An Impact Model or Sub-Model of the Flood

Michael J. Oard

ABSTRACT
Impacts are abundant and arguably the most important geological process in the solar system and need to be placed within the Creation/Flood model. The geological work of impacts is briefly reviewed. About 200 confirmed impacts have struck the Earth, and likely there have been many more. One of these is the Chicxulub impact. Precambrian impacts are the most important for the Creation/Flood model, especially the Proterozoic Vredefort and Sudbury impacts, and multiple large Archean impacts. These large impacts could have destroyed the surface of the Earth. Precambrian impacts could be placed during Creation Week, between Creation and the Flood, or during the Flood. It is more likely that Precambrian impacts occurred early in the Flood. This deduction is reinforced by the Day 4 cratering hypothesis extended to Mars. Stromatolites are common in Precambrian limestones, and a case is made that they are abiological. It is possible that impacts could be the meaning of "the windows of heaven" opening as one of the Flood mechanisms. Many enigmatic geological features and events can possibly be explained by impacts.

KEYWORDS: Archean impact spherules, Chicxulub Impact, Day 4 crating hypothesis, Impacts, Mars, Precambrian impacts, Sudbury Impact, Vredefort Impact

I. INTRODUCTION

Creation scientists are still not sure how or whether comet and/or asteroid impacts should be incorporated into a Creation/Flood model. This was shown by a debate on the subject at the 2013 International Conference on Creationism (ICC). Since development of a comprehensive Creation/Flood model is one of the main purposes of the ICC and the Creation Research Society (Hill, 2021), we need to figure out where to place impacts in the model. Some creation scientists believe impacts are a major component of the Flood (Oard, 2012), while others do not. Impacts are not even mentioned in two recent books on the Flood (Snelling, 2009; Clarey, 2020). Can impacts be ignored? Could impacts have caused the Flood, or are they a sub-model of the Catastrophic Plate Tectonics (CPT) model (Spencer, 1998, 2013)? Could impacts have jump started CPT? These questions cannot be answers until after a thorough examination of the impact data. This paper is a step toward that goal.

The Earth Impact Database (Earth Impact Database, accessed June 18, 2022) lists 190 "confirmed" impacts, ranging in age from Precambrian to Holocene, but it has not been updated for many years. The vast majority of these impacts are recorded from the continents. More recent estimates are available. Osinski et al. (2019) write that there are 195 confirmed impacts on Earth as of 2019 with about two new impacts confirmed each year. Schmieder and Kring (2020) and Lim et al. (2021) report that 200 craters have been confirmed as of 2020, but in 2022 Reimold and Hause (2022) state that there are only 194 impacts with 14 additional candidates that require additional confirmation. So, apparently not all confirmed impacts are confirmed, as Clarey (2017a, p. 71) believes: "…many of these [190 confirmed] impacts have limited physical evidence to support them." I accept the secular data because the requirements to confirm an impact are stringent (see below), and many researchers are skeptical of impact claims. Based on these estimates, I can safely conclude that a minimum of 200 impacts have hit the Earth, as of 2022. Schmieder and Kring (2020) also include 46 locations of what are believed to be impact ejecta and breccia deposits in which the source crater is unknown, indicating that there were more than 200 impacts—likely many more (see below).

The CPT model is the most advanced model, by far. I also believe that impacts followed by differential vertical tectonics, the IVT model, is also significant. The CPT and IVT models have positive evidence, but they still need much work and possible integration. This was shown in the *Flood Science Review*

(Bardwell, 2011) in which 10 “neutral” creation scientists questioned the models, and model advocates had to respond. It is my belief that placing impacts into the Creation/Flood model will greatly advance the model.

With a comprehensible Creation/Flood model, we would have a defensible alternative to evolution, uniformitarianism, and deep time that are dogmatically taught in Western culture from kindergarten through the universities. Moreover, since the Flood is considered an outrageous idea by secular scientists, as well as by liberal Christian scientists and theologians, a comprehensible Flood model would go a long way in showing that all of the Bible can be trusted. We can also place the hundreds of Earth and planetary science challenges within a biblical framework.

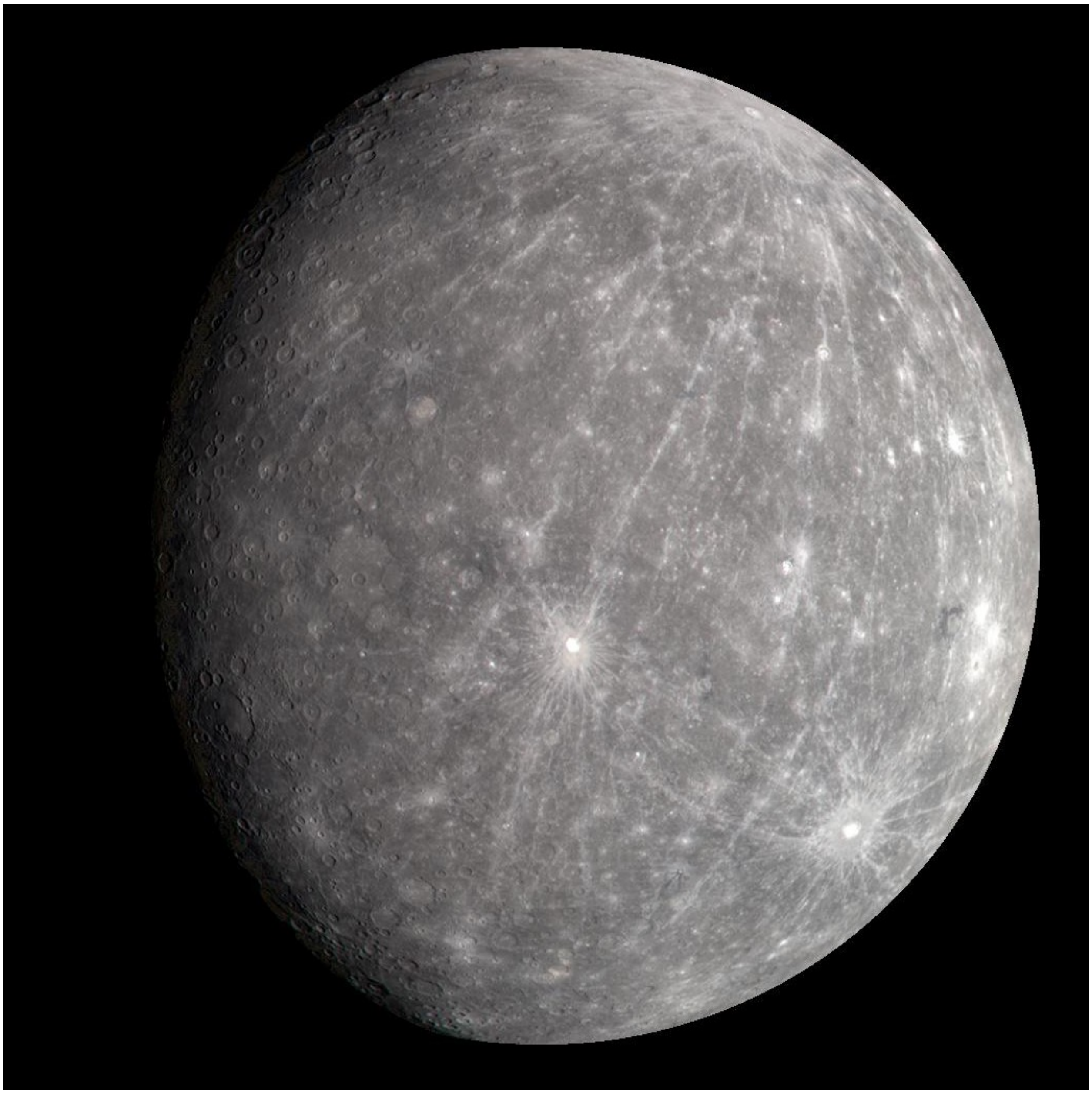

Figure 1. The planet Mercury showing numerous impact craters (NASA).

Figure 2. Callisto, Jupiter’s second largest moon and the third largest in the Solar System, showing numerous impacts taken from NASA’s Galileo satellite in May, 2001 (NASA).

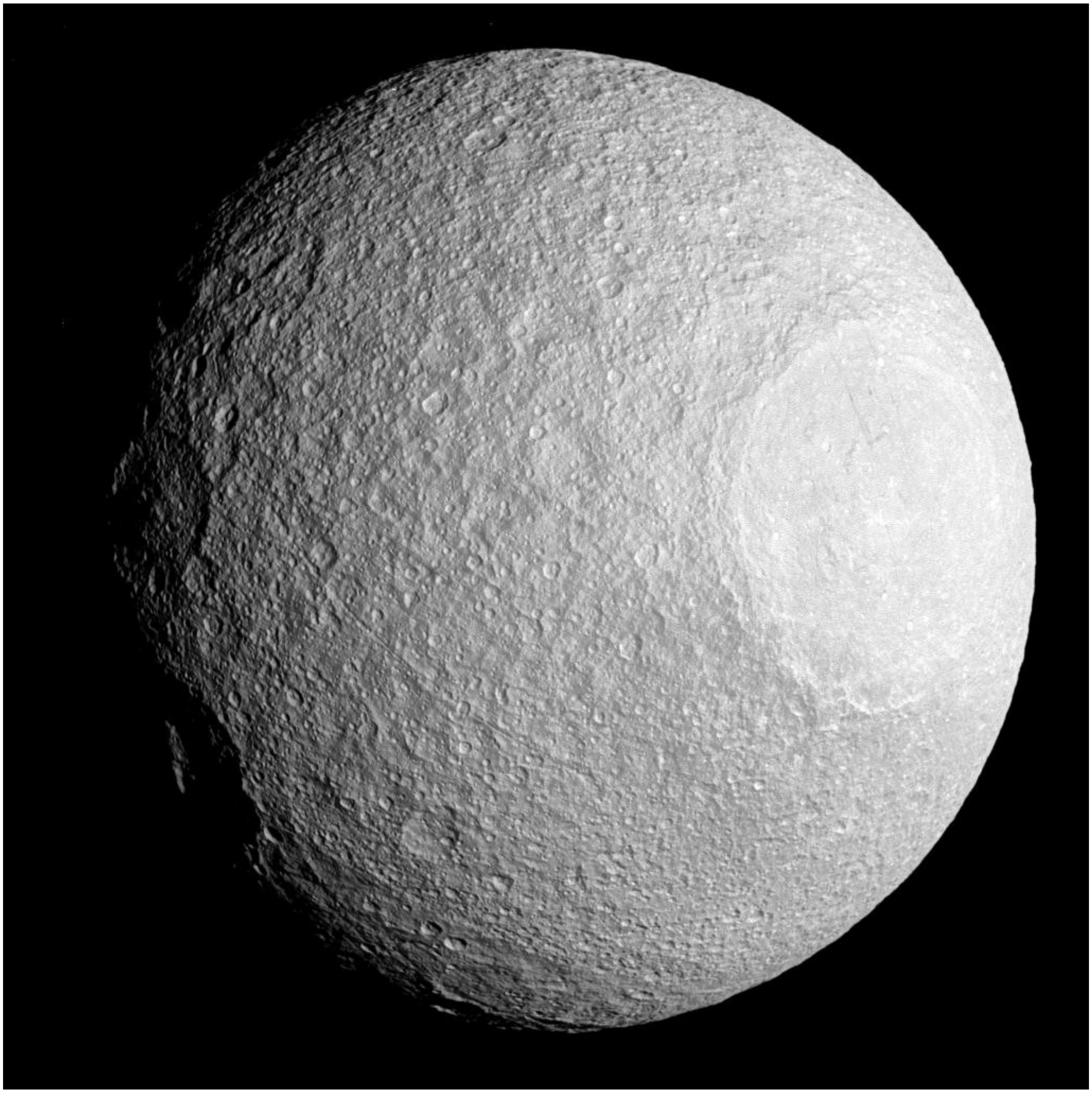

Figure 3. Saturn's moon, Tethys, 1,062 km across taken from the Cassini spacecraft showing numerous impact craters (NASA). The incredibly large Odysseus crater on the right side is 450 km in diameter and covers 18% of the moon.

Figure 4. The ex-planet Pluto from the New Horizons space craft on July 14, 2015, showing many impact craters (NASA).

II. IMPACTS ARE THE MOST COMMON GEOLOGICAL PROCESS IN THE SOLAR SYSTEM

A major reason why we need to incorporate impacts into the Creation/Flood model is because impacts are found on most of the solid bodies of the solar system not resurfaced by lava or debris (Figures 1–4). By comparison, the Earth has very few impact features which also need an explanation. Gibson and Reimold (2010, p. vii) write: "Of all the geological processes having—and still—affecting the planets in our solar system, it is only impact cratering that can lay claim to being ubiquitous." Kenkmann et al. (2014, p. 156) emphasize the importance of impacts: "The heavily cratered surfaces of almost all solid planetary bodies in the solar system emphasize the important role hypervelocity impacts have played in the formation and subsequent evolution of planets and satellites." Melosh (2011, p. 222) corroborates: "In an important sense, impact cratering is the most fundamental geological process in the Solar System" (Melosh, 2011, p. 222).

It was argued up until the 1960s that solar system craters were volcanic caldera because of the strong belief in uniformitarianism (French, 2004), i.e. volcanic processes are observed today, but large impacts are not! In fact, some creation scientists believe that most, if not all, craters are volcanic (Sternberg, 2023). The craters are claimed to be maar craters caused by the heat of accelerated nuclear decay. Even the bowl-shaped crater, Meteor or Barringer crater in northern Arizona (Figure 5), is considered a maar eruption. Maar craters are formed by exploding steam being heated from below. They often end up filled with water (Figure 6). Sternberg claims that shock metamorphism, shatter cones, and impact melt are duplicated by underground nuclear explosions, but he provides no documentation. This is still a far cry from documenting that these features can occur with maar volcanism. In fact, there is a surprising lack of documentation in the whole article.

Figure 5. Meteor or Barringer Crater, northern Arizona (Grahampurse, Wikipedia commons CC-BY-SA-4.0).

There are a number of problems with Sternberg's idea. First, some solar system craters are very large. Several Mars craters are over 1,000 km wide, including the Hellas Crater at 2,400 km in diameter (for instance in Table II). South Pole Aitken at the South Pole of the Moon is 2,500 km in diameter. Second, there may not be enough water to form an explosion of steam. Mars has much water, but it is questionable whether the Moon, Mercury, and many other solid bodies of the Solar System have enough. Third, a huge amount of volcanic debris should circle the crater, especially from the large craters. Notice in Figure 5 that there are no volcanic rocks within or on the inside edge of the crater. There is a lack of volcanic debris surrounding it. Fourth, some craters have long debris trails that do not seem to match a maar explosion (see Figures 1, 2, 8, and 9). Fifth, many craters in the Solar System have a central peak (Figure

7) or a peak ring complex. This is as expected from an impact but not in a maar crater. Sternberg claims that off-center central peaks, some with pits on the top, are more indicative of a volcanic origin, again with no documentation. However, the central peak can be off-center because it depends upon the rebounding dynamics of the bottom of the transient crater and the lithology of the rock. The pit craters at the top of the central peak or peak ring complex can form by several mechanisms, such as explosive volatile release, central peak collapse, and drainage of subsurface melt volatiles (Peel et al., 2019). Sixth, for impacts on Earth, there are many features that seem to be only formed by impacts, such as shatter cones, high-energy planar deformation features (PDFs), and reidite/FRIGN (former reidite in granular neoblastic) zircons. Sternberg has not demonstrated that any of these features can form by volcanism.

