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- **THE RECEDING PHASE OF THE GENESIS FLOOD: EXEGETICAL AND GEOLOGICAL NOTES ON GENESIS 8:1-12**
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Haec Credimus

For in six days the Lord made heaven and earth, the sea, and all that in them is, and rested on the seventh. —Exodus 20:11

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eKINDS Project Paper

The uniqueness of ruminants (Ruminantia) among the even-toed ungulates (Artiodactyla)

Part II: Unique anatomical and physiological traits

Jean K. Lightner

Abstract

In the creationist field of baraminology, one strategy for understanding relationships between creatures is to identify an apobaramin. An apobaramin is a group of organisms that are very distinct from all other organisms, such as chiropterans (bats) which are the only mammals capable of powered flight. In this two-part series we are proposing that ruminants form a clear apobaramin based on both molecular (part 1) and morphologic (here in part 2) characteristics. Many of the unique features of the ruminant stomach are discussed. Osseous headgear is also discussed, as well as its apparent loss from some ruminant families. Further important research necessary to determine if ruminants comprise a single or multiple created kinds is briefly outlined. Ruminants clearly reflect the glory of their Creator, who is all wise and provides for His creatures.

Key Words: Baraminology, ruminant, artiodactyl, rumen anatomy, headgear, cranial appendages, four-chambered stomach

Introduction

One of the purposes of creation research in the field of baraminology is to identify which organisms are truly related due to common ancestry (for an introduction

to baraminology, see Frair, 2000). Unlike evolutionists who assume universal common ancestry, creationists affirm the Biblical teaching that organisms were created according to their kinds and en-

dowed with the ability to reproduce and fill the Earth (Genesis 1). It is recognized that organisms change and adapt as they reproduce and fill the Earth, but these changes do not transform one kind of creature into a fundamentally different type of creature. Instead, based on observed examples of evolution, successful changes require pre-existing complexity and pathways that allow for changes that are adaptive, useful agriculturally, or just

add beauty and interest. This is the opposite direction of what is necessary to support universal common descent, as the latter would require most changes to build complexity (Spetner, 1998; Anderson and Lightner, 2016).

Identification of created kinds (holobaramins, sometimes popularly called baramins) lays the foundation for a better understanding of biology. When only related organisms are used to infer changes over history, a more realistic understanding of how plants and animals can change can be gleaned. We can discard the magical-sounding stories where massive gene gains must have occurred by naturalistic processes in the past to account for groups of organisms (e.g., insect orders) to come into existence (Wolf and Koonin, 2013; Rosenfeld et al., 2016) and we have a robust explanation for the origin of orphan genes (Neme and Tautz, 2013; Tan, 2015; Yao et al., 2017). A better understanding of how organisms are designed to change may have a significant positive impact on agriculture and medicine.

One way to approach the identification of related organisms (holobaramins) is to identify significant, holistic discontinuity between a group of organisms and all others (Wood, 2003). Such a group is known as an apobaramin, consisting of one or more baramins, with all members united by characters very distinct from all other organisms. This implies they do not share common ancestry with organisms outside that apobaramin. Once an apobaramin has been identified, it can be further investigated to see if there is significant, holistic discontinuity within the group. Eventually, one should be able to identify which groups are truly related, belonging to the same Biblical kind.

Examples of apparent apobaramins would be bats (order Chiroptera), odd-toed ungulates (order Perissodactyla, which includes horses, tapirs, and rhinos), and even-toed ungulates (order Artiodactyla, which includes pigs and

peccaries, camels and alpacas, hippos, and ruminants), as species in each of these orders are very distinct from all other organisms. In part one of this series, molecular data was used to demonstrate that ruminants (suborder Ruminantia) mostly cluster together, and do not cluster with any other group. In other words, molecular data support the hypothesis that ruminants form an apobaramin within a larger apobaramin, Artiodactyla. Here the hypothesis is further supported by an examination of two unique traits of ruminants: the ruminant stomach and osseous cranial appendages (headgear).

The Stomach

A simple (monogastric) stomach, as is found in humans and dogs, consists of a single chamber that enzymatically digests food before it passes on to the small intestine. Many herbivores have a more complex digestive system designed to extract nutrients more efficiently from plant food sources. This is accomplished by fermentation in enlarged organs, wherein an abundance of microorganisms break down chemical bonds which their host is not readily able to. In some herbivores the fermentation takes place after the stomach (hind-gut fermentation), where an enlarged cecum and/or colon serves as a large microbial fermentation vat. This is the design in odd-toed ungulates (e.g., horses and rhinos), and several other apobaramins (rabbits and elephants). In contrast, most even-toed ungulates (artiodactyls) have a complex, multi-chambered stomach to allow for fermentation.

While most other artiodactyls possess two or three-chambered stomachs, ruminants are unique in possessing a very distinctive four-chambered stomach comprised of a rumen, reticulum, omasum, and abomasum (Figure 1) that is highly effective at extracting nutrients from a plant-based diet. Each of these chambers has a distinctive mucosal lining, and the digestive glands are limited

to the fourth compartment, the abomasum. The first three compartments are sometimes referred to as the forestomach and the abomasum as the true stomach (Membrive, 2016; Bhamburkar, 2018).

The rumen is partially divided internally by thick muscular bands, called pillars, into a large dorsal and ventral sac, as well as a smaller caudal dorsal and caudal ventral blind sac. The walls of the rumen are lined with papillae which increase surface area and expedite absorption of the products of microbial fermentation, such as short chain fatty acids (SCFAs), B vitamins, and vitamin K (Membrive, 2016; Baldwin and Conner, 2017).

**Identification of
created kinds lays the
foundation for a better
understanding of biology.**

The reticulum is a sac located cranial to the rumen and partially divided from it ventrally by the ruminoreticular fold. Since these two compartments work together and the contents mix relatively freely, they are often referred to together as the ruminoreticulum. The lining of the reticulum includes crests that form four- to six-sided structures, giving it a “honeycomb” appearance. Along the lesser curvature of the reticulum is the reticulo-omasal orifice that serves to promote passage of very small particles to the omasum (Membrive, 2016).

The omasum is generally round or oval. It is lined with semilunar folds that give the interior a book-like or leafy appearance. These folds greatly increase the surface area and allow for considerable water resorption. The result is that the digesta that is passed into the

abomasum is much less dilute than what enters the omasum. The abomasum is the glandular stomach, and functions similar to the stomach of monogastrics (Membrive, 2016).

Although it is sometimes claimed that ruminants in the family Tragulidae do not have an omasum, most recent sources recognize them as having a poorly developed omasum (Martin et al., 2001, p. 159; Masters and Flach, 2015). It has been described as a “sac-like transition zone” that has mucosal folds and stratified squamous epithelium (Agungpriyono et al., 1992, 1995). Stratified squamous epithelium lines the first three compartments in a ruminant stomach; this is a unique defining feature of this apobaramin.

The ruminant stomach can adapt. Experiments on domestic ruminants have shown that diet significantly affects physical and metabolic rumen development (reviewed in Baldwin and Conner, 2017). This not only includes rumen mass, but also development and distribution of papillae. Diets higher

in concentrates were associated with increased papillae density and height in both calves and lambs. Similarly, diet-related differences in morphology of rumen papillae were observed between wild and domestic deer (Lin et al., 2011; Mason et al., 2019), and with seasonal variations in reindeer (Mathiesen et al., 2006).

In addition to evidence that diet can influence the development and function of the ruminant stomach (physiologic adaptation), there are species-specific differences that suggest a heritable component is involved in many cases (Lentle et al., 1996; Clauss et al., 2017; Przybylo et al., 2019). This is consistent with God creating ruminants with the ability to adapt through designed genetic pathways, enabling both short- and long-term changes. Yet, even in this adaptation, the unique characteristics of the ruminant stomach are preserved.

Since they also chew their cud, camelids have often been compared to ruminants in terms of digestion. Initially, anatomists tried to describe the cham-

bers of the camelid stomach using the terms used in ruminants, but this created problems because of fundamental differences in stomach morphology. Today, the three chambers of the camelid stomach are either numbered (C1, C2, C3) or referred to as the proximal, middle, and distal chambers (reviewed in Alzola et al, 2004; Bravo, 2015). The differences in stomach anatomy are so profound that evolutionists believe the complex stomachs of each evolved independently from a monogastric ancestor (Bravo, 2015, pp. 592–602; Vater et al., 2021).

It should also be noted that, in addition to the lack of head gear and the distinctively different stomach morphology of camelids (Tylopoda) compared to ruminants (Ruminantia), there are a host of other anatomic, physiologic, and behavioral differences between these two suborders. Additionally, the pattern of disease and parasite susceptibility is significantly different between camelids and ruminants (Fowler, 2008, pp. 375–385).

Cranial Appendages (Headgear)

Osseous cranial appendages in extant mammals are unique to ruminants. Four of the extant ruminant families are characterized by headgear: horns are found in bovids, antlers in cervids, ossicones in giraffids, and pronghorns in antilocaprids. While each have unique features, they are all comprised of a bony core covered with integument; their development is characterized by similar gene expression profiles (Wang et al., 2019a).

Horns are found throughout the family Bovidae, though in many species they only appear in the male. Horn bone growth in the bovid neonate originates from horn buds, which are derived from skin. Bony processes develop in two directions. The bony growth directed towards the skull will fuse with the frontal bone, providing a solid foundation

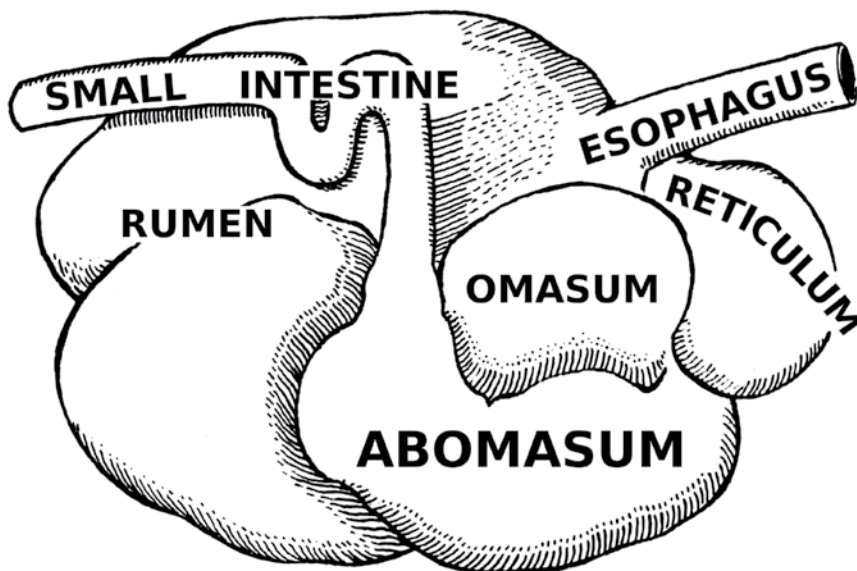


Figure 1. A stylized drawing of the ruminant stomach. [https://en.wikipedia.org/wiki/Ruminant#/media/File:Abomasum_\(PSF\).png](https://en.wikipedia.org/wiki/Ruminant#/media/File:Abomasum_(PSF).png)

for the adult horn. The bony growth directed outwards is covered by a keratin sheath to form the visible portion of the horn (reviewed in Aldersey et al., 2020).

Antlers are unique to cervids; they are the only completely regenerable organ found in mammals. In most species these cranial appendages occur only in the male. They develop annually as an outgrowth of the frontal bone of the skull, and until fully developed, they are covered by a highly vascular layer of sensitive skin known as velvet. As mating season approaches and testosterone levels rise in the male, the antlers harden, and the velvet dries out. A stag will often rub their antlers against objects to remove the flaking velvet. After mating season, testosterone levels fall, osteoclasts dissolve the bone at the base of the antlers, and they fall off (Masters and Flach, 2015, pp. 611–625; Heckeberg, 2017; Wang et al., 2019a).

Ossicones are the headgear of giraffids. Similar to horns, ossification begins separate from the frontal bone. However, they remain detached from the skull (much like scurs in bovids) until sexual maturity and are covered with skin and hair, rather than a keratinous sheath. In contrast, antilocaprid pronghorns develop similar to antlers, or at least fuse much earlier to the skull than horns. They are forked (hence the name pronghorn) and are covered by a deciduous keratinous sheath (Davis et al., 2011; Heckeberg, 2017; Wang et al., 2019a).

Head gear is a trait that can be lost due to genetic mutation. In domestic cattle, four different genetic variants have been characterized in different breeds with polled individuals. These involve complex mutations (indels and/or duplication) on bovine chromosome 1 (BTA 1) in an intergenic region near the centromere. This region is predicted to be a topologically associating domain (TAD), leading to the hypothesis that the mutations affect surrounding genes and/or non-coding RNAs to produce the polled phenotype (Aldersey et al., 2020).

The Chinese water deer (*Hydropotes inermis*) is an extant cervid that lacks antlers. Similar to the two ruminant families that lack head gear (Moschidae and Tragulidae), it has long upper canines. Molecular study supports the popular hypothesis that both the Chinese water deer and the family Moschidae, lost headgear. It is suggested this was through independent pseudogenization of the RXFP2 gene (Wang et al., 2019b). This inference that these RXFP2 pseudogenes are causal is based, in part, on the observation that an insertion in the 3' untranslated region of this gene in sheep is often correlated with the polled phenotype (Lühken et al., 2016).

Relationships among Ruminant Families

The six extant ruminant families are divided into two groups, or infraorders. Tragulidae is the sole extant family in Tragulina; the other five families are grouped in Pecora. If one wants to make a case that ruminants are polybaraminic, then the most reasonable division is between the tragulids (chevrotains or mouse deer) and remaining ruminants. This hypothesis is also supported by our molecular investigation of artiodactyls in part 1 of this series where the two tragulids represented in the study did not fall in the large ruminant cluster (Lightner and Cserhati, 2023). However, three of the four families represented in the main ruminant cluster had at least one species outside the cluster. Further, tragulids are notoriously understudied (Fernández and Vrba, 2005). Nevertheless, the hypothesis that tragulids represent a distinct baramin within ruminants warrants further study.

Because members of Tragulina occur lower in the fossil record (Eocene) than pecorans (Miocene for extant families), evolutionists logically view the tragulid omasum as an organ that became more fully developed through an evolutionary line leading to pecorans

(horn bearers). There are also no horned tragulids, so evolutionists logically believe that pecoran headgear developed later as well. Some hypothesize that headgear arose once among pecoran ruminants; others suggest it arose up to four different times (Davis et al., 2011; Janis and Theodor, 2014).

For creationists holding to a low Flood/post-Flood boundary (at the Cretaceous-Paleogene, or K/Pg), the development of ruminants post-Flood would likely parallel the secular evolutionary progression. While I recognize that significant adaptation can occur because God designed pathways for creatures to adapt (e.g., high altitude adaptation; troglomorphism), I suspect that it is more likely the omasum began as a complex organ, with the ability to decrease in functionality due to adaptation to new food sources, where appropriate. Also, if tragulids are part of the same holobaramin as other ruminants, I would argue they have had a historical loss of headgear as have several pecoran lineages. This latter hypothesis is unlikely to be investigated by evolutionists because of their starting assumptions.

While the pecoran families have remained fairly consistently defined, relationships within these families, as well as between these families, have been highly controversial (Fernández and Vrba, 2005; Davis et al., 2011; Janis and Theodor, 2014). Several possible explanations for this discordance are considered by evolutionists. One explanation is extensive homoplasy (similar form or function among different lineages) combined with poor character selection, as different morphologic studies based on different characters have given differing results (Janis and Theodor, 2014). It is certainly true that if a character is evolvable, or able to change in response to a change in environment or diet, then it can show up a number of different times in different lineages. This parallelism can lead to incorrect conclusions about how these animals are related.

A second possible explanation for the discordant phylogenies is incomplete lineage sorting. In this case an ancestral character was lost in some lineages, but not in others. This also can create a misleading signal when attempting to understand relationships in a group. Finally, introgression (hybridization that brings in new genetics) between lineages is recognized as a possible source (Chen et al., 2019b). Historically, there have been numerous reports of hybridization between bovids and cervids (McCarthy, 2013). Within-family hybridization could also contribute to the difficulty in resolving intrafamilial relationships.

Since the morphologic differences seem to be mostly a matter of modifying or losing an existing structure, any of these may be possible for explaining the discordant phylogenies. However, creationists need to consider one other explanation. Namely, that the families are clearly defined because they were separately created. This, of course, only addresses the confusion on how the families are related to each other; the confusion within families is more likely to be one, or a combination, of the explanations proffered by the evolutionists.

So, plausible creationist hypotheses include 1) a holobaraminic status of ruminants (where differences in the omasum and headgear were derived from created complexity through modification and/or loss), 2) a polybaraminic status with tragulids representing one holobaramin and pecorans a second, and 3) a polybaraminic status with each extant family representing a separate holobaramin (as tentatively proposed in Lightner, 2012).

Regarding the first hypothesis, the location of the Flood/post-Flood boundary would influence the reasonableness of the hypothesis. Otherwise, there are no obvious traits that could not be explained by created complexity followed by modification and/or loss. Tragulids need to be much better studied to make a strong case for or against the second

hypothesis. The third hypothesis leaves un-explained the numerous reports of hybrids between two families (Bovidae and Cervidae) as well as the high degree of similarity in external appearance between them. For example, female deer and antelope can bear a striking resemblance to each other.

Regarding the hybrids between cervids and bovids, it is true that none have been confirmed by karyotype or genetic analysis. Thus, despite the numerous claims of such a cross, with varying degrees of documentation, it is best to consider such hybridization tentative until a genetically confirmed example is found. Clearly, God could have made groups of similar organisms. However, given Adam named the progenitors of these animals, a creationist would be justified in assuming the original progenitors were distinctively different looking, and their offspring would largely retain that distinctiveness.

Summary

In this two-part series, a case has been made for the apobaraminic status of ruminants. In part 1 we demonstrated that most ruminant families cluster together based on the Whole Genome K-mer Sequence (WGKS) method. Further, based on the heat maps, no ruminants clustered with any non-ruminant members of the order Artiodactyla. Here in part 2, I have described two unique anatomical traits: the four-chambered ruminant stomach and osseous cranial appendages. The complexity of this anatomy and associated physiology sets ruminants apart from all other mammals. Since there is no observational evidence that this kind of complexity can evolve, ruminants logically represent a group of animals that do not share ancestry with other extant artiodactyls.

It is possible that ruminants comprise more than one created kind. The most obvious differences are between the headgearless tragulids and the

pecorans, most of which bear headgear. It is also possible that the five extant pecoran families represent distinct created kinds. However, if the latter is the case, a number of putative hybrid reports between Bovidae and Cervidae remain unexplained. It is also unclear why such similar kinds would have been created, given how similar some females from different extant families (cf. cervids with the bovid antelopes) appear today. Further study to test these various hypotheses is warranted, and the inclusion of fossil data may help clarify this.

Finally, it is concluded that the ruminant stomach was uniquely created; it has the ability to evolve, or change, in ways that allow ruminants to adapt and fill the Earth, but still retains its distinctive features. Likewise, osseous headgear was created, although it is not clear if the differences between the pecoran families are from changes in an original design, or if the variation was created separately. Nevertheless, these impressive characteristics of ruminants provide a glimpse of God's splendor and glory; He is the Creator who provides for His creatures so they can reproduce and fill the Earth. May we honor and rejoice in Him (Psalm 96).

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The Receding Phase of the Genesis Flood: Exegetical and Geological Notes on Genesis 8:1–12

Jeffrey P. Tomkins*

Abstract

This multidisciplinary research paper examines Genesis 8:1–12 which describes a critical late-Flood phase of the global Genesis deluge. Johnson and Clarey had previously performed a geological and exegetical analysis of Genesis 7 which documented the immediate pre-Flood events and the majority of the progressive inundation of the Earth from Day 1 through Day 150 (the high-water mark). The present analysis picks up at the beginning of Chapter 8, immediately following the high-water mark of the Flood at the top of the Zuni Megasequence, where the Ark comes to rest in the mountains of Ararat. At this point the Floodwaters began to violently recede off the continents in an important period of late-Flood runoff that created the sedimentary layers of the Tejas Megasequence (Paleogene and Neogene). The important segment of the Flood described in Genesis 8:1–12 encompasses 135 days of significant Earth-shaping activity and is responsible for producing approximately 33% of the total volume of the fossil-bearing layers of the geological column (Phanerozoic). This segment of the Flood is also responsible for the burying of numerous amounts of mammals, angiosperms, and many other plants and creatures living at higher pre-Flood elevations that are not found in lower (pre-Tejas) layers of the rock record.

Key Words: Genesis Flood, receding phase, Tejas megasequence, N-Q Flood boundary, Hebrew exegesis, Genesis Chapter 8

Introduction

The global Flood was forewarned of and preliminarily prepared for in Genesis 6.

In Chapter 7 the Flood initiates with the bursting of the fountains of the great deep on Day 1 with the Flood waters

progressively rising until they reached the Ark on Day 40 (Johnson and Clarey, 2021). The first 40 days of the Flood were largely responsible for the deposition of marine ecosystems and involved the initial megasequences of the Sauk (Cambrian), Tippecanoe (Ordovician, Silurian), and Kaskaskia (Devonian, Mississippian, and Pennsylvanian). At about Day 40, we not only get the float-

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ing of the Ark, but the initial burial of tropical coastal land ecosystems which progressively continue with the global sedimentation of higher and more inland environments represented in the fossil-bearing layers of the Absaroka and Zuni Megasequences. The Flood peaks at the end of Genesis 7 with the high-water mark being about Day 150 where all the highest hills were covered with at least 15 cubits of water (about 22.5–30 feet) represented by the top of the Zuni Megasequence, corresponding to just above the top of the Cretaceous System (Johnson and Clarey, 2021). For a timeline of the global Flood integrated with the megasequences/geological column and global sea level fluctuations, see Figure 1.

While the majority of the initiation and progression of the global Flood occurs within Genesis, Chapter 7, it should be noted that one of the most critical parts of the global Flood occurs during Genesis, Chapter 8. This is interpreted as the receding phase in which huge amounts of Flood runoff are occurring globally on the newly separated continents (Clarey, 2020a). This action is facilitated by the rapid uplift of most of the world’s mountain ranges like the Rocky Mountains in North America and the Andes Mountains in South America. In fact, this phase of the global Flood is so important, that the most recent stratigraphic analysis of five continents indicates that 33% of the total global volume of the Phanerozoic section (Cambrian–Tertiary) of the geological column is composed of Flood runoff sediments known as the Tejas Megasequence (Clarey and Werner, 2023). For a global map of the Tejas Megasequence distribution for the five continents currently mapped, see Figure 2.

