Catastrophic Impact Bombardment Surrounding the Genesis Flood

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ABSTRACT

Much research has taken place in recent years by both geologists and astronomers regarding impacts on Earth. This research has been motivated by the search for evidence to substantiate the hypothesis that an impact of a 10 Km diameter object 65 million years ago caused the extinction of the dinosaurs. Creationists have generally considered Noah's Flood and its aftermath an adequate explanation of the extinction of the dinosaurs, but this does not address the physical evidence of impacts on Earth. This paper points out the geological and physical evidence of impacts and treats Earth impacts as an aspect of God's judgement during the world-wide Flood event. It is suggested that impacts began with the onset of the Flood and continued during and after the Flood year. Solar system evidence suggests a catastrophic event which caused a heavy influx of dust and meteorites in a short time. A companion paper "Geophysical Effects of Impacts During the Genesis Flood" addresses climatic and other effects from an impact bombardment event and suggests that such an event would be survivable for Noah in the Ark.

INTRODUCTION

There has been great interest in the issue of Earth impacts in recent years among geologists, astronomers, and even the public. Near Earth asteroids are being studied in order to assess the hazard to Earth. The Alvarez hypothesis, that an impact near the Yucatan Peninsula led to the extinction of the dinosaurs, has been accepted in many scientific circles. Yet, little has been done by creationist scientists to address the issue of impacts from a young Earth point of view. In the past ten years, much has been learned about Earth impacts and how to identify them on Earth. The evidence of Earth impacts is quite strong for some sites and questionable for others. Much research has been done related to the hypothesis of Louis and Walter Alvarez, and others that a ten Km object struck the Earth at the time corresponding to the Cretaceous/Tertiary boundary, subsequently causing the extinction of the dinosaurs and other species. Some geologists oppose the Alvarez hypothesis and suggest that dinosaur extinctions at the end of the Cretaceous period were caused by volcanic phenomena rather than by impacts. Creationists have acknowledged that impacts have occurred. However, Creationists emphasize the Genesis world-wide Flood and its after effects in explaining extinctions such as of the dinosaurs.

The reasons for this paper and the companion paper on geophysical effects are several. First, there is a need to explain why the Earth differs from other objects in the inner solar system in having relatively few craters. Secondly, it is important to clarify what constitutes evidence of impacts. It appears today that the primary indicator of the Cretaceous/Tertiary impact suggested by the Alvarez team in 1980 is not a clear indicator of impacts at all, namely high concentrations of iridium and other metals at the K/T boundary. Since the publication of the Alvarez paper in 1980 research has identified better indicators of impact in the mineralogical characteristics of shock metamorphic minerals. Better techniques for identifying craters and crater-remnants (astroblemes) on Earth clearly show that craters occur throughout the Geologic Column. Craters are much more numerous on other solar system bodies than on Earth. Creationists have given much attention in recent years to refining models of the Noahic Flood. Impacts from space are powerful events that creationist Earth scientists cannot afford to ignore in developing Flood models. This paper will argue that a significant impact bombardment episode occurred surrounding the Noahic Flood. The Flood and post-Flood catastrophes could have wiped out evidence for many of these impacts. A period of heavy bombardment surrounding the Flood acknowledges the valid objections some scientists have raised about the impact-dinosaur extinction hypothesis and also has potential for explaining cratering evidence on Earth and in the inner solar system.

After briefly addressing the Alvarez hypothesis, some Biblical considerations will look at Earth impacts as an aspect of God's judgement during the Flood. The criteria for identifying Earth impact sites will be examined and related to common arguments for the Alvarez model from iridium abundances at the Cretaceous/Tertiary (K/T) boundary. Examples of a few crater remnants and other impact evidence will be summarized for various locations on Earth. Then evidence will be examined for a catastrophic event in the solar system, from the asteroids, cosmic dust, and cratering in the inner solar system. The second paper "Geophysical Effects of Impacts During the Genesis Flood" will argue that one large impact would be insufficient for causing global extinctions and that Noah and his family could survive a significant bombardment event during the Flood.

The Impact-Extinction Hypothesis

To Evolutionists, the extinction of the dinosaurs (and other species) has been problematic to explain. The Alvarez Hypothesis suggests that one impact event, the collision of a 10 Km diameter asteroid with Earth at around 65 million years ago, caused atmospheric and geologic effects that led to the extinction of the dinosaurs. Many evolutionists would consider this impact to mark the end of the Mesozoic era, often called the age of dinosaurs. It is further suggested that a site just off the coast of Yucatan, the Chicxulub site, is the site of this impact. Many studies have been done of the effects of a 10 Km diameter object in order to attempt to argue for the impact-extinction mechanism. The Alvarez hypothesis, first published in 1980 [3], has enjoyed widespread but not universal acceptance by the scientific community in general. This 1980 paper by Alvarez argues for impact ejecta and dust being distributed world-wide by this impact, based primarily on anomalously high concentrations of iridium and other metals found in a clay layer found at the Cretaceous/Tertiary boundary. The Alvarez team have always suggested a surface impact caused the extinctions because that type of impact ejects much greater quantities of dust into the atmosphere than is the case for a meteor or comet exploding in the atmosphere. The Alvarez paper of 1980 suggests that the ejecta put into the atmosphere from pulverized surface rock would amount to about 60 times the mass of the impacting object [3]. Before the discovery of Chicxulub, the Alvarez team suggested that multiple impacts near the K/T boundary could have been the sources of the iridium. Several criticisms have been put forward against the impact-extinction hypothesis, none of which are arguments originating from creationists [29]. (A very excellent review of the dinosaur extinction issue from a creation perspective is found in Oard [28].)

First of all it is impossible to determine, assuming the accepted dating techniques and the evolutionary geologic column, whether an impact coincides with extinctions. Extinctions are identified in time by the relationships between the fossils and the rock strata, assuming evolution. It has been said that the extinctions at the Cretaceous/Tertiary boundary actually were significant processes which required long periods of time:

> Accumulating paleontologic evidence suggests, however, that many of the extinctions at the end of Cretaceous time were not sudden, sharply defined events, but were continuous over a period of several million years [33, p. 455].

Though many small impacts from space go essentially unnoticed by most people, large impacts are relevant to questions about extinctions. A large impact is an event which is brief but very intense, much more brief than any extinction in the evolutionary view of Earth history. In the Alvarez paper of 1980, the authors point out clearly that they assumed the time for impact ejecta to remain aloft in the atmosphere would be similar to the time frame for ejecta from volcanic eruptions. Research since 1980 has shown this is very likely incorrect [44]. The severe effects of one large impact cannot last more than several months, yet the claim is made that the Chicxulub impact coincided with extinctions. It is actually a pure assumption that the two events coincided in time closely enough to be related. If the extinctions near the Cretaceous/Tertiary boundary were caused by one impact, why would the extinctions be stretched out over such a long period of time? Because of the short term nature of the effects of impacts and new challenges to the idea that one impact could cause global extinctions, in recent years some geologists have suggested there were multiple impacts near the K/T boundary [19, p. 671],[4, pp. 48-9]. There are several known impact structures near the K/T boundary other than the Chicxulub structure. The possibility of bolides has also been put forward. A bolide is an object that explodes in the atmosphere. In such events most of the energy of the impactor goes into the atmosphere rather than into affecting surface rock. A bolide, however, would only generate a very small quantity of dust ejecta compared to a surface impact. Therefore a bolide alone could not cause the extinctions in question.