Figure 6. The three maars at Daun, Germany (from front to rear): the Gemündener, Weinfelder, and Schalkenmehrener Maar (Martin Schildgen, Wikipedia commons CC-By-SA-3.0-mitigated).

III. WHAT GEOLOGICAL WORK DO IMPACTS ACCOMPLISH?

To better understand the effects of impacts for a Creation/Flood model, it is important to understand their geological and geophysical effects. But we must always keep in mind that there will be very few pristine impact craters since subsequent tectonic, erosional, depositional, and volcanic processes can distort, destroy, or partly destroy many impact features (Kenkmann, 2021).

It is assumed that the average velocity of impacts on Earth is about 17 km/sec, because that is what we observe now (Allen et al., 2022). But past impacts in a biblical model are not obligated to follow current average velocities, especially if the solar system ran into a swarm of impactors. In regard to the size of the final crater, a tradeoff occurs between the impactor velocity and mass. The faster the velocity, the less the mass for a given crater diameter.

A. Formation of complex craters

A simple crater is small and bowl shaped. As crater size increases, the cavity becomes a complex crater (Figure 7), the features of which are proportional to the impactor kinetic energy and the inverse of the acceleration of gravity, or 1/g. The threshold diameter between simple and complex craters for the Moon is about 20 km and for the Earth about 3 km. The atmosphere does not diminish the size of stony meteorites greater than 60 m and dense, stronger iron impactors greater than 20 m in diameter (Collins et al., 2012).

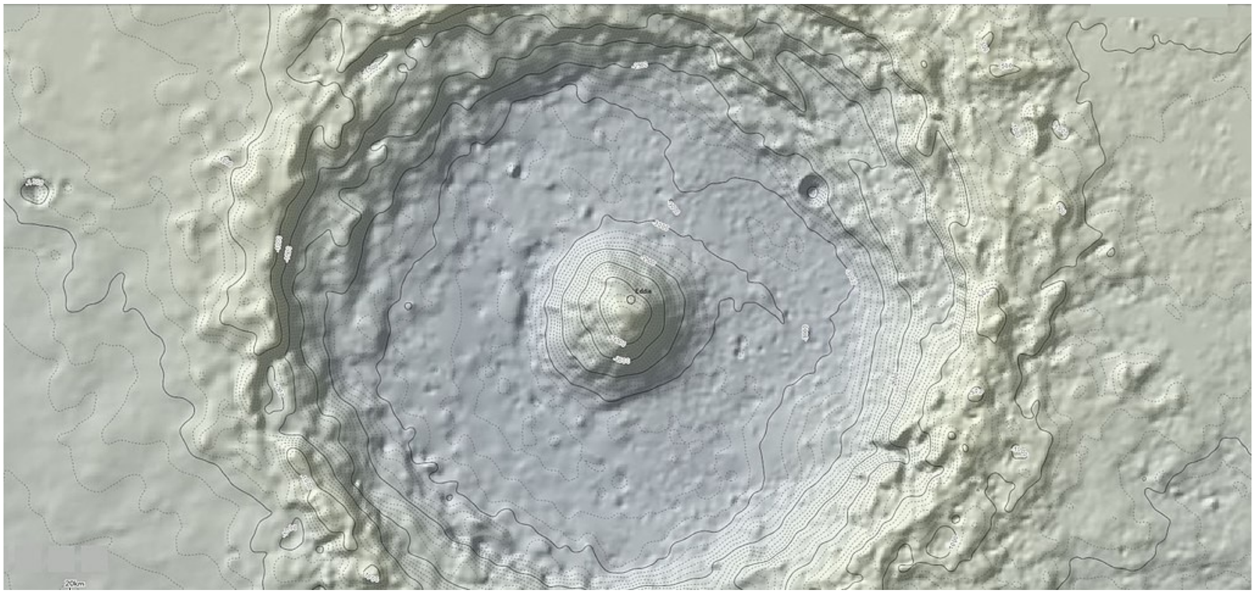

Figure 7. Eddie Crater, Mars, 89 km diameter with a central peak. The topographic map was created using Mars Orbiter Laser Altimeter (MOLA) data with a contour interval of 100 m (Mtraynier, Wikipedia commons CC-BY-SA-4.0)

B. Modification stage

After the bowl-shaped, transient crater is formed in seconds, many variables determine the final shape of the complex crater after about one hour (Oard, 2013b). Complex craters can end up with central peaks, peak rings, a slumped crater rim, or even *flat floors* (Melosh, 2011, p. 274). Usually, small complex craters have a central peak while larger complex craters have a peak ring. Larger craters especially can have a flat floor. Mangold et al. (2012, p. 4) state: “Above 100–150 km [on Mars] complex craters often do not have well-developed central peaks, due to collapse and crustal scale relaxation on impact.”

Most of the top volume of the transient crater represents rock or sediment blasted outward as impact ejecta or vapor, thinning the crust. The bottom of the cavity is displaced downward and the sides of the bowl are compressed sideways and upward, presumably by plastic flow of rock. Many variables determine the shape of the 3-dimensional, saucer-shaped final crater, such as the lithology, layering, and rock strength of the target body (Senft and Stewart, 2007), as well as the size, composition, velocity, and impact angle from the horizontal of the impactor.

After compression, the bottom of the transient crater rebounds upward. The rebounding rock acts like a fluid, but the process is not well understood (Wünnemann and Ivanov 2003; Riller et al., 2018). The center can sink and rise again one or more time. The depth at which the bottom becomes “frozen” determines the shape of the final crater. At the same time, the inner rim slumps into the crater, and the final crater diameter is usually around 60% greater than the transient crater and much shallower (Melosh, 2011, p. 226).

If the central uplift or peak ring "freezes" while rising, it produces a gravity high, such as found with lunar craters, called mascons (Wieczorek and Phillips, 1999). Since the crust is thinned and the center uplifted, impacts with central peaks or peak rings will have an uplifted Moho (Melosh and Ivanov, 1999). A negative gravity anomaly usually forms an annulus around the central peak or central peak complex because the annulus is often filled with lighter, broken up rock. Sometimes, the collapse of the dynamic central uplift was so efficient that the impact basin ended up with a negative gravity anomaly. Negative gravity anomalies are predominant within Earth impact craters (Grieve and Pilkington, 1996). Whether a crater is a mascon with a positive gravity anomaly in the center or whether the whole crater is a negative gravity anomaly depends on several variables (Searls et al., 2006). As a result, some impact structures do not have an uplifted Moho (Glikson et al., 2016b). This could be due to the relatively small size of these craters or to post-impact modification. All these modifications to the transient crater amazingly take very little time. The final crater shape is usually set within about 400 to 800 sec (Ivanov, 2005).

C. Impact melt

During an impact the lower crust and upper mantle are heated, and the impactor and some of the target rock melt. The amount of melt is usually considered proportional to the velocity and mass of the impactor, i.e. its kinetic energy (Melosh, 2011, p. 253). Small craters produce little impact melt while the larger impact craters may have considerable impact melt. For instance, a 200-km diameter crater could produce 10^4 km^3 of melt, while a 600-km diameter crater might produce 10^5 km^3 of melt (Elkins-Tanton and Hager, 2005).

D. Impacts in water

Impacts in water of course are somewhat different from those that strike land and are complicated to model. If the impact is small compared to the depth of water, there will be little cratering on the bottom (Wünnemann et al., 2007). For asteroids with diameters about the depth of the water or greater, the water will have little or no effect on the cratering process. The outward push of water will cause a mega-tsunami. The most significant effect of impacts striking water is that a fair amount of water will be blasted up into the air (Spencer, 1998). Water rushing into the cavity would tend to diminish tsunami effects, however. Furthermore, large tsunamis, say 100 m amplitude, approaching shallow water will break far offshore but still roll inland a fair distance (Korycansky and Lynett, 2005).

E. Long-term relaxation

After formation, the final crater may change shape or relax with time. Relaxation is by gravitational forces that usually cause basin uplift or isostatic rebound. Isostatic rebound can happen quickly within the uniformitarian timescale. Elkins-Tanton and Hager (2005, p. 224) state: "Alternatively, the lithosphere may rebound isostatically over approximately the next 10^4 yr, on a time scale similar to that predicted for post-glacial rebound on Earth …" Isostatic rebound can happen even more quickly, depending upon the temperature and viscosity of the lower crust and upper mantle. Secular estimates of Earth's mantle viscosity are often too low (Oard and Mogk, 2022)

F. Moon mascons should have relaxed by now

Mascons on the Moon should relax with time toward isostatic equilibrium (Hikida and Wieczorek, 2007), but the relaxation time seems to be variable. Some mascons have not relaxed at all, which presents a minor anomaly to uniformitarian solar system science in that some of these basins with mascons are considered very old, formed during the "Late Heavy Bombardment" (LHB): "The remaining enigma, then, is why Newton, Copernicus, and Ladon have retained such large amplitudes of Moho relief, as they do not appear to be the youngest" (Mohit and Phillips, 2006, p. 5). One would have thought the mascons would have relaxed by now, *if* they are that old.

IV. THE DAY 4 CRATERING HYPOTHESIS

Creation scientists do have an impact model. It is the Day 4 cratering hypothesis that places impacts into a Creation/Flood model (Faulkner 1999, 2000, 2014). This hypothesis proposes that the solar system bodies were *made* from preexisting material created on Day 1, and that during and/or soon after assembly on Day 4, relatively small objects (planetesimals) were still orbiting the solar system bodies and impacting them. The Earth was not affected since it was created *before* Day 4. Thus, the impacts on the highlands of the Moon and practically all the solid bodies of the solar system are the result of Day 4 cratering. Spencer and I had previously calculated that tens of thousands of impacts would have struck the Earth, if the Moon, our nearest neighbor, can be used as an analogue (Oard, 2009; Spencer, 2013). But the Day 4 cratering hypothesis would eliminate practically all of these.

Then a second impacting event occurred, based on the large basins on the near side of the Moon with diameters around 1,000 km that are *superimposed* on the Moon's highland craters. Faulkner ascribes this impacting event to Noah's Flood, which would fit with the confirmed impacts during the Flood (see below). He believes that the impactors affected the Earth and Moon in a matter of days, indicated by the asymmetric distribution of the large craters on the near side (Figure 8) but not the far side (figure 9) of the Moon. Otherwise, if the impacts took more than several days, they would be more randomly distributed (Samec, 2008).

Figure 8. The near side of the Moon showing the giant impact filled with black basalt lava (Gregory H. Revera, Wikipedia commons CC-BY-SA-3.0).

Figure 9. The far side of the Moon (NASA, public domain). Notice only one large crater partially filled with black basalt lave bottom left).

V. CONFIRMED IMPACTS DURING THE FLOOD

Based on the Day 4 cratering hypothesis, the Moon was impacted at the time of the Flood, and according to Faulkner, the Earth was also bombarded at the same time. How many of the confirmed 200 impacts occurred during the Flood? The number of impacts in Flood rocks depends upon the locations of the controversial pre-Flood and post-Flood boundaries. Based on 33 criteria, I have place the Flood/post-Flood boundary in the Late Cenozoic (Oard, 2016, 2017a,b, 2018, 2019b). Clarey (2017b, 2020) reinforced several of these criteria and added two additional lines of evidence.

One example of the 35 criteria is Tertiary coal. It is estimated that between 12.3% and 28.7% of coal resources are Tertiary in age (Holt, 1996). Many early Tertiary coal deposits are very thick and extensive, such as those in the Powder River Basin of northeast Wyoming and southeast Montana. Some of these coal seams are nearly pure and extend about 100 km north-south, 25 km east-west, and range up to 75 m thick (Seeland, 1993). Late Tertiary coal beds are found in several areas of the world, e.g. a Late Miocene coal with polystrate trees in Hungary (Hámor-Vidó et al., 2010), and the Miocene Latrobe coal in southeast Australia that is 100 m thick and covers about 565 km^2 (Holdgate et al., 2007). It is doubtful that post-Flood catastrophes can explain Tertiary coal; its origin must be from the Genesis Flood.

According to Schmieder and Kring (2020), about 30 impacts are less than 1.8 km in diameter and dated less than 1 Ma. Diameters and ages become more uncertain with "time" with diameters generally increasing substantially after 1 Ma. I will assume that all those less than 1 Ma are post-Flood. The Earth Impact Database records 27 confirmed Precambrian impacts dated as old as 2.4 Ga in the uniformitarian timescale (Oard, 2014a), but newer data from Schmieder and Kring (2020) list 30 Precambrian impacts. It is uncertain whether these Precambrian impacts occurred during the Genesis Flood—a question analyzed in depth below, since this question is important for the Creation/Flood model. So, of the 200 confirmed impacts, 140 Phanerozoic impacts are from the Genesis Flood. Some of these Phanerozoic impacts are significant.

VI. THE CHICXULUB IMPACT

The most significant Phanerozoic impact for a Flood model is the buried Chicxulub impact, centred on the north shore of the Yucatán Peninsula of southern Mexico (Figure 10). Clarey (2017a, 2020) is sceptical of this impact. Since the Chicxulub impact is considered the best representation of an impact (Pope et al., 2004), he is essentially challenging the legitimacy of all impacts on Earth, although he admits that some impacts likely struck Earth during the Flood. The impact is dated "very late Cretaceous," and many scientists believe it "matches" the K/Pg boundary and caused the extinction of the dinosaurs and many other creatures. Moreover, the impact could have ignited global wildfires (see below), caused impact winter for about 15 years, and shut down photosynthesis for about 2 years (Senel et al., 2023). Clarey points out the lack of some important impact diagnostic signatures; he thinks the structure could have been primarily caused by volcanism.

No impact structure is ideal, and impact and post-impact processes can mostly destroy the evidence. There is much variability with large impacts (Baker et al., 2016). A comparison of the three largest confirmed impacts, Vredefort, Sudbury, and Chicxulub, indicate many differences, despite what is believed to have been similar impactors before erosion (Grieve et al., 2008).

However, the Chicxulub impact has many favourable features that point to an impact. There is shocked quartz, suevite up to several hundred meters, coesite, a little pseudotachylyte, a small amount of melt, and a few shatter cones (Christeson et al. 2018). There is 130 m of suevite encountered in a new drill hole into what appears to be a peak ring structure (Kring et al. 2017). Suevite is broken-up rock that contains deformed melt rock clasts and glass. Coesite is a high-pressure palynomorph of quartz that requires pressures of 30–60 GPa (Grieve et al., 1996), while stishovite is an even higher pressure palynomorph of quartz. A giga Pascal (GPa) is equivalent to 10 kbar of pressure or a depth of 30 km in the earth. Pseudotachylyte is a special type of broken up rock that contains some frictional melt. It is not necessarily a result of an impact, but also can be caused by catastrophic faulting and landslides (Spray, 1995). Shatter cones (Figure 11) are cone shaped striated rocks, but the exact formation mechanism is unknown. It is believed they form at pressure of 2–10 GPa and possibly up to 30 GPa (Allen et al., 2022).

