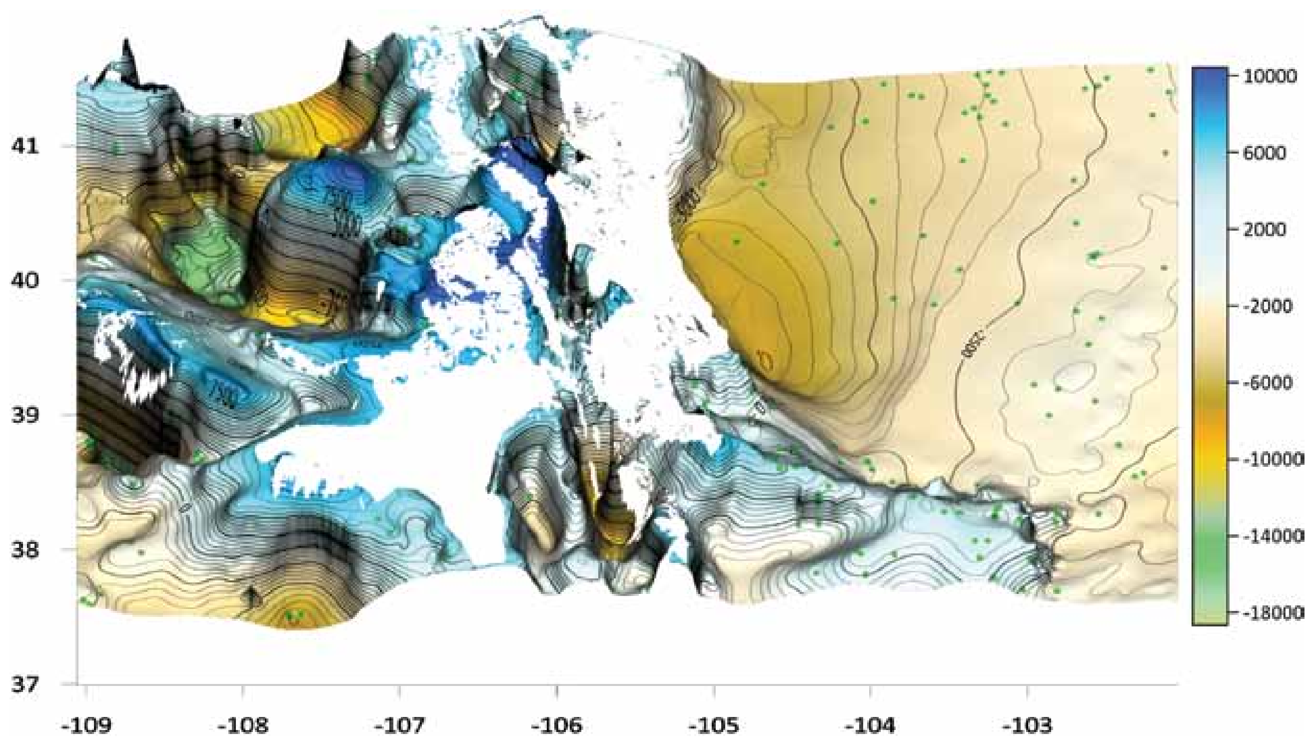

Figure 3 *(above)*. Surfer© 3D surface and contour map of the top of the Precambrian in feet relative to sea level. White areas are those blanked for exposed Precambrian basement and the San Juan and Thirty-Nine Mile volcanic fields (cf. Figure 2). Shown at bottom and left is the latitude-longitude grid. Color scale on right shows feet relative to sea level. Green dots are well locations, showing the distribution of well control.

