Tremendous erosion of continents during the Recessive Stage of the Flood

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The Recessive Stage of the Flood was a time of intense continental erosion. The erosional debris formed the continental margin—a continuous wedge of mostly compacted sediments surrounding the continents. If we can determine which part of this wedge is composed primarily of detritus eroded during the Recessive Stage, some later cementing to sedimentary rock, then estimating the volume of those sediments and rocks could provide a rough quantitative estimate of material eroded from the continents. At present, a total value is not possible, but such an estimate can be made for select areas, providing a methodology that can be expanded to other marginal areas. One such area is the central Appalachian Mountains of the United States and its downgradient continental margin. Research shows an approximate average of 6,000 m of erosion across the Blue Ridge and Piedmont provinces. Another area is the continental margin off south-western Africa. Estimates there show an average 2,400 m of rock eroded off the adjacent continent. Erosion was probably greater in the coastal mountains and plains. Evidence from inselbergs on the coastal plain indicates that this erosional event was as rapid as it was significant. If representative, these studies show that much more sedimentary rocks and sediments existed on the continents than the present average of 1,800 m. Since a large proportion (about 30% or more) of the margin sedimentary rocks are Cenozoic, the Flood/post-Flood boundary must be in the late Cenozoic, assuming the geological column is an accurate chronostratigraphic representation of the rock record.

The Recessive Stage of the Flood was a period of significant continental-scale erosion.[1–3] It was likely composed of two phases, the Ablative or Sheet Flow Phase followed by the Dispersive or Channelized Flow Phase.[4] Thus, channelized erosional features would be superimposed upon the sheet flow eroded features. This prediction is borne out in many places, including the south-west Colorado Plateau of the USA (figure 1), which shows large-scale planation, followed by dissection into canyons and valleys. The first type of erosion has been called the *Great Denudation* in which an average of about 3,000 m of sedimentary rock was eroded from the south-west Colorado Plateau, leaving behind a vast planation surface (figure 2).[5] The eroded volume there is within the estimated 2,500 to 5,000 m of average erosion for the whole Colorado Plateau.[6] The second erosional event is called the *Great Erosion* with Grand Canyon and Zion Canyon, Utah, being examples of dissection, corresponding to the more channelized erosion late in the Flood.[7] But this erosion was not limited to the Colorado Plateau. When Flood water flowed from the continents into the newly deepening ocean basins, the same kind of erosion probably occurred. Equally significant volumes of rock were eroded from other areas, as shown by: erosional remnants, such as Devils Tower[8]; eroded anticlines, such as the San Rafael Swell[9] on the north-west Colorado Plateau (figure 3); and great Coastal Escarpments, such as the 3,500-km-long escarpment that rings southern Africa.[10] This escarpment is about 3,000 m high in south-eastern Africa, but only about 1,000 m high in south-western Africa.

The sediment eroded would have been transported downgradient, and deposited at places where the flow velocity dropped quickly, typically due to a major depth increase in the water—conditions met almost universally along the continental margins. The continental margin consists of the continental shelf, slope, and rise (figure 4), and is composed of a continuous wedge of mostly sediments around all the continents and even large islands. It is one of the most significant geomorphological features on our planet. The sediments in the continental shelf reach 20 km or more in thickness (about 30% of which is likely Cenozoic), but vary in both lateral extent and thickness, depending on the location. These sediments were most likely deposited by sheet flow off the land. Later, after the bulk of sediments had been deposited, channelized erosion was caused by strong currents that swept in wide channels across the sedimentary surface and eroded submarine canyons.[11,12]

If the continental margin is composed primarily of sediments deposited in this manner, then the volume of this wedge is approximately the volume of rock eroded from the continent. While some of this margin sediment may have been deposited early in the Flood, at this point the amount would be difficult to estimate. We cannot simply assume Cenozoic sediments are from the Recessive Stage and pre-Cenozoic sediments are from the Inundatory Stage. Moreover, these time periods are labels applied to the