A. PDFs not necessarily from impacts

Planar deformation features (PDFs) (Figure 12) and shatter cones are considered almost the only proof of an impact by some scientists (French and Koeberl, 2010). However, Clarey (2017a) claims that PDFs can occur with non-impact features, which he believes de-emphasizes PDFs as diagnostic of impacts. It is true that volcanism, tectonics, and even lightning strikes can produce PDFs (Carter et al., 1986; Rice, 1987; Lyons et al., 1993; French and Koeberl, 2010; Glikson et al., 2016a; Melosh, 2017). But the shock pressures are low, while impact shock metamorphism shows multiple planar features from higher pressures (Grieve et al., 1996; Huffman and Reimold, 1996). The characteristics of non-impact PDFs are also different from those of impact PDFs (Hamers and Drury, 2011).

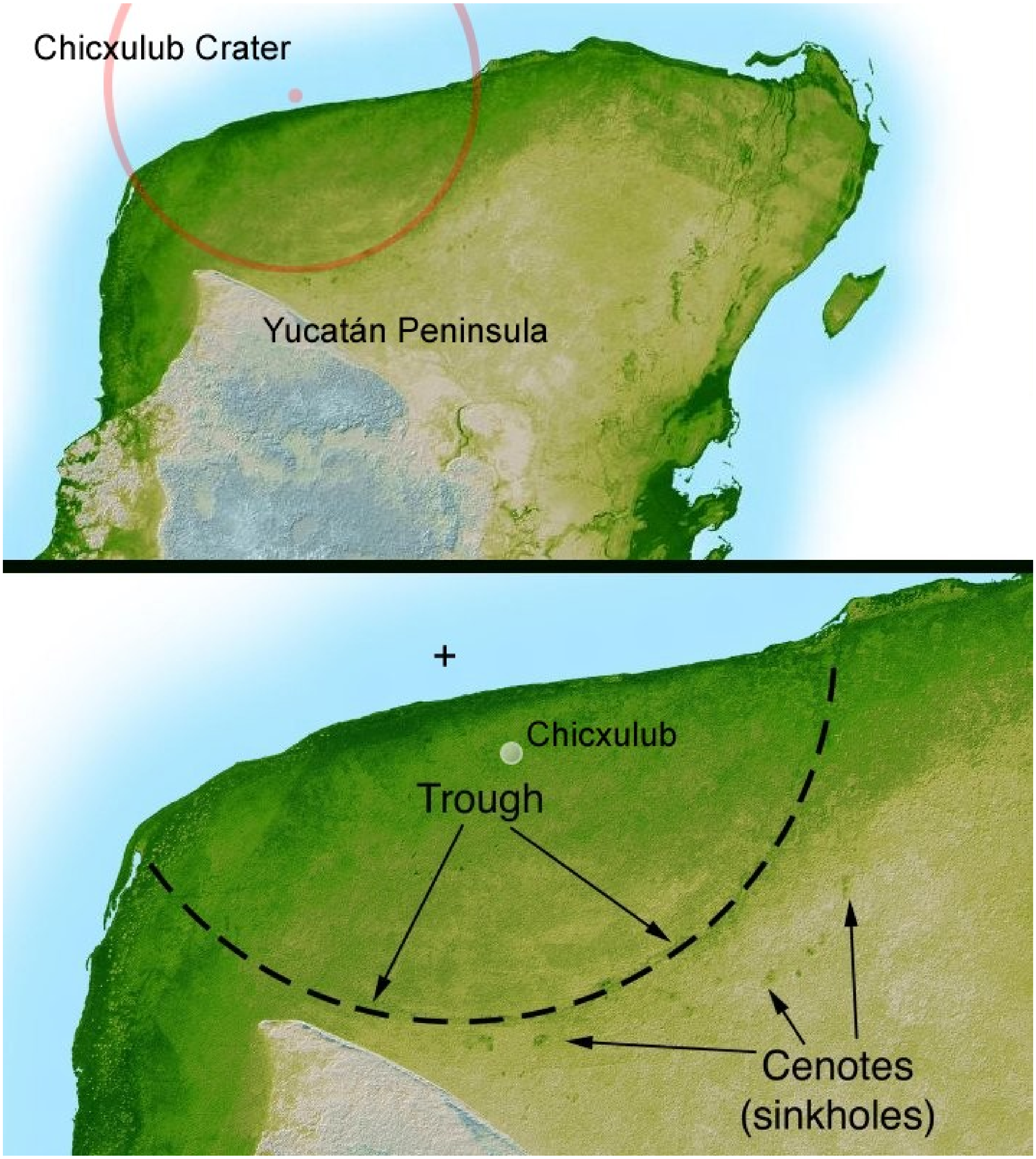

Figure 10. The Chicxulub crater on the northern Yucatán Peninsula, southern Mexico (NASA, public domain). Cenotes (sinkholes) are supposed to form near the rim.

Figure 11. Shatter cone from Steinheim impact crater, Germany (Johannes Baier, Wikipedia commons CC-BY-3.0).

Researchers have discovered that non-impact PDFs are the result of low pressure, formed from <5 or at most 10 GPa, while those >5-10 GPa are from impacts (French, 2004; French and Koeberl, 2010). A pressure of 5 GPa corresponds to the pressure of about 150 km deep in the Earth. Kenkmann et al (2014, p. 159) state: "Shock-deformation effects in minerals and rocks allow the unambiguous identification of impact craters even if the craters are morphologically degraded by erosion as there is no other natural processes capable of producing certain types of shock features." The shock pressure of the PDFs in the Chicxulub structure has been estimated at 10 to 35 GPa (Morgan et al., 2016), well above that from non-impact processes. The new drill core, M0077A, in what seems like a peak ring, has at least ~550 m of shocked granitoid rock with peak PDF pressures of 15–18 GPa (Cox et al., 2020). 99.8% of the quartz grains are shocked (Feigon et al., 2020).

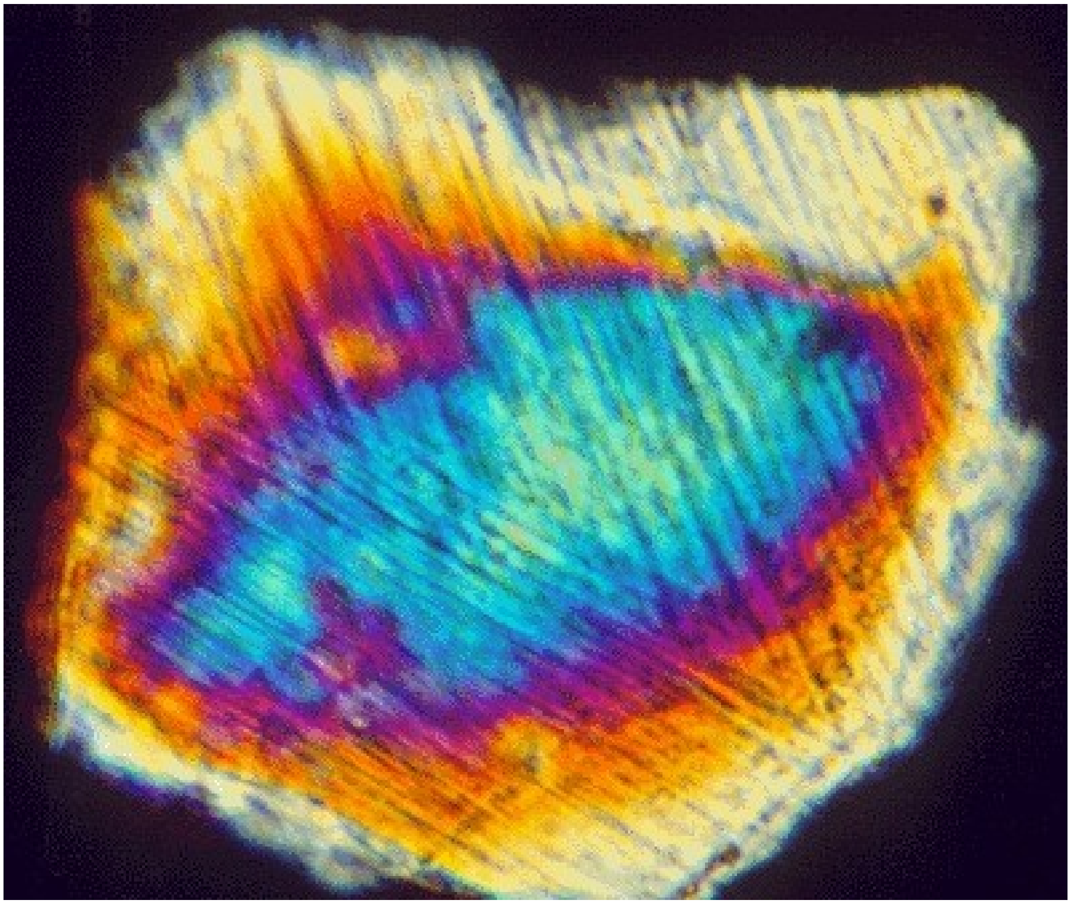
Figure 12. Sand-sized quartz grain (0.13 mm) from the USGS-NASA Langley core showing two well-developed, intersecting sets of shock lamellae produced by the late Eocene Chesapeake Bay bolide impact (Glen A. Izett, Wikipedia commons, PD USGS).

B. The discovery of reidite associated with the Chicxulub Impact

Researchers have recently found another piece of evidence of high shock pressure associated with Chicxulub that is only associated with impacts (Erickson et al., 2017; Timms et al, 2017; Cavosie et al., 2018; Cox et al. 2018; Kovaleva et al., 2019). It is reidite, which can transform into FRIGN (former reidite in granular neoblastic) zircon at temperatures greater than 1200°C. Zircon is transformed to reidite at greater than about 30 GPa, higher than any tectonic or volcanic process on earth. Reidite and FRIGN zircon have been associated with at least 10 impact structures (Plan et al., 2021) and has been associated with the M0077A borehole into the peak ring structure of the Chicxulub impact (Cox et al. 2020; Zhao et al., 2021). It is also associated with the Vredefort impact (Moser et al., 2011; Kovaleva et al., 2019).

C. Few shatter cones, but shatter cones nonetheless

Clarey (2017a) downplays shatter cones that are associated with the Chicxulub impact. There is reason to be cautious since sometimes they are misidentified, mainly with poorly developed ones, such as alleged shatter cones in Libya (Paillou et al., 2004, 2006) that are likely ventifacts caused by wind erosion (Reimold, 2007). Cone in cone structures can superficially look like shatter cones, but they are mainly composed of calcite and often found within shale with the base upward and the apex downward. They are significantly different from shatter cones. Regardless, researchers consider shatter cones as proof of an impact (Osinski and Ferrière, 2016; Lim et al., 2021). Since a few have been found at Chicxulub (Riller et al., 2018), then Chicxulub is likely an impact crater.

D. Summary

When all the impact features are found together in one place, and realizing that shatter cones and high-pressure PDFs are associated with impacts, it seems that the Chicxulub feature represents a true Flood impact. The Chicxulub impact shows impact features that are greatly modified or destroyed by subsequent geological processes. These subsequent Flood features can erode much of the evidence and distort the original impact features. However, the two main diagnostic features and many favourable features do exist, and when all of them are taken together, Chicxulub is very likely a true impact crater (Oard 2019a). It has been greatly modified by post-impact geological processes.

VII. MANY MORE IMPACTS LIKELY OCCURRED DURING THE FLOOD

Many more impacts likely occurred in the Flood than the 140 confirmed impacts, not counting the Precambrian impacts. The following will be speculative, since many of the details have not been worked out and considering that subsequent geological phenomena would mostly erase the evidence for impact craters.

Figure 13. Two splash-form tektites, molten terrestrial ejecta from a meteorite impact (Brocken Inaglory, Wikipedia commons CC-BY-SA-3.0).

A. Stringent impact confirmation criteria

One reason is that the confirmation criteria for an impact are stringent. French and Koeberl (2010) and Zhao et al. (2021) list four main diagnostic criteria for the identification of an impact: (1) shatter cones (Figure 11); (2) PDFs such as shock metamorphic features in quartz (Figure 12); (3) actual impactor evidence, such as pieces of the impactor, tektites, or spherule layers; and (4) high-pressure/high-temperature minerals, such as coesite and/or stishovite. Actual pieces of the impactor are rare. Tektites are mm- to cm-size spherules composed of black, green, brown, or gray natural glass formed from terrestrial debris ejected during meteorite impacts (Figure 13). Most of the time scientists do not know the location of the impact that caused the tektites, which can sometimes be found over wide areas called strewn fields. These four features have been used for a long time as the *only* proof of an impact. French and Koeberl (2010, p. 142) admit that extreme pressure and temperature condition for diagnostic PDFs occur in a relatively small volume near the impact point. This small area could easily be eroded and mixed with sediments, especially in a marine environment. So, PDFs may never be found with some true impacts.

B. How many possible impacts are impacts?
Over the years, many possible craters have been suggested. One of these is the 3-billion-year-old Maniitsog structure in West Greenland (Garde et al., 2012) that has since been rejected because it does not appear in the Earth Impact Database. Another is the 70 km wide Yarrabubba structure in Western Australia (Hand, 2019, Macdonald et al., 2003), which has been accepted because PDFs, shatter cones, and FRIGN zircons have been found. It is now listed in the Earth Impact Database. The age of this crater has been debated, but is now believed to be 2.2 Ga (Erickson et al., 2020; Schmieder and Kring, 2020), making it the oldest confirmed impact crater on Earth.

We would expect scientists to miss many craters because of their stringent requirements. French and Koeberl (2010, p. 142) admit that extreme pressure and temperature condition for diagnostic PDFs occur in a relatively small volume near the impact point. Lower pressure PDFs occur farther way from the impact point, but many of these would be non-diagnostic since non-impact forces can cause such PDFs. That is why there are more 'possible' and 'probable' impacts than confirmed impacts. They are sometimes identified by their arc to circular geomorphology or seismic profile in the subsurface (Glikson et al., 2016b; Rampino et al., 2017). One can understand that many craters would be missed because the four official criteria are ephemeral features. If we go by these criteria only, we would miss many impacts, especially if they are buried or hit the ocean:

> Although these criteria have been selected because they are unique physical products of bolide impact, strict adherence to these criteria means that we cannot positively identify buried astroblemes that are tomographically imaged on three-dimensional seismic data, but are undrilled (Stewart, 2003, p. 929).

Osinski and Pierazzo (2013, p. 15) agree there is a problem of missing many impacts with such stringent criteria:

> Unfortunately, this [evidence of shock metamorphism] requires investigation and preservation of suitable rocks within a suspected structure. However, this is often not possible for eroded and/or buried structures and/or structures presently in the marine environment…even though there is strong evidence for an impact origin.

However, with large circular- or arc-shaped features, we can usually eliminate practically all other such non-impact structures. French and Koeberl (2010, p. 124) recognize the importance of circular features, although they recognize that they are not 100% diagnostic: "Meteorite impacts, especially large ones, are now recognized as the causes of large circular geological structures, major crustal deformation, large volumes of igneous rocks…" So, large circular- or arc-shaped features should be considered as reasonably good evidence for impacts, with reservations (Oard, 2023b,c). We should continue to look for the more diagnostic criteria, of course.