Before the Chicxulub site was discovered and put forward as an impact site, the primary evidence for the Alvarez hypothesis was the abundance of the metal iridium and other metals in a layer of clay which is located at the Cretaceous/Tertiary (K/T) boundary. This clay layer was first studied for its iridium anomaly near Gubbio, Italy in 1978 [4, p. 34]. This layer is about one centimeter in thickness and lies between Cretaceous and Tertiary limestones. A similar layer of clay has been found at a number of other sites around the world which also possess an unusually large concentration of iridium (abundance peaks at about 9 parts per billion) [4, p. 35]. Because iridium and platinum are more abundant in meteoritic material than in the Earth's crust, it is argued that the iridium must come from an impact or impacts.

Some geologists have objected to impact extinction suggesting rather that the iridium abundance at the K/T boundary came from volcanic eruptions [29]. This has also been suggested by creationists, such as Oard [27, p. 12]. It has been pointed out that some of the metallic abundances at the K/T boundary, such as arsenic and antimony, do not match meteoritic material but are more like mantle material [30, p. 1163-4]. It has also been pointed out that material from volcanic eruptions in recent times have been found to be highly enriched in iridium, such as at Kilauea [30, p. 1163]. These and other chemical and isotopic analyses of the K/T boundary clay frequently do not point clearly to either meteoritic or mantle origin, but could be consistent with either source. Several researchers have found that deep sea sediments are frequently enriched in iridium compared to crustal sediments [33, p. 458], [30, p. 1162]. This could imply that the iridium could come from both impact and volcanic sources. Large impacts may also stimulate volcanism in some cases [7]. Various sedimentary and chemical processes could serve to concentrate iridium and certain other platinum group elements [33, p. 458]. All of this leads to the conclusion that the iridium abundances alone are insufficient as indicators of impacts, therefore in this paper iridium abundance will not be considered a reliable indicator of impact, since it can accompany both impacts and volcanism.

Recent research related to the Alvarez hypothesis leads to doubts about the adequacy of one impact to cause the extinction of the dinosaurs. First of all the extinction must be selective, but impacts are deadly in a manner that would not discriminate between dinosaurs and birds, or mammals. A recent report in Science expressed doubts about the asteroid extinction mechanisms:

> Ironically, as more scientists satisfy themselves that an impact did occur, other researchers have begun raising tough questions about whether that impact packed enough punch to make the dinosaurs disappear [25, p. 1518].

The impact extinction model relies on atmospheric effects, primarily darkness and cold, to cause extinctions. Other effects such as wildfires and acid rain have also been mentioned in impact extinction models. The selective nature of the K/T extinctions is a major difficulty for the idea that extinctions were caused by one impact. Though some scientists have suggested multiple impacts could cause extinctions, only a handful of known impact structures are found near the K/T boundary. Chicxulub is far larger than any of the others. The other known sites at the K/T boundary would be limited in their global climatic effects [19], [18].

The above considerations are just a brief look at the Alvarez hypothesis, but the after effects of the Noahic Flood from post-Flood catastrophes and environmental changes provides a very adequate explanation of the extinction of the dinosaurs. Post-Flood volcanism was apparently a major factor. To suggest that one impact could cause dinosaur extinctions globally seems unreasonable. In my opinion, the Chicxulub structure, which may or may not be an impact, is not necessarily related to the end of the Mesozoic era, except possibly in a local sense. This paper will address the issue of Earth impacts in the context of the world-wide Flood. The larger impacts are of more interest since smaller impacts would not have global effects lasting months. Impacts causing global effects would correspond to surface craters at least 15 to 20 Km diameter or impactor objects in the range of 1 to 5 Km diameter and larger. DeYoung and Froede [12, pp. 23, 30], Aldaney [2, pp. 11-12], [1, pp. 133-136], and Parks [31, pp. 144-146] have all suggested that impacts accompanied and perhaps even triggered the Flood in some way. These papers have validity, but some aspects of observational evidence and impact physics are addressed very little in them. The paper by Froede and DeYoung is a very valuable paper which I agree with in many respects. However, Froede and DeYoung do not discuss why shock metamorphism is evidence of impact. Also, the Froede and DeYoung paper, though it includes a graph with impacts showing impactor diameter versus time, no information is given regarding what observational evidence indicates these points represent impacts. Froede and DeYoung's graph also shows an exponential decrease in crater diameter with uniformitarian time. At least some of this decrease in size could be due to larger craters being more easily preserved through erosion processes. Parks [31] and Froede and DeYoung [12] have suggested a planet in the asteroid region exploded to cause much cratering in the inner solar system.

Because impact sites have been found in Flood sediment strata, impacts must have occurred surrounding the Flood. It is not impossible that some impacts could have occurred during the time between the Creation and the Flood, but I would assume these to be very few if any. If an impact bombardment episode began with the onset of the Flood, impacts should be found from in Precambrian rock up through the geologic column, as they are. This is not necessarily meant to imply that all Precambrian rock is necessarily pre-Flood rock, that must be evaluated for each site in question. Also, Precambrian craters known on Earth are relatively few, though they are of significant size. There is also some evidence suggesting what may be impact ejecta in rock considered about 3.4 billion years in age by uniformitarian assumptions [23], [22]. These authors argue for microspherules in South Africa being of impact origin primarily on the basis of the similarities of their composition to Carbonaceous Chondrite meteorites. I believe theological considerations tend to imply that as part of God's judgement, the impacts would begin with the onset of the Flood. Froede and DeYoung also suggest this [12]. This seems consistent with the evidence though it may not be the only possibility. My purpose here is primarily to argue that such an event occurred, not give a detailed model of how it took place.

All the inner planets have an abundance of craters, though Venus has relatively fewer since it has a young surface, resurfaced by volcanism. What if Earth received a number of impacts similar to that of the Moon and Mars? The distribution of the sizes of Earth impact structures shows a power law relationship similar to that for Mars and our Moon. The Moon, Earth, and Mars all show a relationship in which the cumulative total number of impacts is proportional to approximately the square of the diameter of the crater [20, p. 233]. This suggests Earth was struck by the same population of objects that bombarded the Moon and Mars. I would suggest tentatively that the total number of impacts would be on the order of 10 to 20 thousand for Earth, with impacts producing global effects being in the range of 40 to 100 [37]. This is only a very rough figure. Only an event of the magnitude of the world-wide Flood of Genesis could be able to wipe out evidence of so many impacts on Earth. Michael Oard summarized well the logic of an impact event surrounding the Flood:

> Impact craters are common on the inner planets and our moon, which implies that the earth probably was bombarded at some time in the past. We find very few impact craters on the surface of the earth, indicating that catastrophic meteorite bombardment would have occurred either before the Flood or during the Flood. If the pre-Flood earth was a time of climatic and geographic stability, it is doubtful that the meteorite bombardment was before the Flood. The only possibility left is that the event occurred during the Genesis Flood [27, p. 12].

Biblical Considerations

An impact bombardment event during or surrounding the Genesis Flood can be considered an aspect of God's judgement. This seems consistent with end times events described in prophetic passages. It is obvious that impacts are not mentioned in the Bible in relation to the Flood. But it apparently was not God's purpose for Scripture to reveal to us all the mechanics of how the Flood took place. The absence of mention of impacts in Genesis does not rule out the possibility that they occurred. However, the effects of an impact bombardment event need to be considered very carefully in relation to the sequence of events in the Flood account [37]. This paper will look briefly at how the Bible seems to allow for an impact bombardment event of some kind, as long as it does not conflict with specifics of the Genesis Flood account.