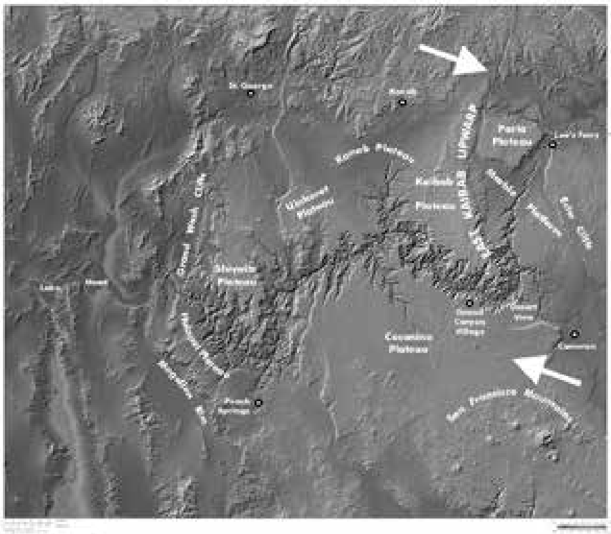

Figure 1. Map of Colorado Plateau and its surrounding provinces. Grand Canyon is on the south-west portion and the San Rafael Swell on the north-west portion of the plateau (map background provided by Ray Sterner and drawn by Peter Klevberg). Arrows point to low areas across the northern Kaibab Plateau and its extension south of Grand Canyon on the eastern margin of the Coconino Plateau.

Figure 2. Planation surface in the Grand Canyon area (view north). North rim of Grand Canyon in the background.

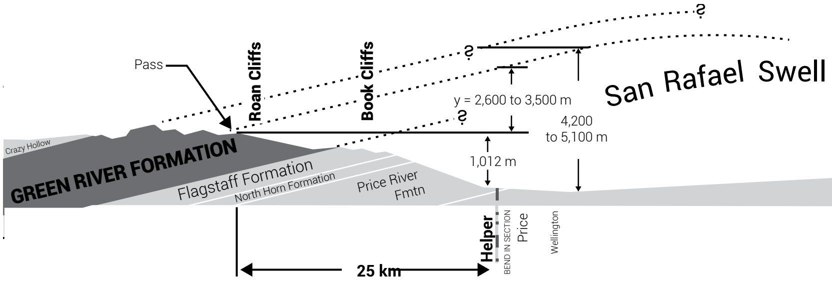

Figure 3. Estimate of 4,200 to 5,100 m of erosion on the north limb of the San Rafael Swell, north-western Colorado Plateau, based on trigonometry and adding the height of erosional remnants at the top Green River Formation (drawn by Peter Klevberg)

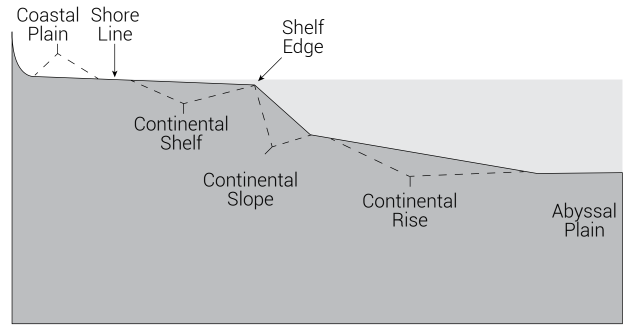

Figure 4. The continental margin consisting of the shallow continental shelf, the steep drop-off of the continental slope, and the gradual decrease in slope of the continental rise (drawn by Melanie Richard)

sediments assuming the geologic column and plate tectonics, e.g. the Atlantic opening up in the Jurassic and Cretaceous.

Nonetheless, given quantified areas of erosion, average thickness values can be calculated for the total amount eroded during the Flood, and minimum estimates for the Recessive Stage can be given by approximations of the Cenozoic sediment thicknesses. However, the total amount of sediments in the margins is currently not known, though scientists are getting closer to being able to estimate it.[13] Still, the world totals will be difficult to estimate; the sediment volume of the Arctic Ocean sediment margin, for example, is unknown and difficult to measure. But it is possible to apply an estimating method to areas where data provide more constraints.