How can we roughly estimate how many of the possible and probable candidates are true impacts? First, we need an estimate of their percentage compared to the confirmed impacts, and secondly, we must estimate how many of these possible and probable impacts are indeed impacts. The first estimate can be determined from a recent comprehensive analysis on confirmed and possible impacts on Africa. These possible impacts are still being investigated. Of course, some will be impacts and some will not. As of

2014, there were 19 confirmed impact structures and 40 proposed sites on Africa (Reimold and Koeberl, 2014). This makes the possible impacts on Africa about twice the established impacts, if all the possible impacts really are impacts, which is doubtful. The estimate of possible impacts being twice as many as the confirmed impacts is close to the estimate of SEIS (Suspected Earth Impact Sites) database, which lists over 500 confirmed, probable, and possible impacts sites (Morrow, 2006). This was at a time when there were only 174 confirmed impacts, making 326 that are probable and possible impacts, or close to double the confirmed impacts.

For the second estimate, we can only be qualitative. I consider a reasonable estimate to be *half* of the probable and possible sites as true impacts. Thus, there would be about 19 more impacts on Africa. If we apply this doubling to other continents, this would add another 140 more impacts during the Flood to those already known for a total of about 280 on the continents. However, Greenland and Antarctic have almost zero recognized impacts because of the ice sheets. However, an impact structure has recently been found in northwest Greenland under the ice (Voosen, 2018). Moreover, some continental areas are poorly represented (Reimold, 2007). The very small number of craters in East Asia is attributed to the complex geology of the area that has likely erased evidence (Lim et al., 2021).

C. Some basins are impact structures

A new continental global survey estimates that there are 764 basins on Earth (Evenick, 2021), but the survey is incomplete since they failed to include the large Belt Basin of western Montana, northern and central Idaho, extreme eastern Washington and adjacent Canada. Evenick recognized eight types of basins: forearc, backarc, strike-slip, intracratonic, rift, foreland, passive margin, and fold and thrust belt. Strike-slip, foreland, forearc, and fold and thrust basins have an obvious tectonic origin. Some of the 66 intracratonic basins, those on cratons, also called cratonic basins, have a 3-D saucer-shape. The shape of these basins could easily be an impact crater (Sears and Alt, 1992; Oard, 2013a). Braitenberg and Ebbing (2009, pp. 559–560) recognize that the origin of these basins is not understood and do not appear to be rifts:

> Large-scale basins form a separate class of basins that are less well understood and show different characteristics and are often called cratonic or intracratonic basins … This terminology reflects that their evolution is not clearly related to rifting or in general extension but that they are of a large-scale.

Even if distorted from a circular plan view, a cratonic basin can still be an impact crater that was subsequently deformed by subsequent geological processes, such as faulting. However, some of the non-cratonic basins, such as the 150 passive margin basins, 75 backarc basins, and 130 rift basins could be caused by impacts. An example of a distorted impact feature by post-impact deformation is the elliptical Sudbury structure (Jahn and Riller, 2009) (Figure 17). It is obvious that many backarc basins in the oceans are caused by extension and are not impact craters, but even some of these in the oceans could be impact craters, such as the Alboran Sea basin in the western Mediterranean Sea (Oard, 2019c,d). Even some of the “backarcs” that are continental could be impact structures, such as the South Caspian Basin and the Western and Eastern Black Sea.

Sears and Alt (1992) speculated that many, generally circular intracratonic basins are large impact craters. They once believed the roughly 400-km diameter Belt Basin was a filled impact crater (Sears and Alt, 1992). Sears later became unsure: “The [Belt] basin appears to have [sic] filled an intracontinental rift system” (Sears, 2016, p. 367), although the dimensions are basin-shaped. The Belt Basin has since been uplifted with the top eroded, as would be expected with relaxation during the crater modification stage. Otherwise, secular scientists rarely believe any of these basins are the result of impacts, probably because of preconceived ideas, since many of the basins are so large that an impact would go against their entrenched uniformitarian beliefs. Another possibility is the cratering statistics over billions of years tell them that very few large impacts should occur after the Late Heavy Bombardment.

D. Large arc-shaped features

Large circular- and arc-shaped features could be the rims or rim remnants of craters, but these have been considered insignificant by French and Koeberl (2010) and Zhao et al (2021) as diagnostic of an impact, although many scientists use circular or arc-shaped features as a possible indicator (Glikson et al., 2016b; Rocca et al., 2017). It was the circular gravity anomalies that first alerted researchers of the Chicxulub impact (Kring et al., 2004). Many of these large-circular arcs are related to basins. This lack of emphasis on morphology is because there are other mechanisms that can cause circular- to arc-shaped geological features: "Crater morphology is not a sufficient argument, because a variety of circular features can be formed by completely different geological processes (e.g. volcanism or salt diapirism)" (Ferrière and Osinski, 2013, p. 106).

Most of other mechanisms apply to *small* circular- and arc-shaped features. However, *large* arcs greater than 30 km in diameter are difficult to explain by processes other than impacts (Oard, 2023b,c): "Continental curvilinear mountain belts and metamorphic terranes are common, but their origins remain largely enigmatic, with multiple hypotheses for their mechanisms of formation" (Lamb and Mortimer, 2021, p. 56). I believe that there are other processes that cause arc shaped features, not related to impacts, for example gravity spreading, but the geological context usually tells us that these are not impact structures. When the arc has outward verging thrusts from a subsided basin, we should be suspicious that the arc-shaped features is the remnant rim of an impact. Such thrusting outward and upward is characteristic of an impact, especially if the top few kilometers were eroded. A good example is the Alboran Sea basin of the western Mediterranean Sea with the Betic and Rif Mountains forming a semicircle on its western side (Oard 2019c,d). In addition, the Alboran Sea is a strongly subsided, extensional basin filled with sediments and a possible central peak. It has a thinned crust, a raised Moho, a gravity high, and high heat flow, further supporting an impact origin. But a word of caution: Each large arc formation needs to be examined on its own merits and not simply dismissed by critics of impacts.

E. A ballpark estimate of the total number of Flood impacts

The question becomes: What percentage of the basins and large arcs were caused by impacts? How many impacts do the Archean spherules represent (see below)? There is no way to know. For a conservative estimate, I will assume that 60 of these basins and spherule layers were caused by impacts. This would bring the total up to 340 mostly continental impacts, but not including Greenland and Antarctica.

Very few craters have been spotted in ocean crust. This could be because of impactors <1km would not leave a crater in the deep ocean (French, 2004). Or it could be that that impact structures from the pre-Flood ocean were subducted down into the mantle during catastrophic plate tectonics. Or, it is a possibility that very few oceanic impacts have been detected because it would be very difficult to apply the four impact criteria. Maybe we are not looking for the right features or the structures have been covered by sediments. If the impacts struck the Earth randomly, and the proportion of oceans was the same before the Flood as after, about 71% ocean and 29% land, and if we include Antarctic and Greenland representing 10% of the land, the 340 continental impacts represent only about 25% of the earth. So, if the impactors hit randomly, we can multiply 340 by 4, which is 1,360 impacts during the Flood. From our analysis of the destruction from confirmed impacts, it is easy to understand that 1,360 impacts would easily have caused global destruction, which is why all of the impacting should be placed in the Flood (see below). French and Koeberl (2010, p. 125) mention that some researchers estimate less than 1000 impact structures that are greater than or equal to 10 km. Given that many impact structures are less than 10 km in diameter, that estimate is close to mine.

VIII. PRECAMBRIAN IMPACTS

Thirty confirmed impacts occurred during the Proterozoic (2.5 Ga–542 Ma) and new information indicates impacts even occurred in the Archean (older than 2.5 Ga) that are not included in any impact database. The two largest Proterozoic impacts are the Vredefort and Sudbury impacts. The meaning of Precambrian impacts is especially crucial for a Creation/Flood model.

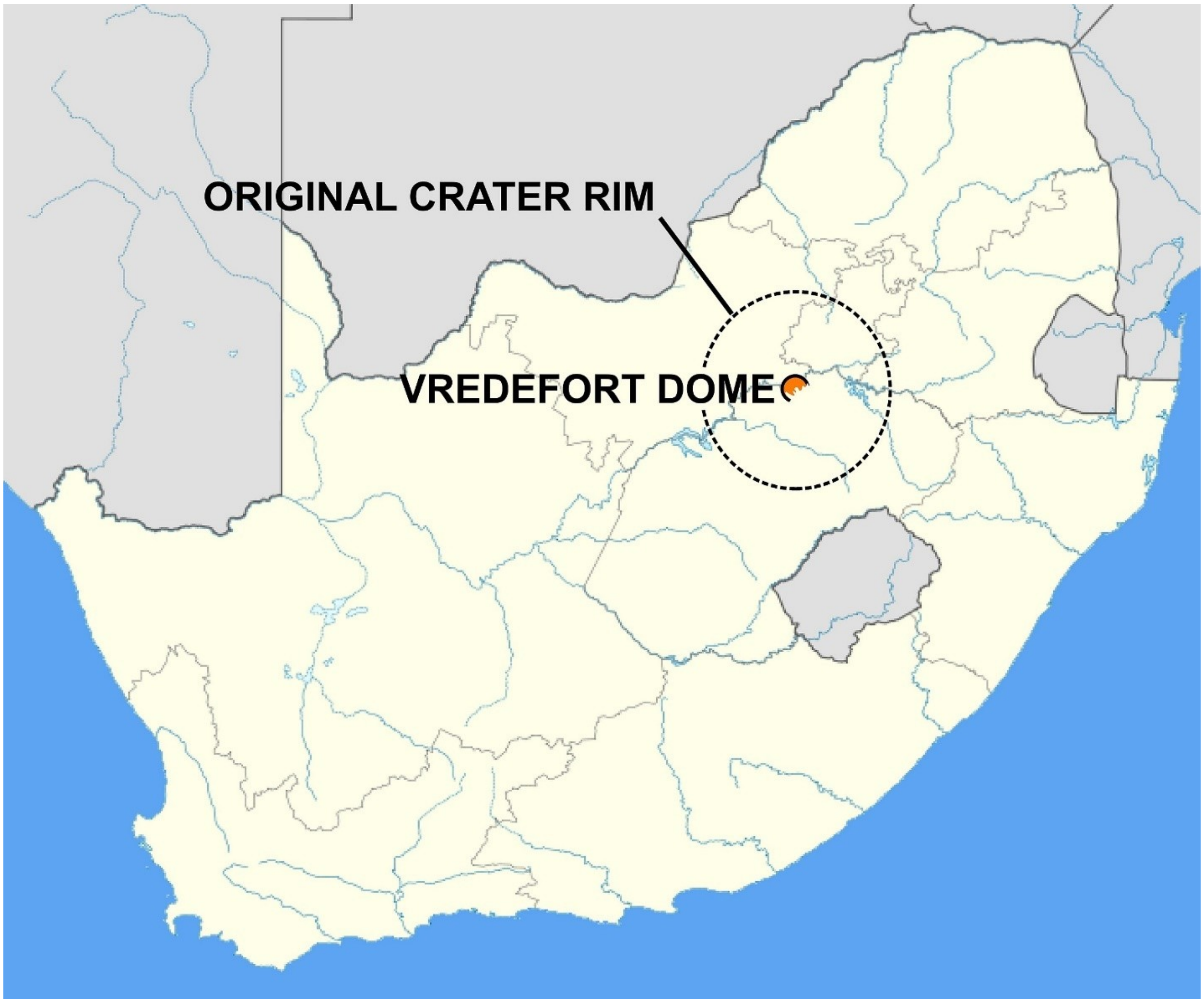

Figure 14. Map of South Africa showing the location of the Vredefort dome and the probable location of its original rim (Oggmus, Wikipedia commons CC-BY-SA-3.0).

A. The Vredefort impact

The largest recognized impact is the 2.0 Ga Vredefort impact in South Africa (Figure 14). This impact crater has only an erosional remnant of the central uplift consisting of a core of crystalline basement rocks uplifted from around 20 km surrounded by a collar of overturned strata that is 90 km in diameter (Huber et al., 2022) (Figures 15 and 16). The origin of the Vredefort impact structure, not modified by subsequent tectonics, was debated for about a hundred years with alternative mechanisms of an internal gas explosion and tectonic uplift (Colliston, 1990; Leroux et al., 1994). But now, it has been confirmed by 43 locations with striated shatter cones or fractured surfaces up to 65 km from the center (Wieland et al., 2006), FRIGN zircon (Moser et al., 2011; Kovaleva et al., 2019), micro-deformation in quartz and zircons (Allen et al., 2022), and coesite with possibly stishovite (Gibson et al., 1998). Vredefort has an uplifted Moho about 7 km higher than the general level in the area, another sign of an impact (Huber et al., 2022). No impact melt remains, except possibly for a 0.5-m-wide mafic dike (Cupelli et al., 2014) and other dikes, 10–65 m wide and up to 9 km long (Kovaleva et al., 2019) likely forced downward from the melt sheet. It is claimed that impact spherules from Karelia, Russia, 10,000 km away, are from the Vredefort impact (Huber et al., 2014), but this is speculative since it is based on radiometric dating of about the same "age" and similar platinum group elements as in the Vredefort dikes.

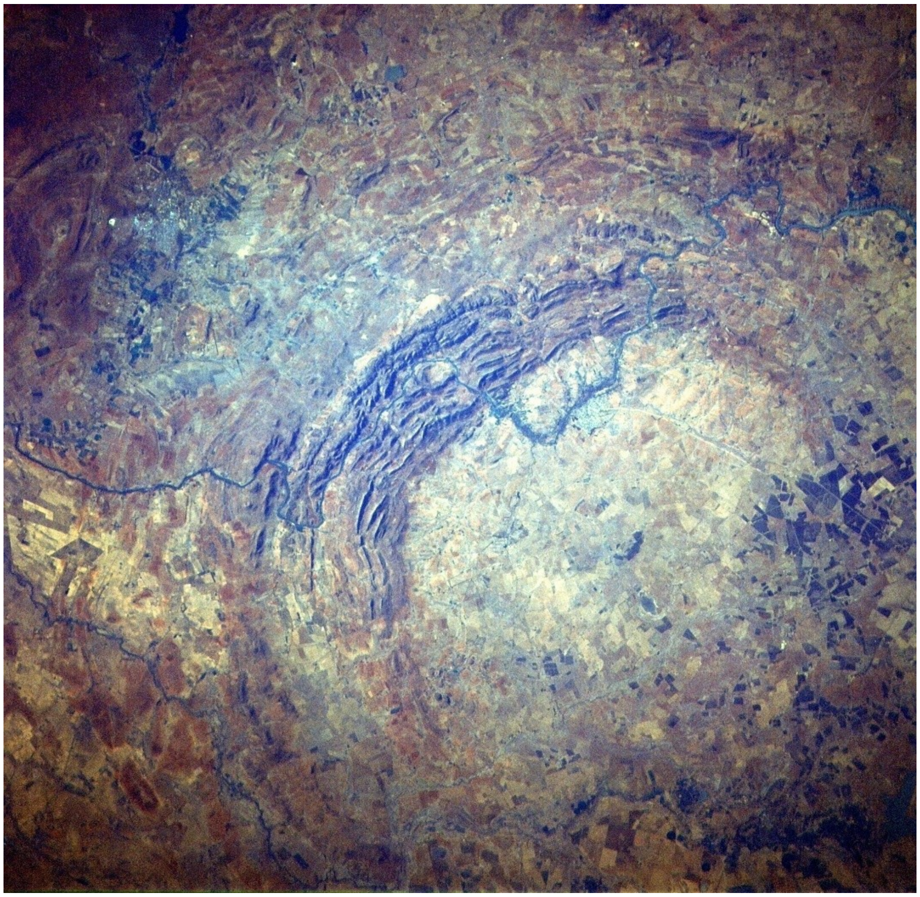

Figure 15. The upturned central portion of the Vredefort impact structure, South Africa (Júlio Reis, Wikipedia commons, PD NASA).