It is important to clarify at this point that Scripture must be given preeminence in authority over scientific models. If a scientific model seems well supported and very plausible it is still out of the question if it clearly conflicts with the Bible. Many scientists have made the mistake of allowing their view of science to determine how Scripture is interpreted. This is a serious mistake. Science can clarify the nature of certain events the Bible describes, but science cannot determine how Scripture is to be interpreted. So, Scripture must not be distorted in order to assemble a scientific model. On the other hand, there is a need to think creatively in order to allow the creationist view of science to be refined. The relationship between biblical and scientific considerations has been clarified very well by Reed and Froede [34].

The Bible seems to mention impacts during certain end times judgement events, especially in Revelation chapters 8 and 9. Revelation 8:8 says "something like a huge mountain, all ablaze, was thrown into the sea (NIV)." It goes on to state, "a great star, blazing like a torch, fell from the sky on a third of the rivers...the name of the star is Wormwood (Revelation 8:10-11)." Revelation 9:1 also mentions a star falling from the sky, which could possibly refer to an impact which may be accompanied by both natural and supernatural effects. In Matthew 24:29 Christ refers to passages in Isaiah 13 and Isaiah 34 which say that the Sun and Moon will be darkened and that "the stars will fall from the sky." Ezekiel 32:7-8 also says, "I will cover the Sun with a cloud, and the moon will not give its light." Though we cannot be sure, it seems plausible that these verses could refer to a solar system catastrophe in the future that causes objects to collide with Earth. These events in Revelation are not purely natural events in a sense because they are miraculously timed to take place according to God's specific judgement timetable. If these are descriptions of impacts, they are impacts that have been deliberately arranged to carry out God's purposes of judgement. The impacts that seem to be described in Revelation 8 are only one relatively small aspect of the entire complex of judgement events described in Revelation. In relation to the rest of God's judgement activity, these impacts are only a minor part of what takes place, though they will be major catastrophes that cause many deaths and much devastation. Like the cases mentioned in Revelation, I believe impacts during the Flood could represent divinely arranged events, appointed to be part of His judgement on the violent world in the time of Noah. This paper is proposing that impacts accompanied the Flood, not that they represent a natural cause of the Flood per se. However, they could trigger some of the Flood's processes. In my opinion, it is not necessary or appropriate to insist on finding a natural explanation for every aspect of the Flood.

Such an impact event during the Flood might be objected to on the grounds that we have no historical accounts or legends of such an event, though there are many ancient legends of a great Flood from different parts of the Earth. There is no compelling reason to expect that an impact bombardment would be described in the Bible. First of all, many details of the experiences of Noah and his family are simply not included in the Bible, so Noah could have seen things that are not in Genesis. Further, if an impact bombardment occurred beginning with the onset of the Flood, the witnesses of the event would all be killed. After the Flood, there were few people present to see such events. We do not have actual descriptions of many geologic processes associated with the Flood, though as creationists we believe in them because they are reasonable inferences based on Scripture and science. It is appropriate to engage in this kind of "model building," so long as we understand that Scripture is much more certain than scientific models. And so, it is very possible that we just do not have any descriptions of it.

Evidence on Earth for Impacts

In approximately the past 15 years a great deal has been learned about impacts on Earth. Craters are plentiful on our Moon and on other solar system bodies but not on Earth. Craters have not been well preserved on Earth due to the many tectonic, sedimentary, and volcanic processes which have destroyed or buried them. How are impacts to be identified on Earth when craters are not often preserved? The following geological features are indicators of impacts from extraterrestrial objects: 1) shock metamorphic minerals, 2) shatter cones, 3) crater or ring structure in the rock strata, 4) shattered rock breccia, 5) melt glasses, 6) meteorites, 7) tektites, 8) magnetic and gravity anomalies that correspond with crater structures and fracture patterns.

The most conclusive indicator of impact is the presence of shock metamorphosed material, either in the form of rock breccia, loose rock, or small tektite spherules. The very extreme pressures and temperatures of an impact cause atomic rearrangement within the rock crystal structure. Melting and instantaneous recrystallization occurs along certain planes in the crystals. The effect produces what is known as shock lamellae, which are fracture lines forming a "V"-shape in the rock. Impact shock causes these lines to exist in very regular crossing parallel sets. Another effect can be observed in X-ray diffraction patterns of the crystals. Whereas a normal quartz crystal, for instance, would exhibit clear discrete spots where the diffraction maxima occur, shocked quartz will exhibit streaked maxima rather than clear points of light [6, p. 708]. The lamellae lines can be seen by looking at a microscope thin section of the rock. Shock pressures are measured in Gigapascals (GPa); one Gigapascal is equivalent to nearly ten million atmospheres of pressure. Planar fractures and shock lamellae begin forming in quartz at a threshold pressure of about 5 GPa. In the range of 15-40 GPa quartz is converted to the mineral stishovite. In the range of 30 to 50 GPa, quartz and stishovite can be converted to coesite. Glassy material can be produced from about 30 GPa and melting occurs over 40 Gpa [10, p. 122]. Volcanic explosions, in contrast, only produce pressures on the order of hundreds of atmospheres, rather than millions [8]. Shock lamellae can also be found in rocks of volcanic origin, but the stress lines will not exhibit such a regular intersecting parallel pattern as is the case for impact lamellae [4, pp. 51], [17, p. 70].

The same intersecting pattern of lines like the tiny lamellae can be macroscopic in the right conditions, in the form of shatter cones. Shatter cones are a macroscopic manifestation of shock metamorphism. Shatter cones are conclusive evidence of impact since no other natural process but impact can generate the rapidly applied high pressures necessary to form them. Striking a shatter cone with a hammer causes the object to break into a number of smaller shatter cones, showing that the stress on the rock forms interlacing cones throughout its interior [8, p. 53]. If the shatter cones at a crater site were undisturbed, their points would point toward the center of the crater.

Other indicators of impact may not be unequivocal evidence when found alone, but can argue strongly for an impact origin if found in combination. This would apply to rock breccia, circular or elliptical uplifted ring structures, circular fracture patterns, magnetic anomalies, and gravity anomalies. The key question for these features is do they correspond to the kind of structure observed in known well preserved craters. Rock breccia and possibly melt glasses form a lens shaped structure that forms the floor of a large crater. Unusual forms of glass form in the crater floors of large impact structures, called diaplectic glasses.

Craters are of two broad types, simple and complex. Simple craters exhibit a bowl structure, with no central uplift. Complex craters may or may not have multiple ring structures and always have a central uplift structure. Every crater has a primary ring and complex craters may have other rings, which form shortly after the impact. The central uplift also forms after the impact as part of the process of stresses being relieved after the impact. Some sites may have formed multiple rings, possibly including Chicxulub, but on Earth the outer rings are usually not well preserved and may be difficult to identify.

One argument for the impact origin of the Cretaceous/Tertiary boundary clay is the presence of sand-sized spherules in this layer in sites all around the world in the locations where this layer has been studied [4, p. 42]. The size of the ejecta particles and their distance from the crater can allow estimates of the energy of the event. Many geologists would consider it impossible for volcanism to propel particles that large all over the world. The sizes of ejecta particles can be an important characteristic distinguishing between an impact origin and a volcanic origin. Volcanic explosions do not have nearly the energy of impact explosions and volcanic explosions are not able to loft larger particles as far or as high in the atmosphere as impacts are capable of.