Estimated erosion from the central Appalachians, USA

The Appalachian Mountains of eastern North America run from Newfoundland, south-east Canada, down the Atlantic seaboard, 2,400 km, into central Alabama. There are distinct physiographic provinces in the southern and central Appalachians from east to west: the Piedmont, the Blue Ridge Mountains, the Valley and Ridge, and the Appalachian Plateau (figure 5). In New England and Canada, the Appalachians are generally characterized by exposures of uplifted crystalline rock.

In addition to estimating the volume of sediments in the continental margin, depth of erosion can be roughly indicated by the rank of coal now at the surface.[14–16] Coal is commonly found in the sedimentary rocks in the Valley and Ridge Province. This coal is mostly high-rank anthracite and medium-rank bituminous coal.

Friedman and Sanders believe that the anthracite coal in the Catskill Mountains of New York indicates that about 6,400 m of rock has been removed there, assuming the persistence of the current temperature gradient.[15] The same method can also be applied in sedimentary rocks west of the Blue Ridge Mountains, where anthracite is also found near the surface. However, if the temperature gradient was higher when the coal formed, less overburden would have been present to form coal and erode.[14] This could occur during Flood deposition in deep basins if the temperatures started hot, but I will assume the present geothermal gradient as a first approximation. Since bituminous coal has a lower rank than anthracite, overburden would have presumably been substantially less in those areas. Even so, it is not unreasonable by this method to project the erosion of thicknesses of sediments and rock to between 4,000 to 6,400 m from atop the Valley and Ridge Province.

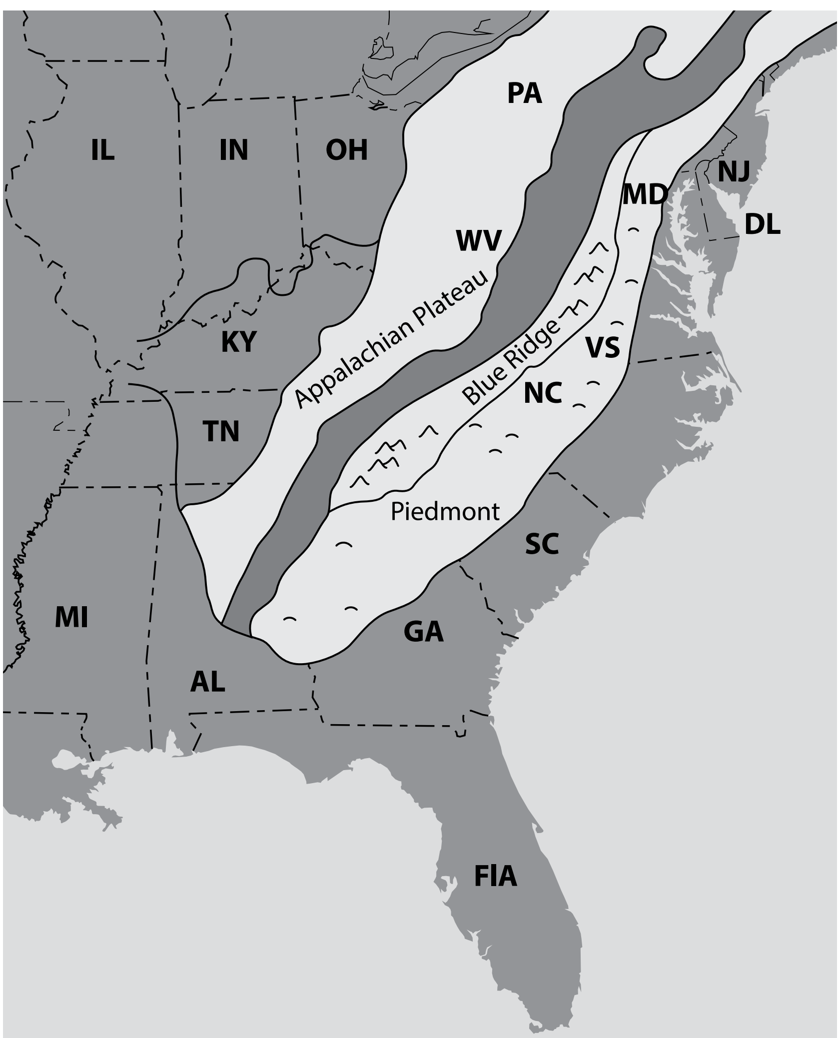

Figure 5. Map of the eastern United States showing the location of the Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateau provinces (drawn by Melanie Richard)