This final phase of the Flood not only has strong significance for explaining the vast amount of sediments in the Tejas, but it also affects the critical paradigm of where the end of the Flood exists in the rock record. The location of the Flood/

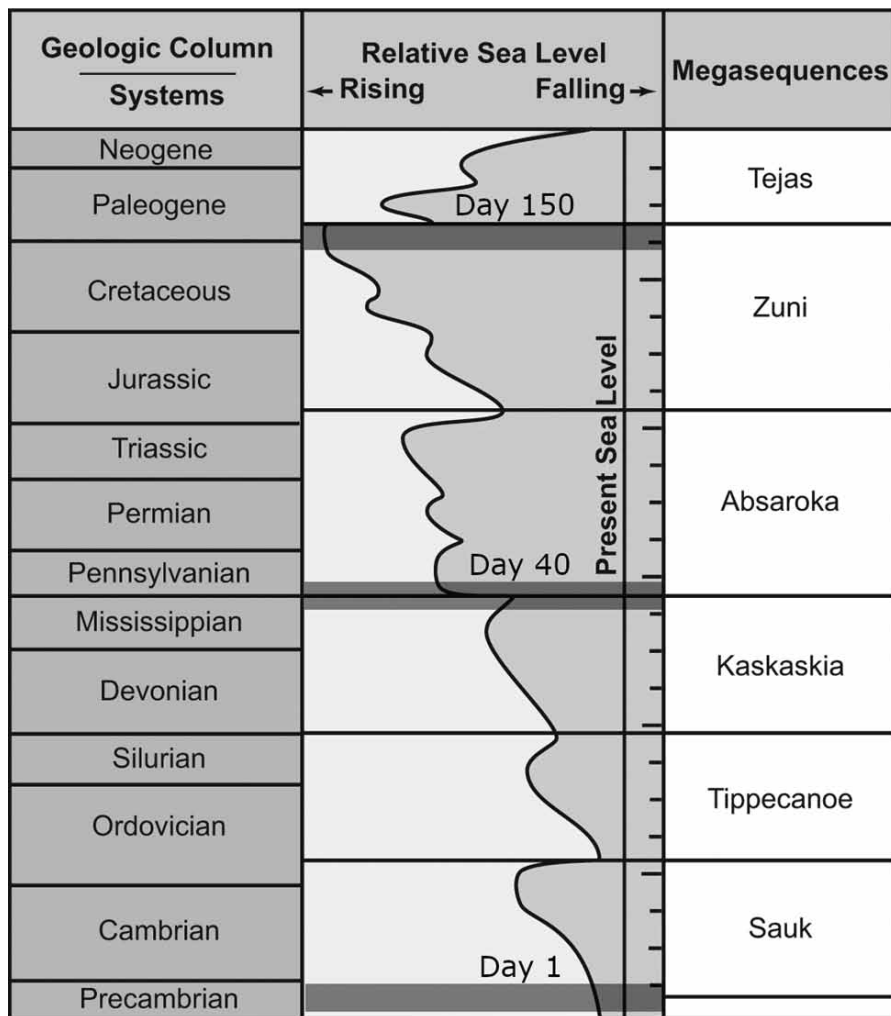


Figure 1. Megasequence/geologic column chart and relative sea level curve for the Flood Year.

post-Flood boundary has been hotly debated in creationist circles for the past several decades (Holt, 1996; Oard, 2004; Oard, 2010a; Oard, 2010b; Oard, 2011; Ross, 2012; Oard, 2013a; Oard, 2013b; Clarey, 2017; Clarey, 2018; Clarey and Werner, 2019; Clarey, 2020a; Clarey, 2020b).

A proper determination of the post-Flood boundary is actually a critical issue to understand because it has direct connections to explaining the enormity of global Tejas strata (about 33% of the total geologic column above the Cam-

brian) along with massive amounts of first appearances of Cenozoic animals and plants (including extensive and thick Cenozoic coal seams). Thus, based on extensive global stratigraphy and paleontology, the post-Flood boundary has been determined to be at the end of the Neogene and beginning of the Quaternary and is known as the *N-Q Flood Boundary* (Clarey, 2017; Clarey and Werner, 2019; Clarey et al. 2021; Tomkins and Clarey, 2021). In addition, a proper post-Flood model also has direct impact on key events such as

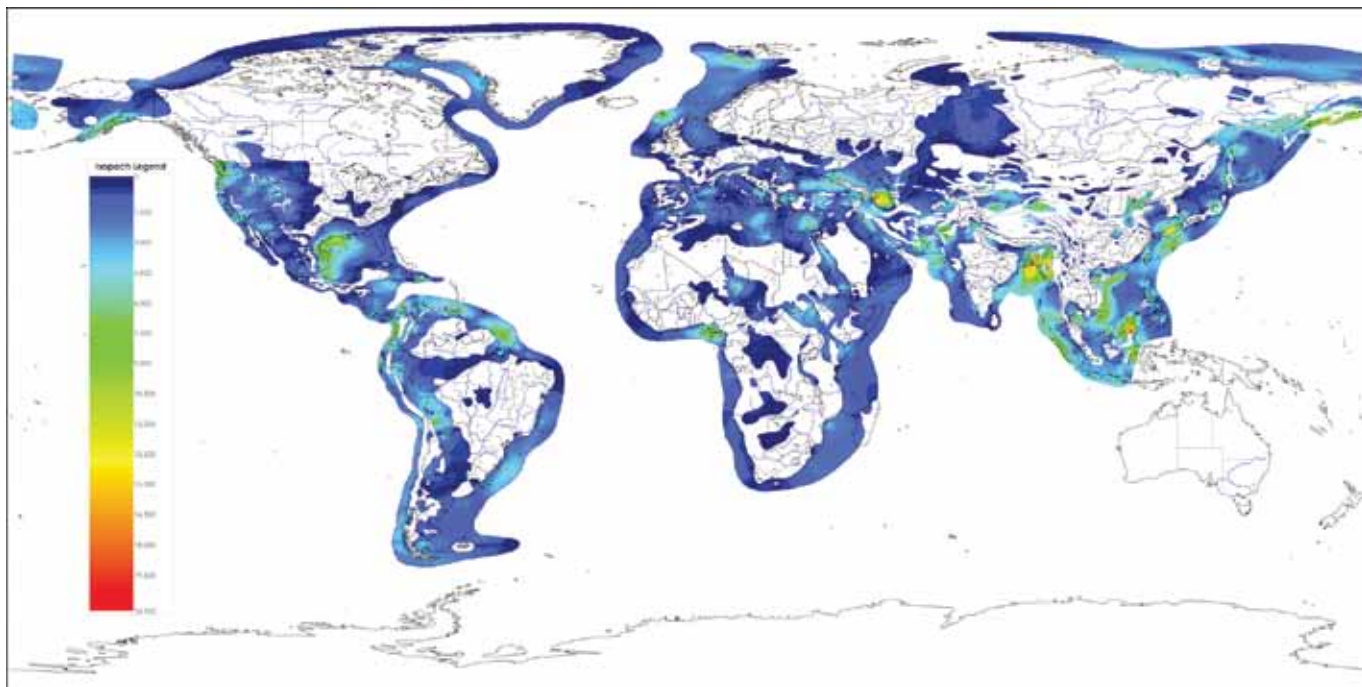


Figure 2. Thickness and extent map of the Tejas Megasequence for the entire world excluding the lower part of Southeast Asia, Australia, and Antarctica. The isopach legend depicts sequence depth in meters by color.

human and animal dispersal from the Ark and the necessity of land bridges associated with the post-Flood Ice Age (Tomkins, 2021c).

Exegetical Methods

Hebrew text analyses were facilitated by Accordance Bible Software (version 14) with the following packages: Biblia Hebraica with Westminster Morphology, Hebrew Masoretic Text with Andersen-Forbes Morphology and Syntax Database, and the Hebrew and Aramaic Lexicon of the Old Testament (HALOT). A hard copy of Owen’s “Analytical Key to the Old Testament” (Volume 1—Genesis to Joshua) was also consulted (Owens, 1991) along with a variety of Hebrew reference grammars as cited in the text. The Hebrew transliterations in the following text are performed in SBL Academic format. English translation unless

otherwise noted, will be in the King James Version.

Genesis 8 Is Historical Narrative

Like Genesis, Chapter 1, and many other parts of the Old Testament, Genesis 8 is Hebrew narrative giving historical truth—not poetry or mytho-history (Johnson, 2011; Drake, 2020; Tomkins, 2021a). This fact is distinctly defined by the Hebrew grammar where the majority of the verbal forms occur in what is known as a *waw*-consecutive in which the verb is prefixed by the letter *waw* and the verb itself is in the imperfect tense. This *waw* + imperfect tense grammatical construct effectively changes the normal imperfect tense (uncompleted action) into a perfect tense (completed action)—hence the alternate, but less preferred definition of *waw*-consecutive. Murphy notes, “The *waw* + imperfect

(*wayyiqtol*) forms the backbone of BH [Biblical Hebrew] historical narrative” (Murphy, 2003). Thus, these verbal forms consecutively and repeatedly describe completed historical events, otherwise termed historical narrative. Since most of the verbal forms in Genesis 8 are *waw*-consecutive, I won’t redundantly repeat this grammatical fact in the following exegesis. If a verbal construct is of a different form and this conveys a significant and insightful meaning, I will take note of that. The style and format of Hebrew exegesis employed in this paper will be the same as that which I have used previously (Tomkins, 2022).

Genesis 8:1

“But God remembered Noah and all the beasts and all the livestock that were with him in the ark. And God made a wind

blow over the earth, and the waters subsided.”

The first verse of Chapter 8 continues the historical Flood narrative of Chapter 7 with the *waw*-consecutive prefixed verb of *zākar* (to remember or acknowledge) with the subject being *Elohim* (God). Instead of the covenant name of God (Yahweh), *Elohim* (a plural of majesty) is used here to indicate God's care not just for Noah and his family but all the creatures on the Ark. A parallel would be the sole use of *Elohim* in Genesis, Chapter 1, where the universe, the Earth and all its life were created. In this case, *Elohim* is also used to indicate the key act of God in bringing forth a new post-Flood world out of the catastrophe of the Genesis deluge that literally destroyed the former world—even creating a new multi-continent Earth as opposed to the nearly singular mega-continent of the pre-Flood world (Clarey, 2020a). Second Peter 3:6 says, “Whereby the world that then was, being overflowed with water, perished.”

The phrase “But God remembered Noah” (*wayyizkōr ’ēlōhīm ’et-nōah*) is not that God had actually forgotten him, but a Hebrew idiom meaning that God began to act on behalf of Noah (Leupold, 1942; Fruchtenbaum, 2009). Kenneth Mathews called it, “covenant language, designating covenant fidelity” in which “God is acting in accordance with his earlier promise to Noah” (Mathews, 1996). It is also noteworthy that the term “remembered” is often found in the circumstance of God's deliverance based on His prior covenantal commitments such as in Israel's exodus and occupation of Canaan (Exodus 2:24; 6:5; Numbers 10:9). But importantly for the progress of the Flood, this phrase marks a key time-point in the Flood narrative in which God acts on behalf of Noah and the entirety of the living contents of the Ark at the specific point of the high-water mark of the Flood (Figure 1). In the sedimentary rock record, this corresponds to the top of the Zuni Megasequence

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or just above the top of the Cretaceous (Clarey, 2020a; Tomkins, 2021b).

And at this high-water mark, we are told that God initiates the process of Floodwater recession with another *waw*-consecutive of *’āḥar* in the causative active Hiphil stem in which He causes a wind (*rūaḥ*) to pass over the Earth and the waters asswaged or subsided (*wayyāšōkkū hammāyim*). Because the word *rūaḥ* could mean spirit or wind depending on the context, Henry Morris conjectured that it probably meant an “invisible force” (Morris, 1976)—referring to God's mighty power at work and His Spirit being the agent. An early Biblical parallel is Genesis 1:2 at the beginning of the Creation Week; “and the Spirit of God moved upon the face of the waters.” An even more significant parallel is later in the book of Exodus 14:21 where Yahweh sent (*wayyōlek*; hiphil *waw*-consecutive of *hālak*) “a strong east wind” (*bērūaḥ qādīm ’azzā*) to dry up the waters of the Red Sea before his people so they could pass over on dry ground. Here in Genesis 8, as in Exodus, they (Noah, his family, and Ark creatures) will eventually also go “through...on dry ground” to disperse

out of the Ark thanks to God's mighty working power of His Spirit in causing the Floodwaters to recede.

This beginning of Floodwater recession or abatement corresponds to the initiation of the Tejas Megasequence sedimentation in the lowermost Paleogene System—the final megasequence of the Flood (Figure 1) (Clarey, 2017; Tomkins, 2021d). The initial sediments of the Paleogene System would be the Paleocene Epoch (Figure 1). For a global map of Tejas sediments on five continents, see Figure 2.

Genesis 8:2

“The fountains also of the deep and the windows of heaven were stopped, and the rain from heaven was restrained”

Genesis 8:2 in the continuation of historical narrative begins with another *waw*-consecutive of the verb “to close” (*sākar*) in the third masculine plural. The plural object is the fountains (*ma’yān*) of the great deep (*tāhôm*) and the windows of heaven were stopped/closed. It can be logically assumed that this entails the near stoppage of new continental separation and rifting that had completely separated the pre-Flood mega-continent (Pangea), beginning in the Triassic System (part of the Absaroka Megasequence). By the end of the Zuni Megasequence (end of the Cretaceous), all of the world's major continents had been completely separated from one another. However, much new seafloor continued to be made after this separation, right up to the Late Neogene System (N-Q post-Flood boundary). In addition, while the most severe rain occurred during the first 40 days of the Flood, it can also be assumed in this verse that all ongoing rain during the first 150 days of the Flood had also been stopped at this point with the rain (*gešem*) being held back (*kālā*) or restricted to facilitate the eventual drying of the earth.

Genesis 8:3

“And the waters returned from off the earth continually: and after the end of the hundred and fifty days the waters were abated.”

This verse is key to the action and nature of the receding phase of the Flood. The sentence starts with the *waw*-consecutive of the verb *šûb* in the third plural indicating that the waters were returning to the oceans from off the earth (the newly separated continents). The English gloss “continually” is taken from the verb *hālak* (qal infinitive absolute) plus the verb *šûb* (qal infinitive absolute) to form what Bandstra calls a “circumstantial abstract of manner” (p. 429) that indicates the progress of the verbal process (Bandstra, 2008). Joüon and Muraoka helpfully say concerning this grammatical construction (p. 397), “and the waters receded in a continuous fashion (the second infinitive strengthens the idea of continuity expressed by *וַיָּשׁוּב*)” (Joüon and Muraoka, 1991). Waltke and O’Connor note that this construction typically involves “main verbs of motion” often using *hālak* and that “the intensifying infinitive does signify repetition or continuance” (p. 589). Thus, the literal gloss of the two connected verbs (*hālôk wāšôb*) is a continuous “going and returning” which shows that the initial phase of Flood runoff involved a massive directional movement with an ebb and flow action.

An additional observation is that the Hebrew verb *hālak* (to walk) is used in other places of the Old Testament to refer to the directional movement of water. An early instance of this usage of water-flow in a specific direction is Genesis 2:14, “And the name of the third river is Hiddekel: that is it which goeth toward (*hālak*) the east of Assyria.” Another water flow example is Psalm 104:10, “You make springs gush forth in the valleys; they flow (*hālak*) between the hills.”

As noted in the introduction, this action was facilitated by mountain range uplift and accompanied by the formation of large basins on land (adjacent to the mountains) and immediately offshore in the oceans (Figure 2). In this regard, Hebrew scholar William Barrick has been involved in authoring several exegetical papers which convincingly show that Psalm 104:6–9 clearly discusses several important aspects of the final phase of the global Flood (Barrick, 2018; Barrick et al., 2020). Specifically in Psalm 104:8, Barrick et al. note, “the grammar and structure of the Hebrew text itself is to take the normal word order of a Hebrew sentence (the verb followed by the grammatical object) and translate ‘the mountains rose; the valleys went down.’” Indeed, John J. Owens, the late Hebrew scholar in his classic *Analytical Key to the Old Testament* (Vol. 3) also takes the same normal grammatical approach to Psalm 104:8—giving a similar analytical exegesis, but helpfully saying that the valleys “sank down” (Owens, 1991). As noted by Barrick et al. in regard to Psalm 104:8, “Such terminology fits well with tectonic activity occurring as the Floodwaters sought the lowest elevation as the mountains were rising” and “This corresponds with the only way for a global Flood to drain: some areas of the crust and mantle must rise and others must sink” (Barrick et al., 2020).

Thus, Psalm 104:8 is directly connected with the text of Genesis 8:3, but adding more tectonic detail that actually fits perfectly with global geological data. For example, directly adjacent to the Rocky Mountains (which are Tejas sediments) are large basins that are filled with thousands of meters of Tejas sediment and corresponding Tertiary fossils (e.g. Green River Basin, Powder River basin, etc.), including massive amounts of coal formed from huge temperate forests that were living at higher pre-Flood elevations. These massive vegetation mats were from plant material torn off and deposited in large intermountain

basins (Clarey et al., 2021). The same basin-based geological and paleontological features are also found associated with the Andes Mountain range in South America (Tomkins and Clarey, 2021). Furthermore, massive amounts of sediments also poured into offshore ocean regions (Figure 2), forming large regions of Tejas ocean deposits like the Whopper Sand in the Gulf of Mexico (Clarey, 2015), and many offshore oceanic coal seams in Southeast Asia and in the Arctic Ocean (Clarey et al., 2021).

One of the reasons that about 80% of the world’s mountains formed in the early receding phase (Tejas or Tertiary) is the crustal thickening along continental boundaries due to runaway subduction during the Flood Year. This overthickening caused simultaneous isostatic adjustments all over the globe. Thicker crust sinks lower and rises higher. As creation geophysicist John Baumgardner said:

Under conditions of isostatic equilibrium, continental regions with thicker crust usually display higher surface topography. For example, relative to a region with a 35 km crustal thickness, a zone with a 60 km crustal thickness, for the densities quoted above, would have a surface 14,500 feet higher (Baumgardner, 2005).

The end to verse 8:3 also gives us the time-point of the Flood being at the 150-day mark. This part of the verse also includes the word *miqšēh* which means “from the end.” From this end point of the high-water mark of the Flood at Day 150, the highly significant runoff phase of the global Flood begins which involves the deposition of a whopping 33% of the total global volume of the fossil-rich geological column (Clarey and Werner, 2023).

Genesis 8:4

“And the ark rested in the seventh month, on the seventeenth day of

the month, upon the mountains of Ararat.”

The phrase “And the ark rested” (*wattānah hattēbâ*) begins with the *waw*-consecutive-prefixed verb *nūah* meaning to come to rest or settle and indicates a completed action. Bandstra indicates that the verbal mood to be in the declarative past for a material event (2008, p. 430). The object of the verb is the arthrous noun for “the ark,” *hattēbâ*.

We are also told that the Ark rested in the seventh month on the seventeenth day on the mountains of Ararat which would have occurred 150 days after the Flood started. While the exact location of the Ark landing has been debated, we can assign it with some certainty to a mountainous region in modern Turkey known as the Kagizman Ridge which formed at the end of the Zuni Megasequence, fitting perfectly with the high-water mark of the Flood to provide the most logical geological structure to rest on (Clarey, 2019). Kagizman Ridge is part of the same range of mountains that contains present-day Mount Ararat (Figure 3). However, Mount Ararat was primarily formed post-Flood during the Pleistocene (Ice Age) and is mostly of volcanic origin. Therefore, present day Mount Ararat is likely not the landing site for the Ark. But the mountains in the ridge directly to the west of it would be ideal. Kagizman Ridge formed at the high point of the Flood (end Cretaceous or Day 150) and extends over 100 miles east-west with some peaks over 10,000 feet. No younger sediments were deposited on top of the ridge after it formed either, only on its flanks, supporting this interpretation (Figure 4). It is referred to as a paleo-ridge (Clarey, 2019). Because the Hebrew word for mountain is in the plural *‘al harê ‘ārārāt* (the mountains of Ararat) this ridge of mountains makes it a strong candidate for the landing site.



Figure 3. Google Earth image of the area around Mt. Ararat, including Kagizman Ridge. The line of the section (north-south) depicted in Figure 4 is shown.

Genesis 8:5

“And the waters decreased continually until the tenth month: in the tenth month, on the first day of the month, were the tops of the mountains seen.”

The Flood-water recession narrative continues in verse five where we are told that the recession of the Floodwaters was still occurring after the Ark rested on high ground with the descriptive phrase, “And the waters decreased continually.” This progressive abatement of

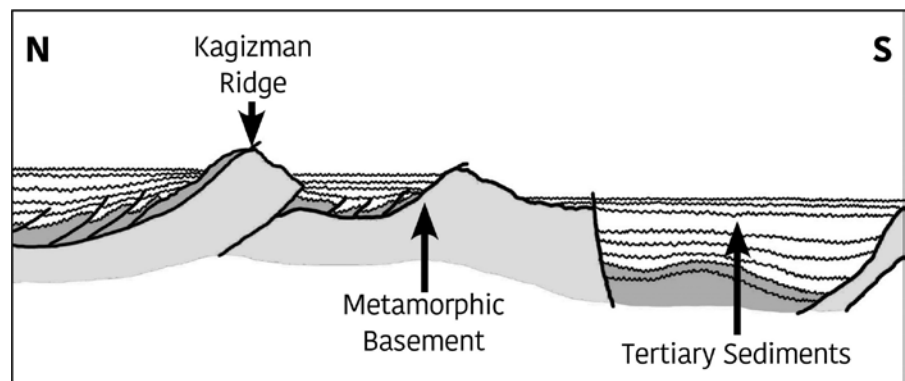


Figure 4. Schematic of north-south section (from Figure 3) showing the geology of Kagizman Ridge; adapted from an earlier study (Keskin, 1994).

the Floodwaters went on from the initial resting of the Ark on the mountains of Ararat for 2½ months until the point when the tops of the newly uplifted mountains were finally visible. The fact that it took another 45 days to get to this point illustrates the truly horrific nature of this massive global event.

This verse actually starts off with the plural noun for “waters” and tells us that they were (*hāyā*) going (using the verb *hālak* as discussed above in verse 3) and the verb *hāsēr* (to diminish). The Hebrew clause “*wəhammayim hāyū hālōk*” is a similar construction to that noted in 8:3. Once again we have the main verb followed by an infinitive absolute plus another infinitive absolute. The infinitive absolute of *hālak* in this verse as noted in one Hebrew reference grammar, “vividly expresses the gradual progression of the main verb” (van der Merwe et al., 2017). Furthermore, because the chain of three verbs includes the qal perfect of *hāyā* followed by the two qal infinitives *hālak* and *hāsēr*, this means that the whole clause denotes a process (Bandstra, 2008). The use of the two infinitives is also considered to be an emphatic combination (*halōk wəhasōr*)—meaning “going and decreasing” (Leupold, 1942). This emphatic and directional process being described is the violent Flood runoff across the continents and into the oceans as noted above beginning with its initiation in Genesis 8:3 at the time of the Ark resting in the mountains of Ararat.

The Hebrew text also tells us that the “heads” (*rō’sī*) of the mountains (*hehārīm*) were “caused” to be seen or observed (niphāl perfect of *rā’ā*). The plural noun “heads” is typically translated as the tops of the mountains. Not only were the Flood waters receding at this time as indicated by the text, but we know from the geological data that many of the world’s major mountain ranges were formed while the Tejas was being deposited (late-Flood sediments).

This also indicates that widespread mountain uplift was still occurring at this time which would have facilitated and increased the velocity of continental runoff.

Genesis 8:6–7

“And it came to pass at the end of forty days, that Noah opened the window of the ark which he had made: And he sent forth a raven, which went forth to and fro, until the waters were dried up from off the earth.”

While the Ark was securely settled, Noah and the others needed to wait until the Floodwaters had receded enough and the land was dry enough and vegetation had time to grow for them to leave the Ark. However, this would take another seven months. But this was also a time of continuing continental and mountain-range uplift, facilitating the recession process as noted previously. In total, Noah, his family and the animal contents of the Ark would end up being inside the Ark for slightly over a year (371 days altogether).