Ejecta of special interest are tektites and microtektites. These are very small glassy objects (microtektites being less than 1 mm in diameter) that are found in certain areas known as strewn fields, including in sea floor sediments. Tektites have been melted and re-solidified; they are usually spherical, ovoid, or tear drop in shape since they solidified in air. Tektites are often found near craters. There are tektites which could be volcanic in origin, but these objects are usually distinguished by the presence of water or gases which are never found in impact tektites. Volatile material has been removed from impact tektites, and there can be other compositional differences as compared to volcanic tektites [23, pp. 960-1]. It is important that the volcanic origin be ruled out first before confidently labeling a particular site as of impact origin.

Earth Impacts in the Geologic Column

Recent years have brought forth a great deal of geological research into Earth impacts. Of the eight types of indicators of impact listed above there are a significant number of sites throughout the world where several are present. Geological literature will commonly suggest that there are 120 or more Earth impact sites [17, p. 66]. The following table (Table 1) shows that Earth impact sites are found throughout the geologic column. Data for this table comes from two different sources. The first is a list of 88 sites from Richard Grieve, published in 1982 [18, pp. 27-8]. This list from Grieve is taken from a table of sites considered “probable impacts.” All of these sites show evidence of shock metamorphism and Grieve ranks them in their state of preservation of the crater structure. Some sites have been omitted from Grieve’s published list due to incomplete information. The second is a list from O. Richard Norton, who has assembled a very conservative list of 60 sites which are probable impact structures, published in 1994 [26, pp. 413-415]. Norton gives some information on the type of evidence of impact for each site, generally corresponding to the eight indicators above except that gravity and magnetic anomalies are not considered. Norton’s list did not include the Chicxulub site in Yucatan; this site has been added to the Mesozoic category. Eleven sites in Norton’s list lacked complete information, primarily on the estimated age. These eleven sites were omitted, giving a total of 50 sites considered. Norton’s list is a very small sample but it consists of points that I believe we can have a high degree of confidence of their impact origin, with the possible exception of Chicxulub.

Geologic Column Label	**Evolutionary Age (Ma)**	**No. of Astroblemes, Grieve-88 sites**	**No. of Astroblemes, Norton-50 sites**
Recent	< 1	5	7
Upper Cenozoic	1 - 5	7	3
Lower Cenozoic	5 - 65	14	7
Mesozoic	65 - 100	11	3
Upper Paleozoic	100 - 300	27	15
Lower Paleozoic	300 - 600	20	12
Precambrian	> 600	4	3

Table 1 Earth astroblemes in relation to the Geologic Column. Ages are in millions of years before present, by evolutionary age estimates. Data from Grieve [18] and Norton [26].

These crater data sets should only be considered small representative samples. Solar system evidence of impacts would imply numbers of impacts on Earth of possibly ten thousand or more. The important question is what has happened to thousands of Earth impacts? Astroblemes occur on Earth in all types of rock. Since many impacts occur in sedimentary rock that would be considered by creationist geologists to be deposited by the Flood, it logically follows that impacts were occurring after these depositional events. Erosional and tectonic processes during and after the Flood could have destroyed evidence for many impacts. Table 1 shows the largest number of craters in the Upper Paleozoic category.

A few Earth impact sites and evidence of their extraterrestrial origin will now be considered, merely as representative examples. First is the case of the Chicxulub site off the coast of Yucatan. This site is considered the best candidate for a K/T dinosaur extinction-causing impact because of its assumed age of 65 million years and its size being appropriate to fit the Alvarez hypothesis. Actually, the Alvarez hypothesis does not necessarily hinge on the Chicxulub site being of impact origin, but there is now a great weight of opinion in favor of it. The Chicxulub site was included in Table 1 in the Norton data primarily to show that it makes no difference in the conclusions of this paper. If the Chicxulub site were found not to be of impact origin, but of volcanic origin as some argue, this leaves the Alvarez hypothesis without a single adequate impact site. Without the Chicxulub site, the Alvarez team might be forced to advocate that there were a few smaller impacts occurring around the world at the end of the cretaceous period, rather than one as large as Chicxulub.

Actual evidence for the impact versus volcanic origin of the Chicxulub structure in Yucatan is controversial. The Chicxulub site does not possess evidence as clear as many other impact sites on Earth. The Mexican Oil Company Pemex sponsored much of the actual field work on the site in the 1960's. First, there are concentric circular magnetic anomalies that match with a ring of fault structures in the cretaceous limestone. The site is at a depth of approximately 400 meters below the sea floor, and is a circular structure about 200 Km in diameter, about half under the ocean and half under the continent. A boulder bed found in Cuba and another layer of material found in Haiti have been said to be impact ejecta. There have also been core samples drilled at around the center of the Chicxulub structure, where shocked and melted rock should be present if it is an impact. The drill cores have been purported to contain shocked quartz, but some drill cores have been lost and some scientists dispute the drill core evidence and claim it is of volcanic origin. It is very possible the Chicxulub structure could be of volcanic origin. Meyerhoff, Lyons, and Officer [24, p. 4] claim that the drill cores of the site showed lamellae that were irregular such as volcanic or tectonic lamellae and not like the regular parallel arrangement of impact lamellae. Also, they report that the melt sampled in the cores was not of chemically homogeneous composition as should be the case for impact melt sheets. Meyerhoff was directly involved in the work with the drill cores. Other considerations are from seismic and stratigraphic studies which appear to indicate a structure fitting the complex crater type, with a central uplift. The circular structures and magnetic anomalies are not as clear an indicator of impact as the presence of shock minerals, so the origin of the Chicxulub structure is still an open question. From a creationist point of view, there is no compelling motivation to treat the Chicxulub site as an impact site, since as creationists we do not need an impact or impacts to explain the disappearance of the dinosaurs.

Another possible impact structure near the Cretaceous/Tertiary boundary is found just off the coast of Virginia in Chesapeake Bay. Some controversy has surrounded this site regarding its origin but recent research seems to point more clearly to an impact origin [32]. The Chesapeake Bay site would be the largest known impact structure in the United States. The site began to be considered as impact related from studies of the breccia deposits in and around it, known as the Exmore boulder bed. Recent U.S. Geological Survey seismic reflection studies have very likely detected a two-ringed complex crater structure. Some important areas of the center of the structure had not yet been drilled for core samples as of the writing of the above paper, but even so, several clues point to impact. The central peak-ring structure is about 25 Km in diameter and is surrounded by a 30 Km wide annular trough. The annular trough is bounded by a terraced effect from concentric normal faults. Lightly shocked quartz grains and impact glass has been found in the trough area as well. The outer rim is estimated to have been 85 Km in diameter. In this Chesapeake bay location, Cretaceous rock overlies Paleozoic and Precambrian rock. The impact structure cuts through 650 meters of strata, mostly Cretaceous but reaching up to upper Eocene strata at the surface. The structure penetrates over a kilometer into basement Paleozoic and Precambrian rocks [32, p. 692]. The Chesapeake structure is very similar in many respects to the Ries Crater in Germany, which is somewhat smaller. One important conclusion from this site is that the Cretaceous and Eocene strata must have been laid down before the impact. This would imply that the impact occurred either during or after the Flood.