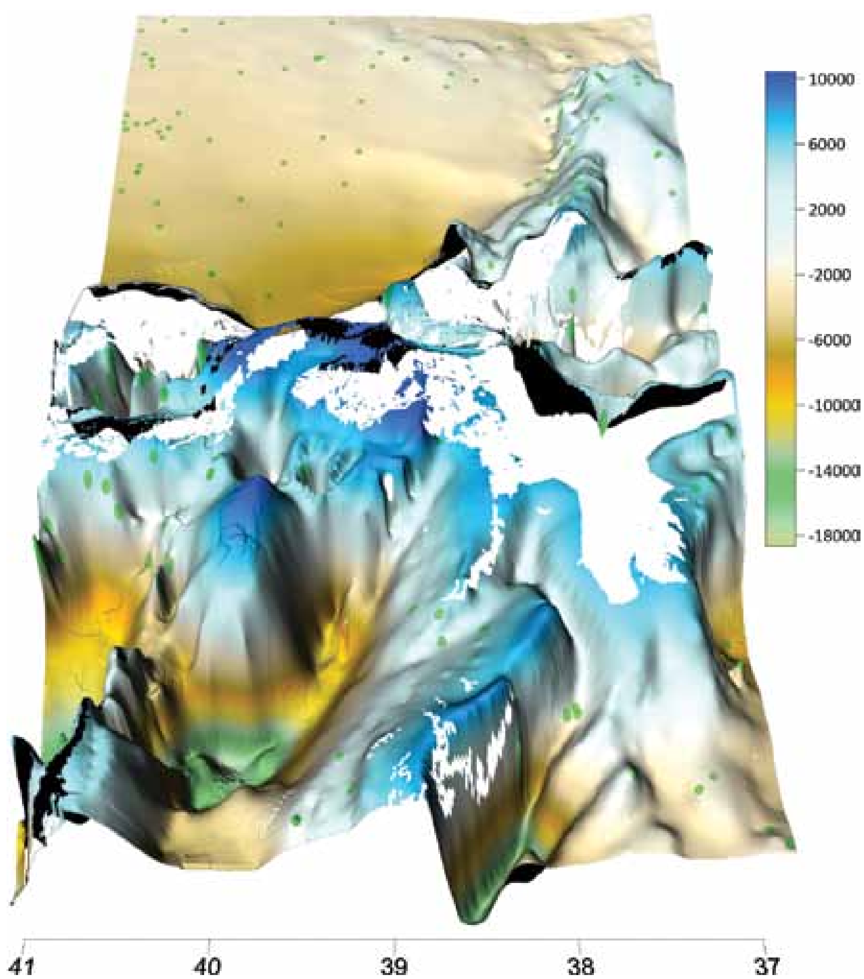

Figure 4 *(right)*. Surfer© 3D surface of the Precambrian basins of Colorado, viewed towards the east. Degrees latitude at bottom, the color scale in feet relative to sea level at right.