Noah begins the process of testing the condition of the Earth forty days after the point at which the tops of the mountains were seen in verse 8:5. We are told that Noah opened a window that he had made in the Ark. Presumably this is the window that God told Noah to make in the Ark in Genesis 6:16. The verb used to elaborate Noah’s action is *pātaḥ* and is the basic verb “to open” and is here used to refer to a previously made window that must have been cut high up in a side wall of the Ark (Genesis 6:16). And it must have been of such a kind that it could be opened just for this purpose. In the text, the clause “which he had made” (*’āšer ’āśā*) clearly modifies the noun “window” even though it follows the word “ark” in Hebrew.

So, is this the first instance of Noah opening a window on the Ark? In verse five it says, “on the first day of the month, were the tops of the mountains seen” implying that Noah was possibly watching the Flood recede somehow. Nevertheless, Noah does not send any birds out to ascertain the state of the earth until 40 days after the Ark had come to rest. Calvin’s commentary on the verse is thought-provoking. He says, “After he had perceived the ark to be resting on solid ground, he yet did not dare to open the window till the fortieth day; not because he was stunned and torpid, but because an example, thus formidable, of the vengeance of God, had affected him with such fear and sorrow combined, that being deprived of all judgment, he silently remained in the chamber of his ark” (Calvin, 1554 (translation reprint 2009)).

Noah initially tests the condition of the earth by sending forth a raven (*’ōrēb*)—a scavenger bird that would have no problem landing on most types of exposed terrain and eating carrion of the decaying carcasses of creatures not buried in the sediments but perhaps could be found on the exposed points of land. In fact, we are told that Noah sent (*šālah*) out the raven which is described flying back and forth which according to the Hebrew literally means “he went forth, going forth and coming back” (*wayyēšē’ yāšō’ wāšōḥ*). The verb *yātsā’* is used with the absolute infinitive of *šūḥ* indicating that it merely flew back and forth. Perhaps it was repeatedly coming back and landing on the Ark or just making the distinctive noise of a raven as it flew around the Ark. At this point, the preliminary raven test does indicate that portions (high points) of the earth are not Flooded anymore and eventually the raven does not return anymore and the verse ends with “until the waters were dried up from off the earth” (*’ad-yəḥōšēt hammayim mē’al hā’āres*).

Genesis 8:8–9

“Also he sent forth a dove from him, to see if the waters were abated from off the face of the ground; But the dove found no rest for the sole of her foot, and she returned unto him into the ark, for the waters were on the face of the whole earth: then he put forth his hand, and took her, and pulled her in unto him into the ark.”

Another bird is chosen by Noah for the continuing purpose of gathering information on the status of Floodwater recession and drying of the ground. In this case, the dove (*yônâ*) with generic article is a more clean-natured bird. Doves, and the larger species known as pigeons, also have very large flight muscles and can cover vast areas of territory quickly and efficiently. But in contrast to ravens, they normally don't eat carrion, prefer valleys to mountainous regions, and like clean and dry areas for nesting (Sarfati, 2018).

That seven days had elapsed since the sending of the raven can be deduced from the use of the words “to add or do again” (*yāsap*) and “another” (*’ahēr*) (see verse 10). These elapsed week-long periods between successive missions of the birds implies Noah's patience coupled with his desire to monitor how far the Floodwater abatement had progressed. Interestingly, the word for ground (*’ādāma*) is used at the end of verse 8 as opposed to *’ereš* which in the Flood context infers the earth. Perhaps Noah is clearly looking for some dry ground—even if it is just the region immediately around the Ark.

The initial mission of the dove was that it; “found no rest for the sole of her foot, and she returned unto him into the ark” before evening. This clearly conveyed the information that some water was still upon the surface of all the Earth. The narrative tells us how he put

out his hand and took her and brought her to him into the Ark. Additionally, the dove in verse 8 had been sent forth, “from with him,” (*mē’ittô*)—a phrase not used in reference to the raven denoting that the tamed and friendly dove was closer to Noah than the raven (Cassuto, 1964). This is also implied when the dove is said to return “to him.” In fact, the verbal form for “he put out his hand” is *šālah* is in the intensive *Piel*.

The key geological point in this passage is that “the waters were on the face of the whole earth” and the receding phase of the Flood is still in force and has more recession yet to occur.

Genesis 8:10–11

“And he stayed yet other seven days and again he sent forth the dove out of the ark; And the dove came in to him in the evening; and, lo, in her mouth was an olive leaf plucked off: so Noah knew that the waters were abated from off the earth.”

The time space between dove excursions was one week apart. Noah stayed or waited (*yhl*) another seven days which implies his continuing patience (*wayyāhel ’ōd šib’at yāmim*). In this second outing, the dove is sent forth from the Ark and returns in the evening (*’ereḥ*). The fact that we are told that the dove returned in the evening implies that this second outing took longer than the first. The freshly plucked (*tāraap*) olive leaf indicates that the olive trees were starting to sprout. Olives not only grow from seeds, but also from cuttings and can tolerate salinity, a wide pH range, and stony ground (Sarfati, 2018). Thus, olives would be some of the first vegetation to begin producing foliage in the aftermath of the Flood. Research into the recovery of the volcanic ash-covered desolate ground of the Mount Saint Helens region in Western Washington

following the 1980 eruption showed a rapid recovery of vegetation exhibited within a year of the eruption (Clarey and Sherwin, 2020; Thomas, 2020).

Verse 11 ends with the completed action of Noah knowing that the waters were abated from off the earth (*wayyēda ’nōaḥ kī-kallū hammayim mē’al hā’āreš*). This does not necessarily mean that the land surrounding the Ark was dry enough to disembark, but that there were dry pockets of vegetation recovery that contained the beginning sprouts of olive trees and other plants—probably at higher elevations.

Genesis 8:12

“And he stayed yet other seven days; and sent forth the dove; which returned not again unto him any more.”

This final outing of the dove a week after the last excursion when it had returned with a freshly plucked leaf brings the series of bird tests to a conclusion. The clause “which returned not again unto him any more” (*wālō ’-yāsapa šūb-’elāyw ’ōd*) is very interesting. The verb *yāsap* in the qal perfect is negated which literally means not to do something again (or add to) and it is followed by the qal infinitive of *šūb* (to return). Bandstra does a wooden translation of this clause as “and not she more returned to him again” (Bandstra, 2008). In other words, before, the dove would go and return, but not again. This previous process has now been terminated. Thus, this verse largely concludes the receding phase of the Flood narrative.

We can assume at this point that the Floodwaters have mostly receded off the continents although the majority of the land is still not totally dry. This also infers that the activity of mountain range uplift has also largely ceased. However, from evidence of Pleistocene volcanic activity (immediate post-Flood) we can also assume that aerosols of ash

particulates are still being added to the atmosphere which will facilitate the post-Flood Ice Age and its accompanying development of land bridges for global human and animal dispersal from the Middle East (Tomkins, 2021c). I will elaborate on this post-Flood narrative contained in Genesis 8:13–22 in a following companion paper.

Conclusion and Summary

In a previous paper, Johnson and Clarey published a geological and exegetical analysis of Genesis, Chapter 7 (2021). Genesis 7 documents the immediate pre-Flood events and the majority of the progressive inundation of the global Flood from Day 1 through Day 150 (the high-water mark), near the top of the Zuni Megasequence which corresponds to just above the top of the Cretaceous. This current analysis continues the Flood narrative at the beginning of Chapter 8 where immediately following the high-water mark of the Flood, the Ark comes to rest in the mountains of Ararat. At this stage the Floodwaters begin to violently recede off the continents in an important period of late-Flood runoff that creates the sedimentary layers of the Tejas Megasequence (Paleogene and Neogene) both onshore and offshore (Figure 2).

Genesis, Chapter 8:1–12 encompasses a total of 135 days of significant Earth-shaping and sediment deposition activity. In fact, this key sectional narrative of the late-Flood phase of the Genesis Deluge in which the recession of the Floodwaters take place creates a huge 33% of the total volume of the fossil-bearing global geological column (Phanerozoic). This phase of the Flood also accounts for most of the continental mountain range uplift, massive basin formation (at the base of mountain ranges), huge offshore oceanic sediment deposits, and global canyon formation (e.g., Grand Canyon in North America) (Clarey, 2018; Clarey, 2020a; Clarey et

al., 2021; Tomkins and Clarey, 2021). This part of the Flood is also responsible for the burying of numerous mammals, angiosperms (including large coal seams), and many other plants and creatures living at higher pre-Flood elevations that are not found in lower (pre-Tejas) layers of the rock record (Clarey et al., 2021). In addition, this receding Flood narrative in Genesis 8 fits with the conclusion that the post-Flood boundary is at the top of the Tejas (Neogene), known as the *N-Q Boundary* (Clarey, 2017; Clarey and Werner, 2019; Clarey et al. 2021; Tomkins and Clarey, 2021).

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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

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).

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 spe-

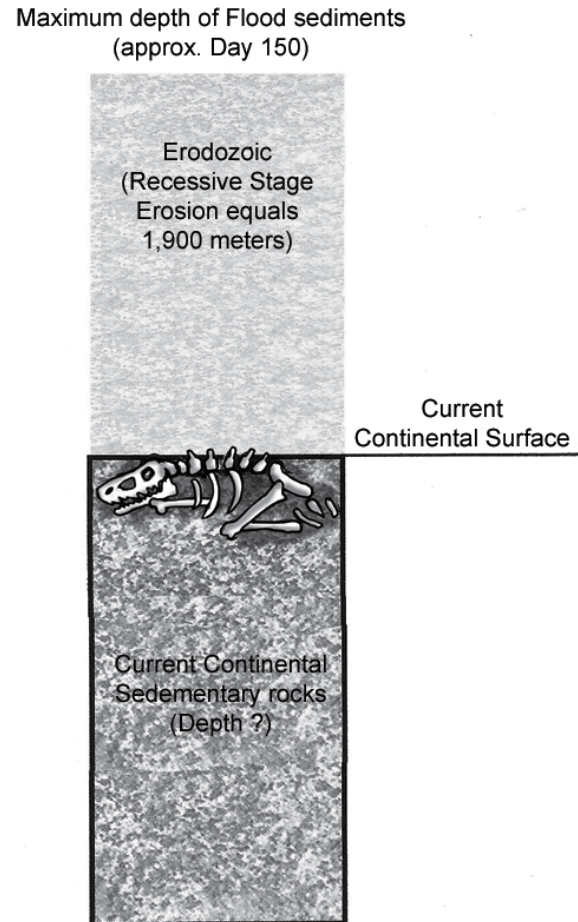


Figure 1. A block diagram representing the sediments and sedimentary rocks at Day 150 made up of an average thickness of ~1,900 m of sediment eroded during the Recessive Stage plus the current volume of sedimentary rocks presently on the continents, which is unknown (Oard et al., 2023; drawn by Melanie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

cific 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 volcanoclastic 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 km² (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 ca-

tastrophes. 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 km² (Frye et al, 1956), while the inferred maximum area was around 1.5 million km² (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 km². The area outside the blanked regions measured 224,770 km², resulting in blanked pixels totaling 44,831 km². 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 km³. The average thickness of the Flood-derived rock column would therefore be

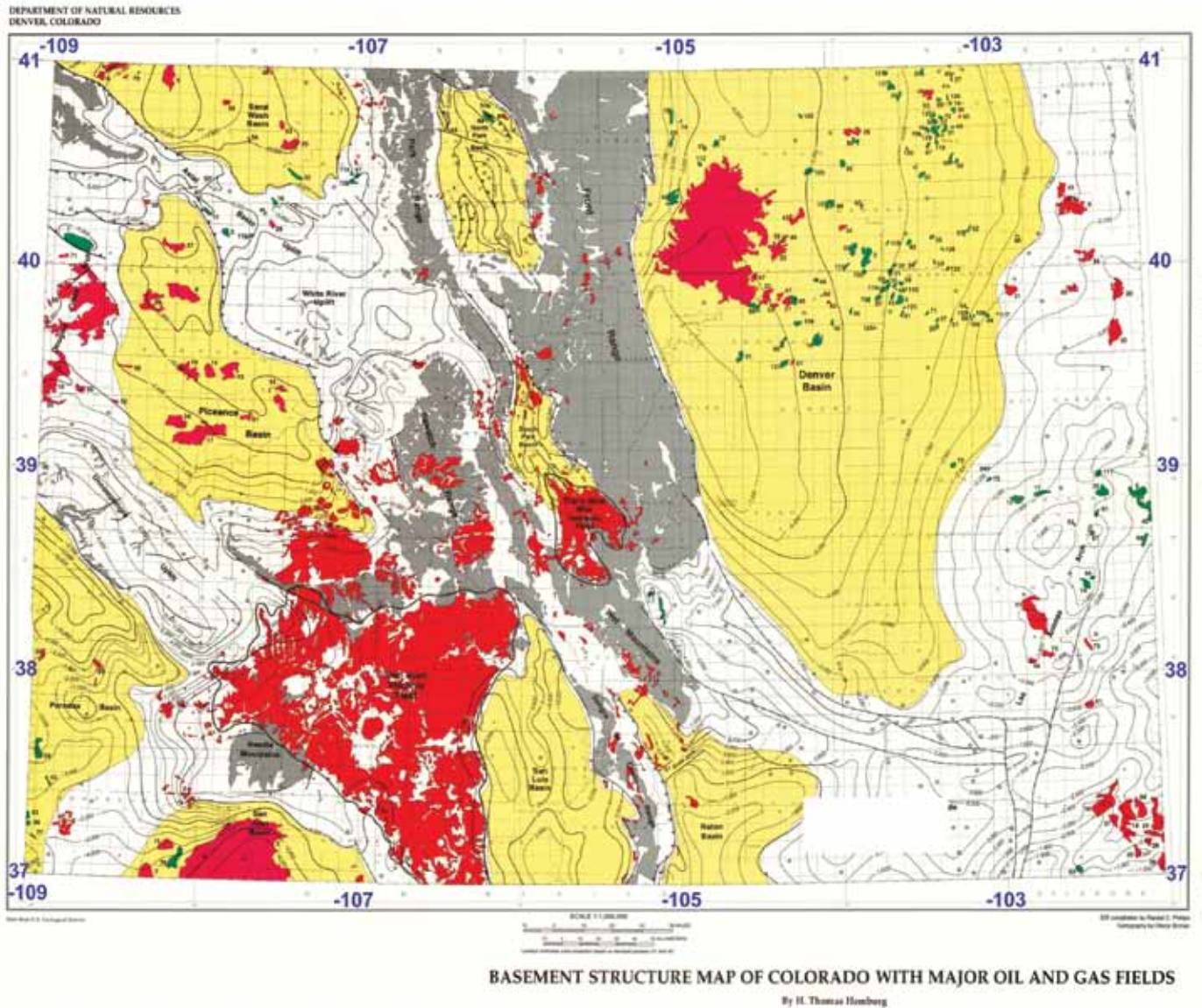


Figure 2. The Colorado Geological Survey map of the top of the Precambrian (Hemborg, 1996) was used to create a basal diluvial boundary grid. Contours are in feet relative to sea level, sedimentary basins in yellow, oil and gas fields in green, exposed Precambrian crystalline rocks in gray, and volcanic 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

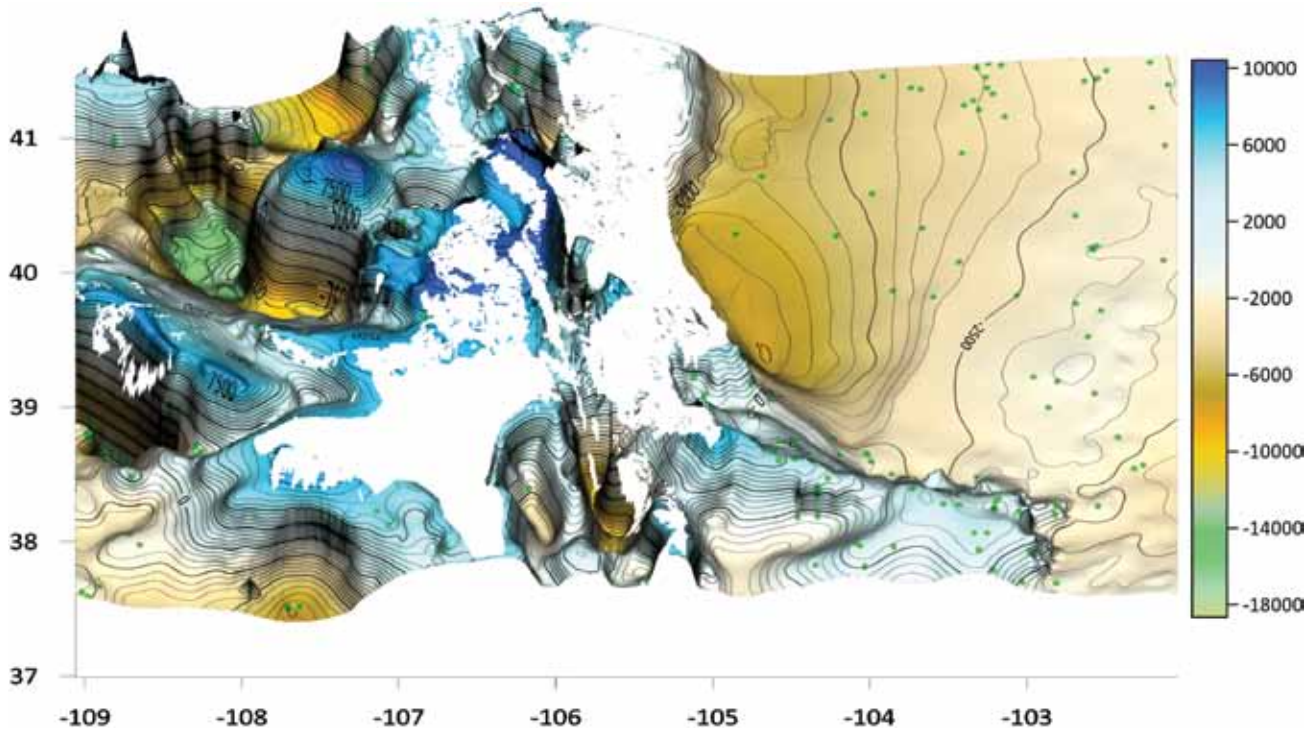


Figure 3 (*above*). Surfer© 3D surface and contour map of the top of the Precambrian in feet relative to sea level. White areas are those blanked for exposed Precambrian basement and the San Juan and Thirty-Nine Mile volcanic fields (cf. Figure 2). Shown at bottom and left is the latitude-longitude grid.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

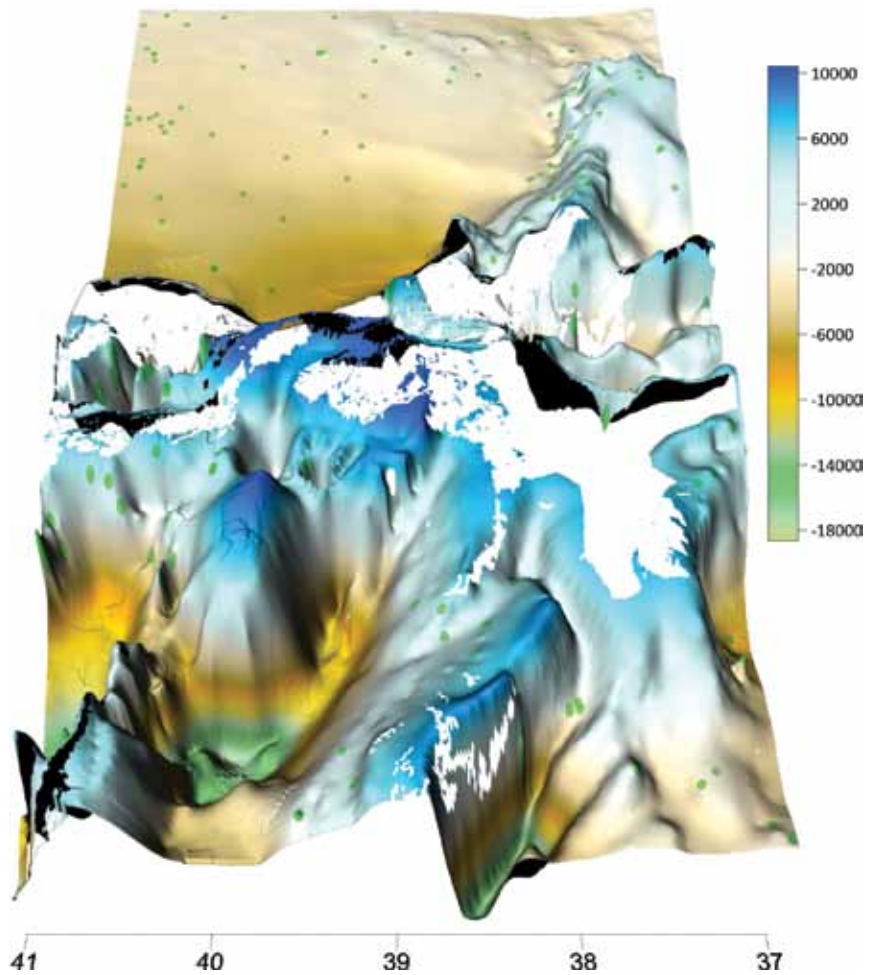


Figure 4 (*right*). Surfer© 3D surface of the Precambrian basins of Colorado, viewed towards the east. Degrees latitude at bottom, the color scale in feet relative to sea level at right.

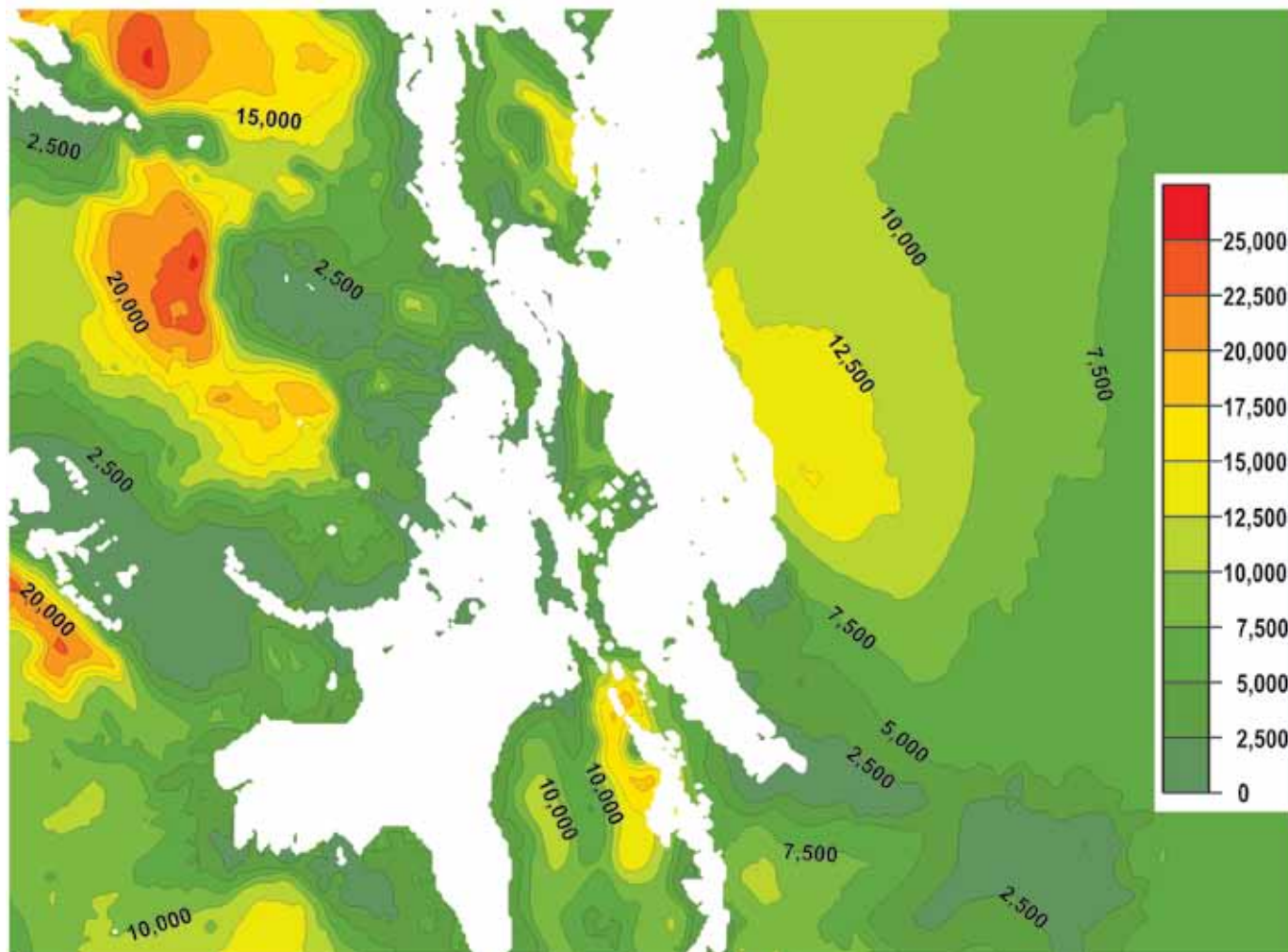


Figure 5. Surfer© isopach map of the diluvial rocks in Colorado (in feet). White areas are crystalline basement and volcanic rock exposures not included in the calculations.