The Vredefort crater diameter has been estimated to range anywhere from 170–300 km or more. The diameter of an impact, especially if much eroded, is difficult to determine, which is why the diameter ranges are sometimes broad. The lower estimates are based on geophysics, computer modeling, locations from the center of various impact diagnostic features, and scaling from small impacts (Turtle and Pierazzo, 1998; Ivanov, 2005; Huber et al., 2022). However, most estimates of the diameter of the Vredefort impact have been 250–300 km in diameter, some of the latest being Manzi et al. (2019), Schmieder and Kring (2020), and Kenkmann (2021). An updated model based on newer data on the distance of impact features from the center shows that the crater diameter is about 250 km (Allen et al., 2022). Reimold and Hauser (2022, p. 1) consider 250 km diameter for Vredefort conservative.

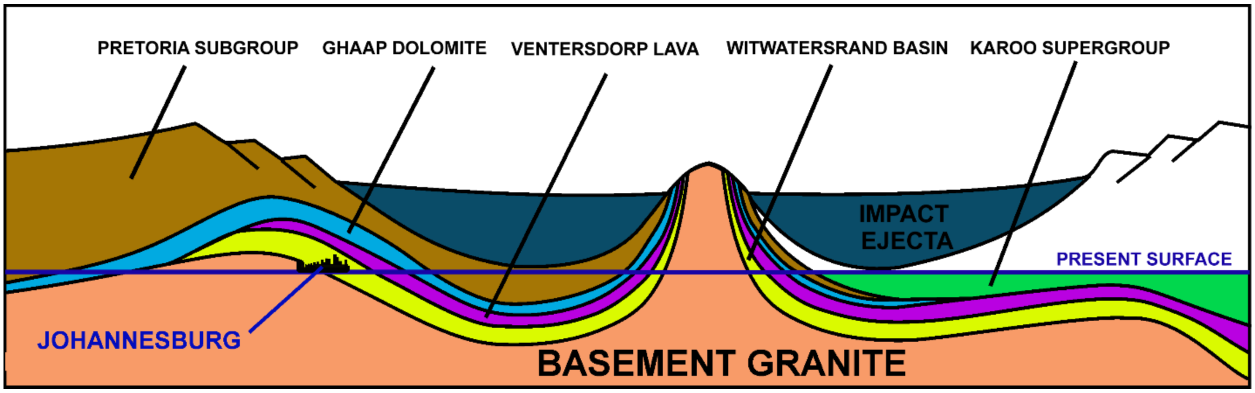

Figure 16. A schematic NE-SW cross section through the Vredefort crater showing how the underlying strata were distorted by the meteor impact, the amount of erosion, and the present surface (Oggmus, Wikipedia commons CC-BY-SA-3.0).

B. The Sudbury impact

Controversy also has surrounded the 1.85 Ma Sudbury structure in southern Ontario, Canada (Figure 17). However, numerous shatter cones and ultrahigh pressure microdiamonds are now found around the Sudbury structure (Naldrett, 2003). After much confusion, the Sudbury structure is considered a 3 km thick stratified melt sheet that differentiated during solidification (Therriault et al., 2002). The melt sheet has been deformed, likely by NW-SE shortening (Lenauer and Riller, 2012). It is considered the second largest confirmed impact, variably estimated at 130–250 km diameter with most estimates about 200-250 km in diameter (Huber et al., 2020).

C. The Vredefort and Sudbury impacts indicate massive erosion of continental shields

The reason why the uplifted central dome of Vredefort and the melt sheet of Sudbury are all that mainly remain from these impacts is likely due to great erosion of the area that erased the craters. It is estimated that 5 km of erosion occurred in the Sudbury area and 8–11 km in the Vredefort area (Senft and Stewart, 2009). This erosion emphasizes that impact structures have been variably eroded, and so just remnants are all that we should expect.

The Sudbury and Vredefort impact sites are located on the southern Canadian and the African Kaapvaal Shields, respectively, and is an indication of great erosion of these two shields, which could be applied to all shields. Five kilometers of erosion at Sudbury is similar to uniformitarian estimates of 3–11 km of erosion over the large Superior Province of the Canadian Shield (Celal Şengör et al., 2022). It is likely that the Canadian Shield is part of the early Flood Great Unconformity (McDannell and Keller, 2022). Such immense shield erosion could be the origin of much of the sedimentary rock in the Flood. Much of this erosion must have been from Precambrian basement rocks, since Paleozoic and Mesozoic erosional remnants indicate that the Phanerozoic cover was only a kilometer or two thick (Ambrose, 1964). This Phanerozoic cover was subsequently deposited after the Great Unconformity was carved, then mostly eroded, which fits well with the Recessive Stage of the Flood (Walker, 1994). But the timing of erosion of the continental shields within the Creation/Flood model is still an active area of creation research.

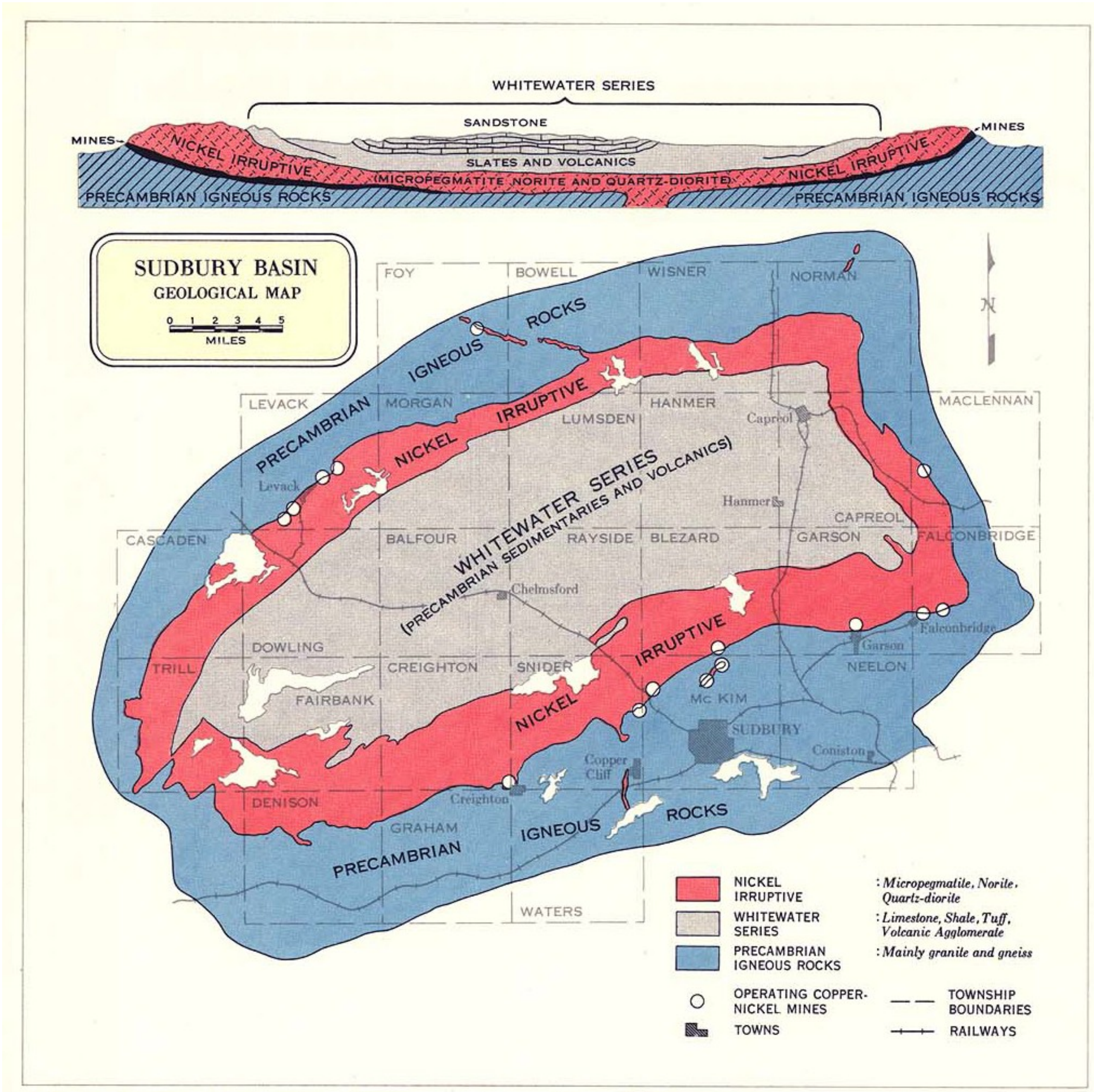

Figure 17. Geological map of Sudbury Basin (Natural Resources Canada, Wikipedia commons public domain).

D. Huge Archean impacts

Not included as confirmed impacts is the surprising and once controversial discovery of impact spherule layers in Archean (older than 2.5 Ga) sedimentary, volcanic, and volcaniclastic rocks in Western Australia and eastern South Africa (Simonson et al., 2000). The spherules are about 0.1–4 mm in diameter and form layers ranging from 0.4 to 70 cm thick. The layers are extensive, covering hundreds of kilometers (Glass and Simonson, 2012), and some claim that they can be correlated between Western Australia and South Africa, implying global events (Ozdemir et al., 2019). The rocks that contain the spherule layers are many kilometers thick. They have been dated by secular scientists to between 3.47 and 2.49 billion years (Smith et al., 2016).

Other processes can form spherules (French and Koeberl, 2010), but these Archean spherule layers also contain associated minerals or geochemical anomalies, such as high platinum group element (PGE) anomalies, indicative of impacts. Some researchers once considered these spherule layers volcanic, and the associated PGEs were thought due to hydrothermal enrichment (Keoberl et al., 1993). But impact spherules are different from volcanic-caused spherules (Simonson et al., 2004; French and Koeberl, 2010, p. 147). Shocked quartz and high-pressure rutile (TiO_2-II) has been found associated with the Western Australia spherule layers (Rasmussen and Koeberl, 2004; Smith et al., 2016), pointing to an impact origin. A more detailed analysis of two cores has shown that the PGEs are very high in the spherule layers and sometimes within the shale and chert layers between (Mohr-Weshheide et al., 2018; Ozdemir et al., 2019). Although offering strong support for an impact origin (Lowe, 2013), the exact origin of these PGEs is debated (Ozdemir et al., 2019). Chromium isotopes also confirm an impact origin for the spherules (Kyte et al., 2003; Mohr-Westheide et al., 2018). These Archean spherule layers are no longer controversial.

Frustratingly, craters have not been found for these "times," and the number of layers would suggest that large impacts occurred more quickly than the uniformitarian cratering rate would claim. However, one would expect that a crater and shocked minerals would not be found, since such features would easily be destroyed afterwards or struck the ocean—both in secular and creation science earth history.

The number of Archean impacts and their size are debated. Some count 21 spherule layers (Ozdemir et al., 2019), but some of the layers are close together and can be from the same impact, which is likely why Schmieder and Kring (2020) list 11 impacts. Other suggest between 3 and 13 impacts.

The area and thickness of the spherule layers point to large impactors, but it is unknown how large. Some scientists claim that the impacting bodies were 10–100 km in diameter (Johnson et al., 2016)! A 10 km impactor would produce a crater about 100 km in diameter. Modelling the spherule layers suggests that the impactors were ~30-70 km in diameter (O'Neill et al., 2020). Lowe et al. (2014) believe the impactors were 20–70 km in diameter, and Johnson and Melosh (2012) believe the impactors ranged from 6–73 km in diameter. Krull-Davatzes et al. (2014) calculated that one spherule bed likely represented a 30 km diameter impactor that would leave a crater 560 km in diameter. Thus impactors 10-100 km would result in gigantic craters and huge devastation on Earth. Such large Archean impacts have profound implications for the Creation/Flood model.

IX. WHAT IS THE MEANING OF PRECAMBRIAN IMPACTS?

Where do these Precambrian impacts fit within the Creation/Flood model? I will assume that uniformitarian dates for the Precambrian can be used in a relative sense, which should still be a question for future research. I will start by summarizing the likely effects of large impacts.

A. Large Precambrian impacts would likely destroy the Earth's surface

I will focus on the destruction caused by the three largest confirmed impacts, and what this information tells us. The devastation on the Earth depends upon many variables, but the devastation can be correlated to the final crater size, proportional to impact energy.

In a recent article, Rampino (2020) estimated an impact crater with a final diameter of 100 km or more would produce global effects. Craters smaller than 100 km would produce local to regional destruction. The hot air blast with very strong winds greater than 200 m/sec would devastate a large area around the blast. Wildfires would break out. The impacts that hit the oceans would cause mega-tsunamis. Rampino (2020) roughly estimated that the radius of devastation from the Chicxulub impact from a 10-km diameter impactor could be a diameter of 1,000–2,500 km or ~0.6–4% of the global surface area. Moderate devastation would cover a larger area. These figures are speculative and debated with some estimates even greater among uniformitarian scientists. Chicxulub was only one major impact among several.

Considering just the 250-km-diameter Vredefort and the 200-km-diameter Sudbury impacts, the Earth Impact Effects Program (Collins et al., 2005) calculates that, if it were an asteroid with a density of 2.8 gm/cm^3, traveling at an assumed average impact velocity of 17 km/s, and striking the Earth at an average angle of 45°, the devastation would be global in scale. For the Vredefort impact, the asteroid would be 28 km in diameter and the fireball would extend out to over 2,000 km with a maximum wind of 294 m/s at that distance. The strong winds are caused by the peak overpressure from the blast and would travel radially from the target and decrease exponentially. As the air blast spreads out, the maximum wind decreases. According to the program, it would be 89 m/sec at 4,000 km, 61 m/sec at 5,000 km, and 52 m/sec at 5,500 km away. A wind speed of 50 m/s would topple wood frame houses, severally damage any rooves, and blow down 30% of the trees (Collins et al., 2005). These winds would devastate most of the area within a circle of radius about 5,500 km, or an area of 9.5×10^7 km^2. For the Sudbury impact, the projectile would be 20 km in diameter and the max wind would be 51 m/sec at 4,000 km, devastating an area of 5.0×10^7 km^2. Since these impacts were 180° apart, the combined area devastated would be 14.5×10^7 km^2, which compares to the area of the current continents of 14.8×10^7 km^2

However, the Earth Impact Effects Program has a major flaw, and that is the blast would follow the curvature of the Earth (Collins et al., 2005). The peak overpressure would spread aloft along the line of sight because of the curvature of the Earth. Therefore, the wind would decrease much more rapidly away from the blast for the large impacts. The fireball would reach approximately the same distance. The effect of the Earth's curvature would be minor for the small to moderate sized impacts. Based on further information from Toon et al. (1997), strong winds and the fireball from Vredefort would reach only about 2,000 km and Sudbury around 1,800 km with the combined area of severe damage covering 2.28×10^7 km^2, which is only 15% of the current continental area.