This paper and the second paper examine the possibility that the impact bombardment began at the onset of the Flood, and that this triggered some of the tectonics associated with the Flood. The possibility of a relationship between impacts and tectonics has been discussed by M. Fischer [11]. If the bombardment episode began with the Flood, we would expect to find some evidence of large impacts in Precambrian and Paleozoic strata. We would not expect to find large numbers of craters of Precambrian age, due to the destructive nature of the Flood. But a number of Precambrian astroblemes are known, mainly in Australia and Canada. Also, tektites could exist where craters no longer exist. Following is an example indicating an Earth impact from Precambrian strata, which I assume would be antediluvian rock or rock laid down early in the Flood event. First, the Sudbury structure (Canada), then tektite evidence.

The Sudbury structure is found in Ontario in very extensive layers of igneous and metamorphic rock known as the Sudbury Igneous Complex, which are over 2.5 Km in thickness. Radiometric dates place the age of the area at 1.85 Billion years. The structure has been highly modified after the collision by sedimentary processes. The original Sudbury crater would have been approximately 220 Km in diameter. Evidence of impact includes shatter cones and shocked quartz [42, p. 306]. The stratigraphy of the impact site includes very thick clast-free melt layers which are consistent with melted material in a crater floor. There are also some layers with very large clasts, up to 100 meters in size [42, p. 308]. During the impact event material flows outward and then back inward as the outer rim undergoes collapse and slumping. In addition to the usual collapse moving material inward to fill the crater floor with brecciated rock, sedimentary processes deposited other material in the crater and eroded away some of the rim. A variety of sedimentary and metamorphic processes are indicated after the impact by the stratigraphy of the site. These include post-impact formation of 600 m of shales and siltstones, 850 m believed to be turbidite deposits, hydrothermal deposits of Pb-Cu-Zn ores from waters passing through hot breccia layers below, and one layer near the surface which is a breccia in a matrix of carbonaceous material believed to be of organic origin. The presence of turbidite deposits implies the structure was submerged after it formed. Characteristics of the structure would imply an initial transient cavity diameter of 110 Km, which collapsed to about 220 Km. Initial depth of the transient cavity would have been 28 to 37 Km. This initial cavity is estimated to have formed in about 80 seconds and the collapse of the rim to 220 Km diameter would have taken place in about 30 minutes. The impactor would have had a kinetic energy of approximately 8.6×10^{30} Ergs; this corresponds to an object diameter of 10 to 15 Km and a speed of possibly 20 Km/second. The above facts imply the possibility of a large impact immediately before the Flood or early during the event. The crater was then modified and filled by underwater turbidity flows and other sedimentary processes during the Flood.

Tektites are found mainly in four areas across the Earth, two of which are quite large, the North American and the Australasian strewn fields. The Australasian strewn field has been said to cover about one tenth of the Earth's surface, from southern Australia, covering most of Indochina, and reaching as far as the southeastern coast of Africa and southern India [15, p. 252]. The other strewn field, which may be the largest (covering about 9 million square kilometers), is the North American, which encompasses the Gulf of Mexico, Cuba, Central America, and continues westward in a band across the Pacific Ocean. The North American strewn field is distributed in a belt that reaches about half way around the Earth [15, p. 252]. The Chesapeake structure seems ideally placed to be the source of the tektites in this area. Other smaller strewn fields are the Ivory Coast field off the western coast of northern Africa and the Czechoslovakian strewn field. The Australasian tektite field covers a vast area and though the source of all of it is not known, there are large impact structures in Australia, such as Acraman, which is purported to be 590 Million years in age and possesses a crater rim of nearly 90 Km diameter [46, p. 221-2]. The Acraman impact may have taken place shortly after the beginning of the Flood and could be a source of some of these tektites. The North American tektite field would be dated much later, according to the geologic column. The time frame in which these tektites were laid down would be a worthy topic of further research.

Recent studies have shown that the shock mineral coesite as well as shocked quartz are present in some areas within both the North American and Australasian tektite fields. This includes studies of sea floor sediment core samples in which minerals were identified by X-ray diffraction [16, p. 435]. At some sites in the Australasian field Stishovite was also found, which argues very strongly for an impact origin. The authors of this study also point out that volcanic ash is always present as well in these tektite layers. "The search for shocked quartz and coesite was complicated by the presence of volcanic ash at all the sites [16, p. 436]." Thus, there is clear evidence of both impacts and volcanism occurring simultaneously. There is some other evidence that many metallic spherules in sea floor sediments may be of extraterrestrial origin even though the spherules may not be composed of shock minerals. Some ejecta could be produced by an impact that may not form shock mineral material. This ejecta could produce tiny spherules indistinguishable from volcanic ejecta, considering outward appearance and size alone. Studies have been done on the composition of spherules from ocean sediment. Some of these particles match well the composition of asteroids in their trace metal content [13, p. 1120]. Iridium is one of the trace metals of importance, others are Ruthenium, Cobalt, Chromium, Nickel, Osmium, Antimony, to name a few. Cosmic dust, including these spherules, is to be expected in ocean sediments if impacts were occurring during the Noahic Flood.

Solar System Evidence for Impact Bombardment

The abundance of craters throughout the solar system is obvious. The surfaces of Mercury, our Moon and many other moons in the solar system are covered with craters that have not been eroded away or buried as has been the case on Earth. However, on some solar system bodies there are markedly fewer craters because active volcanism has covered many of them. This applies especially to Venus, Mars (to a lesser degree than Venus), Io (at Jupiter), and some of the icy moons of the outer planets. A major impact bombardment event in the solar system would be expected to be accompanied by an increased influx of cosmic dust as well as of larger macroscopic impactors. Snelling and Rush, in an important paper in the Creation Ex Nihilo Technical Journal [36, p. 39], showed that cosmic dust should not be used by creationists to argue against the evolutionist time scale for the Moon or the Earth since the evolutionist scenario for the history of dust influx is consistent with the amount of dust found on the Moon's surface. Snelling and Rush's analysis of the dust influx rate brought them to the conclusion that the best estimate for the dust influx is about 10,000 Tons per year for the Earth and the Moon. If Snelling and Rush are correct, then young-age creationists must conclude that a significant dust influx event occurred. At the rate of 10,000 Tons per year for 10,000 years the amount of cosmic dust on the Moon's surface would be totally negligible, possibly immeasurable. If we assume a similar influx rate for the preflood period, there should still be a negligible amount of dust on the Moon today. Yet, there is a measurable amount of cosmic dust on the Moon, and cosmic dust has also been found in Earth sediments. What is the origin of the cosmic dust then, if the Earth and Moon are young? A young Earth and Moon does not allow enough time for the amount of cosmic dust to accumulate at present rates. Holding to a young age of 10,000 years or less therefore implies that an event occurred to cause much of the dust influx and meteorite collisions in a relatively short time.

In the evolutionary view of the history of the solar system, most impacting objects producing craters would be expected to come from the ecliptic plane, roughly speaking. Collisions from objects in highly inclined orbits would be relatively unusual, although there could be some exceptions to this from the comets and asteroids. This is a natural consequence in the accepted evolutionary Nebula model of solar system origin. The late-heavy bombardment period is believed to have ended at something over three billion years ago. In this scenario, the implication is that for over half of our solar system's history, the meteoritic influx rate (of all sizes of objects) has not changed dramatically. Thus, after the initial planetary formation period, uniformitarian assumptions are applied to solar system cratering. Uniformitarian long-age assumptions regarding cratering would lead to two primary conclusions: 1) that apart from major resurfacing processes, the surfaces of many bodies would be saturated with craters, and 2) that the distribution of craters would be symmetrical or nearly so across the solar system and over the surfaces of bodies. These are the implications of the basic Nebula model; though today many catastrophic collision and capture processes are also proposed to explain the solar system.