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 Mid-continent Rift and what such an enigmatic basement rift may mean within Biblical Earth history. Understanding the volumes of this region both with

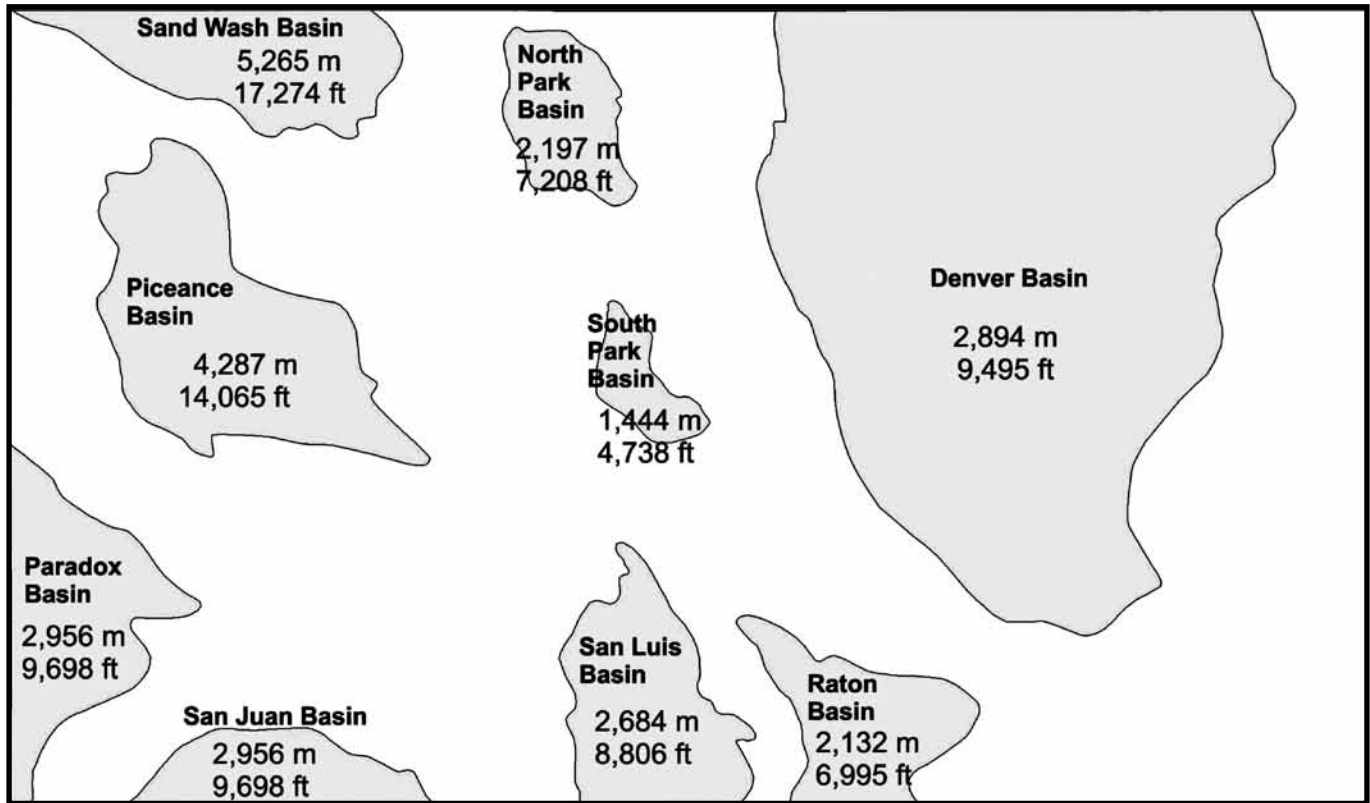


Figure 6. Sedimentary basins of Colorado as shown by Hemborg (1996) with average thicknesses in meters and feet, respectively.

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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The Central and Southern High Plains Animals Likely Buried in the Flood

Michael J. Oard

Abstract

The upper diluvial boundary is difficult to determine in some areas, such as the Arctic coast of North America and the fossil locations of Australian marsupials. An even more difficult area is the top layers of sedimentary rocks of the southern and central High Plains where numerous mammal and other fossils are buried. Despite evidence of a post-Flood paleoenvironment of Agate Fossil Beds National Monument and Ashfall Fossil Beds State Historic Park, they likely are within the Ogallala Group (two or more formations). The Ogallala Group is widespread and thin and was spread hundreds of kilometers east. About half of its top was subsequently eroded. Quartzite rocks from the Rocky Mountains are marked with percussion marks indicating torrential flow. Some quartzite cobbles and boulders have spread 800 km from their source in the southern Rocky Mountains and are found on valley interfluves in central Texas. Most of the fossils in the Group are of animals not living today or during the Ice Age. It is difficult to explain how many millions of animals were buried in the southern and central High Plains with a post-Flood scenario. It is easier to explain that the animals were buried during the Genesis Flood. The apparent post-Flood features can be explained by the BEDS Model. Grass seed fossils associated with a rhino could be because grass fossils are very abundant in the Ogallala Formation.

Key Words: Agate Fossil Beds National Monument, Ashfall Fossil Beds State Historic Park, Australian marsupials, Devil's Corkscrews, Flood/post-Flood boundary Ogallala Group, tracks

Introduction

I have long been interested in the location of the important upper diluvial boundary and have advocated that the

boundary is in the Late Cenozoic: the Miocene, Pliocene, or Pleistocene. My conclusion is based on 35 scientific criteria from Clarey and myself (Oard et

al., 2023). We cannot be precise using the geological column because there is *not* a one-to-one correspondence with Biblical Earth history. In addition, uniformitarian scientists sometimes redate fossils or events, for example with the Antarctic Ice Sheet (see below). I have also advocated that we need to examine each location on its own merits with

multiple criteria, since individual criterion can be equivocal. I have found that most areas are easy to determine, but there are a number around the world that are more challenging.

One of these locations includes the Late Cenozoic sediments and fossils along the Arctic Ocean of North America (Oard, 2018). Despite a few possible post-Flood features, the big picture indicates that the upper diluvial boundary along the Canadian Arctic coast is above the Pliocene, while the boundary along northern Alaska seems to be near the Miocene/Pliocene boundary.

The Australian marsupial fossil locations are another challenging area with ages claimed to be as old as Late Oligocene. But there is more to the story. These fossils were once dated as Pleistocene, which makes sense, since they seem to be post-Flood. Because of the “stage of evolution” with some “primitive” features of the fossils and a lack of “dates,” the ages of the marsupials were pushed back farther and farther into the past. Secular scientists finally arrived at the Late Oligocene for some fossils. So, I agree with Arment (2020) that Australian marsupials, not including those in the early Cenozoic found on all continents, are post-Flood. The determination is valid for only the Australian marsupial locations (Oard, 2022). In this same vein, if secular geologists decide to push an obvious post-Flood feature back older than late Cenozoic, then so be it. They redated the post-Flood Antarctic Ice Sheet to be ten times older than before and placed its beginning in the early Cenozoic (Strahler, 1987, p. 254). The Australian marsupials and the Antarctic Ice Sheet clearly show why we cannot take uniformitarian “precise” dates seriously.

The Central and Southern High Plains Mammals

An area that is even more difficult than the examples above would include the



Figure 1. Devil's Corkscrews, Agate Fossil Beds National Monument, Nebraska (University of Nebraska, public domain).

top layers of sedimentary rocks of the central and southern High Plains of the United States with its mammal and other fossils. McClenagan (2022) concluded that the Agate Fossil Beds National Monument, northwest Nebraska, and Cita Canyon, northwest Texas, mammals are post-Flood. Akridge and Froede (2005, 2011) and Akridge and Akridge (2008) came to a similar post-Flood conclusion for the mammals and other fossils buried at Ashfall Fossil Beds State Historic Park in northeast Nebraska. I have never been to Cita Canyon, so I won't comment on it, except to mention the types of fossils reported by McClenagan. However, I came to a different conclusion for Agate Fossil Beds National Monument, Ashfall Fossil Beds State Historic Park, and other locations in the region (Oard, 2009, 2010).

Agate Fossil Beds National Monument

One of the major valleys or canyons carved into the top of the High Plains

of the United States is the Niobrara River Valley that contains Agate Fossil Beds National Monument. It shows evidence for both a post-Flood and a Flood paleoenvironment.

Evidence That Supports a Post-Flood Paleoenvironment

It is easy to understand why McClenagan came to his post-Flood conclusion since there are features that would indicate a post-Flood paleoenvironment, such as unpermineralized bones, mammal tracks, and the “Devil's Corkscrews (*Daemonelix*),” spiral burrows with the bones of an extinct beaver within some of them (Figures 1 and 2), as summarized in Table I.

The Bonebeds

The bonebed contains thousands of bones representing what are believed to be 9,000 mammals. The bones are mostly disarticulated and jumbled together but not badly broken or abraded.

McClenagan points out that the mammal bones were deposited as lenses within the bottom of channels cut into the top of the upper Harrison Formation, part of the Ogallala Group.¹ The bones are mostly found within two hills: Carnegie and University Hills (Figure 3). McClenagan believes the channels with the mammals were carved post-Flood into the top of the Ogallala Group.

Most of the bones are from three types of extinct animals: a small rhinoceros, the strange chalicothere, and a huge entelodont (terrible pig) that ranges from 150 to 900 kg in weight. The bones are packed into fine-grained sand, sometimes lithified; calcareous silt; and volcanic ash.

McClenagan believes that 100 mummified, small “gazelle-camels” (Figure 4), found 3 km east of the two hills, were buried in post-Flood “loess” in the Lower Harrison Formation. The fact that these animals are found together and articulated would favor a post-Flood paleoenvironment. One problem is that the animals are considered as deposited within the lower Harrison Formation, deeper into the Ogallala Group that McClenagan (2022, p. 6) believes is from the Flood: “One of the last continental-scale sedimentary units laid down by the Flood in North America is called the Ogallala Formation.” Besides, these animals are never found within Ice Age sediments (see below).

Features That Support a Flood Interpretation

But it is best to examine all the features not only from this location, but as many

¹ The Ogallala is given group status in Nebraska and South Dakota and divided into three formations. However, many geologists believe one cannot subdivide the Ogallala because it is a heterogenous formation. Since the focus is sites in Nebraska, I will refer to it as a group.

features as possible in the surrounding area of the central and southern High Plains of the United States. When I applied multiple criteria (Oard, 2014), I believe the evidence better favors a Flood explanation.

The strongest evidence for this is the channels with the fossils seem more

likely part of the Ogallala Group, composed of sand, cobbles and boulders, ash layers, and a “caliche” cap that varies in thickness from 1 to 245 m. Such cut-and-fill channels and their sediments are *common* and considered part of Ogallala Group (Diffendal, 1982). The fossils in Agate Fossil Beds National Monument



Figure 2. Kiosk showing four spiral beaver burrows (left) and the interpretation (right) from Agate Fossil Beds National Monument.

Table I. Features that support a post-Flood paleoenvironment at Agate Fossil Beds National Monument.

Unpermineralized bones
Mammal tracks
The Devil’s Corkscrews
Articulated, mummified gazelle camels that are buried together in “loess”
Bones little broken and abraded
Massive number of bones in lenses at the bottom of channels

are found near the bottom of the two hills (Figure 5) and are covered with sediments that fill the channels.

The dimensions of the Ogallala Group point to it very likely being deposited in the Flood. The present area of the Ogallala Group is huge, around 768,000 km² (Frye et al., 1956), but it has been heavily eroded from an inferred maximum area of around 1.5 million km² (Figure 6) (Heller et al., 2003).

Since the bones are all jumbled together, the Agate fossil beds better represent the erosion, reworking, and re-deposition forming a large bonebed within Ogallala Group. The fossils must have been originally buried nearby, since the reworking and redeposition did not cause much bone breakage and abrasion. This is what would be expected with multiple cut-and-fill features (Heller et al., 2003, p. 1124). Moreover, the sediments are either well-lithified or unlithified.

Remnants of cobbles and boulders of the Ogallala gravel are found as far east as central Texas, generally on top of higher areas, such as on inter-stream divides (Byrd, 1969, 1971). This coarse gravel has been called the Uvalde gravel but is really an eastern extension of the Ogallala gravel. It is *not* associated with well-developed river terraces. The gravel near Uvalde is found 120 to 300 m above the Rio Grande River. It is about 23 m thick at one location. The fact the gravel is well above the river indicates significant channelized erosion happened *after* deposition over a wide area. Some of cobbles and boulders have been reworked into the river valleys and onto terraces. Based on the interfluvial outcrops in central Texas, the Ogallala gravel has been transported about 800 km from its nearest source in central New Mexico. Byrd (1971, p. 7) stated that the origin of the Uvalde (Ogallala) gravel is a major uniformitarian problem:

“A major problem of origin and history of the Uvalde gravels exists because there is no apparent direct



Figure 3. University and Carnegie Hills erosional remnants at Agate Fossil Beds National Monument (Urban, Wikipedia Commons PD US NPS).

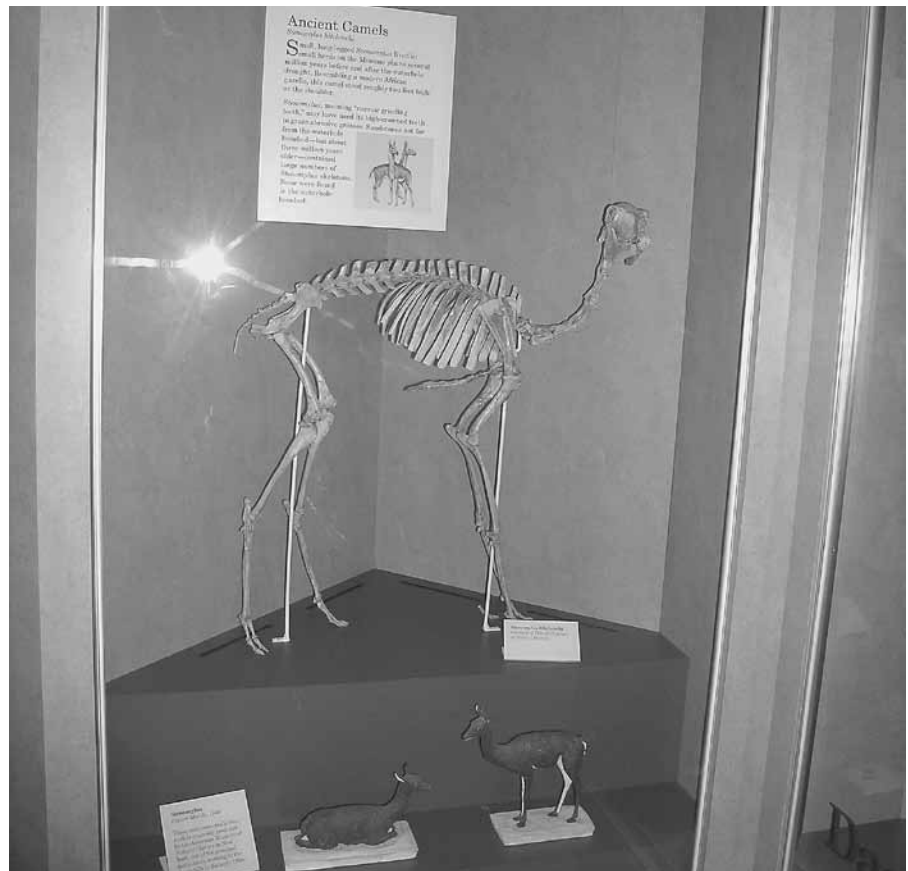


Figure 4. Skeleton of the “gazelle camel” at Agate Fossil Beds National Monument.

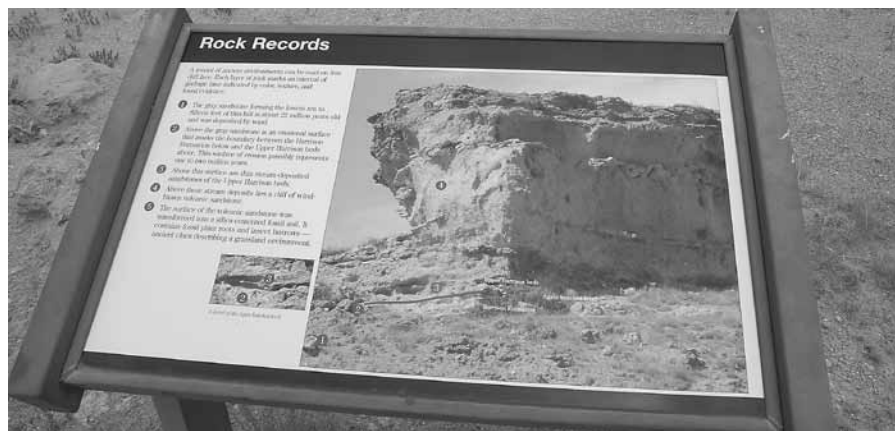


Figure 5. Kiosk showing that the fossils came from near the base of the hills with sandstone interpreted as wind-blown from Agate Fossil Beds National Monument.



Figure 6. Distribution of the Ogallala Group on the central and southern High Plains of the United States (modified from Thornbury (1965) and Heller et al. (2003) by Melanie Richard). Map shows observed (black) and inferred (shaded) original distribution.

connection between the Uvalde gravels and existing drainage in central Texas. Transportation of gravels of such large size is beyond the competence of existing rivers. No source for such coarse siliceous gravels exists in the major basins of present central Texas streams.”

Moreover, the vast majority of the mammals are extinct and never associated with the Ice Age (see below). Many bonebeds occurred during the Flood, such as huge dinosaur bonebeds. It would seem that a bonebed of 9,000 mammals would be typical of the Flood and not a post-Flood signature. How would so many individuals end up being buried in a small area, and why would they show little breakage and abrasion? Each animal must die in the vicinity of the bonebed and be transported to the same exact same spot, which should take some time after the Flood in which case the bones should become weathered and abraded. And even more telling is that there are mainly three types of extinct mammals. Why wouldn't there be many other types of animals if the deposit represents burial in one or more post-Flood catastrophes?

The hills represent erosional remnants of massive High Plains erosion. At least two planation surfaces occur in the central and southern High Plains. One starts in southeast Wyoming and extends well out into Nebraska (McMillan et al., 2002). It is called the “gangplank.” Another planation surface, mainly in northwest Texas is the Llano Estacado. These planation surfaces are on top of the Ogallala Group and is a signature of the Recessive Stage of the Flood (Walker, 1994).

The Devil's Corkscrews are found *within the walls* of the valley. McClenagan admits that the walls are part of the Ogallala Group, deposited in the Flood. Therefore, the Devil's Corkscrews were formed during the Flood and indicate live animals during deposition of the Ogallala Group. Table II summarized the

evidence for a Flood interpretation of the Agate Fossil Beds National Monument.

The Loess Question

I believe the loess is just a uniformitarian interpretation of a silt layer. Siltstone layers within the geological column are sometimes claimed to be loess, such as late Paleozoic loess from a supposed ice age in western North America (Soreghan et al., 2008). Ice Age loess is practically always found on top of the Ogallala Group and does not occur within it. The claim of Ogallala Group loess is similar to that made for many of the sandstones in the western U.S. that are claimed to have been deposited by wind. Whitmore et al. (2014) examined the classic “wind-blown” sand in the west, the Coconino Sandstone, and discovered that it is highly likely that the sand was deposited in water. The 100 gazelle-camels have their heads turned back in the “death pose,” indicating suffocation, similar to many other Flood animals. How these mammals were mummified is unknown.

Ashfall Fossil Beds State Historical Park

There are several other areas of the central and southern High Plains that can add information. One of these is Ashfall Fossil Beds State Historical Park in northeast Nebraska. Two hundred species of mammals and a few reptiles and birds have been found. A graveyard of rhinos buried in volcanic ash is the main attraction of the site with a shelter built over them, called the Rhino Barn (Figure 7). The ash ranges from a few cm to 3.5 m thick and many of the animals are found within or just below the ash.

Evidence That Supports a Post-Flood Paleoenvironment

Several creationists concluded that the area is post-Flood (Akridge and Froede,

Table II. Features that support Flood deposition at Agate Fossil Beds National Monument.

Fossils within cut-and-fill sediments are part of the Ogallala Group
Ogallala Group is thin over a huge area
Fossils of 9,000 animals
Part of the Group is well lithified
Exotic hard rocks from the Rocky Mountains spread 100s of kilometers east
Vast majority of animals extinct and never associated with the Ice Age
Mainly three types of extinct mammals
The hills with the bones are erosional remnants left during valley channelized erosion
Two planation surfaces cap the Ogallala Group
The Devil’s Corkscrews are from the walls of the valley and within the Ogallala Group



Figure 7. The Rhino Barn above a graveyard of rhinos buried in volcanic ash at Ashfall Fossil Beds State Historic Park.

Table III. Features that support a post-Flood paleoenvironment from Ashfall Fossil Beds Stage Historical Park.