Keeping this figure in mind, let us turn to the volume of sediments found in the continental margin. Geologists believe that these sediments were derived from the Appalachians.[17] In a Flood scenario, this erosion would mostly have occurred during the Recessive Stage.[17,18] Poag and Sevon state: "The primary forcing mechanisms considered have been tectonic and isostatic uplift and subsidence … ."[19] The total amount of differential vertical motion between the Appalachians and the basement below the continental margin sediments is believed to have reached 14 km![20] Isostatic uplift—a secondary tectonic force caused by the removal of overburden—would have added to the tectonic uplift in areas being eroded, and would have added to subsidence in areas receiving sediments.

Fortunately, the continental margin in the central-eastern United States has been intensely studied by geophysical and direct drilling methods into the top layers. Poag and Seven indicate that the total amount of siliciclastic (non-carbonate and non-'precipitate') sediment offshore is 1.377 million km^3 (about 33% of it Cenozoic) over an area of about 500,000 km^2 between latitudes 36° and 42° N and longitudes 39° 30′ and 78° W.[17] This estimate includes the continental rise that stretches far to the east of the coastline. The average thickness in this area is 2,700 m. Non-clastic sediments such as carbonates, salt, and gypsum were omitted, granting that they were directly deposited chemically or biologically from the water, and not eroded from inland areas. However, in the Flood model, these chemical sediments may have been eroded from the continents first. If we include these chemical sediments, the estimated average thickness of margin sediments likely would be about 3,000 m.

The central Appalachians, from the Piedmont west to the Valley and Ridge Province, cover an area of around 315,000 km^2 between 36° and 42° N latitude.[12] Based on the total volume of sediments and sedimentary rock in the continental margin wedge, assuming west-to-east water currents, and assuming that all that sediments originated from those provinces, the most general calculation reveals that an average thickness of about 4,400 m was eroded from this region. The assumption that erosion and deposition was west to east is probably a good assumption because the strong uplift of the eastern United States relative to the offshore area would result in strong water currents flowing east. The continental margin sediments are still thick south of 36°N and north of 42°N. So, I will assume any north-south component would not be significant.

It is probable that most of the sediments offshore would have originated from east of the Appalachian divide, which is mostly in the Blue Ridge Mountains, because erosion would have greatly accelerated during uplift of the eastern United States during the Flood. If all the sediments originated east of the divide, a maximum estimate, the eroded area would have been reduced by approximately 30%, and the eroded thickness of the remaining area would have averaged around 6,000 m. This range agrees well with the range derived from coal rank studies in the Valley and Ridge Province.

Most of the erosion of the central Appalachians appears to have happened along the continental divide in the Blue Ridge Province, and in the Piedmont Province just to the east. These provinces consist almost entirely of exposed igneous and metamorphic rocks stripped of overlying Flood sediments. To the west, the Valley and Ridge Province has clearly been eroded, but retains significant sedimentary thicknesses in the Appalachian Basin, with strata exceeding 10 km today. If erosional estimates are reasonable, sedimentary rocks in this basin may have once reached 14 to 16 km in thickness with 4 to 6 km being eroded during Walker's Zenithic Phase and the Recessive Stage. So, it is likely that the original Appalachian Basin extended east to the eastern edge of the Piedmont. The presence of basement igneous and metamorphic rocks in the Blue Ridge and Piedmont provinces suggests more intense erosion in those areas, suggesting that much of the continental margin sediments were derived from both overlying sedimentary rocks and some deeper igneous and metamorphic rocks. This erosion formed a rough planation surface on the Piedmont Province[21] which was later dissected during the Channelized Flow Phase. Also, hundreds of water and wind gaps throughout the Blue Ridge and Valley and Ridge provinces were carved by channelized erosion.[22,23]