It has been previously pointed out that there are some clear examples of asymmetrical crater distribution in the solar system [39, pp. 519-20]. These are cases where the number of craters observed is not constant over the entire surfaces of objects. Asymmetrical crater distribution argues for catastrophic events in the solar system. In Table 2, crater data has been compiled for our Moon [21], Mars [43], Venus [45], and Ganymede (at Jupiter) [14]. For all cases, the craters have been categorized into North polar, equatorial, and South polar regions by drawing the equatorial band from -19.5 degrees latitude to + 19.5 degrees latitude. This separates the spherical surface into three equal areas. Venus crater data comes from the Magellan spacecraft; the Ganymede data comes from the Galileo mission, both of these made available by the Lunar and Planetary Science Institute, Houston, Texas. The Lunar data is the same data used for Figure 1 in the 1994 paper by Spencer on the solar system [39, p. 520]. The Lunar data did not include the South Pole Aitken basin, recently discovered through the Clementine mission, so that site has been added to the South Pole group. The Aitken basin is the largest known impact in the entire solar system. It is apparently very ancient and is approximately 2,500 Km in diameter.

	Moon	Venus (Largest)	Venus (All)	Mars	Ganymede (Largest)	Ganymede (All)
North Pole	9	19	315	8	12	71
Equator	19	11	301	11	19	88
South Pole	20	17	305	10	16	65
Total Craters	48	47	921	29	47	224

Table 2 Number of craters in equal-area latitude bands. Venus and Ganymede data from LPI crater databases, based on Magellan and Galileo spacecraft results.

Table 2 shows a trend toward more impacts near the Southern Pole than the Northern Pole for the Moon. This could possibly be the case for Mars as well but there is a need for a larger crater data set. The entire Ganymede crater set shows a different trend than is shown by the 47 largest sites, with more impacts in the North region than the South region. The distribution of craters on Venus is unlike any of the other planets, with craters essentially randomly or nearly randomly distributed across the entire surface. The Venus and Mars craters also do not show a higher concentration in the equatorial region, as the accepted evolutionary view of the origin of the solar system would imply. Also on Venus, though the entire planet has been resurfaced by dramatic volcanism, very few of Venus' craters have been altered or covered by volcanic or tectonic processes [41, p. 28].

The symmetry of the crater distribution on Venus and asymmetry of the craters on other inner solar system objects can be explained quite naturally if the solar system is young and a catastrophic event occurred. Slow gradual cratering over thousands of years from a variety of unrelated objects would tend to produce a more random crater distribution on surfaces. But a catastrophic event in the solar system that caused many craters in a short time could produce a more asymmetrical pattern. If the volcanism on Venus occurred after the catastrophe, then the craters now found on Venus may be unrelated to the catastrophic bombardment itself. The uniform cratering on Venus may be the type of random pattern that would be expected from present meteoritic phenomena, whereas the cratering on our Moon, Mars, Mercury and elsewhere may have come from a dramatic event of some kind in the history of the solar system.

Mars is worthy of special mention regarding its cratering and volcanism. Table 2 does not show an obvious trend in the crater distribution for Mars. However there is a great dichotomy between Mars' Northern and Southern Hemispheres. There is a region known as the northern lowlands which has been resurfaced by volcanism. This region is an approximately circular region of about 7,700 Km diameter centered at 50 degrees North latitude. The Southern hemisphere has more ancient cratered terrain and is higher in elevation. One of the largest impact sites known on Mars, known as Hellas, is located in the Southern hemisphere antipodal to the massive volcano Alba Patera, which is one of a group of large volcanoes in the Northern hemisphere on a feature known as Tharsis. Tharsis is a large bulge encompassing a huge area of Mars' surface. Recently, researchers have suggested interesting possibilities for explaining these features on Mars. It is possible similar processes could be related to some volcanism in Earth's past. A new theory known as Antipodal Volcanism, suggests that the Hellas impact (and possibly other impacts) produced the Tharsis bulge and caused volcanism on the opposite side of the planet as result of refraction and reflection of the shock waves from a large impact [7]. It has also been suggested that the large northern lowland region of Mars is actually a giant impact basin or a group of large overlapping impacts that stimulated great volcanic events [40, p. 213-14, 228]. These considerations on Mars imply that some volcanic processes on Earth could be related to massive impacts, if there were large impacts approximately antipodal to the volcanic activity.

What kind of event in the solar system could have caused a bombardment event at the time of the Noahic Flood? Froede and DeYoung [12] have suggested that a planet similar to the other terrestrial planets existed in the region between Mars and Jupiter. This former planet exploded by an unknown process, producing many fragments that led to meteoritic impacts on the planets. In this scenario, the asteroids would have originated from the catastrophic disruption of this planet. Though this has been suggested by a number of scientists, it is an idea that is not considered seriously today by astronomers, mainly because of what is known of the composition of the asteroids across the asteroid belt. The asteroids do have varied orbital and physical characteristics that could suggest a catastrophic origin. They have obviously undergone many collisions. On the other hand, there are many asteroids in fairly regular orbits, not highly elliptical or inclined. Furthermore, several of the larger asteroids are nearly spherical, including the largest, Ceres [43, p. 226]. The rotation characteristics of asteroids greater than about 150 Km diameter do not fit the relationship expected of collision fragments [39, p. 521]. All this is simply to say that the asteroids may not all have a single common origin and a destroyed planet in my opinion is an inadequate explanation for the characteristics of the asteroids.

The density of the asteroids and the type of minerals that predominate in the different regions of the asteroid belt do not agree well with the idea of a disrupted planet. In the disruption of such a planet there would be no natural process that would produce a sorting of the objects by density or mineral content. The composition of the planet would not make any difference in this. Gravity does not sort collision fragments by density, though it could sort by size. But, a sorting by density, not size, exists among the asteroids. There are currently 14 recognized composition classes of asteroids. These many types of objects are categorized into three superclasses as igneous, metamorphic, and carbonaceous (carbonaceous are called “primitive” in the scientific literature). The best way to describe the difference between these superclasses is in density and volatile content. Carbonaceous Chondrite objects are in the primitive category, having some relatively low boiling point material. Other objects made up mainly of iron and nickel would be considered igneous. Some classes of asteroids are of unknown composition and are only distinguished by their spectral characteristics. The asteroids follow a density pattern generally similar to that followed by the planets, the inner planets have fewer volatile compounds where the temperature is greater near the Sun and the outer planets (and their moons) have much higher volatile content where the temperature is lower. This may exist for the created purpose of stability in composition in the different regions of the solar system. Figure 1, adapted from R. P. Binzel, et. al. [5, p. 91], illustrates this relationship, showing percent abundance as a function of distance from the Sun. Igneous asteroids are of higher density than carbonaceous asteroids.
This distribution of the asteroids is better understood as a created relationship, not as a result of a planet disruption. The evolutionary explanation of the density and composition of the planets and the asteroids relates to condensation from the proto solar nebula depending on the temperature as a function of distance from the Sun. The planets were apparently created with this pattern, it seems logical that the asteroids could be created with the same pattern. On the other hand, asteroids have obviously undergone many collisions. Rather than supposing the