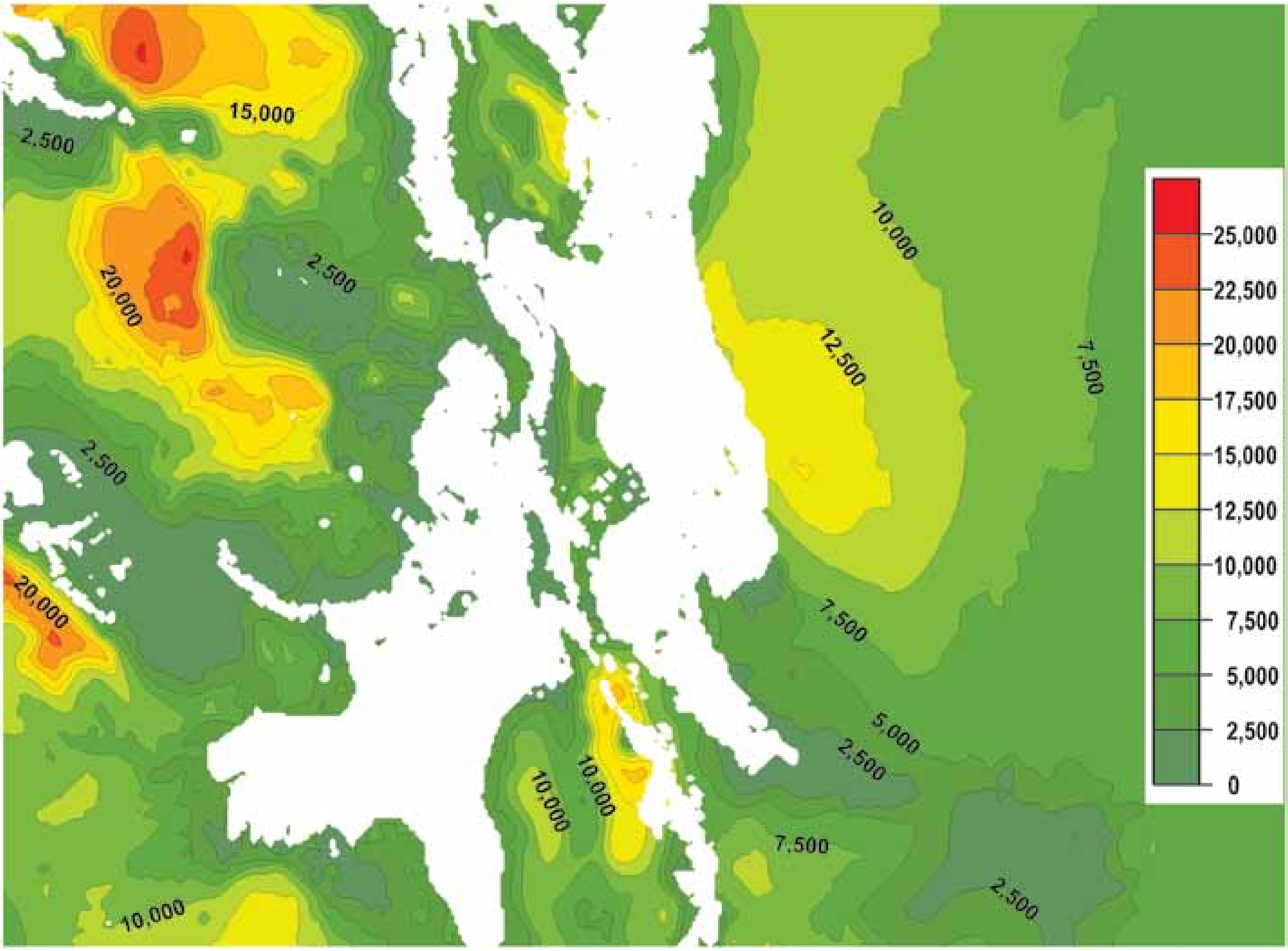

Figure 5. Surfer© isopach map of the diluvial rocks in Colorado (in feet). White areas are crystalline basement and volcanic rock exposures not included in the calculations.

Paradox Basin, the Piceance Basin, and the Sand Wash Basin (Table I). Some of these extend into neighboring states; we only calculated the volumes within the borders of Colorado. As we complete neighboring states, total volumes for those basins will be possible.

Conclusions

Assuming our boundaries, we have calculated the average thickness of the diluvial rock record in Colorado at 2,320 m (7,612 ft.). The greatest thicknesses are in the basins to the northwest, with 5,265 m (17,274 ft.) for the Colorado part of the Sand Wash Basin and 4,287 m (14,065 ft.) in the Piceance Basin. Uncertainties include the areas of the volcanic fields blanked and the small volume of the Precambrian sedimentary rocks of western Colorado that were not included.

This method can be applied to any defined geographic area where sufficient geologic information exists to map the boundaries. We are planning to eventually encompass North America, allowing an evaluation of existing volumetric estimates in great detail. It can also be applied to different countries or continents. Colorado was chosen to show the procedure, since it has easily-available data and relatively few complicating factors. We will soon address areas with more complexity, initially examining the volume of sedimentary rocks around and within the Mesoproterozoic Midcontinent Rift and what such an enigmatic basement rift may mean within Biblical Earth history. Understanding the volumes of this region both with