The reader may wonder how so much erosion can occur during Flood runoff. Erosion is related to the bed shear force, which is proportional to the 4th power of the velocity.[24] So, if velocity doubles, the bed shear force increases by 16. If the velocity quadruples, the bed shear force increases by about a thousand times. The great differential vertical tectonics between the Appalachians and the offshore basement would greatly accelerate the water flow off the continent and cause massive erosion.

To understand the extent of the erosion during the Recessive Stage of the Flood, we can look at the present topography. The highest elevation in the present Appalachian Mountains is Mount Mitchell, in western North Carolina, which reaches 2,037 m, exceeding Clingman's Dome in eastern Tennessee by 12 m. Most of the peaks in the Appalachians today are much lower. So the late-Flood erosion being discussed removed up to three times the present day relief. Various factors could have affected both past and present elevations, but it is clear that a significant percentage of the rock record formed in this region was eroded during the latter stages of the Flood.

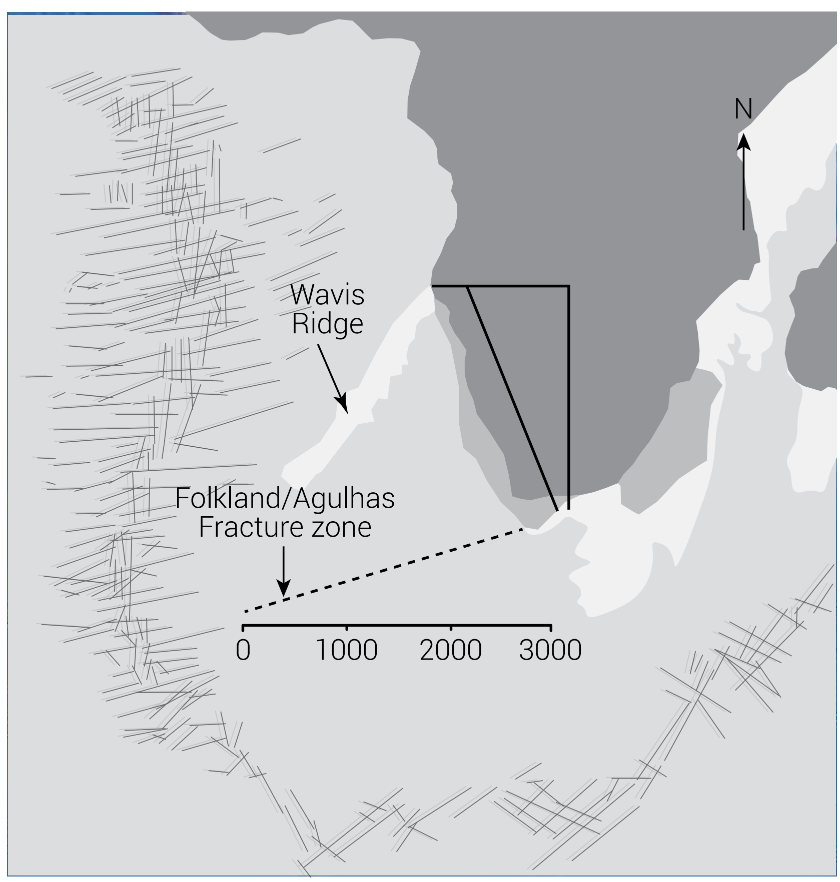

Figure 6. Map of southern Africa and the adjacent oceanic margin (drawn by Melanie Richard). Large arrows show direction of runoff during the uplift of southern Africa. Lines in south-west Africa show the two areas of estimated continental erosion of south-west Africa. Scale in kilometres.