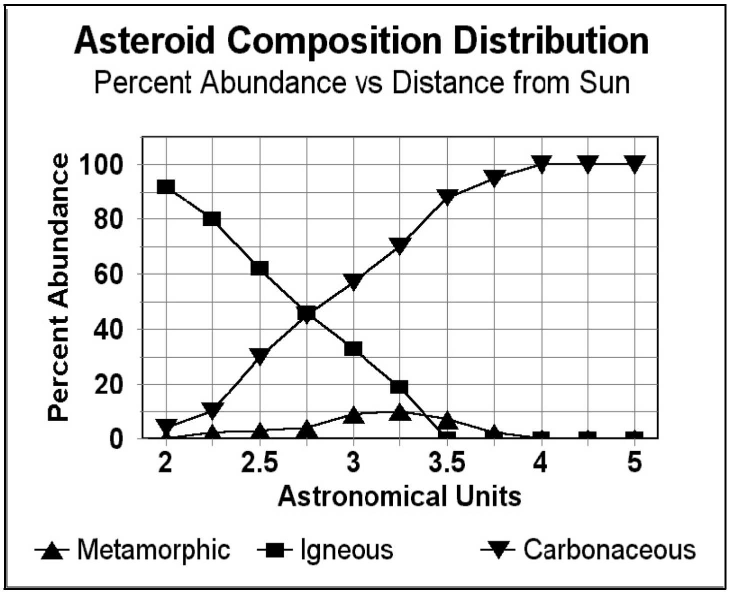

Figure 1 Adapted from Binzel, et. al. Asteroids are roughly sorted by density.

destruction of a planet in the asteroid region, it seems more reasonable that the larger objects are created objects and some of the smaller asteroids may be fragments from collisions. This is also reasonable in the light of the rotation characteristics of the asteroids [39]. This argues against the comments of Froede and DeYoung [12] regarding the source of the objects striking Earth at the time of the Flood. There is a need to evaluate various scenarios based on celestial mechanics considerations. I believe that a solid debris field passing through the solar system may be a better explanation. An object "swarm" like this could also cause the bombardment to be periodic or episodic in some way. Such a debris field may explain cratering in both the outer and inner regions of the solar system. A debris field passing through the solar system would allow for the possibility of larger asteroids being created and smaller asteroids being collision fragments. Creationists should not adopt any one model too quickly, such as a destroyed planet between Mars and Jupiter, before other possibilities are investigated seriously.

Other possibilities are suggested by recent discoveries. A planet breakup in the inner solar system does not explain the cratering records of objects in the outer solar system. A major collision or break up event could also be a possibility in the outer solar system near Neptune [38]. Small objects such as collision fragments or comets in the Neptune region tend to be perturbed toward the inner solar system, so objects from the outer solar system could reach Earth. Recently small objects often described as "snowballs" or "mini-comets" have been discovered to be bombarding Earth's atmosphere at a rate of about 20 per minute [35]. They are vaporized high in Earth's atmosphere. The source of these objects is not known; even their existence may be uncertain. Could they represent remnants of some more severe event in the past?

CONCLUSION

The Alvarez hypothesis that an impact caused the extinction of the dinosaurs has generated much research into Earth impacts. Though erosion and various other geological processes have altered Earth impact structures, it is now fairly clear how to identify such structures on Earth, at least in many cases. There is clear evidence from shock minerals and other observations that impacts have occurred on Earth. However, the hypothesis of extinctions being caused by one impact is not an acceptable explanation of the dinosaurs from a creation point of view. Rather than using an impact to explain dinosaur extinction, as creationists we must attempt to explain Earth impacts in the context of a young Earth and a world-wide Flood. The aftermath of the Noahic Flood is a very adequate explanation for what happened to the dinosaurs.

Though impacts are not mentioned in Scripture in relation to the Flood, this does not rule out the possibility of such events. Indeed, impacts would seem consistent with God's judgement. Allowing for there being impacts during the Flood creates many additional possibilities for geological mechanisms that can explain Earth's features. Since impacts exist in Precambrian strata, impacts could have begun immediately before the Flood and continued during the Flood year as well as after that. In some cases it is possible that even craters in Precambrian rock could have actually taken place after the Flood, after erosion removed many layers of Flood sediments. These considerations lead to the conclusions that a) an impact bombardment event occurred, possibly beginning immediately before the onset of the Flood, b) volcanism was occurring at the same time, and c) impacts continued into the postflood period. The number of known astroblemes and meteorites on Earth are probably not indicators of the number of impacts that occurred. That must be resolved from other considerations. The best indicator of the number of impacts on Earth would very likely be the cratering record of our Moon. Creationist geologists must consider the effects of impacts in explaining Earth's geology.

REFERENCES

[1] Aldaney, Jeremy, **Asteroids and their Connection to the Flood**, (letters section) Proceedings of the 1992 Twin-Cities Creation Conference, Twin-Cities Creation Science Association, (1992).

[2] Aldaney, Jeremy, **Asteroid Hypothesis for Dinosaur Extinction**, Creation Research Society Quarterly, Vol. 31, June 1994, p 11-12.

[3] Alvarez, Luis, W., Alvarez, Walter, Asaro, Frank, Michel, Helen V., **Extraterrestrial Cause for the Cretaceous-Tertiary Extinction**, Science, Vol. 208, Number 4448, June 6, 1980, pp 1095-1108.

[4] Alvarez, Walter and Asaro, Frank, **The extinction of the dinosaurs**, Understanding Catastrophe, Janine Bourriau, Editor, 1992, Cambridge University Press.

[5] Binzel, Richard P., Barucci, M. A., and Fulchignoni, Marcello, **The Origins of the Asteroids**, Scientific American, October 1991, pp 88-94.

[6] Bohor, Bruce F., Modreski, Peter J., and Foord, Eugene, E., **Shocked Quartz in the Cretaceous-Tertiary Boundary Clays: Evidence for a Global Distribution**, Science, May 8, 1987, pp 705-9.

[7] Broad, William J., **New Theory Would Reconcile Rival Views on Dinosaurs' Demise**, New York Times, December 27, 1994, pp C1, C10.

[8] Dietz, Robert S., **Astroblemes**, Scientific American, Vol. 205, No. 2, 1961, pp 50-58.

[9] Dietz, Robert S., **Demise of the Dinosaurs: A Mystery Solved**, Astronomy, July 1991, pp 32-37.

[10] Feldman, Vilen I., **The Conditions of Shock Metamorphism**, Geological Society of America Special Paper 293: Large Meteorite Impacts and Planetary Evolution, Editors B.O. Dressler, R.A.F. Grieve, and V.L. Sharpton, (1994).

[11] Fischer, Michael J., **A Giant Meteorite Impact and Rapid Continental Drift**, Proceedings of the Third International Conference on Creationism, Robert E. Walsh, Editor, Creation

Science Fellowship, Inc., (1994), pp 185-197.

[12] Froede, Carl R. and DeYoung, Don B., **Impact Events within the Young-Earth Flood Model**, Creation Research Society Quarterly, Vol. 33, June 1996, pp 23-34.

[13] Ganapathy, R., Brownlee, D. E., and Hodge, P. W., **Silicate Spherules from Deep-Sea Sediments: Confirmation of Extraterrestrial Origin**, Science, Vol. 201, Sept. 22, 1978, pp 1119-1121.

[14] **Ganymede Crater Database**, http://cass.jsc.nasa.gov/research/gc/gchome.html, Lunar and Planetary Institute, Houston, Texas. (LPI Home Page URL: http://cass.jsc.nasa.gov).