A bonebed of mostly articulated rhino fossils at the Rhino Barn
Coprolites
Bite marks on bones
Minimal permineralization
Grass fossils associated with a rhino
Unborn and baby rhinos
Tracks
A few animals similar to today
Fossils well preserved
Hatchling turtle bones

2005, 2011; Akridge and Akridge, 2008), a reasonable conclusion based on what seems like obvious post-Flood indica-

tors (Table III), such as mammal tracks, grass seed fossils associated with the bones (Figures 8 and 9), baby rhinos

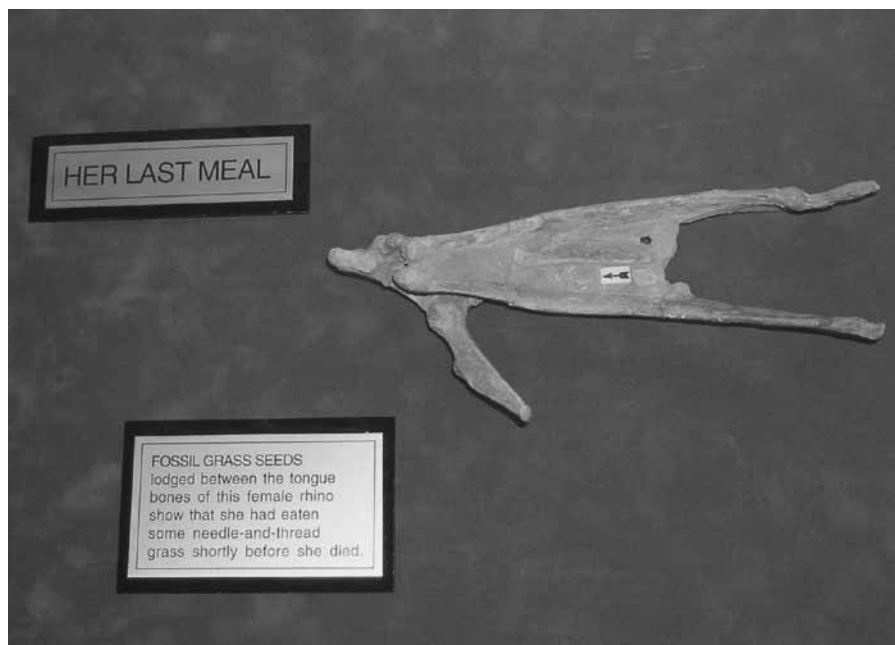


Figure 8. Grass seeds within the mouth fossils of a rhino at Ashfall Fossil Beds State Historic Park.

(Figure 10), and unborn baby rhinos (Figure 11).

Features That Support a Flood Interpretation

Despite evidence for a post-Flood paleoenvironment, a number of features point to Flood deposition (Oard, 2009, 2011a). The most important is that the formations are part of the Ogallala Group that provides strong evidence it was laid down during the Flood (see above). McClenagan (2022) acknowledges that the Ashfall Fossil Beds State Historical Park are within the Ogallala Group, and hence from the Flood. This is opposite to the conclusion of Akridge and Froede (2005, 2011) and Akridge and Akridge (2008).

Although the volcanic ash is unlithified, the Ash Hollow Formation that contains the ash is a well-lithified sandstone. To lithify sand, hundreds of meters of overburden are required (Oard and Klevberg, in press), and in this case the overburden was eroded and the fossils exposed at the surface. This is a predictable pattern in the Genesis Flood.

Moreover, the Ogallala Group, including the Ash Hollow Formation, contain exotic cobbles from the Rocky Mountains with percussion marks (Helland and Diffendal, 1993). These exotic rocks are found associated with the fossils. Percussion marks (Figure 12) are indicative of torrential flow of water and are not forming today on hard rocks (Oard, 2013). Such long-distance transport of resistant rocks with percussion marks is a Flood signature (Oard, and Klevberg, 1998).

Warm-climate organisms, such as crocodiles (Voorhies, 1971), alligators, and large tortoises are also found, indicating a climate unlike that of Nebraska either during the Ice Age or at present (Figure 13). Thomasson (2005, p. 193) tells us the significance of the large tortoise fossils: "This fauna is consistent with a grasslands paleoenvironment,

and the presence of the tortoise suggests moderate temperatures that rarely, if ever, fell below 32 degrees F.” The volcanic ash bed, and other abundant ashes within the Ogallala Group would have caused a volcanic winter (Oard, 2019). Therefore, warm-climate fossils should be absent, especially in this continental interior location. Moreover, many of the fossil organisms are unusual and never associated with the Ice Age (see below).

Petrified wood is also found (Figure 14). In order to petrify wood, silicon dioxide must be absorbed into the wood before it rots. This process makes sense during rapid Flood deposition, but not after the Flood (Oard and Klevberg, 2022). Table IV summarizes these Flood indicators.

Other Locations

I have examined other locations of the central and southern High Plains. One of these locations is the classic mammal fossil area of southwest Kansas, where the Lava Creek B ash layer, assumed from the last Yellowstone super-eruption, is found. I earlier discovered this ash within the pediment capping gravel in the Upper Wind River Basin, southeast of Yellowstone. Since pediments are typical of rapid, channelized Flood runoff within a valley (Oard, 2014b), the Lava Creek B ash was deposited late in the Flood, which also means that all the previous Yellowstone super-eruptions also occurred late in the Flood. This deduction is reinforced by the features in and around Yellowstone National Park, Wyoming, USA. The Ice Age started right after the Flood in the high elevations of Yellowstone, and the ice eventually accumulated to about 1,000 m above the valleys (Licciardi and Pierce, 2018). If any of the super-eruptions occurred during the Ice Age, the heat would have melted much ice and caused massive megafloods and debris flows down the adjacent valleys during the Ice Age, which is absent.

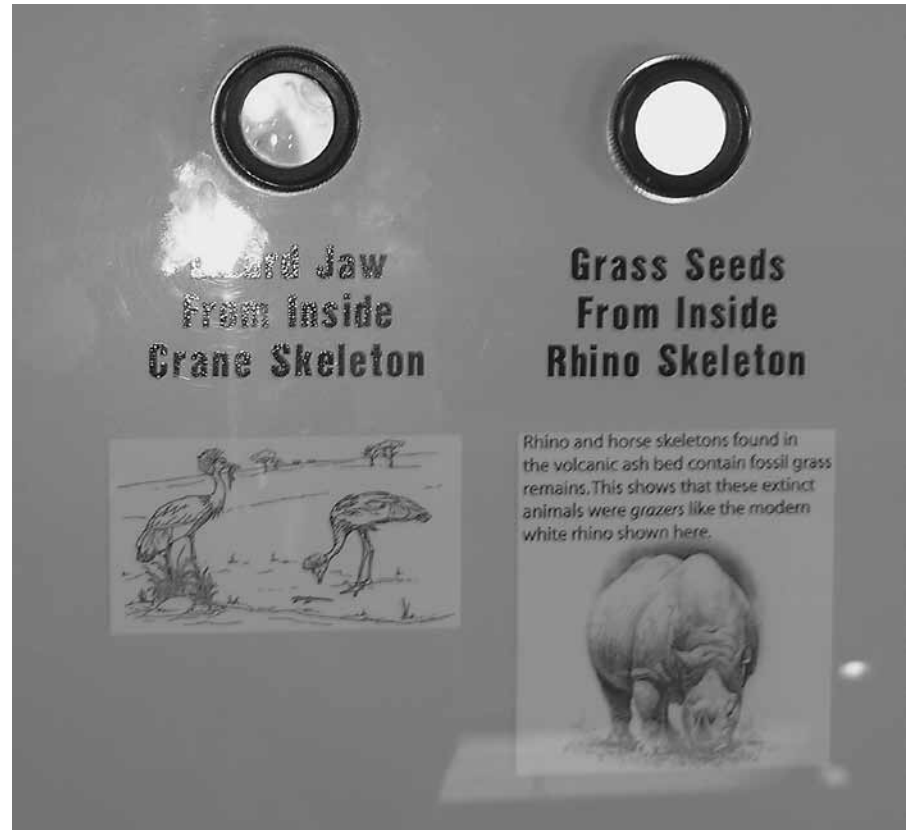


Figure 9. Grass seeds with the body of a rhino at Ashfall Fossil Beds State Historic Park.

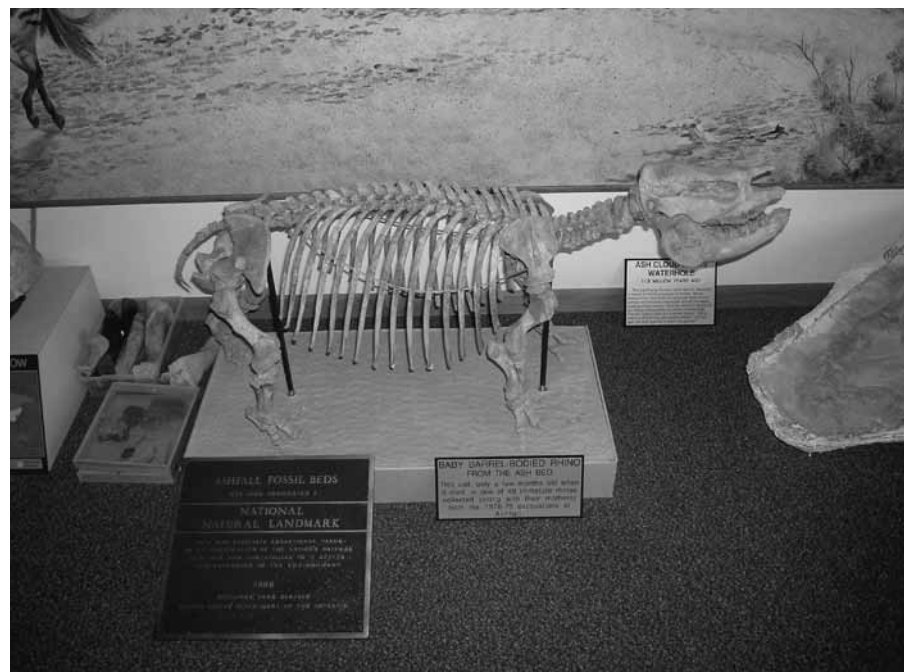


Figure 10. A baby rhino at Ashfall Fossil Beds State Historic Park.



Figure 11. An unborn baby rhino at Ashfall Fossil Beds State Historic Park.



Figure 12. Percussion marks on a rock from the Rocky Mountains in Toadstool Geologic Park, extreme northwest Nebraska.

Based on the location of the Lava Creek B ash in southwest Kansas, I determined that numerous mammal fossils

from that area are from the Flood (Oard, 2014a). Since this ash is dated at 650,000 years, the Flood/post-Flood boundary in

southwest Kansas was determined to be in the mid Pleistocene. Pleistocene sediments do not automatically mean Ice Age sediments, since many Pleistocene sediments have nothing to do with the Ice Age. Some basins have over 1000 m of Pleistocene sediments. For instance, Pleistocene sediments are 3000 m thick in the 400-km diameter South Caspian Basin (Richardson et al., 2011). Southwest Kansas was never glaciated, but Hibbard (1944) correlated the mammals to the lower portion of the four-ice-age scheme farther northeast, although there is no physical connection of the area to the Ice Age. The four-ice-age scheme is obsolete and has been superseded by about 50 ice ages of variable intensities that repeat at regular intervals according to the astronomical theory of the ice ages (Walker and Lowe, 2007).

The ash also occurs at Gilliland, north central Texas above mammal fossils (Hibbard and Dalquest, 1967) that would be from the Flood. This of course assumes that the ash can be correlated to the Lava Creek B Yellowstone super-eruption.

Mammal fossils, likely from the eroded walls of Blanco Canyon, about 50 km east of Lubbock, Texas, are likely from the Flood (Oard, 2014a), but some of the animals could have died in the valley during the Ice Age. Blanco Canyon is another canyon, south of Cita Canyon, that is also cut in the Llano Estacado planation surface on top of the Ogallala Group.

Most of the Fossils Point to a Flood Paleoenvironment

The fossil locations have animals of types never associated with Ice Age deposits or from the present. The fossils include oreodonts, four-tusked elephants, three-toed horses, rhinoceroses, bear dogs, chalicotheres, huge pigs, horned rodents, gazelle-sized “camels” 60 cm tall, giraffe-like camels, 4-horned pronghorn, saber-toothed deer, etc. McClenagan reports fossils from Cita Canyon from a

zebra-like horse and a 3-toed horse that are not known today or from the Ice Age in North America.

Some of the animals from Cita Canyon could be from the Ice Age or present environments, such as the deer, pronghorn, peccary (pig), giant ground sloth, giant armadillo (glyptodont?), saber-toothed cat, short-faced bear, raccoon, rabbit, badger, lynx, giant land tortoise, turkey, and ibis. Assuming the wall strata is from the Flood, being part of the Ogallala Group, it is difficult to tell whether some of the animals are Flood or post-Flood. It likely depends upon whether the fossils are or were part of the wall strata that was eroded into the canyon, or died during or since the Ice Age within the canyon. McClenagan (2022, p. 11) recognized this distinction: “It is important to distinguish between fossils located in situ in the Ogallala beds and fossils located in a basin carved into the Ogallala.” Of course, if the fossils were eroded from the Ogallala beds and lying in the basin, it would be difficult to tell whether they are from the Flood or post-Flood. More research is required for Cita Canyon.

What Should Millions of Mammals Buried in the High Plains Strata Tell Us?

A more basic question should be asked. The fossil locations in valleys and canyons carved into the Ogallala Group are widely scattered and highly fossiliferous. Therefore, it can be assumed that the vast areas in between are also highly fossiliferous. Thomasson (2005) reinforces this deduction by writing that the Ogallala sediments contain numerous vertebrate fossils. We can conclude that many millions of mammals are buried in the top strata of the central and southern High Plains.

If the animals were buried in the Ogallala Group, advocates of the post-Flood position need to believe the following: (1) the animals multiplied and



Figure 13. Giant tortoise fossil with its current range in the tropics and subtropics at Ashfall Fossil Beds State Historic Park.

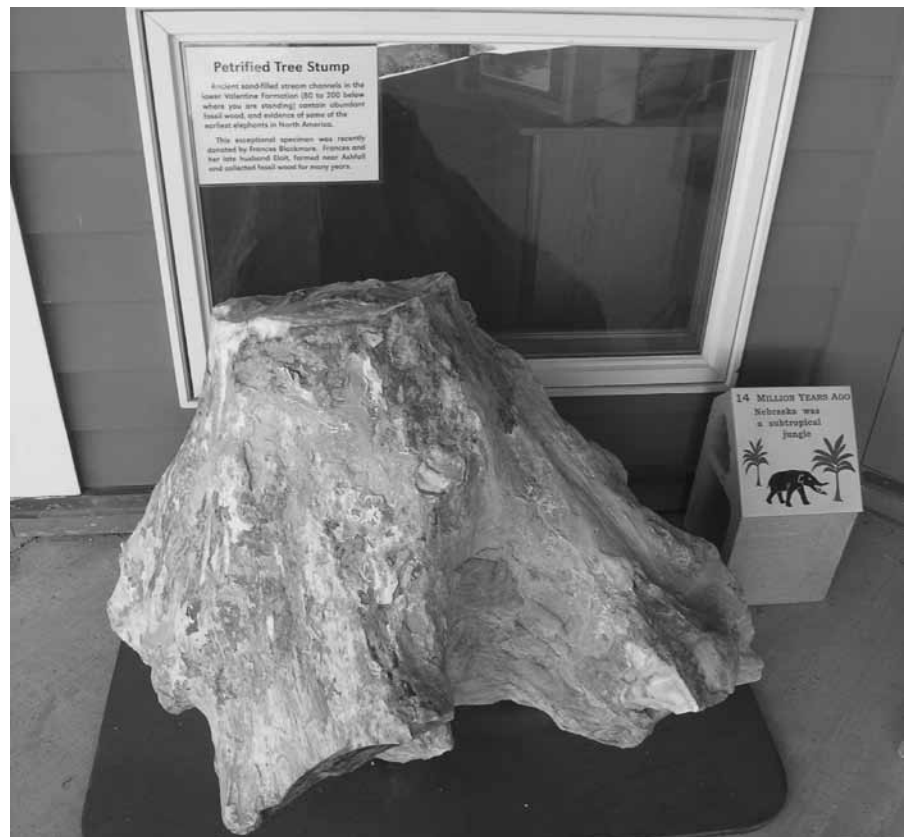


Figure 14. Petrified wood from Ashfall Fossil Beds State Historic Park.

Table IV. Features that support Flood deposition from Ashfall Fossil Beds Stage Historical Park.

Formations part of the widespread, thin Ogallala Group in the Midwest
Ash Hollow Formation with unlithified ash is a well-lithified sandstone
Exotic hard cobbles from the Rocky Mountains spread 100s of kilometers east
Percussion marks on some rocks
Warm-climate organisms, such as crocodiles, alligators, and giant tortoises
Petrified wood
The many ash beds of the Ogallala Group would support “volcanic winter”
Many unusual animals, not associated with the Ice Age

spread from the “Mountains of Ararat,” (2) they had to round the Bering Land Bridge between Siberia and Alaska and spread south-southeast down the ice-free corridor during the Ice Age, (3) the population mushroomed probably into tens of millions, (4) some post-Flood catastrophe buried many millions of mammals and laid them down in a thin layer over an enormous area with power to carry boulders 800 km, (5) hundreds of meters of erosion subsequently occurred in the area, and (6) the eroded sediments are not found anywhere nearby.

How Are the Seeming Post-Flood Features Explained?

If most of these mammals and associated features are from the Flood, how is all of the evidence of a post-Flood environment to be explained? The BEDS Model can account for the millions of dinosaur tracks, millions of dinosaur eggs, and scavenged bonebeds early in the Flood (Oard, 2011b). BEDS stands for Briefly Exposed Diluvial Sediments in which a local fall in the level of the

Floodwater results in the exposure of a bedding plane. Then a local rise in the Floodwaters buries tracks, eggs, dead animals, and trace fossils that are on the bedding plane, preserving them in the rock record. I believe that the evidence for live mammals on the central and southern High Plains can also be explained by the BEDS model. On a briefly exposed bed or beds, mammals can embark, make tracks, herd up, and die together when the Floodwater rose and covered the area. Most of the features of Tables I and III can be explained by the BEDS model, but the lack of permineralization of the bones and the grass seeds are difficult to explain. Permineralization is one of the criteria for a Flood paleoenvironment (Oard, 2014c). However, it is not an absolute criterion, as some dinosaurs from the Flood are not permineralized.

The Grass Seeds Could Be from the Sediments

Grass seeds have been found inside a rhino skeleton and mouth (Figures 8

and 9). I had earlier thought that grass could have grown in a short time on BEDS in a warm, humid climate, but grass seeds would take a fair amount of time to germinate, grow, and then produce seeds. An alternative explanation of the grass seeds associated with the rhino is that they ended up associated with the rhino by chance, since the Ogallala Group has numerous seed fossils:

“The abundant fossil seeds (Elias, 1942), however, are far more significant to the field stratigrapher and are to be found in virtually any good exposure of the Ogallala formation in northern Kansas.... It is rare indeed that an exposure of Ogallala rocks does not reveal at least one kind of fossil seed.” (Frye et al., 1956, pp. 7, 38)

Thomasson (2005, p. 185) reinforces this conclusion: “This is especially true of the grasses, which are very abundant in the Tertiary fossil record of the Great Plains.”

The grass seeds and grazing vertebrate in the Ogallala Group were transported to where we find them in the Ogallala Group today. Then where did they originate and why were so many animals and paleoenvironmental indicators found together? It is likely that organisms were buried in the Flood by paleoenvironments, not only by vertical ecological zones, but also by *horizontal ecological zones*. Terrestrial organisms from different paleoenvironments were overwhelmed, transported, and buried together in the Flood. In the case of the Ogallala Group, the paleoenvironment was from a pre-Flood grass paleoenvironment with its grazers, and even some browsers.

The Question of Where to Place the Ogallala Group Within the Flood

A major question is where to place all the evidence for live animals within the Flood. Creation scientists, includ-

ing myself (Oard, 2013; Clarey, 2018), have written that the Ogallala Group is from the Recessive Stage of the Flood. Then how can all this evidence for live mammals be explained late in the Flood when Genesis 7:21–23 would imply that all animals that breathed air and lived on land died by the peak of the Flood?

Conclusion

The mammals and other animals entombed in the sediment layers at the top of the central and southern High Plains show some features that seem to come from a post-Flood paleoenvironment. However, a closer look at these locations provides other evidence that the fossils were buried in the Flood, mainly because they are likely entombed within the Ogallala Group that contains many millions of vertebrate fossils. This sediment is thin and widespread with exotic rocks, some with percussion marks, spread hundreds of kilometers east from the Rocky Mountains. Some of the sediment is lithified, and most of the fossils are of extinct types never found in the Ice Age. Furthermore, some fossils indicate a warm paleoenvironment, unlike those from the Ice Age.

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Towards a More Realistic Young-Earth Ice Sheet Model:

A Shallow, Isothermal Ice Ridge with a Frozen Base

Jake Hebert

Abstract

In 1976 M.W. Mahaffy published a basic ice-sheet model which did not make the usual steady-state assumption of constant height and which allowed for time-varying ice accumulation rates. For this reason his model should be of interest to creation researchers, who can use it to model the rapid growth of post-Flood ice sheets. This paper provides a brief overview of the theory and assumptions behind Mahaffy's model and its solution. The model is used to simulate the rapid growth of a long but thin isothermal ice ridge. The results are then compared with the results from the Vardiman model. A suggested technique for using the Dansgaard-Johnsen and Mahaffy ice sheet models to estimate annual layer thicknesses near an ice divide is also presented.

Key Words: Ice core, ice sheet, ice ridge, Larry Vardiman, M.W. Mahaffy, Ed Bueler, Ice Age, computer modeling, annual layer thicknesses

Introduction

Creation-based ice sheet models are still in their infancy. In 1993 Dr. Larry Vardiman of the Institute for Creation Research published an analytical model (Vardiman, 1993, 1994, and 2001) for the rapid formation of thick ice sheets within the 4500 years since the Genesis Flood. Vardiman's model assumed that post-Flood annual ice accumulation was very high immediately after the Flood and then decayed exponentially

to today's "slow and gradual" values. It also implicitly assumed that the downward speed of the surface ice was proportional to the height of the ice sheet (Hebert, 2021, p. 179). As Vardiman noted, his effort was preliminary, and although this assumption simplified the mathematics, it was not completely physically realistic. Hence there is a need for improved creation-based ice sheet models to better compare and contrast creationist and uniformitarian ice sheet predictions.

Glaciologists have already devised ice-flow models which do not necessarily involve uniformitarian assumptions and which could conceivably be used to simulate the rapid growth of post-Flood ice sheets. One such model is the quasi-analytical ice-sheet model of M.W. Mahaffy, which he published in 1976. I have already used this model to simulate the growth of an isothermal ice dome in the 4500 years since the Genesis Flood (Hebert, 2022). This paper combines Vardiman's accumulation model with Mahaffy's ice sheet model to simulate the growth of a long (horizontal aspect ratio of 5:1) but relatively thin isothermal ice ridge.

The next sections provide a brief introduction to ice core basics and ice sheet modelling. These subjects are covered in much more depth in Bueler (2016) and Hebert (2021, 2022).

Ice Sheet Fundamentals

Glaciologists drill ice cores at *ice divides*, topographical "highs" named for the fact that ice on one side of the divide flows one way, and ice on the other side of the divide flows the other (Figure 1). For a perfectly flat surface, ice is deposited in perfectly horizontal layers. Assuming no shifting of the ice divide during buildup, ice at the divide will flow neither to the right nor left, but will move straight down as additional layers are added. It is also possible for the ice to form a dome around the divide, so that ice flows radially outward from the divide, not just right and left.

In fact, the azimuthally-symmetric ice dome is one of two simple, "archetypal" ice sheet geometries that can be modelled in just one horizontal dimension. The (infinitely) long ice ridge is the other (Paterson, 1980, pp. 19–24). The ice divides in Greenland are long and elongated (Anonymous), causing the two major Greenland ice domes to be elongated ridges (Paterson, 1980, p. 9). Hence this ridge geometry is also of interest. I have used the Mahaffy model to simulate the rapid post-Flood formation of an azimuthally-symmetric ice dome in a previous paper (Hebert, 2022). Here I use the Mahaffy model to simulate the rapid growth of a long (horizontal aspect ratio of 5:1) post-Flood ice ridge.