Estimated erosion from south-west Africa

Although the coal rank technique has not been applied in south-west Africa, an estimate of erosion can be obtained from the volume of the continental margin sediment wedge (figure 6). Data from wells and geophysical surveys have allowed scientists to estimate the amount of marginal sediments off Namibia and western South Africa.[25] Their goal was to expand their work to the entire continent, starting from this test region. They confined their area of interest to that between the submarine Walvis Ridge to the north and the Falkland/Agulhas fracture zone that impinges on the southern tip of Africa. Fracture zones commonly are the result of uplift of a ridge adjacent to a deep trough. These ridges would likely block much of the sediments coming from the north or south, and, therefore, provide a reasonable estimate of continental erosion from south-west Africa.

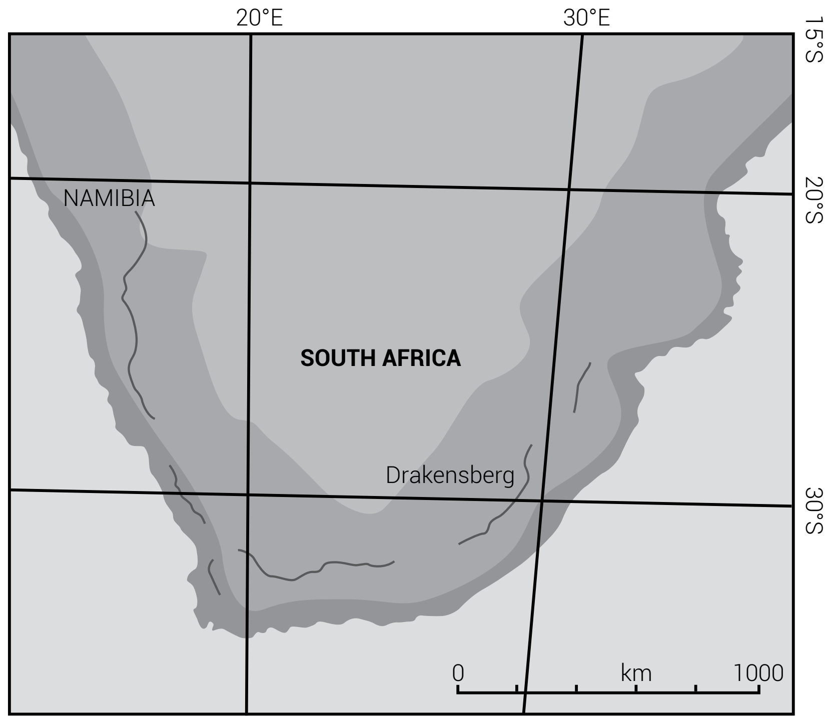

Figure 7. Plan view of the Great Escarpment with some large gaps that parallels most of the coast of southern Africa between 100 and 160 km inland for 3,500 km (drawn by Melanie Richard)

Sediments of the continental margin here especially occur in several deep basins. The Walvis and Orange basins are situated largely beneath the continental shelf, and contain up to 8,000 m of sediments.[25] Based on geological cross sections of the margin, these sedimentary rocks thin rapidly offshore, pinching out about 1,000 km offshore.[25] These two basins are approximately 1,500 km long, running north-south. The estimated area of deposition between the Walvis Ridge and the Falkland/Agulhas fracture zone is about 1.5×10^6 km^2 and the average thickness of the margin sediments is approximately 3,200 m. The top 33% of the sediments are dated as Cenozoic, while the majority of the sediments are Jurassic and Cretaceous, by uniformitarian scientists. However, for our purposes here the dates do not matter, since they may be quite arbitrary. It is likely that these basins started to form at the peak of the Flood, the Zenithic Phase, and continued through the Recessional Stage, when strong differential vertical tectonics occurred between the continents and the ocean floors,[26] which would stretch and fracture the transitional crust.[27] Such is the case on the East Coast of North America,[28] as well as off south-west Africa. So, as a first estimate, I will assume that most of the margin sediment was deposited during the Recessional Stage of the Flood.