But the airblast and fireball are only two effects from a large impact. The blast would send debris and vapor on ballistic trajectories over much of the Earth (Toon et al., 1997; Toon et al., 2016; Bardeen et al., 2017). The vapor would condense into spherules. The debris and spherules that failed to overcome the Earth's gravity would accelerate toward the Earth and hit the top of the atmosphere at velocities a little less than the escape velocity. Strong heating to around 1600°K would occur and radiate upward and downward. The process is complicated and controversial with several variables to consider (Belcher, 2009; Belcher et al., 2009), but it appears that the radiation would be enough to *cause global wildfires* by first igniting lichen, grass, pine needles, etc. (Goldin and Melosh, 2009; Robertson et al., 2013; Toon et al., 2016). The optical depth from the impact and wildfire soot would shroud the Earth in total darkness stopping photosynthesis. The submicron particles would cause impact winter that would last for years. Acid rain and air pollution would be intense. The ozone shield would mostly disappear.

These impact effects assumed an impact crater the size of Chicxulub, but the Vredefort and Sudbury impacts would be much stronger. It is probable that that these two impacts would destroy the surface of the pre-Flood Earth. The Archean impactors would be about the same size as Vredefort and Sudbury, or even larger. The total devastation would be even worse.

B. When did Precambrian impacts occur in the Creation/Flood model?

It behooves creation scientists to include Precambrian impacts into the Creation/Flood model. There are three possible times to place the Precambrian impacts: 1) during Creation Week (Dickens, 2018; Dickens and Snelling, 2008; Snelling, 2009, pp. 623–645), 2) between Creation Week and the Flood (Humphreys, 2014), and 3) during the Flood. Number 2 can be eliminated right away, since Precambrian impacts would likely destroy all life after Creation and before the Flood, and we know this did not happen.

Dickens and Snelling (2008) show a correlation or chronology between Creation Week events and Archean to Late Mesoproterozoic time using radiometric dates in a relative sense. The Neoproterozoic

(1,000–540 Ma) is believed to be an early Flood record. They believe the Vredefort and Sudbury impacts of the Paleoproterozoic (1,600–2,500 Ma) would have struck on Day 2 of Creation Week. The Archean impacts would occur during Day 1, according to their chronology, when the Earth was covered by waters below the expanse. The expanse was created between the waters on Day 2 with the waters below still covering Earth. So, presumably continental crust must have existed below the surface of the water, since the Vredefort and Sudbury impacts are on continental crust. Continental crust did not "appear" above the water until Day 3. There are other Mesoproterozoic impacts that would have occurred on Day 3 or after (Osinski et al., 2022), which would be locally destructive. Why would God bombard the earth with dozens of large impacts during Creation Week, even on Day 1 and 2?

It seems more reasonable to place these impacts in the early Flood, which would imply that the pre-Flood/Flood boundary is below the Precambrian sedimentary rocks and associated igneous and metamorphic rocks. These impacts would have struck Earth early in the Flood (Spencer, 1998). This deduction has tremendous implications for a Flood model. Thus, Precambrian impacts could have caused the Flood, since they have enough energy, or they can be incorporated as a sub-model within CPT, possibly causing CPT.

C. Why are there very few metazoans in the Precambrian?

However, many creation scientists have assumed the lower diluvial boundary is near the top of the Precambrian sedimentary rocks, based on the abundance of metazoans. For instance, Austin and Wise (1994) and Wise and Snelling (2005) have developed five criteria they think are diagnostic of the lower diluvial boundary near the Precambrian/Cambrian boundary. However, Froede and Oard (2007), Oard and Froede (2008), and Oard et al. (2023) found them equivocal. Dickens (2018) and Dickens and Snelling (2008) also do not think these five diagnostic criteria for a Precambrian/Cambrian lower diluvial boundary are significant, since they place the Lower Flood boundary at the Mesoproterozoic/Neoproterozoic boundary.

D. What about stromatolites?

Stromatolites are especially common in the Precambrian and take many years to grow. Then how could the Precambrian be from early in the Flood? Stromatolites are considered one proof that the Precambrian must represents Creation Week and/or pre-Flood environments because of the amount of time they represent:

> "The fact that stromatolites and these bacteria [that built the structure] are among the major fossils of the Precambrian rock record, and then are virtually absent in Phanerozoic rocks and are rare today, suggests that these stromatolites were a significant part of an important late Creation Week/pre-Flood hydrothermal biome" (Snelling, 2009, p. 634).

However, the belief that stromatolites occurred during Creation Week is also a problem, since it takes years for them to grow. For instance, abundant stromatolites occur in the early Mesoproteroozic Belt Supergroup, up to 20 km thick, in the northwest United States and adjacent Canada, including Glacier National Park (Figure 18) that would be a record of Day 3 according to Dickens and Snelling (2008).

E. Stromatolites in the rocks may be abiological

Creation scientists need to consider whether stromatolites in the sedimentary rocks may be abiological. There are many reasons for this (Table I). One main reason is that stromatolites are relatively abundant in the Cambrian and Lower Ordovician (Campbell, 1976; Reid and Browne, 1991; Druschke et al., 2009; Coulson, 2018, 2021). Coulson (2018; 2021) has analyzed stromatolites in southwest Utah that occur at 11 distinct beds within a thickness of 300 m and cover several tens of thousands of square kilometers. Practically all Flood geologists assume that the early Paleozoic was deposited in the Flood—a major problem for biological stromatolites during the Flood. Since Coulsen (2108, 2021) thinks the early Paleozoic stromatolites are biological, he places the pre-Flood/Flood boundary in the upper Paleozoic.

Figure 18. View on top of layer of dolomitic stromatolites in Glacier National Park, Montana.

1. Phanerozoic stromatolites imply much time that is not available in the Flood
2. Modern stromatolites are not analogs for those in the rocks
3. Laminations practically all within carbonates but modern stromatolites not often in carbonates
4. Laminations commonly coarse-grained today but those in the rocks fine grained
5. Modern stromatolites predominantly isolated columns but are connected in the rocks
6. Microorganisms common today but rare in rock stromatolites
7. Erosion and a rough surface of stromatolites today but little erosion of those in the rocks

8. Some stromatolites are in dolomite that requires very hot water

Table I. Reasons why stromatolites in the sedimentary rocks may be abiological.

However, stromatolites are not uncommon above the early Paleozoic within Flood sedimentary rocks. Secular researchers have claimed many stromatolites in the Triassic, believing that they had a chance to grow after the massive Upper Permian extinction, when numerous grazing animals went extinct (Perri and Tucker, 2007; Woods, 2009; Chen et al., 2014; Luo et al., 2014; Huang et al., 2022). Coulson (2021) recognizes Triassic stromatolites but believes most are only a few meters thick and occur over few stratigraphic intervals, which in itself should be a problem for the Flood.

Figure 19. Stromatolites from Shark Bay, Western Australia (Happy Little Nomad, Wikipedia commons CC-BY-SA-2.0).

Controversial claims have been made for other times in the Phanerozoic, such as the Devonian Old Red Sandstone in western Orkney Islands (Fannin, 1969) and the Navajo Sandstone in Utah (Eisenberg, 2003). Peters et al. (2017, p. 487) dispute that Phanerozoic stromatolites occur only in the aftermath of mass extinctions and show a plot of relatively abundant stromatolites in the Phanerozoic: “The aftermath of major mass extinctions are not well correlated with stromatolite resurgence.” But, if we consider the broader category of microbially induced sedimentary structures (MISS), such as structures claimed to be from biofilms, then the Phanerozoic has more MISS than the Precambrian (Davies et al., 2016). If stromatolites in the Paleozoic and Mesozoic are biological, how could the Flood be a real historical event?

A second reason why stromatolites in the rocks are likely abiological is that those in the rocks are different from the living stromatolites (Figure 19). Reid et al. (2003, p. 45) write: "Indeed, in the past decade, it has been suggested that the coarse grained shark Bay buildups [of today] are inappropriate analogs for ancient stromatolites, which are typically composed of microcrystalline carbonate (micrite)."

Figure 20. Close up of a Shark Bay stromatolite as displayed in the Museum of the Rockies, Bozeman, Montana.

The non-analogue problem is probably why researchers have difficulty defining a stromatolite. Most researchers simply assume that stromatolites in sedimentary rocks are biological and define stromatolites this way. Others contend that a non-genetic definition should be applied. I prefer the definition from Bosak et al. (2013, p. 22) of stromatolites as "attached, laminated, lithified sedimentary growth structure(s) accretionary away from a point or limited surface of initiation."

A third deductions is that stromatolite laminations in the rocks are practically always within carbonates (Schopf, 2006; Chen et al., 2014). Schopf (2006) states: "Almost all known ancient stromatolites are or were originally of calcareous composition." However, modern stromatolites bind all kinds of sediments (Schieber, 1998; Jahnert and Collins, 2012). For instance, Shark Bay stromatolites bind particles that are not carbonates.

Fourth, the laminations in the rocks are fine-grained micrite, while those today are predominantly coarse-grained (Figure 20) (Logan, 1961; Riding, 2000; Reid et al., 2003; Bosak et al., 2013). The Bahama stromatolites often bind sand-sized particles (Reid and Browne, 1991; Planavsky and Ginsburg, 2009).

Fifth, modern stromatolites are commonly isolated columns (Figures 19 and 20) (Reid and Browne, 1991. Those in the rocks are rarely isolated (Jahnert and Collins, 2012) but are commonly connected, usually by laminations.

Sixth, stromatolites in sedimentary rocks rarely preserve microorganisms or organic matter (Hofmann, 1969; Grotzinger and Rothman, 1996; Seong-Joo et al., 1999; Riding, 2000; Schopf, 2006), but microorganisms are common in stromatolites today (Jahnert and Collins, 2012). Awramik (2006, p. 700) admitted: "Only rarely are microfossils found in ancient examples, but many researchers consider stromatolites to be the products of microbe-sediment interaction, and so to be fossils." The Precambrian sometimes has abundant microfossils (Brasier et al, 2006; Tice and Lowe, 2006), so the microorganisms found associated with stromatolites may occur by chance. Schopf (2006, p. 873) writes: "Unfortunately, even this criterion [preserved microfossils or trace fossils] falls short, since the mere presence of fossilized micro-organisms within an ancient stromatolite-like structure cannot demonstrate that the structure accreted as a direct result of microbial mat-building activities."

Buick et al (1981, p. 164) reinforce this caution:

> "In particular, it is difficult to *prove* that a structure is the product of microbial activity. Even if microfossils or their traces (moulds or glide trails) are preserved with a purported organo-sedimentary structure (a rare occurrence according to Awramik, 1976), this does not prove that living microbes were responsible for sediment accretion" [emphasis and parentheses his].

Bosak et al. (2013, p. 37) also say: "That said, the incorporation of biological materials into precipitating carbonates does not in and of itself demonstrate that microbial mats templated accreting laminae."

The only organisms available in the Precambrian to bind stromatolites are blue-green algae and bacteria, since other organisms had not evolved within the evolutionary paradigm, but today the binding microorganisms are motile diatoms with mucilaginous tubes and eukaryote algae (Awramik and Riding, 1988). I wonder whether it can be shown that the former could form microbial mats and bind particles at all?

Seventh, stromatolites in rocks rarely show erosion, while modern ones show erosion and a rough surface (Cohen et al, 1997; Jahnert and Collins, 2012). Stromatolite domes within the rocks commonly branch into high relief columns, but this morphology is rare in modern stromatolites (Bosak et al., 2013; Chen et al., 2014).

Eight, some stromatolites are dolomitic (Figure 18). Primary, stoichiometric, and ordered dolomite, precipitated directly from solution, requires temperatures greater than 100°C but probably well over that temperature (Oard, 2022a,b). Even if the dolomite is caused by replacement of limestone, hot temperatures are still required. It is unlikely biological stromatolites can form under these conditions.

X. THE DAY 4 CREATION HYPOTHESIS EXTENDED TO MARS REINFORCES PRECAMBRIAN IMPACTS DURING THE FLOOD

The Day 4 crater hypothesis extended to Mars provides more evidence that Precambrian impacts occurred during the Flood. Because of a recent research project on the floods of Mars (Oard, 2023a, 2024a,b), I have accepted the Day 4 cratering hypothesis because of its cratering pattern (Figure 21) and its unusual remnant crustal magnetism (Figure 22). The magnetism consists of east-west magnetic anomalies found mainly in portions of the southern highlands. Remnant magnetism implies a strong magnetic field once existed on Mars, but how the magnetism was imprinted into the crust is enigmatic.

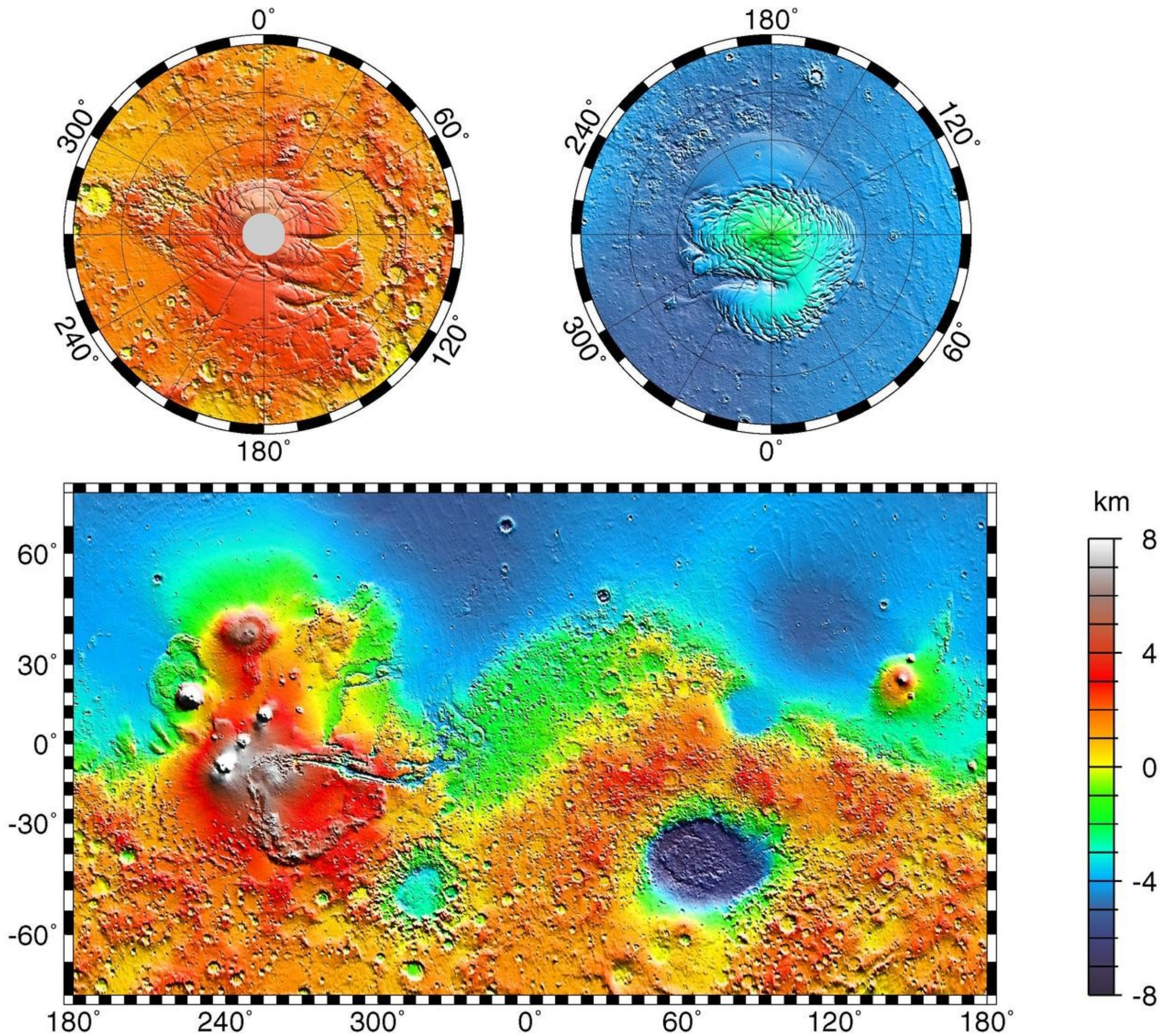

Figure 21. Map of Mars topography, including the north and south polar areas from the Mars Orbiter Laser Altimeter (MOLA) (NASA).