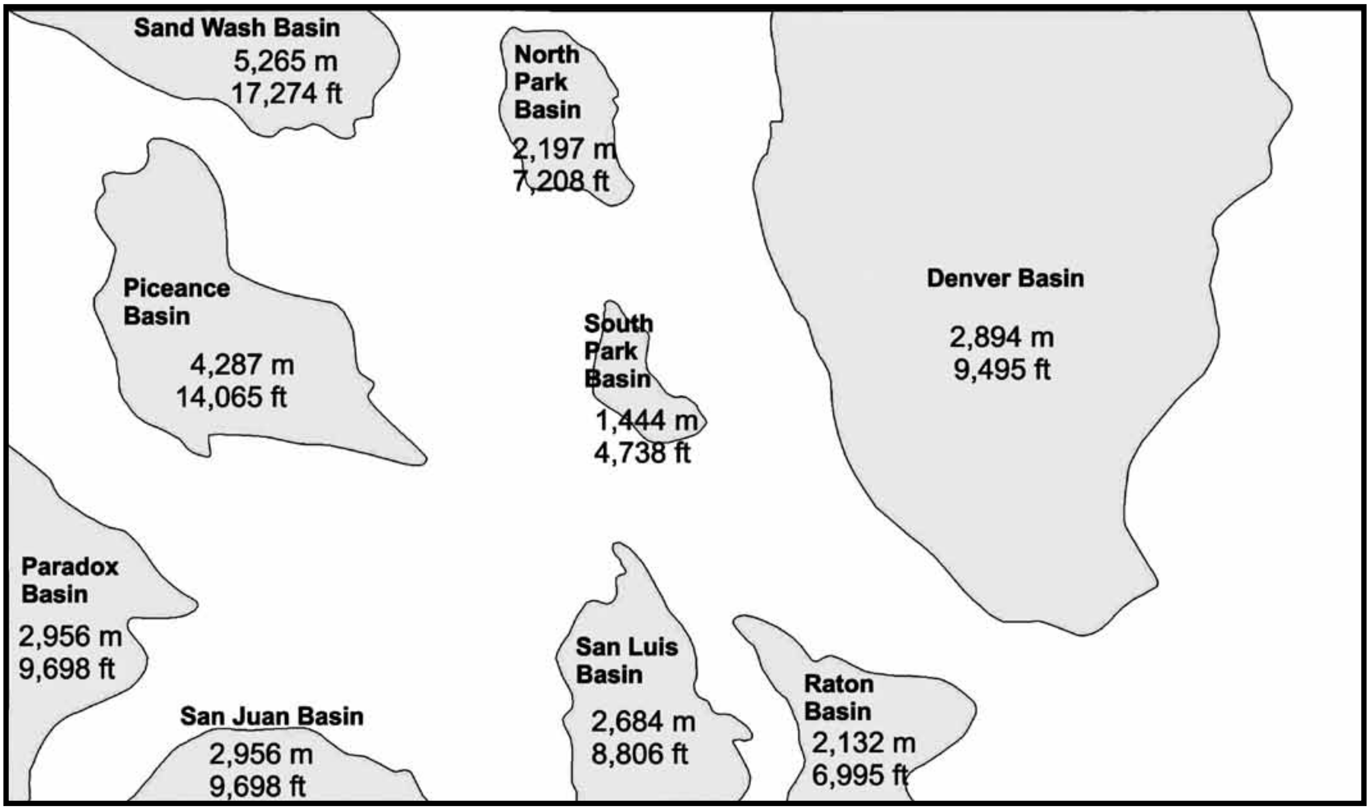

Figure 6. Sedimentary basins of Colorado as shown by Hemborg (1996) with average thicknesses in meters and feet, respectively.

Table I. Volume, area, and calculated average thicknesses for Colorado sedimentary basins.

	Vol. (km^3)	Area (km^2)	Average Thickness (m/ft)
North Park Basin	8,582	3,907	2,197 (7,208')
South Park Basin	2,681	1,857	1,444 (4,738')
Denver Basin	163,129	56,367	2,894 (9,495')
Raton Basin	12,253	2,898	2,132 (6,995')
San Luis Basin	20,803	7,752	2,684 (8,806')
San Juan Basin	12,221	4,134	2,956 (9,698')
Piceance Basin	55,873	13,034	4,287 (14,065')
Paradox Basin	28,434	8,263	3,441 (11,289')
Sand Wash Basin	37,816	7,182	5,265 (17,274')

and without this feature may provide unique insights into the nature of the early Flood.

Once the volume, distribution, and average thicknesses of diluvial rocks are calculated for a region or continent, those values can be combined with maps of late-Flood erosion to generate a more accurate understanding of the total amount of sediment deposited on the continents early in the Flood. From this, it will hopefully be possible to being examine the cycle of erosion, transport, and deposition during the Deluge.

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