Ignoring possible isostatic adjustments, the underlying bedrock is locked in place. So a horizontal layer that reaches bedrock can no longer move downward, and its vertical velocity must be zero. Also, stresses on the ice layer thin the layer over time. If no melting occurs, the total number of true annual layers will equal the ice sheet's true age (in years). In that case, finding the *average* annual layer thickness is trivially easy: it is simply the height of the ice sheet divided by the number of years the ice sheet has been in existence. However, finding a *particular* layer thickness at a given depth is much more difficult, since the stresses that induce thinning vary with depth and time. Annual layers often consist of multiple visible

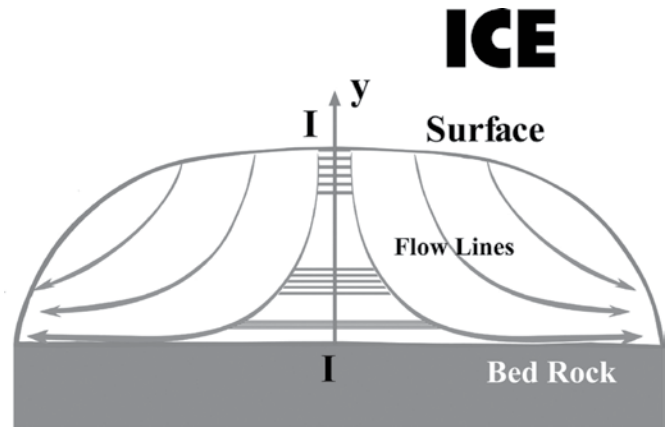


Figure 1. An idealized ice divide. Ice left of the divide flows to the left, and ice right of the divide flows to the right. Ice at the divide location must move straight down. Image courtesy of Michael J. Oard.

bands. Creationists argue that uniformitarian glaciologists are mistaking visible bands for annual layers and are seriously overcounting the number of true annual layers within the ice cores (Oard 2005, 2006).

Ice sheet models typically ignore variations in ice density, which are tiny even for thick ice sheets (Cuffey and Paterson, 2010, pp. 12–13). Hence, most ice sheet models assume incompressibility, i.e., that the ice has a constant density (Paterson, 1980, p. 12; Cuffey and Paterson, 2010, p. 286). Glaciologists often use the letters u , v , and w to indicate ice velocities in the x , y , and z directions, respectively. The condition of constant density implies that the divergence of the velocity field is zero everywhere:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \quad (1)$$

Although the volume of the ice sheet as a whole may increase via the deposition of additional ice, a particular layer of the ice sheet maintains a constant volume over time (assuming no melting or calving of the ice). Stresses cause the layer to thin, but with a corresponding increase in horizontal surface area so that the layer's volume remains constant.

Methods

The Mahaffy model

As noted earlier, Mahaffy's (1976) ice-sheet model does *not* assume the ice to be in steady state. It utilizes Glen's Flow Law

(Glen, 1955; Nye, 1957; Paterson, 1980, pp. 13–16) and the assumption of incompressibility, and it effectively treats the ice as isothermal. Mahaffy’s solution is obtained by solving the stress balance equations for a small parcel of ice. However, in order to simplify the mathematics, his model ignores normal stresses, as well as vertical shear stresses. In other words, he assumes that the ice sheet is deformed only by shear in the horizontal directions.

Mahaffy’s model allows for non-level bedrock terrain, but here we make the simpler assumption that the bedrock under the ice is perfectly flat. We assume no melting at the base of the ice sheet, so the ice is frozen to the bedrock. Readers needing a refresher in the basics of ice sheet modeling may refer to Bueler (2016) and Hebert (2022).

Consider the generalized ice sheet depicted in Figure 2. The height of the ice h is a function of the horizontal coordinates x and y , as well as time t . We will use $H = h(0, 0, t)$ to denote the height at the center of the ice sheet, i.e., the divide location.

Consider a thin column of ice of height $h(x, y)$ and a square base with sides of length 1 meter (Figure 3). For the moment we ignore the horizontal motion of ice in the y direction. If $u(z)$ is the (height-dependent) horizontal ice velocity in the x -direction, we may define q_x to be the volume of ice per unit length that flows horizontally (in the x -direction) into the vertical column in a time dt .

$$q_x = \int_{z=0}^{z=h} u(\Delta y) dz = \int_{z=0}^{z=h} u(1 \text{ meter}) dz = \int_{z=0}^{z=h} u dz \quad (2)$$

If $q_x(x)$ equals $q_x(x+1)$, so that $\partial q_x / \partial x = 0$, there will be no net inflow or outflow of ice into the column (in the x direction), and, absent any additional ice deposition from above (as precipitation), the ice column’s height will remain constant. If $q_x(x+1)$ is greater than $q_x(x)$, so that $\partial q_x / \partial x > 0$, there will be a net outflow of ice from the column, which will tend to cause the height of the ice column to decrease. Similarly, if $\partial q_x / \partial x < 0$ there is a net inflow of ice into the column, causing the column height to increase.

Similar relationships hold for the y -direction. Hence, at a given location in the x - y plane, the height $h(x, y, t)$ of the ice is governed by the continuity equation:

$$\frac{\partial h}{\partial t} = \dot{b}_i - \frac{\partial q_x}{\partial x} - \frac{\partial q_y}{\partial y} \quad (3)$$

The net horizontal flow of ice into or out of the column will tend to change the height h , but so will the deposition of accumulating ice, indicated by \dot{b}_i . In general, \dot{b}_i is a function

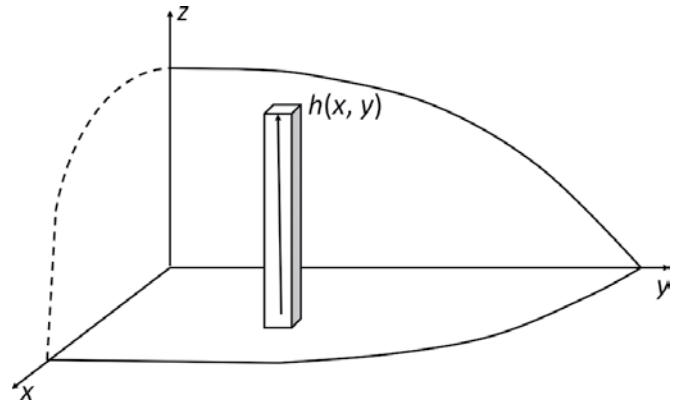


Figure 2. Coordinate system used in Mahaffy’s ice-sheet model.

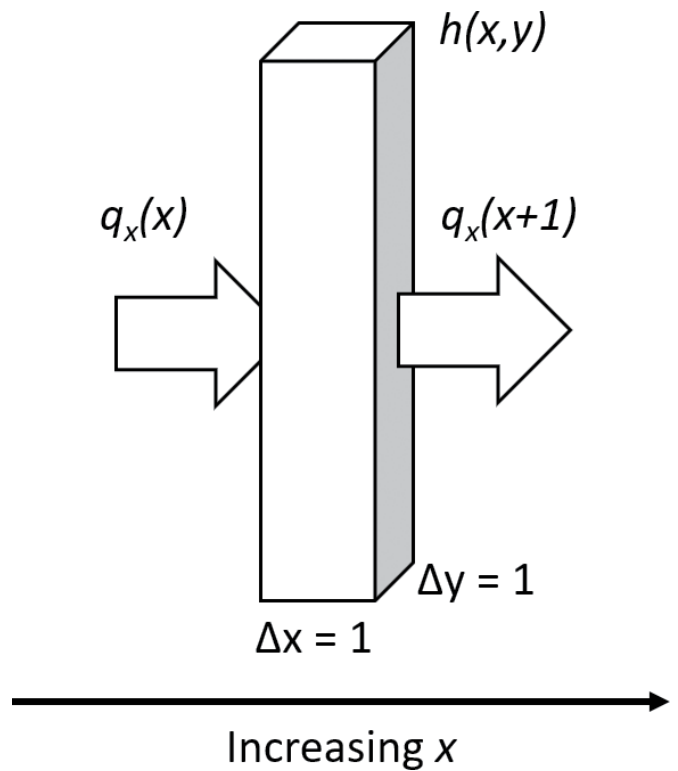


Figure 3. Horizontal fluxes (x -direction only) of ice flowing into and out of a column of ice.

of both position (x, y) and time t and has units of meters of ice per year. After making some additional assumptions about the relative sizes of rates of change of the velocities relative to

one another (which allowed some derivatives to be neglected), Mahaffy (1976) derived the following expressions (Paterson, 1980, p. 43) for the horizontal ice fluxes:

$$\begin{aligned} q_x(x, y, t) &= -\frac{2}{5} A(\rho g)^3 \alpha^2 \left(\frac{\partial h}{\partial x}\right) h^5 \\ q_y(x, y, t) &= -\frac{2}{5} A(\rho g)^3 \alpha^2 \left(\frac{\partial h}{\partial y}\right) h^5 \end{aligned} \quad (4)$$

where

$$\alpha = \left[\left(\frac{\partial h}{\partial x}\right)^2 + \left(\frac{\partial h}{\partial y}\right)^2 \right]^{\frac{1}{2}}, \quad (5)$$

is the magnitude of the surface gradient. A is the temperature-dependent “softness” of the ice, ρ is the density of ice (910 kg/m³), and g is the acceleration due to gravity, 9.81 m/s². Details are provided in Mahaffy (1976) and Paterson (1980). If we define

$$\Gamma = \frac{2}{5} A(\rho g)^3 \quad (6)$$

we may combine Equations (4) into a single expression for the flux vector \bar{q} :

$$\bar{q} = -\Gamma h^5 |\nabla h|^2 \nabla h \quad (7)$$

Obtaining the solution

Bueler (2016) observes that we can express the continuity equation (3) in terms of the flux vector \bar{q} :

$$\begin{aligned} \frac{\partial h}{\partial t} &= \dot{b}_i(x, y, t) - \bar{\nabla} \cdot \bar{q} \\ \frac{\partial h}{\partial t} &= \dot{b}_i(x, y, t) + \bar{\nabla} \cdot \left(\Gamma h^5 |\nabla h|^2 \nabla h \right) \end{aligned} \quad (8)$$

He then draws our attention to similarities between Equation (8) and the two-dimensional heat equation:

$$\rho c \frac{\partial T}{\partial t} = f + \nabla \cdot (\kappa \nabla T) \quad (9)$$

In Equation (9), f is the heat source term, ρ is density, κ is thermal conductivity, and c is specific heat. Dividing both sides of Equation (9) by ρc , the result has the same mathematical form as Equation (8):

$$\frac{\partial T}{\partial t} = F + \nabla \cdot (D \nabla T), \quad (10)$$

provided that we define D and F as

$$\begin{aligned} D &= \frac{\kappa}{\rho c} \\ F &= \frac{f}{\rho c}. \end{aligned} \quad (11)$$

The choice of the letter D in Equation (10) is appropriate, since the heat equation is really a diffusion equation: a localized temperature “spike” will diffuse outward, with the peak becoming shorter and broader over time. Note that the same thing will be true for an ice peak. If we suppress any further deposition of ice, so that $\dot{b}_i = 0$, the already-deposited ice flows in such a way that a peak becomes shorter and broader over time, while the total ice volume remains constant. We can thus treat the flow of the ice as a diffusion problem if we define our position and time-dependent ice “diffusivity” to be

$$D(x, y, t) = \Gamma h^5 |\nabla h|^2 \quad (12)$$

Bueler (2016) described how to solve Equation (8) using an explicit, finite difference solution with adaptive time-stepping, and he provided a sample MATHLAB code for doing so. I “translated” his code into an IDL code that I titled `mahaffy_ridge_var_precip.pro`, and I used my version to simulate the growth of a long isothermal ice ridge. Details and subtleties of the method are given in Bueler (2016).

Although the deposition and flow of ice is actually a continuous process, we must model it as a discrete two-step process. At the very beginning of a particular time step Δt , a layer of ice is instantaneously deposited. If $\Delta t = 1$ year, the entire year’s total ice accumulation is deposited at the very start of the time interval. During the remainder of the time step, no more ice is deposited, but the already-deposited ice is allowed to flow/diffuse. At the beginning of the next time step, another layer of ice is instantaneously deposited. During the remainder of the second time step, the ice (now consisting of two deposited layers) is allowed to diffuse/flow some more. This deposit/diffuse process is repeated for the duration of the simulation.

It is worth noting that when a layer of ice is instantaneously deposited (at the very start of the time interval), it has no velocity at all, including no downward velocity w . Instead, the layer is instantaneously deposited, already “in place” as it were. Rather, the vertical velocity w refers to the velocity of the ice *while it is in the process of diffusing* during the remainder of the time interval.

Greenland accumulation rates

Accumulation rates may be expressed in several different ways. Sometimes it is expressed as \dot{b}_i (meters or centimeters of ice

equivalent per year). It may also be expressed as \dot{b}_w (meters or centimeters of water equivalent per year) or as \dot{b} (grams per square centimeter per year). The relationships between these different expressions are (Cuffey and Paterson, 2010, p. 94):

$$\dot{b}_i = \frac{\dot{b}}{\rho_i} = \dot{b}_w \frac{\rho_w}{\rho_i} \tag{13}$$

Oard (2005, pp. 2, 6) cites accumulation rates \dot{b}_w reported by Ohmura and Reeh (1991) at the locations of major deep Greenland ice cores (GISP, GISP2, NGRIP) of between 20 and 24 centimeters of water equivalent per year. Using Equation (13) and the densities of ice and water, this translates into about 22 to 26 centimeters of ice per year.

A more recent study (Bales et al., 2009) reported average Greenland accumulation rates \dot{b} of about 30 g/cm²/year for the entire ice sheet, as well as for elevations above 2000 meters. This translates into an ice accumulation rate \dot{b}_i of about 33 centimeters of ice per year. For this simulation I used the more conservative value of $\dot{b}_i = \frac{\lambda_H}{\tau} = \lambda_H/\tau = 24 \text{ cm/year} = 0.24 \text{ meters of ice per year}$.

Results

Application of Vardiman’s model

I used Vardiman’s (1993, 1994, 2001) accumulation model

$$\dot{b}_i = \frac{\lambda_H}{\tau} (\Phi e^{-t/\Psi} + 1) \tag{14}$$

Vardiman used the symbol \dot{b} for his ice accumulation rate, but here I use \dot{b}_i to be consistent with the notation already used above. The parameter Φ , used to “scale up” the amount of Ice Age precipitation compared to the present-day value, was set at 61.5. This resulted in an initial ice accumulation rate of 15 meters of ice per year. The e-folding time Ψ is the time required for the initial post-Flood accumulation rate to drop to 37% of its initial value. As in Hebert (2022), I set it to 255 years. These parameter choices produced the accumulation curve shown in Figure 4.

Ridge growth simulation

As in Hebert (2022), the ice softness A was set to $1.0 \times 10^{-16} \text{ Pa}^3 \text{ year}^{-1}$ (Bueler, 2016, p. 16). The simulation was run with 101

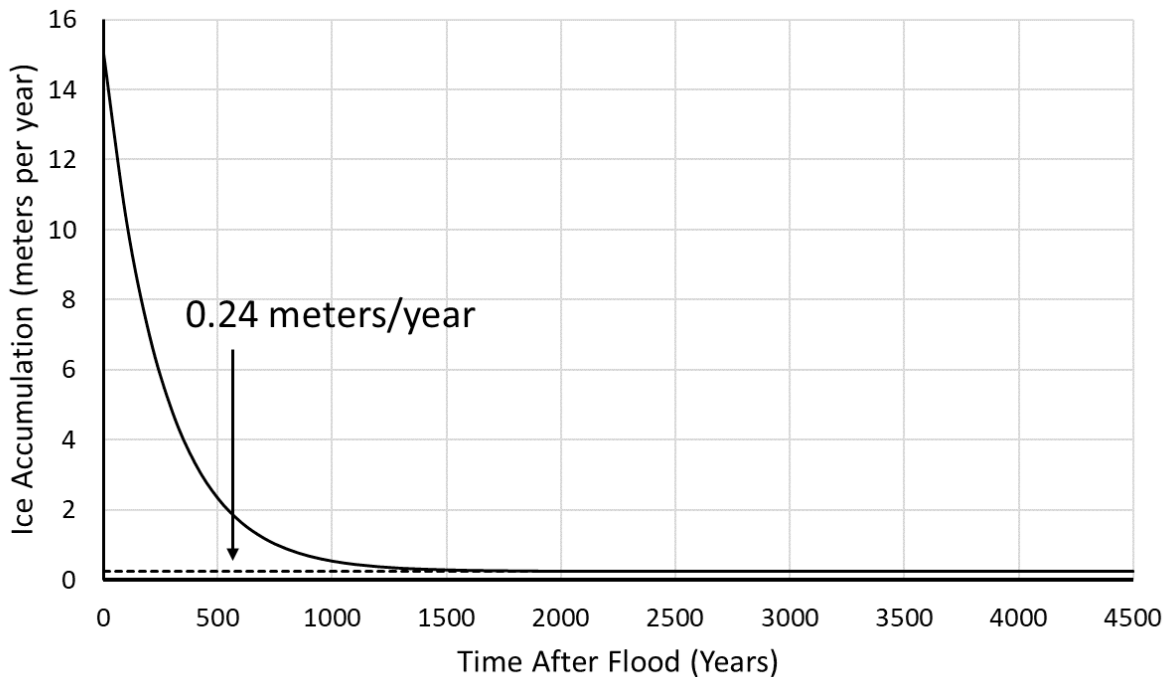


Figure 4. The accumulation rate (meters of ice per year) used in this exercise, calculated from Vardiman’s model using values of $\Phi = 61.5$, $\Psi = 255$ years, and $\lambda_H/\tau = 0.24$ meters of ice per year. Note that the accumulation rate asymptotically approaches $\lambda_H/\tau = 0.24$ meters/year as t goes to infinity.

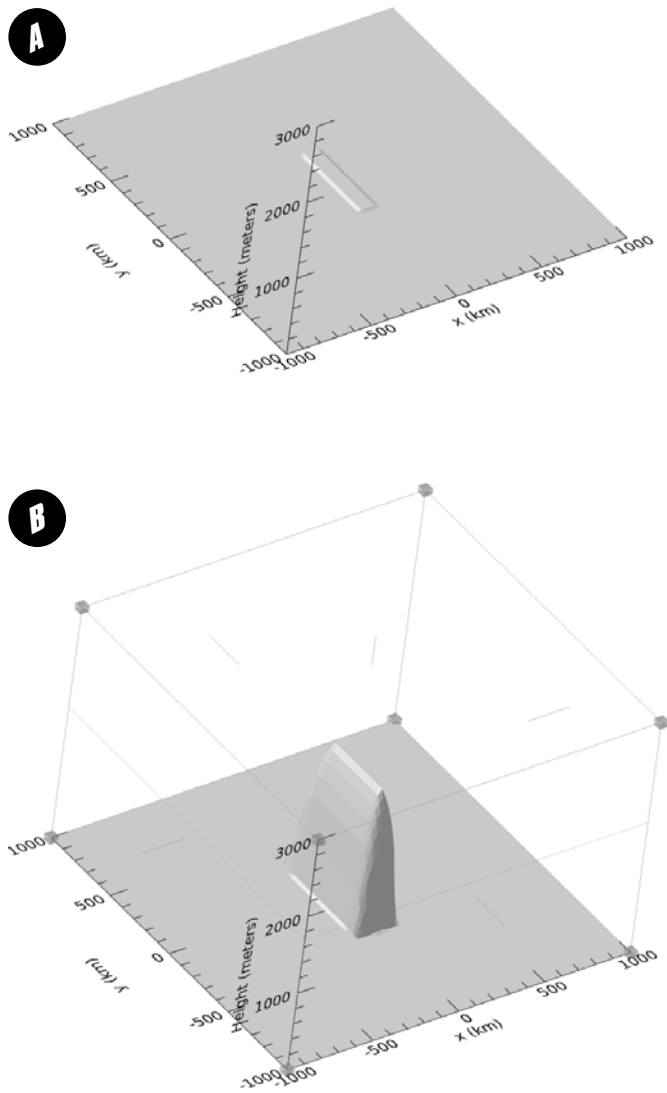


Figure 5. a) 15-meter-thick slab of ice deposited at $t = 0$ years after the Flood and the resulting ridge at b) $t = 150$ years after the Flood. The ridge height is greatly exaggerated compared to the ridge's horizontal dimensions.

grid points in both the x and y directions. The starting ridge half-width was 100 kilometers, and the starting half-length was 500 km. Because the horizontal plotting surface was 2000 km by 2000 km, this resulted in a horizontal grid resolution of $\Delta x = \Delta y = 20$ km. In the Creation/Flood Ice Age model, snow is deposited over large areas in the form of 'snowblitzes' (Oard, 2006, pp. 77–81). Thus one can legitimately expect the starting size of the ice ridge to be rather large, even after just one year of deposition.

Although the ice is initially deposited in perfectly rectangular sheets, diffusive rounding at the edges causes the ice ridge

to become more elliptical over time. I instructed my code to deposit the ice in a way that mimics the overall shape of the ice sheet, while withholding precipitation from a two-pixel-thick border encircling the outermost part of the ice sheet. Hence, at all times ice was deposited inside nearly all the ice sheet's interior.

The results are shown in Figures 5, 6, and 7. Initially the ice sheet is a perfectly flat rectangular slab with a starting height equal to the first year's total ice accumulation of 15.0 meters (Figure 5a). Because the slab surface is perfectly flat (surface slope $\alpha = 0$) the driving stresses are zero, except at the edges. These edge stresses cause the slab edge to become rounded as the ice spreads outward. After 150 years, the ice divide is about 1700 meters high (Figure 5b), but the rectangular shape of the ridge's base has largely been maintained. Figure 6 shows the ridge after 500, 1500, 3000, and 4500 years. The ridge attains a maximum height of about 2425 meters at $t = 775$ years and begins to subside after that. However, after some subsidence, the ice sheet thickens again so that after 4500 years, the height is 2480 meters. The base has become noticeably more elliptical in shape (Figure 7).

Consistency checks

Although ice accumulation was deposited in such a way as to be symmetrical about the lines $x = 0$ and $y = 0$, my IDL code did not assume the ice ridge itself to be symmetrical about those lines. Yet one would expect the growing ridge to exhibit this same symmetry. This was indeed the case. Also, because the ice is incompressible, the total volume of ice deposited in 4500 years should equal the final dome volume. Summing the total volume of ice deposited over 4500 years and directly calculating the ridge's final volume both yield 1.6319×10^{15} m³ of ice, as expected. Finally, it is encouraging that the final ridge has a pointed "peak," with non-zero slope (Figure 7) just slightly east, west, north, and south of the divide. This result is expected from theory: since driving stresses are proportional to surface slope, a final slope of zero on either side of the divide location would prevent ice on either side of the divide from flowing outward.

However, the slope at the divide itself (Cuffey and Paterson, 2010, p. 357), calculated using points on *opposite* sides of the divide, will be zero. This must be the case, since by symmetry, horizontal velocity at the exact center ($x = 0$, $y = 0$) of the ice sheet must be zero. Since horizontal motion of the ice is driven by surface slope, the surface slope, calculated in this way, must also be zero at the location of the divide itself. To an observer standing at the very center of the large ridge in Figure 7b, the surface will appear flat, although the surface slope becomes negative relatively rapidly as one moves away from the divide.