A. Large impacts destroy magnetism
When an impact strikes the surface, it destroys the magnetism by excavation, shock, and heating (Hood et al. 2003). The magnetic destruction depends upon the size of the crater. The large impacts will destroy all the crustal magnetism, while the small to medium ones will destroy only part of the magnetism. If the magnetic field still existed on Mars, some of the magnetism would be restored in the craters, especially within the impact melt that commonly accumulates in the center of the crater. The restored magnetism likely would be different than the large alternating anomalies found in the crust. The strength of this crater magnetism would depend upon the strength of Mars magnetism at the time.

Many of the abundant small to medium sized craters show little or no change in the intensity and polarity of the crustal magnetism, and therefore would likely have occurred on Day 4. However, some areas of Mars lack magnetism or are weakly magnetized, including the large impact basins; the large volcanic areas, such as the Tharsis rise and Elysium Mons; Valles Marineris; and much of the northern lowlands. This would mean the magnetic field had already weakened or decayed by the time these features were formed: “Magnetic disruption near large impact craters such as Hellas and Argyre establishes that magnetization came before the impacts…” (Jurdy and Stefanick 2008, p. 38).

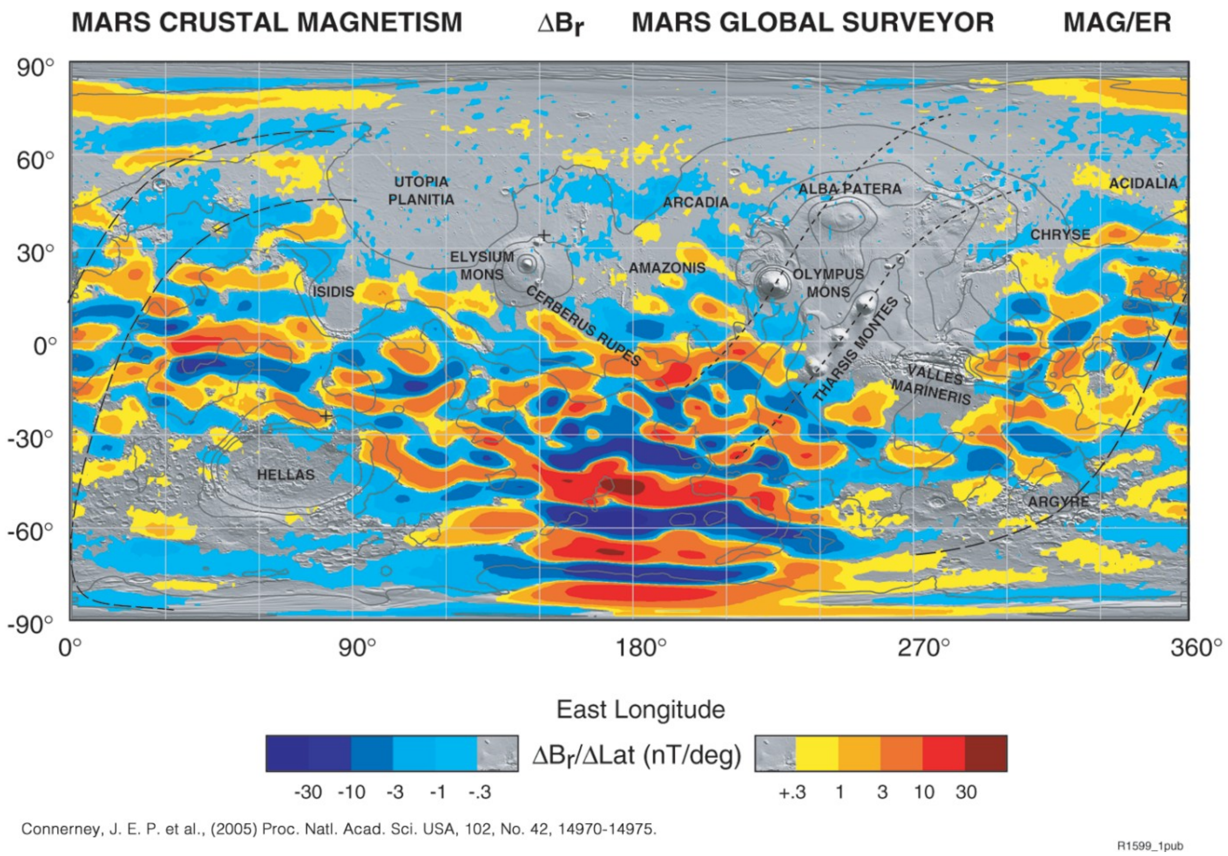

Figure 22. Map of Mars crustal magnetism (NASA). Notice that alternating positive and negative anomalies and that some areas have little or no magnetism.

Volcanic regions would also thermally demagnetize an area, but the magnetization did not recover later (Lillis et al. 2008), implying that the huge volcanism on Mars came well after Creation. If there was even a slight magnetic field after volcanism, cooling of ferromagnetic minerals in the crust would have produced a thermoremanent magnetic field (Lillis et al. 2013b). However, the magnetism associated with volcanism is too complicated and cannot be used to time the volcanism (Lillis et al., 2013a). The reason for this is that the heat of the magma would *variably* erase the original magnetic signature of the crust.

Valles Marineris occurs on the eastern side of the Tharsis volcanism and likely formed during the time of Tharsis, possibly by to radial cracking, so would not have crustal magnetism. The reason why the low northern plains are either not magnetized or weakly magnetized in some areas is unknown.

B. Impact timing based on the decay of Mars magnetic field

Within Biblical earth history, planetary magnetic fields began at Creation and were caused by circulating electrical currents in a liquid core (Humphreys and De Spain 2016). This is basic electrodynamics. However, secular scientists know such a magnetic field would decay by friction and would last only thousands of years. Because they believe that the solar system is billions of years old, they have been forced to invent a “dynamo” as the cause of the magnetism. The dynamo somehow keeps generating the electrical current in the molten core. Planetary scientists have many ideas on how the dynamo is supposed to work, but the dynamo is still hypothetical (Humphreys and De Spain 2016). The invention of a dynamo is similar to other *ad hoc* hypotheses used to account for the many contradictions in the evolutionary/uniformitarian paradigm, such as the Oort cloud for the origin of long-period comets.

Humphreys (personal communication, 2021) has calculated the half-life for the decay of Mars' magnetic field, built in at Creation, as 308 years. Using this, we can place many of the numerous small to medium sized impacts on Day 4 of Creation, when the magnetic field was very strong. The magnetism continued high after Day 4 but would gradually decay. Mars crustal depth is assumed to be 40 km (Vervelidou et al., 2017), and so impact craters greater than 300 km are expected to completely erase the magnetism. The large impacts and some small to medium impacts came later—after the magnetic field had become very weak.

Is it possible to roughly time the large impacts within the Day 4 cratering hypothesis? Figure 23 shows the decay of Mars' magnetic field with time since Creation with a half-life of 308 earth years. After four half-lives in 1232 years after Creation, the magnetic field would be 1/16 as strong; after five half-lives in 1540 years, it would be 1/32 as strong; after six half-lives at 1848 years, it would be 1/64 as strong; and after seven half-lives in 2156 years, it would be 1/128 as strong and nearly zero.

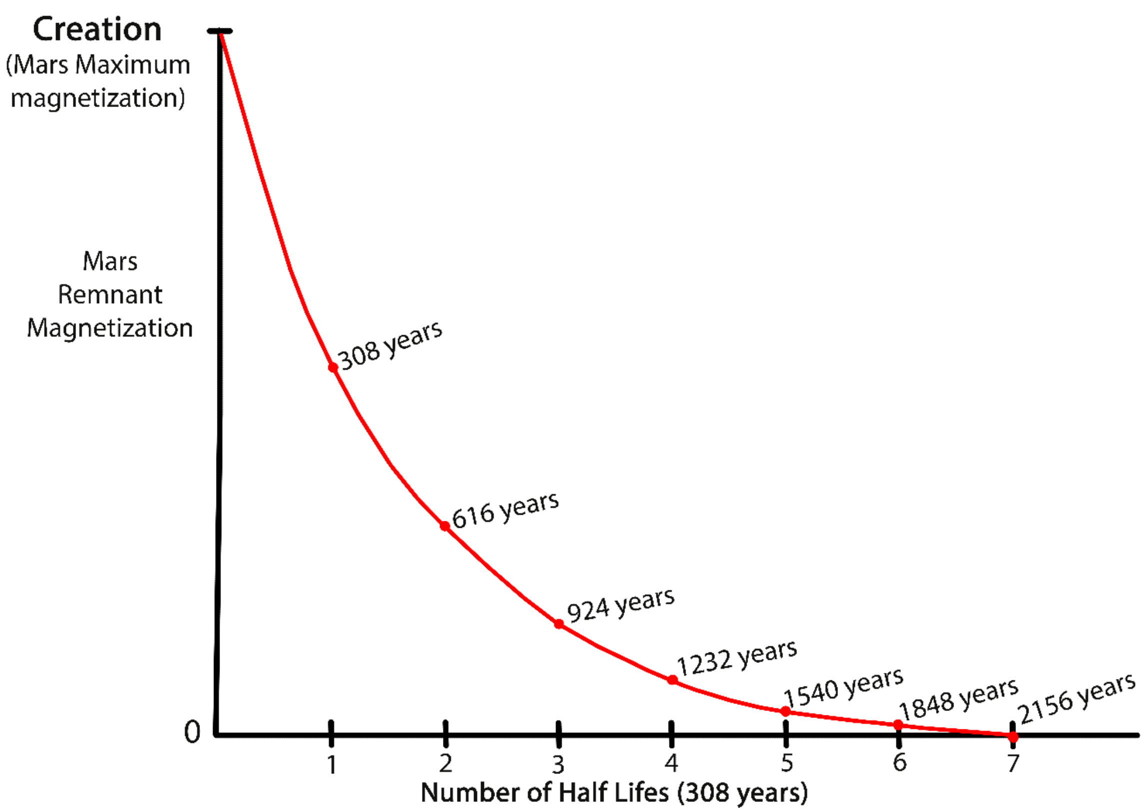

Figure 23. Decrease in Mars magnetism with a half-life of 308 years over 7 half-lives (drawn by Melanie Richard).

C. Later impacts can be timed to about the time of the Genesis Flood

Magnetism in impact craters greater than 300 km can roughly time their age with respect to the decay of the magnetic field (Lillis et al., 2013a; Vervelidou et al., 2017), since these impacts should have destroyed the crustal magnetism. But if the magnetic field still existed, magnetism should be partially reestablished, depending upon the strength of the magnetic field at the time of impact. Unfortunately, Vervelidou et al. (2017) include many craters greater than 1,000 km that have not been established. An impact origin of Chryse Planitia has been proposed, but it is still uncertain.

As it turns out, all the craters have been re-magnetized a variable amount. The four largest, recognized impact craters have very weak magnetism as shown in Table II (Vervelidou et al., 2017). The values are close to the same, indicating that they impacted Mars at about the same time. The magnetic field could have been a little higher in these large craters right after formation, since post-impact processes, such as chemical alteration, crustal thinning, and hydrothermal activity, can reduce the magnetism (Vervelidou et al., 2017). The weak magnetism from the four largest impact craters suggests that the magnetic field had not yet died out but was weak. The timing would be around 1,500–2,100 years after Creation, which is in the ballpark for the time of the Genesis Flood, 1656 years after Creation according to the Masoretic text. Some small to medium impacts would also have occurred at the same time. The Flood on Mars likely were cause by impacts and massive volcanism (Oard, 2024b).

Impact crater	Diameter of crater	Diameter of impactor	Max Magnetization A/m)
Utopia Planitia	3,400 km	>500 km	0.16
Hellas	2,400 km	~500 km	0.18
Isidis	1,500 km	300 km	0.13
Argyre	900 km	160 km	0.11

Table II. The four largest impact craters on Mars, their diameters, the assumed impactor size, and their maximum magnetization from Toon et al. (2010) and Vervelidou et al.(2017)

D. Source of impactors

Faulkner suggested that the Flood impacts resulted from a narrow, intense, swarm of asteroids, some very large, travelling on parallel paths that only impacted Earth and the Moon. But they likely also struck Mars. Since Mars and the Earth's moon are similarly cratered and are far apart from each other, a similar flux of impactors must have passed through the space between. With such a large field of impactors, it is possible that the impacts struck the entire solar system, but this is a subject for future research.

XI. COULD IMPACTS EXPLAIN THE BIBLICAL MECHANISMS OF THE FLOOD?

The two biblical mechanisms of the Flood are: "on that day all the fountains of the great deep burst forth, and the windows of heavens were opened" (Genesis 7:11). The meaning of these terms is uncertain (Boyd and Snelling, 2014). One point seems clear is that there is a grammatical period after the two mechanisms. Then verse 12 states: "And rain fell upon the earth for forty days and forty nights." It would seem that the 40 days and nights of probably continuous, global heavy rain was caused by the two mechanisms. It does not appear that the windows of heaven being opened refers to the rain itself, although the majority of commentators would connect the two.

If the "windows of heaven were opened" does not mean the rain, what does it mean? Could the phrase be describing the opening of the heavens to impactors? And as we have seen, impacts occurred during the Flood. Just because there were impacts during the Flood, does not mean that Noah's Ark was a "bunker." It is obvious that God would protect the occupants of the Ark from not only impacts (Genesis 8:1), but also from volcanoes and tsunamis in shallow water that could overturn the Ark.

During impacts on the pre-Flood ocean or on the Floodwaters, there is little doubt that a great amount of liquid water and vapor would be blasted up into the atmosphere and a little beyond: "Second, impacts into the ocean would vaporize enormous quantities of water. This would have a couple of effects, one of which could be to contribute to the intense rains of the Flood" (Spencer, 1998, p. 569). Wünnemann et al. (2007, p. 1893) state: "Another important difference between continental and oceanic impacts is the vaporization of water expanding as a vapor cloud in the upper atmosphere. Earth's climate and atmospheric circulation may be severely perturbed by the injection of a large amount of vapor …" The above statement was made assuming one impact. However, with multiple impacts occurring close together very early in the Flood, it is easy to see how a huge amount of water vapor would end up in the atmosphere. Spencer (1998), citing Croft's (1990), estimate that a 10 km impactor hitting water could vaporize 10^{15} to 10^{17} kg of water. This is close to the volume of all the water vapor in the atmosphere. Thus, numerous impacts would be expected to produce an enormous amount of water vapor and rain. This water would be spread quickly all around the earth by the upper winds and rain out *globally*. Cloud condensation nuclei would be abundant from the debris and ash that is also spread throughout the atmosphere by impacts, as well as from volcanic eruptions. The particles would not cause global cooling because of the warm oceans that soon covered the Earth. Water has a high heat capacity and would cool very slowly thereby keeping the lower atmosphere warm during the Flood. Rainfall from impacts would tend to slow up as their number decreased early in the Flood. But, it would still take many days before all of the upper atmosphere water rained out. The impact mechanism can *easily* explain 40 days and nights of heavy rain all over the Earth.