Estimating offshore sediments

Geologists today apply the plate tectonic paradigm to their work, and estimates of continental margin sediment volume were calculated by assigned time period starting in the Upper Jurassic. Although the 'time' South America supposedly broke away from Africa is the Lower Cretaceous, there are synrift sediments that were deposited during active rifting in the upper Jurassic.[25] But a total volume can be derived by simply adding the time-specific volumes they provide. Volcanic rocks and carbonates are not included in the calculation because they were assumed to have formed *in situ* and not from continental transport and erosion. The total volume of eroded siliciclastic rocks from the continent is about 3.7×10^6 km^3 (of which about 1.2×10^6 km^3 is dated Cenozoic).

This is a conservative estimate of bulk sedimentation because although the volcanic rocks were obviously formed *in situ*, most of the carbonates were probably eroded from the continents and redeposited offshore. These carbonates likely precipitated *in situ*, but the original carbonate probably originated from eroded continental deposits and dissolved in the runoff. The amount of carbonate rock is roughly 30% that of the siliciclastic sedimentary rocks.[25] If the carbonates are added back in, the total volume eroded from south-west Africa is around 4.8×10^6 km^3.

Estimating erosion from southern Africa

We know less about the erosion from this area of southern Africa than we do about the central Appalachians, but a rough estimate of the area and average depth of erosion from south-west Africa is possible. During continental uplift and/or sinking of the ocean basins or both, the continent experiences deformation, forming domes and basins.[29] Widespread early erosion formed a planation surface called the African Surface.[30] In south-west Africa, the Great Escarpment lies about 100 km inland, and separates two planation surfaces: a coastal plain and an inland planation surface (figure 7). Farther east lies the Kalahari basin or inland plain, between the elevated plateaus of south-east Africa and that of Namibia and western South Africa. The coastal areas of south-east Africa are quite high, forming the Drakensberg escarpment about 3,000 m high.

The method follows that used for the Appalachians. Since the south-west African escarpment is not that high, I will estimate the amount of erosion from the west slopes of the Drakensberg westward between the Walvis Ridge and the Falkland/Agulhas Fracture Zone. The Walvis Ridge approaches the coast at about 20°S, while the Falkland/Agulhas Fracture Zone comes close to the southern tip of South Africa at 35°S. I will also assume east-to-west water currents perpendicular to the coast caused by continental uplift relative to the ocean basin to the west. This area is approximately 2 x 10^{12} m^2. When we divide the total amount of sedimentary rock and sediment offshore by the area eroded, we get an average of 2,400 m. There will likely be more intense erosion nearer the coast causing the Great Escarpment. This is because it was the locus of change for the new flow gradient, and acceleration of the eroding waters would have been rapid there.

Evidence for rapid erosion

During this erosive stage of the Flood in Africa, a continent-scale planation surface, called the African Surface, was created, broken by local domes and basins created by differential uplift.[29,30] Planation surfaces, especially of this magnitude, are not forming today.[11,12,31] Therefore, they cannot be explained by uniformitarian geomorphology. It is a powerful argument for the Flood because its Recessive Stage predicts the large-scale erosional features—both from sheet erosion and channelized flow—that we see today.

Although the Recessive Stage of the Flood lasted for months, initial rates of erosion (more closely tied to flow velocity) could have been much more rapid. As the coastal escarpment of south-west Africa, around 1,000 m high, eroded, it likely migrated inland over 100 km from where it started near the coast.[12] Given that the Great Escarpment rings southern Africa for 3,500 km, the volume eroded from near the coast to the location of the Great Escarpment is quite

Figure 8. Sunrise at Spitzkoppe, a 600 m tall inselberg on the coastal planation surface in the Namibia Desert, Africa (from Wikipedia)

large. The erosion is too much and too fast for the usual uniformitarian estimates.[32]

The coastal planation surface in the Namibian Desert has numerous granite inselbergs surrounded by basal pediments, similar to the Piedmont east of the Blue Ridge Mountains.[33] An inselberg is an erosional remnant that generally rises above a planation surface. The most famous inselberg in south-west Africa is Spitzkoppe, which rises 600 m above the desert floor (figure 8). Its height provides a minimum estimate of the depth of erosion in that area. Spitzkoppe is composed of granite. Since granite is plutonic, it was most likely covered by a significant amount of overburden, which was also eroded. Thus, we know that at least 600 m, and most likely much more, was eroded from the Namibian Desert.