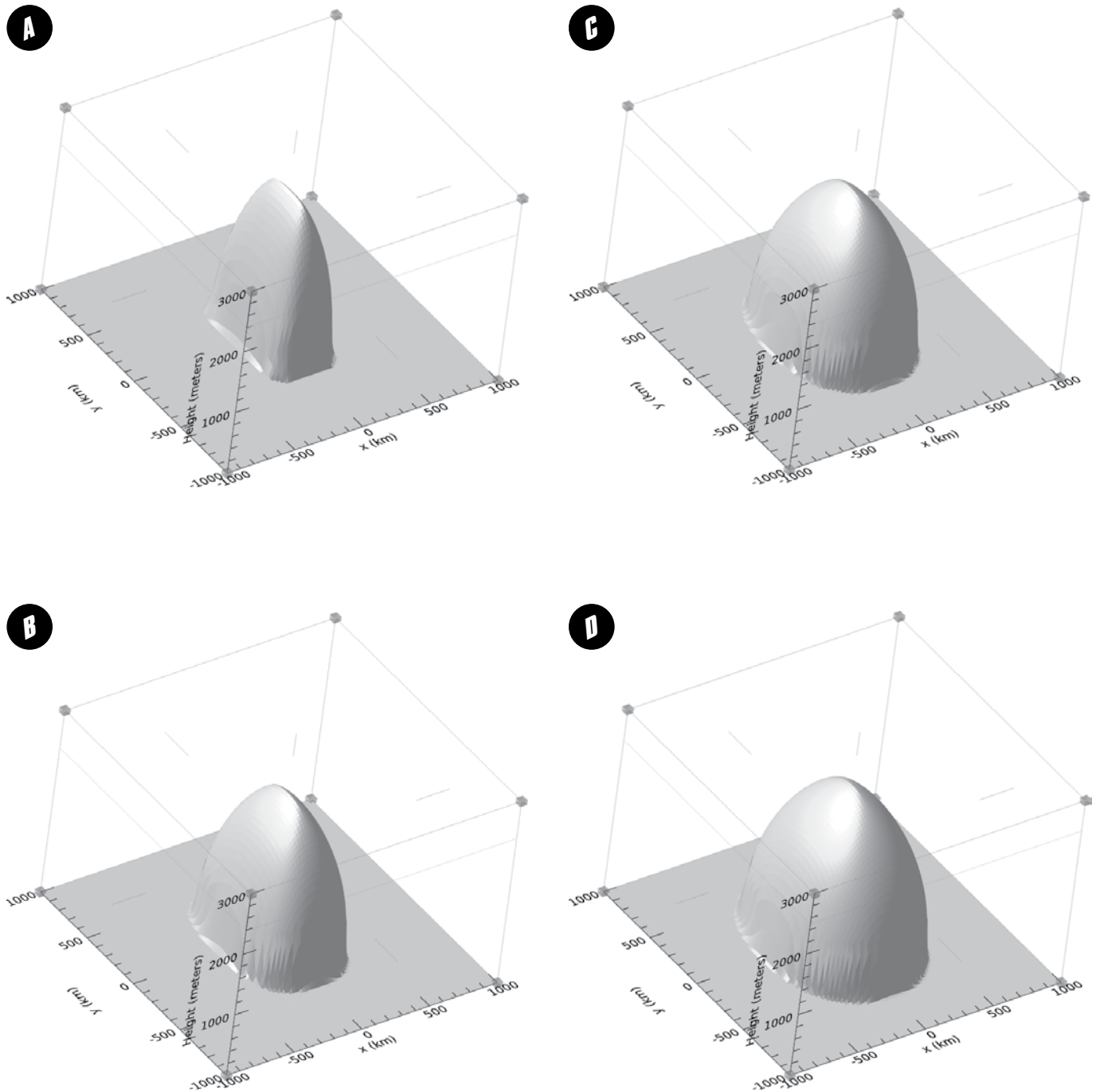


Figure 6. The ice ridge calculated from Mahaffy’s model using Bueller’s diffusive solution for a) 500 years, b) 1500 years, c) 3000 years, and d) 4500 years. The ridge height is greatly exaggerated compared to the ridge’s horizontal dimensions.

Discussion

Unlike the case for the azimuthally symmetric dome, agreement with Vardiman’s model is quite poor (Figure 8). Also, the final height of the ridge is 2480 meters, about 500 meters less than the

~3,000 meter height at the location of the GISP2 core (Meese et al., 1997). The lower final height of the ridge compared to the dome makes sense, because thinning of the ice at a location begins when ice begins to diverge or flow outward from that

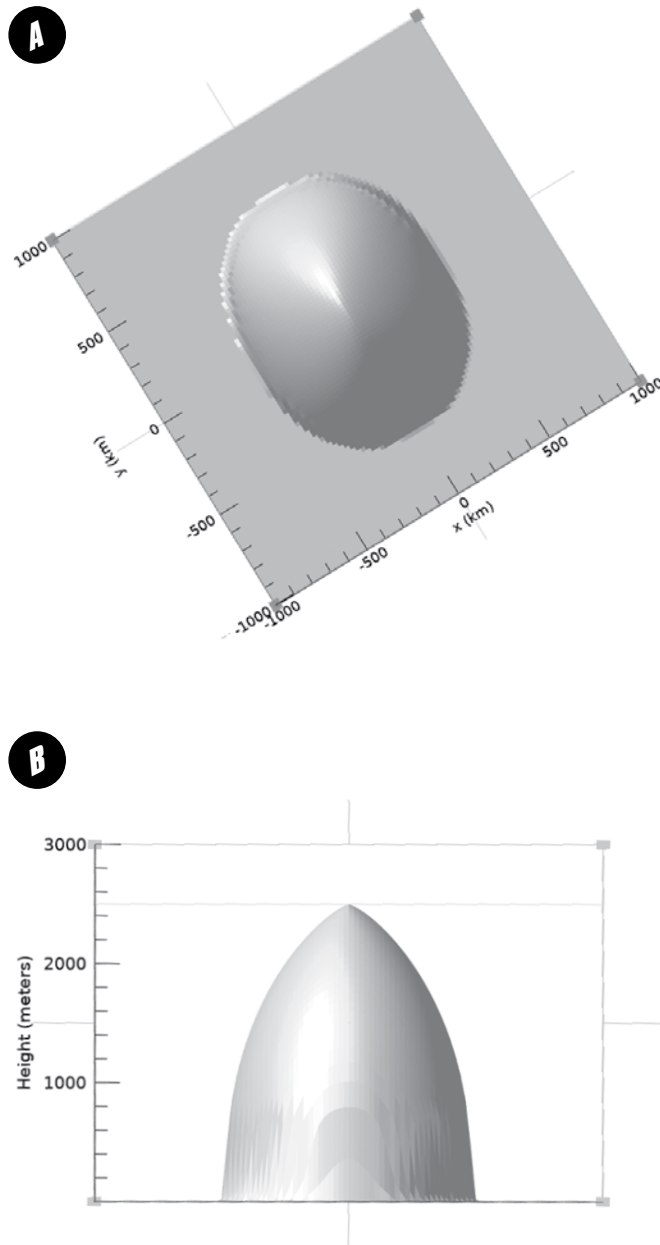


Figure 7. (a) Map view and (b) longitudinal view of ice ridge at $t = 4500$ years.

location. That in turn, happens when the surface slope at that location becomes non-zero. The slope at a location just barely right or left of the ridge center becomes non-zero much more quickly than in the case of the dome (compare Figure 5b with Figure 7c in (Hebert, 2022)). Therefore ice in the case of the ridge thins for a much longer time than in the case of the dome, which greatly decreases the final height of the ice ridge.

Since this lower final height is much less (~ 500 meters) than the true final height of about 3,000 meters at well-known Greenland core locations, is it cause for concern? I don't think so. The assumption of a perfectly flat surface does not match the true topography in Greenland or in Antarctica. In the case of our simulated dome, the resulting ice sheet was still quite thick because thinning at the center of the sheet did not begin until thousands of years had elapsed. Hence, little dome height was "lost" as the ice diffused outward. Because of the narrow horizontal aspect ratio in the case of the ridge, however, thinning of the ice begins much sooner, resulting in a much greater overall "loss" of height. In reality, the interior of an ice-free Greenland is bordered by regions of higher bedrock elevation (Figure 9). It may be that these higher bedrock elevations on Greenland's coasts act somewhat like retaining walls, preventing the ice from flowing laterally to some extent. Since the volume of the ice remains constant, the interior Greenland ice sheets are forced to grow taller. Hence a more realistic simulation might have resulted in a higher final height for the ice ridge. It would also have resulted in a narrower final aspect ratio, which seems more appropriate for Greenland ice sheets.

Future Research

Biblical creationists should be especially interested in ice behavior at or near ice divides, since these are the locations where ice cores are drilled. In particular, we would like to know the true thicknesses of annual layers near a divide. Here, I outline a procedure that could possibly be used to this end.

The Dansgaard-Johnsen model (1969) is similar to the Mahaffy model in that it treats normal stresses and vertical shear stresses as negligible, so that only shear stresses in the horizontal plane are considered. It is a two-dimensional model, so strictly speaking, it is only valid for an infinitely-long or very long ice ridge. The model provides an expression (p. 281, Equation 7) for the vertical velocity w as a function of height z above bedrock, but at some non-zero distance x away from the divide (but far from the edge of the ice):

$$w(x \neq 0, z, t > 0) = \begin{cases} -\frac{kz^2}{2h} & 0 \leq z \leq h \\ -\frac{k(2z-h)}{2} & h \leq z \leq H \end{cases} \quad (15)$$

As best as I can tell, the derivation for this particular expression does not assume H to be constant in time, although it was derived for an already-existing ice sheet of (considerable)

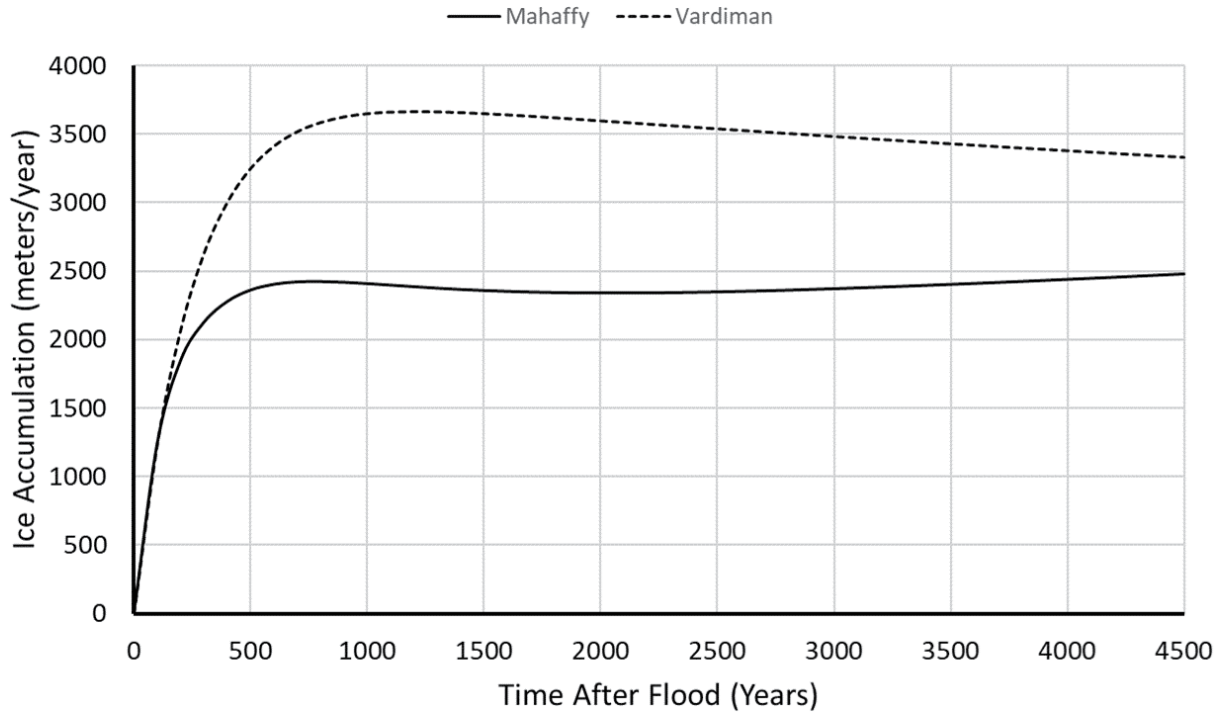


Figure 8. Height of the ice divide H as a function of time, calculated from both the Mahaffy and Vardiman models and using in both cases the values of Φ , Ψ , and λ_H/τ specified in the text and Figure 4.

thickness H . Here, in order to be consistent with the notation used by Dansgaard and Johnsen, we are using H to represent the ice sheet height close to, but not directly at, the ice divide. Since the slope of the ice sheet is very shallow near the divide, H is a good approximation to the height of the ice sheet at the divide location. The value h is some fraction of H , usually $1/3$ to $1/2$ (Schwander et al., 2001, p. 4244). I assume that h is always the same fraction f of $H(t)$ for all times $t > 0$, say $h(t) = f \cdot H(t)$, although this assumption may “break down” for a very thin, nascent ice sheet. Applying the boundary condition that $w(t) = -w_s(t)$ when $z = H(t)$ allows us to obtain an expression for $k(t)$, so that we can re-write Equation (15) (for $t > 0$) as

$$w(x \neq 0, z, t > 0) = \cdot$$

$$\begin{cases} -\frac{w_s(t)z^2}{f[2-f]H^2(t)} & 0 \leq z \leq f \cdot H(t) \\ -\frac{w_s(t)[2z-f \cdot H(t)]}{[2-f]H(t)} & f \cdot H(t) < z \leq H(t) \end{cases} \quad (16)$$

The time-rate of change of annual layer thicknesses is related to the partial derivative of w with respect to height z above bedrock,

$$\dot{\epsilon}_{zz} = \frac{\partial w}{\partial z} = \frac{1}{\lambda} \frac{d\lambda}{dt} \quad (17)$$

Moreover in the absence of melting, the time rate of change of the height of the ice sheet must necessarily be the difference between the accumulation rate and the downward speed $w_s(t)$ at the surface, and this must be true for all x and y :

$$\frac{dH}{dt} = \dot{b}_i(t) - w_s(t) \quad (18)$$

Since the Mahaffy code specifies the accumulation rate $\dot{b}_i(t)$ for all x, y , and t , and since the Mahaffy code’s output gives us $H(x, y, t)$, Equation (18) may be used to obtain $w_s(t)$ at the ice core’s location. These values of $w_s(t)$, together with the output values of $H(t)$, may be inserted into Equations (16) and (17) in order to calculate layer thicknesses as a function of time t and height z .

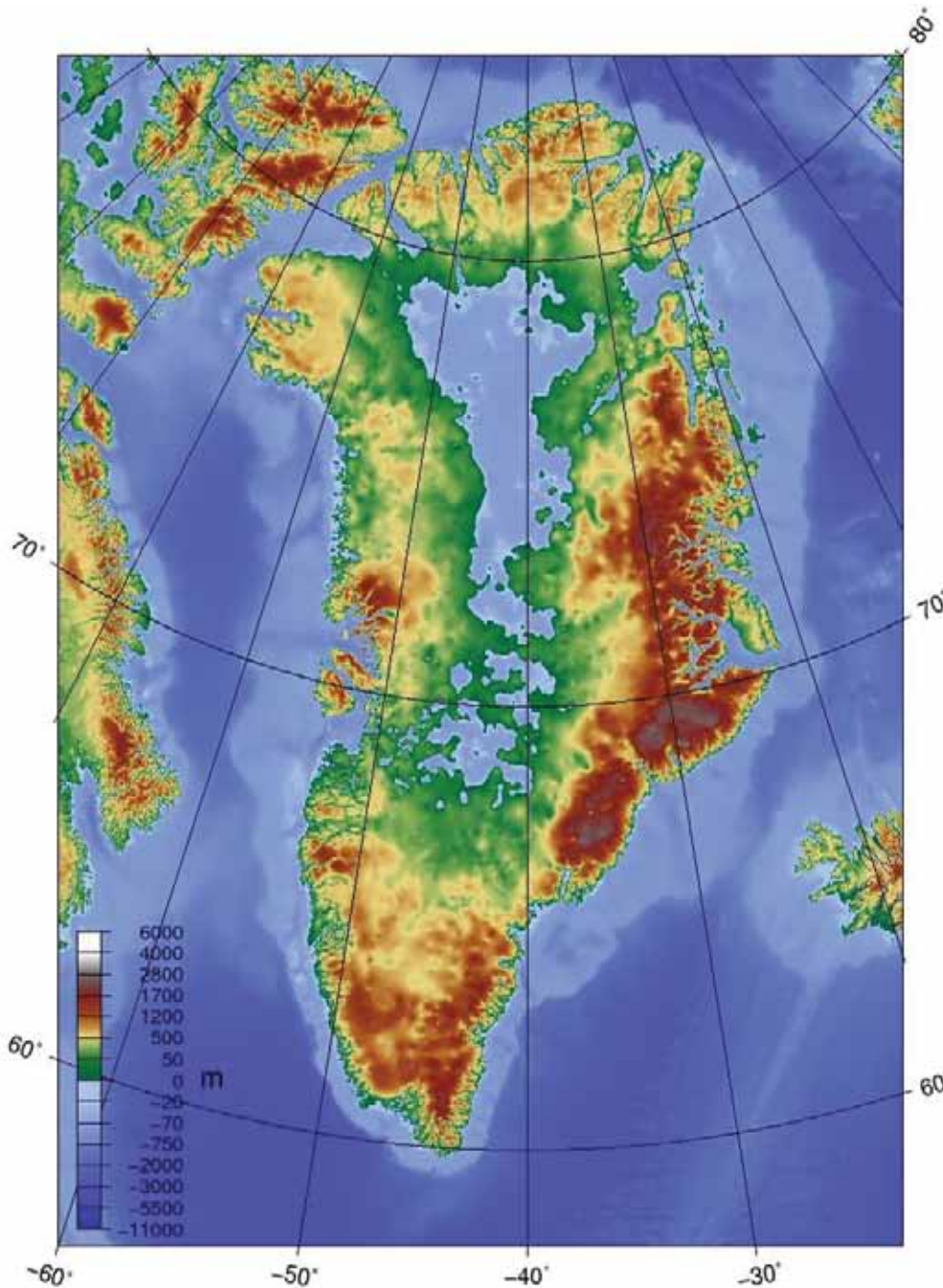


Figure 9. Bedrock topography for an ice-free Greenland. Image Credit: Skew-t, Wikimedia Commons. Creative Commons Attribution-Share Alike 3.0 Unported license. https://commons.wikimedia.org/wiki/File:Topographic_map_of_Greenland_bedrock.jpg.

Some (very) preliminary work suggests that the amount of thinning in 4500 years near the center of an ice sheet is almost negligible, although I do not yet trust these preliminary calculations sufficiently to publish them. I invite careful scrutiny of

distance from the divide will probably also be good estimates for layer thicknesses at the divide location.

Although the Dansgaard-Johnsen model is an older one, it has been used even within the last twenty years or so (see

my reasoning in this section of my paper.

In Hebert (2022), I expressed concern about using Mahaffy's model to estimate annual layer thicknesses, since Mahaffy's model assumes that the ice is deformed only by horizontal shear, ignoring both vertical shear and normal stresses/strains. However, normal stresses and strains cannot be ignored at an ice divide (Paterson, 1980, p. 43). Since horizontal velocity at the divide is always zero, there is no horizontal shear at the divide and, by symmetry, there is no vertical shear there, either. Rather, the ice layers are thinned via horizontal extension due to normal stresses (Cuffey and Paterson, 2010, p. 357).

However, this difficulty may be circumvented by using the model to determine layer thicknesses, not at the ice divide itself, but at some distance away from the divide. Moreover, Weertman (1961, p. 953) noted that these normal or longitudinal strains are only important for smaller ice sheets, about 30 kilometers in width. Since the Antarctic and Greenland ice sheets are much larger than this, it may still be possible to use the Mahaffey and Dansgaard-Johnsen models to obtain estimates of annual layer thicknesses near the center of a large ice sheet. Moreover, because the surface slope is very shallow for very large ice sheets, layer thicknesses calculated some small

Schwander et al., 2001) to provide preliminary estimates of annual layer thicknesses within the EPICA Dome C core.

The more sophisticated Blatter-Pattyn model (Blatter, 1995; Pattyn, 2003) could also be used for this purpose. It is my hope that perhaps other creation researchers will be able to build upon these efforts, as estimates of these thicknesses could possibly enable us to strengthen the argument that the Greenland and Antarctic ice sheets are young.

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Letters to the Editor

The policy of the editorial staff of CRSQ is to allow letters to the editor to express a variety of views. As such, the content of all letters is solely the opinion of the author, and does not necessarily reflect the opinion of the CRSQ editorial staff or the Creation Research Society.

Regarding the Paper on the Dolomite Problem

Oard (2020) advocates that we consider a primary igneous origin for sodium-, potassium-, calcium-, and magnesium-rich deposits commonly called evaporites. It would certainly be a fitting emergence for the salt dolomite with chemical formula $\text{CaMg}(\text{CO}_3)_2$.

Surprisingly Oard now takes a U-turn from his previous article by trying to solve the *dolomite problem* with magnesium-bearing lime-rich hydrothermal water (Oard, 2022). He now expects abundant hydrothermal water delivered primary dolomite. However, this required a tremendous hot water flow of about 150°C with an unlimited amount of magnesium and lime available (partly his own words from his abstract). Such a water flow cannot exist in atmospheric conditions. To keep the water from flashing to steam, a pressure of 5 bar is required. While creationists are all concerned to offer solutions to problems that uniformitarians have only poor or non-existent answers to, wouldn't this system/model/recommendation create a bigger dolomite problem? For example, how much water is required to deposit the huge amounts of dolomite with a density of $2,840 \text{ kg/m}^3$? Where are such water flows seen today? How much energy is required and would the excess water not cook Noah's Ark? Why isn't there any water left in the crystals? And why did this waterflow not dissolve all sodium chloride which is abundantly deposited in between dolomite at many locations?

One reference Oard made contains actually tests descriptions and results. Arvidson and Mackenzie (1999) describe

the dolomite producing tests on page 266: "The precipitation experiments ranged in temperature from 115° to 196°C , using solutions having variable mixtures of CaCl_2 , MgCl_2 , and NaHCO_3 under various pCO_2 atmospheres. The original dolomite seed grains retrieved from the reactor after these experiments showed clear evidence of precipitation of new material of dolomite composition. The composition, texture, and extent of development of this new phase was variable." Their Table 3 shows the concentrations of the ingoing water by up to 123 bar. Unfortunately, their report doesn't give the concentrations of the outgoing water. Given the duration of the test (about 5 days of continuously pumping) and the minor amount of crystal synthesized we will generously assume that 10% of the ingoing minerals were deposited. But note that precipitation only continues as long as the water is oversaturated, so 10% is likely the absolute max. Based on the reported Ca^{2+} concentration (about 0.01 moles/ $\text{kg-H}_2\text{O}$) that goes into the reactor, the required amount of water to produce one mole of dolomite is 1000 kg. The energy consumption to heat that water from 25°C to 150°C is 1.25×10^5 kcal.

The activation energy to form one mole of dolomite (=184.401 gram) directly out of hot water is 31.9 kcal (Arvidson and Mackenzie, 1999). Page 274: "Activation energy can be understood as the size of the energy barrier that reactants must surmount in order to become products." Since this is much smaller than the energy required to heat the water, it can be neglected.