XII. WHY NOT VERY LARGE IMPACTS ON EARTH?

The Day 4 cratering hypothesis has the very large impact basins of 1,000 km and greater on the Moon and Mars as occurred during the Flood. Such large impacts do not seem to have occurred on Earth. Could the Earth have been missed by chance, or did God protect the Earth from the large impactors while allowing some of the small to medium impactors to strike the Earth, as He saw fit. We must remember that God started the Flood (Genesis 7:11), directed the Flood (Psalm 29:10), and ended the Flood (Psalm 104:6–9). Impact specialist, Wayne Spencer once wrote that God guided the impacting, and probably still does:

> "But whether we place impacts in Creation Week or at some other time, it seems inescapable that some unknown factor reduced the effects of impacts on the earth. Some sort of intelligently directed bombardment that limited objects trajectories could also be a possibility, but this is very close to Faulkner's hypothesis also. It is very difficult to imagine some natural physical effect that would so dramatically reduce the number of impacts on earth. Thus, some degree of supernatural protection of earth from impacts seems to be a necessity, regardless of when they took place. If supernatural protection of earth is a possibility, this in turn opens up the possibility of impacts in the solar system at some time prior to the Flood" (Spencer, 2014, p. 324).

XIII. FEATURES OF THE EARTH POSSIBLY EXPLAINED BY IMPACTS

Many enigmatic sedimentary rocks and features are observed on the Earth. CPT can explain some of these, but some can potentially be explained by impacts. The following are several possibilities that need future research.

A. Great deformation of Precambrian rocks

The Precambrian rocks are often highly deformed and deposited in rifts and basins, such as the North American Midcontinent Rift System (Reed, 2000). Eriksson et al. (2004, p. xviii) state: "Despite being highly deformed and metamorphosed, ancient Precambrian rocks do offer advantages." Numerous impacts would not only cause much deformation of the Earth's crust, but also would produce some igneous and metamorphic rocks.

B. Creating the Great Unconformity and other unconformities

The Great Unconformity was first defined at the bottom of the Grand Canyon between Precambrian igneous and metamorphic rocks and the Cambrian Tapeats Sandstone. Many creation scientists have assumed the Great Unconformity was carved early in the Flood. There is also another major unconformity separating Precambrian sedimentary rocks from igneous and metamorphic rocks in the bottom of the Grand Canyon (Oard, 2014b). Uniformitarians believe that unconformities take many millions of years to form by slow deformation and erosion. In the case of the Great Unconformity, there is about one billion years of time missing at the contact, but the contact is often conformable (Figure 24).

Figure 24. Conformable contact at the Great Unconformity between the Cambrian Flathead Sandstone and the Belt Supergroup, Lahood Formation, in the Bridger Mountains, northeast of Bozeman, Montana, USA (Peter Klevberg is pointing to the contact). One billion years of missing time occurs at the contact.

Uniformitarian scientists now recognize that the Great Unconformity has a wide extent over North America, as seen on top of the upper continental crust. It is essentially a huge planation surface with occasional monadnocks. It is likely that the Canadian Shield is part of the Great Unconformity (McDannell and Keller, 2022). Based on the erosion of the Sudbury impact (see above), many kilometers of rock were eroded. Then the Canadian Shield was covered by Paleozoic and Mesozoic rocks (Ambrose, 1964), which mostly eroded off during Flood recession. The Great Unconformity has been greatly uplifted or down-dropped since formation. In the northern Rocky Mountains, it is often found at the top of the mountains, i.e. flat-topped mountains of granite and/or gneiss (Figure 25). The Great Unconformity may be one continental-scale surface or a series of regional-scale unconformities. The Great Unconformity also occurs on other continents (Peters and Gaines, 2012). Impacts would be expected to cause very fast currents with enormous turbulence when they strike the pre-Flood ocean. Such currents and turbulence would also be expected to cause tremendous erosion over large areas, especially in shallow water. Multiple impacts would be a powerful mechanism for the formation of the Great Unconformity by pulverizing kilometers thick rock. The eroded sediments could be the source of sedimentary rocks on North America.

Figure 25. Close up of remnants of a mountaintop planation surface, Beartooth mountains, south central Montana and north central Wyoming. The planation surface is carved on granite and gneiss of the upper crust, faulted to different heights, and likely represents the Great Unconformity.

Impact tectonics and strong currents would also be expected to cause other unconformities during the Flood. Deformed crustal or sedimentary rocks can be rapidly planed flat by impact currents and turbulence, likely followed by further sedimentation. These angular unconformities, such as the one at Siccar Point, Scotland, was one early reason for rejecting Noah's Flood, but impacts can rapidly produce angular unconformities.

C. Mechanism for the formation of ultrahigh pressure minerals and diamonds

Uniformitarian scientists were greatly surprised by the discovery of ultrahigh pressure minerals and microdiamonds (Yan and Zhang, 2019). Ultrahigh pressure minerals, including coesite and stishovite, and microdiamonds are now found in more than 43 locations, mostly in mountains (Oard, 2021; Yan and Zhang, 2019). The uniformitarian scientists assume that continental rocks were driven around 100–400 km deep into the mantle at a subduction zone (Green, 2005). Then they were somehow rapidly exhumed to the surface. This scenario is postulated despite the fact that continental crust is not supposed to subduct, at least not until ultrahigh pressure minerals and microdiamonds were found.

It is well known that impacts can easily produce ultrahigh pressure minerals (Goresy et al., 2001). Impact diamonds, sometimes larger than 0.5 mm, are associated with some impact craters (Masaitis, 1998). These impact diamonds are likely different from diamonds originating from kimberlite pipes.

D. Generating a huge amount of sediment in the first 150 days

Numerous impacts on the earth would blast a huge amount of sediment up into the atmosphere and even beyond that would later sink into the Floodwaters. This could explain the origin of the vast amount of sediment produced during the first 150 days of the Flood, which is about 3,500–4,000 m average on all the continents (Figure 26) (Oard et al., 2023).

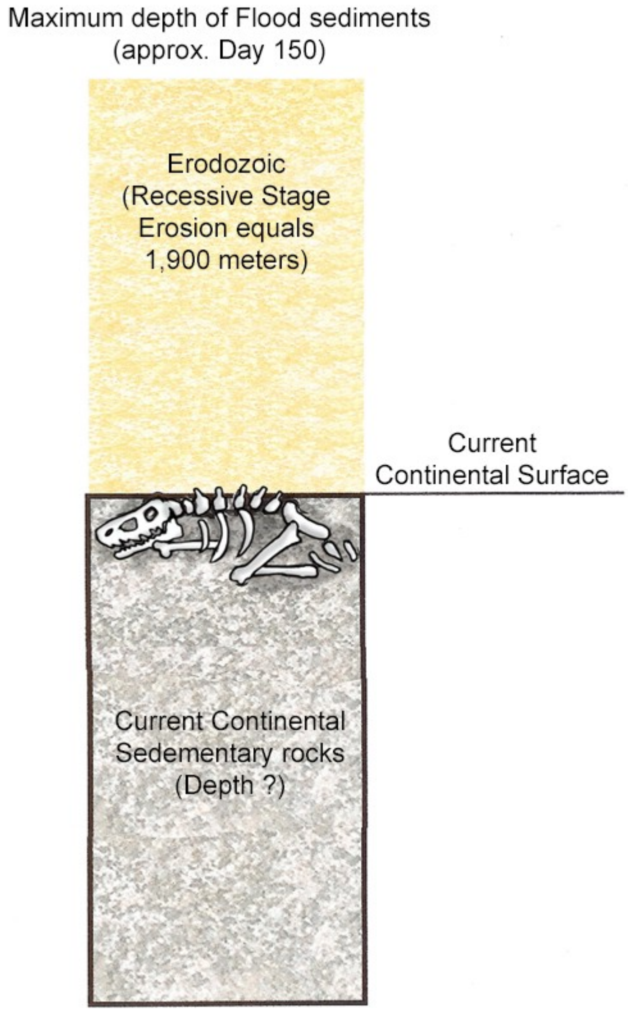

Figure 26. A block diagram representing the sediments and sedimentary rocks at Day 150 made up of the remaining continental sediments with an unknown thickness and 1900 m that has been eroded during the Recessive Stage (drawn by Melanie Richard).

E. The generation of ubiquitous fine-grained sediments

The sedimentary rocks of the earth contain roughly 20–25% sandstone; 20–25% carbonates; and 50% mudstones and shales, which are a mixture of silt and clay size particles (Boggs, 2012). Other geologists give somewhat different percentages, for instance Ilgen et al. (2017) believe that mudrocks make up about two-thirds of all sedimentary rocks. Conglomerates probably make up less than 1% of sedimentary rocks: "Conglomerates are common in stratigraphic successions of all ages but probably make up less than 1 percent by weight of the total sedimentary rock mass" (Boggs, 2012, p. 114). Carbonates are chemical sediments that came out of solution from the Floodwater. They would not be included in the inventory of siliciclastic sediments, the vast majority of which are fine grained.

Present processes of erosion produce much conglomerate, but uniformitarian scientists have millions of years to break the conglomerate down into small particles. However, creation scientists must postulate a rapid mechanism for the comminution into small particles. Although it may be possible that the CPT mechanism can generate much fine-grained sediment, I would expect more conglomerate in Flood rocks in that model.

For example, the origin of silt for siltstone and loess is much debated and not completely known, despite several possible mechanisms (Smalley et al., 2005; Soreghan et al., 2016). Silt particles are the most abundant particle size in sedimentary rocks (Wright, 2007) and glacial grinding likely is not an efficient process for forming silt (Wright, 1995). It is known that sand eroded from granite or gneiss has Moss defects and with *great energy*, the sand can be broken down into silt: "To produce silt in nature, on a large scale, very energetic processes are required" (Assallay et al., 1998, p. 61). Such comminution of rocks to fine particles of silt is more efficient and occurs rapidly when there are particles of various sizes in turbulent flow:

> "The tumbling of sand alone in water resulted in very little comminution or silt production… However, the addition of gravel-sized ceramic spheres to simulation a mixed-size sediment load in a turbulent, high-energy fluvial environment, produced rapid comminution and particle size reduction" (Wright et al., 1998, p. 25).

The silt production occurs when large particles crush the smaller particles (Smith et al., 2002). Clay can originate from the alteration of volcanic ash.

Impacts followed by very fast currents and extreme turbulence can potentially account for the production of an overwhelming abundance of silt, and do it within the short biblical time scale.

F. Accounting for the Precambrian and Paleozoic abundance of quartz arenite

Quartz arenites are believed to make up about 33% of all sandstones according to Boggs (2012, p. 111), a percentage he got from Pettijohn (1975). Quartz arenite is a bit hard to define (Garzanti et al., 2019). Some think that the amount of quartz grains needs to be greater than 90% while others believe it needs to be greater than 95% (Pettijohn, 1975). In contrast with today and the Quaternary, quartz arenites in sedimentary rocks are generally both compositionally (predominantly quartz) and texturally mature (mostly rounded). Textural maturity is caused by mechanical wear, winnowing, sorting, and rounding, and mineralogical maturity occurs when more labile minerals are broken up or dissolved and the harder, more chemically resistant minerals remain. Mineralogical maturity is a rather vague concept that expresses the ratio between relatively durable detrital grains, such as quartz, chert, zircon, tourmaline, and rutile, and other less mechanically or chemically resistant minerals, such as feldspar, amphibole, pyroxene, or olivine (Garzanti, 2017).

Quartz arenites are especially abundant in the Precambrian and Paleozoic (Dott, 2003), especially the Neoproterozoic and early Paleozoic that Dickens and Snelling (2008) identify with the early Flood. Some of them cover a large area and can be very thick, such as the 1,000-m thick Precambrian Athabaska Formation of northern Saskatchewan, Canada that covers 104,000 km^2 (Pettijohn et al., 1987, p. 179). The Thelon Formation in the northwest Territories of Canada is of similar extent. The Proterozoic Roriama Formation in Venezuela is greater than 2,500 m thick and exists as erosional remnants in the form of high plateaus. The Cambrian/Ordovician Jura Quartzite, a metamorphosed quartz arenite, is astonishingly 5,300 m thick (Soegaard et al., 1989)! A vast sheet of quartz arenite with a volume of 15 million km^3 was laid down in northern Africa from the Atlantic coast to the Persian Gulf in Cambrian/Ordovician times by paleocurrents flowing north (Avidgad et al., 2005). Quartz arenite can sometimes be thin but widespread, such as the Ordovician St. Peter Sandstone that thinly outcrops over much of the middle USA over an area of 582,750 km^2 (Hoholick et al., 1984).

Wind could be a rapid mechanism for the formation of rounded quartz gains, but wind action would not occur because of the unlikely possibility of a gigantic wind storm in the short time scale of the Flood. Whitmore et al. (2014) examining the best example of a “wind” deposited sandstone, the Coconino Sandstone, and discovered that the sand grains are not that rounded. They presented evidence that the sandstone was laid down in water. Kuenen (1959) experimented with sand in a tumbler and discovered that the action of water rounds sand very slowly. Garzanti et al. (2019) discovered that water transport northward offshore of the Namib Desert, Namibia, does not round sand. However, Kuenen’s fluviatile experiment was unnatural in some respects in that the bottom was hard concrete and not loose sand, the grains were never in suspension, and low velocities of 84 cm/sec were used that caused little saltation. The water flowing north along southwest Africa probably has weak turbulence to round grains. Folk (1951) suggests that with enough energy, rounded sand could occur. Rounding is mainly a matter of the grains hitting other grains hard enough, which occurs much more efficiently by wind than by water in *today's* environments. But if turbulence in water is greatly increased, such as would occur with meteorite impacts early in the Flood, then it is likely that rounding can occur rapidly and produce a prodigious amount of quartz arenite sand. Mineralogical maturity from the erosion of granites or gneiss can happen with impacts by heating and dissolution of the more unstable grains, leaving behind mainly quartz.

G. Banded-Iron Formations

Some of the Archean spherule layers are below banded iron formations (BIFs), suggesting a possible link with impacts (Glikson, 2006). Such field relationships at least imply that BIFs were deposited in the early Flood, possibly by the eruption of hydrothermal water during the very early Flood (Oard, 1997).

XIV. CONCLUSIONS

Impacts occurred during the Flood. The two largest impacts, the Precambrian Vredefort and Sudbury impacts, likely occurred in the early Flood and would have destroyed much of the surface of the pre-Flood continents. Large impacts also occurred during the Archean, implying that practically all, if not all, Precambrian sedimentary rocks were deposited during the early Flood. Impacts could have caused the Flood or been a secondary mechanism along with CPT. Impacts could potentially explain numerous enigmatic geological features of the Earth; seven examples were given. It is important to consider impacts and Precambrian events and sedimentary rocks within a comprehensible Flood model.

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