Today, the vertical slopes of Spitzkoppe are eroding by means of cliff retreat toward the centre of the inselberg. The rate was recently measured and was found to be two to three times faster than the rate of the nearly horizontal pediments. This is not surprising since steep slopes erode much faster than horizontal surfaces.[34] But this raises another question: why would an inselberg like Spitzkoppe persist over geologic time? The creation of tall inselbergs requires *rapid* erosion by a catastrophic flow of water, and the persistence of these features requires a limited amount of time since their formation. Both are problems for uniformitarian geologists.[12] Moreover, numerous inselbergs exist on all continents,[12] indicating a global catastrophic event.

Implications

These calculations demonstrate how the Flood model both predicts the existence of characteristic geomorphic and geologic features, and then provides a basis for calculations that some uniformitarian geologists cannot make, because their paradigm excludes thought along those lines.

The most obvious demonstration of the superiority of the Flood model is the explanation of the vast volumes of eroded rock and sediment from the continents during the Recessive Stage of the Flood. Erosion rates would have been almost unimaginable at their maximum. The Flood model predicts not only continent-scale erosion, but the geographic locations of maximum erosion—i.e. at the maximum change in gradient caused by the relief between the continents and ocean basins. It also predicts the deposition of transported materials at the point where the change in water depth caused the current velocity to drop abruptly, creating the continental margin sediment wedge. These wedges are ubiquitous and their relative volumes provide indications of where erosion and deposition was greater, and where it was less. This can assist us in our understanding of how much material might have been removed from adjacent areas, and how large the affected areas might have been.

And obviously, estimates of Flood sediment thickness on the adjacent continental crust, like at the San Rafael Swell, USA, help constrain the volume of eroded sediment transported to the continental margins. Values for the central Appalachians and south-west Africa do not represent average continental erosion, but do provide some scale against which it could be estimated. The average depth of sedimentary rocks on all the continents is estimated to be 1,800 m.[35,36] That seems quite large until it is compared to the thicknesses eroded and deposited along the continental margins, or in areas such as the Colorado Plateau, USA, where estimates of thickness eroded have been made by secular geologists. It is not unreasonable to suggest that the average thickness of sedimentary rocks on the continents just before the Recessive Stage may well have been 50% more than now.[37]

Another implication concerns the location of the Flood/post-Flood boundary. Erosion and deposition on the scale observed on the continental margins could only have happened in the Flood. These findings suggest that the Flood could not have ended until the late Cenozoic. For example, the sediments off the East Coast of the United States are estimated to have a total volume of 1.34 million km^3. Of that, about 33% are dated as Cenozoic, which is a large percentage, making it unlikely that the Cenozoic sediments can all be explained by post-Flood catastrophism.[20] It is likely that even the Mesozoic sediments on the continental margins are from the Recessive Stage, but this refinement is beyond the scope of this paper. Likewise, the thick continental margin sedimentary wedge in the northern Gulf of Mexico contains about 12 km of Cenozoic sedimentary rocks.[38] Thick Cenozoic sedimentary rocks are found along other continental margins, strongly indicating that the Flood/post-Flood boundary is in the late Cenozoic.

If so much erosion occurred on the continents late in the Flood, then it is an inescapable conclusion that much of the surficial sedimentary rock we see, even that dated as very ‘young’, such as Cenozoic, is actually ‘older’ than where it has been assigned. That is, some is likely from the late Inundatory Stage, the Zenithic Phase, as the Flood was reaching its peak. There are exceptions, of course, but those do not lessen the force of this conclusion. It appears that Flood sedimentation on the continents was highly non-linear, with most of what we see preserved today having been deposited in the earlier stages of the Flood.

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