So, the total energy consumption to produce 1 mole of dolomite is thus 1.25×10^5 kcal. To produce 1 m^3 of dolomite with a weight of 2,840 kg 1.93×10^9 kcal (= 8.06×10^{12} Joules) are required. That is basically the energy of the water-flow through that specific cubic meter wherein the dolomite is deposited. After delivery, this $15,400 \text{ m}^3$ water is still at 150°C so contains still all this energy and is immediately available to cook the Flood environment. This is just for one cubic meter of dolomite and must be multiplied considering the abundance of dolomite deposits.

Whilst these points are severe objections to the proposed model, we may note one other major argument against this model that Arvidson and Mackenzie (1999) in the abstract mention — namely — only protodolomite was produced. Protodolomite contains less magnesium than ordinary dolomite. So, this all is not even a proof that we can synthesise dolomite using Mg-rich water.

A magma solidifying in the different layers of salt (dolomite is just another salt) seems a more straight-forward explanation (Heerema, 2009, 2018, 2022). It requires only a fraction of all this energy plus it releases the heat during a slow cooling process, which can account for the present geothermal gradient as Oard refers to (2022, p. 26).

**Stef J. Heerema and
John D. Matthews
Netherlands
Dorset, UK**

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Reply to Heerema and Matthews

I welcome comments and criticisms of my work, but I am confused by some of the statements in this letter. I did not advocate for an igneous origin of “evaporites” in Oard (2020). I only mentioned evaporites, in particularly gypsum or anhydrite, as sometimes associated with dolomite. I gave three *possible* sources for carbonates: (1) hydrothermal fluids (“fountains of the great deep”), (2) carbonates created during Creation Week, or (3) as igneous rocks from carbonatite lavas. Of course, carbonates could have multiple origins (polyfinality). In regard to an igneous origin of carbonates, I pointed out that carbonatite lava, by definition over 50% carbonate, is known to have erupted in the past with one occurrence today. My focus was not on evaporites, whether as precipitates or as igneous rocks in the Flood.

So, I am not taking a U-turn in Oard (2022), which deals with the origin of dolomite. The Arvidson and McKenzie (1999) article is a lab experiment, different than what would occur during the Flood. It essentially concludes that hot water is needed to precipitate dolomite. Heerema and Matthews seem to indicate that I believe these hot water flows occurred at atmospheric conditions, as they state: “Such a water flow cannot exist

in atmospheric conditions.” They also ask: “Where are such water flows seen today?” I was of course referring to the Flood and not the surface today. Despite Arvidson and McKenzie (1999) obtaining protodolomite, heat would aid the formation of more stoichiometric and ordered dolomite (Li et al., 2015), which is not perfect as observed in dolomites in the rock record.

Although Heerema and Matthews indicate a big problem for heating Floodwater and forming dolomite, various Flood mechanisms can readily produce the heat, such as hydrothermal flows, igneous flows, volcanism, meteorite impacts, etc. The source of Mg or lime should not be a problem. Seawater today is 10–100 times supersaturated with Mg (Warren, 200a0); the Mg likely being a leftover from the Flood. The source of Mg could be from the pre-Flood ocean, hydrothermal flow, dissolving of rocks during Flood catastrophism, volcanism, etc. The source of lime (CaO) could be the three possibilities mentioned in Oard (2020).

As far as cooking the Ark inhabitants, not all the Floodwater would be hot. I stated: “*Local*, very hot early Floodwaters have several implications...” (Oard, 2022, p. 26, emphasis mine). Besides,

God protected the Ark from not only cooking in hot water, but also being hit by a meteorite, floating over a volcanic eruption, floating into shallow water during a breaking tsunami, etc., as indicated in Genesis 8:1a.

I would question how much NaCl exists between layers of dolomite. Any association between dolomite and evaporites must be investigated. I have not made up my mind on the igneous origin of evaporites, since I do not have enough information. Research on more evaporites is needed. The Messinian evaporites that occur on the bottom of the Mediterranean Sea at different subbasin elevations, and even on land, seem contrary to an igneous origin. They have a volume of 2.5 million km³ and are dated as Late Miocene (5.97–5.33 Ma) in the conventional chronology (Oard, 2017). As I stated, more investigation is required. Another thought is that dolomite could be produced by more than one mechanism.

Michael J. Oard

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Errata

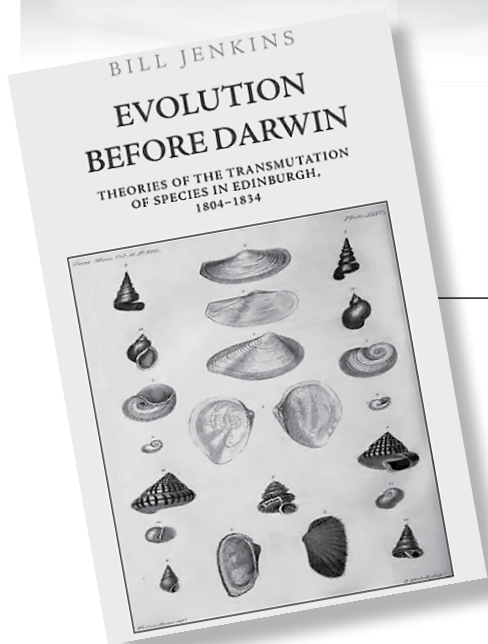
There was an error on page 152 in the last sentence of the Figure 1 caption in Matthew Cserhati’s paper “Baraminic placement of *Homo heidelbergensis* based on molecular data,” *CRSQ* 59(3):151–159.

The affected sentence in the caption for Figure 1 should be:

“Darker colors denote higher similarity values between species which are closer relatives, whereas lighter colors denote lower similarity values.”

The original incorrectly had the darker and lighter colors reversed.

Media Reviews



Evolution Before Darwin: Theories of the Transmutation of Species in Edinburgh 1804–1834

Bill Jenkins

Edinburgh University Press,
Edinburgh, 2021, \$24.95

When Charles Darwin mused on the origin of his theory of biological transformation, he gave primacy to the collection of data. In his *Autobiography* (Barlow, p. 119), Darwin declared he “worked in true Baconian principles, and without any theory collected facts on a wholesale scale.” Yet author Jenkins’ research (2021) reveals that Darwin’s student experience exposed him to a vibrant community of people who were very interested in the latest evolutionary theories, of which many aspects were later incorporated into his magnum opus *On the Origin of Species*.

At age 16, Darwin enrolled as a student in Edinburgh University, following in the footsteps of his grandfather and father who gained their grounding in medicine there. His comments on transformism in Scotland are very brief, and relate to just one incident involving the naturalist Robert Grant whose

lectures Darwin attended (Shortly after this, Grant became Professor of Comparative Anatomy at University College London.):

“He one day, when we were walking together, burst forth in high admiration of Lamarck and his views on evolution. I listened in silent astonishment, and as far as I can judge, without any effect on my mind. I had previously read the *Zoönomia* of my grandfather, in which similar views are maintained, but without producing any effect on me. Nevertheless it is probable that the hearing rather early in life such views maintained and praised may have favoured my upholding them under a different form in my *Origin of Species*.” (Barlow, p. 49)

These remarks have been interpreted as evidence that Darwin was an objective scientist and did not depend on the views of other advocates of transformism. Frequent references to “my” theory served to reinforce his claim to be an original thinker. However, for anyone who is impressed by Darwin’s own account of his intellectual journey, Jenkins’ book will be an eye-opener. The scientific method owned by Darwin was an after-thought and his words are rhetoric.

Jenkins has put together a readable and scholarly account based on his graduate program of study. The theme is the

extent to which transmutation of species was held in academic circles in Edinburgh, especially in the 1820s. However, it is not until the end of the book that the spotlight falls on the youthful Darwin in the years 1825–1827. The ten pages devoted to him are entitled “The legacy of Darwin’s Edinburgh years.”

The book introduces Edinburgh’s university system and how it compared with the situation in England. Academic staff in Oxford and Cambridge were churchmen and their students devoted significant time to classical languages or mathematics. By contrast, in Edinburgh, the heritage of the Scottish Enlightenment was still strong and the curriculum incorporated this philosophical tradition. Students were able to select the courses they wanted to study, with degrees characterised by a broad range of subject matter. Professors were not required to affirm a confession of faith. Consequently, English students from dissenting backgrounds found that universities north of the border were not only options for them, but also were not prescriptive on content. “This vibrant, tolerant environment was a world away from the paternalistic, clerical atmosphere at the contemporary English universities” (p. 32).

Another ingredient for this story is the impact of the geological theories of Abraham Werner. One might think that James Hutton's *Theory of the Earth* (1788) would be dominant in Edinburgh, but this was not the case. A major factor in explaining this is the towering figure of Robert Jameson, regius professor of Natural History in Edinburgh from 1804 until 1854. Jameson was also the Keeper of the University's Natural History Museum, editor of the *Edinburgh Philosophical Journal* and the *Edinburgh New Philosophical Journal*. Jameson visited Freiberg in 1800 to meet Werner and develop his own thinking. One outcome, in 1804, was the first edition of his textbook *A System of Mineralogy*. Another outcome, in 1808, was when he became the founder and life president of the Wernerian Natural History Society and editor of the Society's *Memoirs*. By Jameson's well-attended lectures, his tutorials and field-trips, his own publications and his editorial work, he had many opportunities to promote Wernerian geology as superior to the approach of Hutton.

Werner and Hutton provided different perspectives on time. For Werner, Earth history was a progression from a primeval ocean to the present day. By contrast, Hutton's apparently endless recycling meant that the Earth's system was essentially static. Whilst Werner presented time as an arrow, Hutton's mental image was a cycle (Gould, 1987). Jameson could see progression in the rocks, from Primary to Secondary to Tertiary. In the Introduction to his book on mineralogy, he used a footnote to probe thoughts about transmutation:

"Thus in botany and zoology the questions, Were all animals and plants originally created as we at present find them, or have they by degrees assumed the specific forms they now possess? Are certain species become extinct? In what order and whither have they migrated? What change has climate produced?"

(Jameson, 1804, xix-xx; Jenkins, pp. 76-77).

The first of these questions is about the fixity of species, and Jameson had predecessors and colleagues who affirmed that species do not change with time. Jenkins identifies a few who were sympathetic with this view, but suggests that the dominant influence was known as "The Great Chain of Being." In particular, he cites William Smellie's words published in 1790 about the "chain of existence" that defines the natural order. Organisms have a place in the chain that is complete and unchanging. Any break in the chain would affect the whole. Jameson's predecessor in the chair of Natural History, John Walker, was a strong advocate of this concept, and in 1797 was emphatic:

"There therefore appears to be no Species of Plants or Animals entirely lost, or any new Species formed. The Transmutation of Species either in Plants or Animals, is a vulgar error" (pp. 40-41).

The Great Chain of Being is actually a philosophical concept that has caught the imagination of Greeks, Medieval scholars, Deists and some Theists (Lovejoy, 1964). Jameson's questions were published the year after Walker died, and they point to a change of direction toward transformism.

Jenkins finds a strong connection between Werner's arrow of time and the way variations in animals and plants were used as evidence for transmutation. The question, "have they by degrees assumed the specific forms they now possess?" has variation in mind. Linnaeus is often cited as a leading figure holding to the fixity of species, but in his later years he was impressed by observed variations and modified his thinking to have fixity operating at a higher taxonomic level. In his judgment, new species could arise by hybridisation (p.42; See also Gould, p. 423). Buffon was a strong advocate of the Great Chain of Being, but he too

recognised the reality of "sensible varieties." Some thought Buffon was an early advocate of transmutation, but others limited the sense of his words to refer to "trifling" differences. Historically, these different perspectives were not resolved and they appear to have continued in our own day.

By the 1820s, transmutation issues were discussed on numerous occasions in lectures, publications and student societies. Jenkins shows that the leading influences came from France via Jean-Baptiste Lamarck and Étienne Geoffroy Saint-Hilaire. Nevertheless, the Edinburgh scholars who absorbed their lead were not slavish disciples. They were uncomfortable with internal drivers of transformation and agreed with Geoffroy that external factors were more important. Perhaps the most significant figure in this is Robert Grant, who was enthusiastic about Lamarck when talking with Darwin, but was actually closer to Geoffroy in his thinking. Indeed, Grant had spent time with Geoffroy in Paris. The details are in Jenkin's book, but what is clear is that Charles Darwin was in Edinburgh at just the time when transmutation questions were being asked and discussed. Furthermore, issues later appearing in Darwin's writings on the origin of species are just the same issues as he was exposed to as a student. Jenkins expresses the situation with these words:

"However, knowing what we now know about the prevalence of transformist ideas in Edinburgh in the later 1820s, it is implausible that he came upon the ideas he shared with Geoffroy and Lamarck quite as independently as he and many subsequent historians have suggested" (p.190).

Darwin's assessment of Geoffroy is contained in one short paragraph in his *Historical Sketch* (incorporated into the later editions of the *Origin*) which communicates nothing of his international

influence. It is a useful exercise to contrast this with the assessment of Jenkins:

“Darwin’s entire model of the action of variation and selective pressure exerted by the organism’s conditions of life was, of course, very close to Geoffroy’s opinion published a few years earlier in 1831 that ‘[i]f those modifications lead to harmful effects, the animals which undergo them will cease to exist, to be replaced by others, with forms modified to suit the new circumstances’. We do not know if Darwin ever read these words, but the parallels with his own views at around the time he was formulating the theory of natural selection are striking. We know that Geoffroy never developed a fully worked out theory of evolution by means of natural selection, but he was certainly thinking along these

lines in the late 1820s and early 1830s” (p.188).

Jenkins’ book is valuable for clarifying the intellectual climate when Darwin was a student at Edinburgh University. It is implausible that Darwin was not exposed to transformism for he was mingling with people exploring these issues; indeed, most of their discussions were relevant to *On the Origin of Species*. Those who think Darwin was either suffering from a strange form of amnesia, or that his words are rhetorical in order to portray himself as an independent thinker, have a strong case.

The book casts light on the issue of “fixity of species,” which was influenced more by the Great Chain of Being than a close reading of the book of Genesis. Fixity was very important for Darwin’s later argument that all variation, whether from breeding of domesticated animals

and plants or whether observed in the wild, is evidence for evolution by natural selection. For Darwin, it was a clear choice between fixity of species, with no variation, and fluidity of species, with a postulated extensive supply of variations that explained how the Tree of Life was formed. But Linnaeus, Buffon (probably), von Baer and Richard Owen would not have agreed. Their understanding of observed variations was much more limited, incapable of accounting for the Tree, but nevertheless explaining what may be described as the Forest of Life. Using more modern vocabulary, they would have said that microevolution cannot be extrapolated to macroevolution. However, Jenkins does not appear to have engaged with this issue, especially after he places Linnaeus alongside Erasmus Darwin in the same sentence.

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“Whether Lamarck’s theories were the catalyst that led key figures in Edinburgh such as Jameson and Grant to interpret the fossil record in evolutionary terms, or whether they were well on the way to doing this already, inspired perhaps by earlier transformist thinkers such as Linnaeus and Erasmus Darwin, is a question that is impossible to answer” (p.102).

What Jenkins’ book does do, implicitly rather than explicitly, is to provide an explanation of how Darwin came to his views on the fixity of species: The polarisation of fixity (by creation) versus fluidity (by transmutation) was part of the intellectual culture of Edinburgh during the 1820s.

The reason these historical issues are relevant is that they impact our understanding of science. The “Scientific Method” is presented to students and to the public as the way to achieve objective knowledge about our world. Human actors are not part of the methodology.

Rather, scientists are said to use the method to achieve objectivity. Darwin’s reference to Baconian principles and to starting without any theory was designed to claim objectivity. The message was: Before Darwin there was darkness and confusion, but when Darwin presented his data-rich case, the light was switched on! There are many dangers when this approach to science is adopted (Ratzsch, 2000; Pearcey and Thaxton, 1994). What students really need to hear is that there is a cultural backdrop to science, and that human actors cannot avoid being part of the methodology of science. Students today are told that evolutionary science brought about cultural change, but the reality is that cultural change led to the emergence of evolutionary science. *Evolution before Darwin* gives us a clearer window to describe and understand the flow of the history of these ideas.

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Robinson, D.A., and D.P. Cavanaugh. 1998. A quantitative approach to baraminology with examples from the catarrhine primates. *CRSQ* 34:196–208.

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Margulis, L. 1971a. The origin of plant and animal cells. *American Scientific* 59:230–235.

Margulis, L. 1971b. *Origin of Eukaryotic Cells*. Yale University Press, New Haven, CT.

Hitchcock, A.S. 1971. *Manual of Grasses of the United States*. Dover Publications, New York, NY.

Walker, T.B. 1994. A biblical geologic model. In Walsh, R.E. (editor), *Proceedings of the Third International Conference on Creationism* (technical symposium sessions), pp. 581–592. Creation Science Fellowship, Pittsburgh, PA.

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4. **Senior Member** Voting or sustaining members who are age 65 or older.
5. **Life Member** A special category for voting and sustaining members, entitling them to a lifetime membership in the Society.
6. **Subscriber** Libraries, churches, schools, etc., and individuals who do not subscribe to the Statement of Belief.

All members (categories 1–5 above) must subscribe to the Statement of Belief as defined on the next page.

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* Student members are required to complete the bottom portion of this form.
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Creation Research Society

History—The Creation Research Society was organized in 1963, with Dr. Walter E. Lammerts as first president and editor of a quarterly publication. Initially started as an informal committee of 10 scientists, it has grown rapidly, evidently filling a need for an association devoted to research and publication in the field of scientific creation, with a current membership of over 600 voting members (graduate degrees in science) and about 1000 non-voting members. The *Creation Research Society Quarterly* is a peer-reviewed technical journal. It has been gradually enlarged and modified, and is currently recognized as one of the outstanding publications in the field. In 1996 the CRSQ was joined by the newsletter *Creation Matters* as a source of information of interest to creationists.

Activities—The Society is a research and publication society, and also engages in various meetings and promotional activities. There is no affiliation with any other scientific or religious organizations. Its members conduct research on problems related to its purposes, and a research fund and research center are maintained to assist in such projects. Contributions to the research

fund for these purposes are tax deductible. As part of its vigorous research and field study programs, the Society operates the Van Andel Creation Research Center in Glendale, Arizona.

Membership—Voting membership is limited to scientists who have at least an earned graduate degree in a natural or applied science and subscribe to the Statement of Belief. Sustaining membership is available for those who do not meet the academic criterion for voting membership, but do subscribe to the Statement of Belief.

Statement of Belief—Members of the Creation Research Society, which include research scientists representing various fields of scientific inquiry, are committed to full belief in the biblical record of creation and early history, and thus to a concept of dynamic special creation (as opposed to evolution) both of the universe and the earth with its complexity of living forms. We propose to re-evaluate science from this viewpoint, and since 1964 have published a quarterly of research articles in this field. *All members of the Society subscribe to the following statement of belief:*

1. The Bible is the written Word of God, and because it is inspired throughout, all its assertions are historically and scientifically true in all the original autographs. To the student of nature this means that the account of origins in Genesis is a factual presentation of simple historical truths.

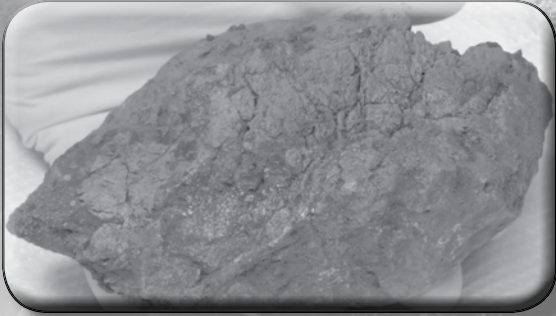
2. All basic types of living things, including humans, were made by direct creative acts of God during the Creation Week described in Genesis. Whatever biological changes have occurred since Creation Week have accomplished only changes within the original created kinds.

3. The Great Flood described in Genesis, commonly referred to as the Noachian Flood, was a historical event worldwide in its extent and effect.

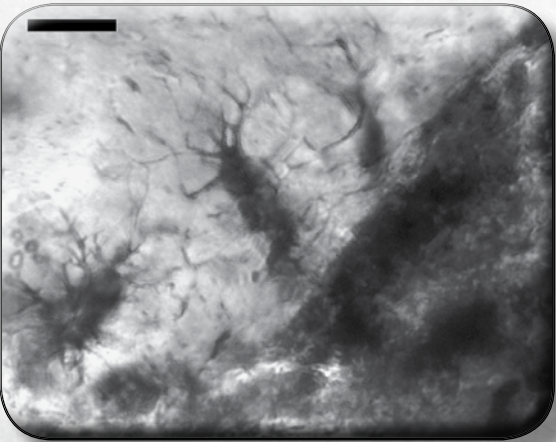
4. We are an organization of Christian men and women of science who accept Jesus Christ as our Lord and Savior. The act of the special creation of Adam and Eve as one man and woman and their subsequent fall into sin is the basis for our belief in the necessity of a Savior for all people. Therefore, salvation can come only through accepting Jesus Christ as our Savior.

iDINO II

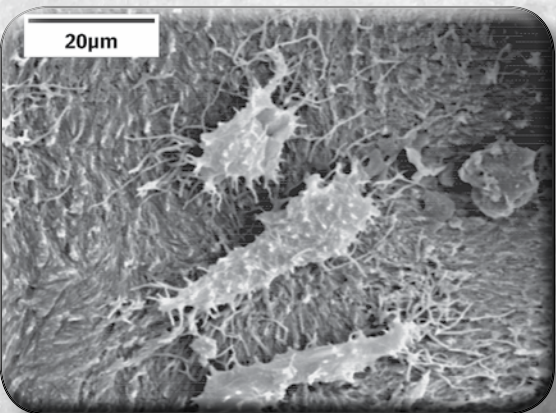
Investigation of Dinosaur Intact Natural Osteo-tissue



A fragment of the *Triceratops* brow horn. Fragments, such as this one, still contain tissue and cells.



Microscopic examination of tissue extracted from a *Triceratops* horn reveals bone cells still present.



Electron microscope picture of intact bone cells still in tissue extracted from a *Triceratops* horn.

How can pliable, stretchable tissue survive inside dinosaur fossils for over 65 million years?

How can this tissue still contain intact cells and even dinosaur proteins?

How can this fragile biological material survive for so long?

The answer to these questions directly challenges the current, evolutionary-biased, geologic timescale.

The Creation Research Society began its iDINO research initiative for the purpose of studying soft tissue in dinosaur fossils. The first phase of the project detected pliable, unfossilized tissue in a brow horn of a *Triceratops*. Within this tissue were intact osteocytes (bone cells). Some results from the iDINO project have been published in a technical microscopy journal and presented at an international microscopy conference. The Spring 2015 issue of the *Creation Research Society Quarterly* also features a special report of the iDINO project. Plus, to further spread the important information about soft tissue, the Society is developing a video (Echoes of the Jurassic).

The **second phase** of the project (iDINO II) will look more extensively at the process of tissue preservation. Evolutionists have offered various theories of how this tissue could survive for millions of years. iDINO II will methodically investigate these preservation claims, assessing their plausibility.

The iDINO results have already provided a strong challenge to the evolutionary worldview. More extensive and detailed examination may provide even stronger evidence that the age of dinosaur fossils is far less than 65 million years. To this end, the Society continues to seek those willing to fund this project with either one-time gifts or monthly donations.

For more information contact us at (928) 636-1153 or crsvarc@crsvarc.com.

Also visit <http://tinyurl.com/nphm2c4> for project updates and details.



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