[15] Glass, Billy P., **Possible correlations between tektite events and climatic changes?**, Geological Society of America Special Paper 190, (1982) pp 251-256.

[16] Glass, B. P. and Wu, Jiquan, **Coesite and shocked quartz discovered in the Australasian and North American microtektite layers**, Geology Vol. 21, May 1993, pp 435-438.

[17] Grieve, Richard A. F., **Impact Cratering on the Earth**, Scientific American, April 1990, pp 66-73.

[18] Grieve, Richard A. F., **The record of impact on Earth: Implications for a major Cretaceous/Tertiary impact event**, Geological Society of America Special Paper 190, 1982, pp 27-28.

[19] Grieve, R. A. F., **When will enough be enough?**, Nature, Vol. 363, June 24, 1993, pp 670-671.

[20] Grieve, R. A. F. and Dence, M. R., **The Terrestrial Cratering Record, II. The Crater Production Rate**, Icarus, Vol. 38, 1979, pp 230-242.

[21] Horz, F., Grieve, R., Heiken, G., Spudis, P., & Binder, A., **Lunar Surface Processes**, Lunar Sourcebook: A User's Guide to the Moon, (1991), Cambridge University Press, Cambridge, England, 118-119.

[22] Lowe, Donald R., and Byerly, Gary R., **Early Archean silicate spherules of probable impact origin, South Africa and Western Australia**, Geology, Vol. 14, January 1986, pp 83-86.

[23] Lowe, Donald R., Byerly, Gary R., Asaro, Frank, Kyte, Frank, **Geological and Geochemical Record of 3400-Million-Year-Old Terrestrial Meteorite Impacts**, Science, September 1989, pp 959-962.

[24] Meyerhoff, Arthur A., Lyons, John B., and Officer, Charles B., **Chicxulub Structure: A Volcanic Sequence of Late Cretaceous Age**, Geology, January 1994, pp 3-4.

[25] Morell, Virginia, **How Lethal was the K-T Impact?**, Science, Vol. 261, Sept. 17, 1993, pp 1518-19.

[26] Norton, O. Richard, **Rocks from Space: Meteorites and Meteorite Hunters**, Mountain Press Publishing Company, Missoula, Montana, (1994).

[27] Oard, Michael J., **Response to Comments on the Asteroid Hypothesis for Dinosaur Extinction**, (letters section) Creation Research Society Quarterly, Vol. 31, June 1994, p 12.

[28] Oard, Michael J., **The Extinction of the Dinosaurs**, Creation Ex Nihilo Technical Journal, Vol. 11, No. 2, 1997, pp 137-154.

[29] Officer, Charles, **Victims of Volcanoes**, New Scientist, Feb. 20, 1993, pp 34-38.

[30] Officer, Charles B. and Drake, Charles L., **Terminal Cretaceous Environmental Events**, Science, Volume 227, No. 4691, March 8, 1985.

[31] Parks, William S., **The Role of Meteorites in a Creationist Cosmology**, Creation Research Society Quarterly, Vol. 26, March 1990, pp 144-146.

[32] Poag, C. Wylie, Powars, David S., Poppe, Lawrence J., and Mixon, Robert B., **Meteoroid mayhem in Ole Virginny: Source of the North American tektite strewn field**, Geology, vol. 22, August 1994, pp 691-694.

[33] Rampino, Michael R., **A non-catastrophist explanation for the iridium anomaly at the Cretaceous/Tertiary boundary**, Geological Society of America Special Paper 190, Leon T. Silver and Peter H. Shultz, Editors, (1982), Geological Society of America, Boulder, CO.

[34] Reed, John K., and Froede, Carl R. Jr., **A Biblical Christian Framework for Earth History Research Part III — Constraining Geologic Models**, Creation Research Society Quarterly, Vol. 33, No. 4, March 1997, pp 285, 289-90.

[35] Snelling, A. A., **Cosmic Snowballs Bombard the Earth?**, Creation Ex Nihilo Technical Journal, Vol. 11, No. 3, 1997, pp 255-6.

[36] Snelling, Andrew A., and Rush, David E., **Moon Dust and the Age of the Solar System**, Creation Ex Nihilo Technical Journal, Vol. 7, No. 1, (1993), pp 2-42.

[37] Spencer, Wayne R., **Geophysical Effects of Impacts During the Genesis Flood**, Proceedings of the Fourth International Conference on Creationism, Robert E. Walsh, Editor, Creation Science Fellowship, Inc., (1998, this volume).

[38] Spencer, Wayne, R., **Revelations in the Solar System**, Creation Ex Nihilo, Vol. 19, No. 3, June-August (1997), p 28.

[39] Spencer, Wayne R., **The Origin and History of the Solar System**, Proceedings of the Third International Conference on Creationism, Robert E. Walsh, Editor, Creation Science Fellowship, Inc., Pittsburgh, PA, (1994), pp 513-523.

[40] Spudis, Paul D., **Multi-ring basins on the terrestrial planets**, The Geology of Multi-Ring Impact Basins: The Moon and Other Planets , Lunar and Planetary Institute, Houston, Texas, Cambridge University Press, (1993).

[41] Stofan, Ellen R., **The New Face of Venus**, Sky and Telescope, August 1993, pp 22-31.

[42] Stoffler, D. and Deutsch, A., et. al., **The Formation of the Sudbury Structure, Canada: Toward a unified impact model**, Geological Society of America Special Paper 293, (1994), pp 303-316.

[43] Taylor, S. R., **The Role of Impacts**, Solar System Evolution, Lunar and Planetary Institute, Houston, Texas, Cambridge University Press, (1992), pp 165.

[44] Toon, O. B., Pollack, J. B., and Ackerman, T. P., et. al., **Evolution of an impact-generated dust cloud and its effects on the atmosphere**, Geological Society of America Special Paper 190, 1982, pp 188-190.

[45] **Venus Crater Database**, http://cass.jsc.nasa.gov/research/vc/vchome.html, Lunar and Planetary Institute, Houston, Texas (LPI Home Page URL: http://cass.jsc.nasa.gov).

[46] Williams, George E., **Acraman: A major impact structure from the Neoproterozoic of Australia**, Geological Society of America Special Paper 293, (1994) pp 209-224.

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Earth Impacts, the Geologic Column, and Chicxulub

Some CRSQ readers will be aware of the papers on Earth impacts which I presented at the Fourth International Conference on Creationism, August 1998 (Spencer, 1998). Following are some comments on research I have done on the subject of impacts since the publication of these papers. I would like to mention Earth crater data obtained after the publication deadline of the ICC Proceedings, a minor error in the paper, and some recent findings relevant to the subject from the scientific literature.

In the ICC Proceedings paper, "Catastrophic Impact Bombardment Surrounding the Genesis Flood" I presented a table giving data on Earth astroblemes in relation to the Geologic Column. Table 1, page 559 of the Proceedings gives two data sets from Earth crater data compiled by O. Richard Norton, an astronomer and educator, and Richard Grieve of the Canadian Geological Survey, Canada. The Norton data set was only 50 points, but was recent data from 1994 while the Grieve data was from 1982 and included 88 points. The 50 point data set included good information on the sites and is a set where there is a high confidence of them being impact sites. The Grieve data set of 1982 was considered a very authoritative list at the time and it has been quoted and used by many other authors since. The Grieve data from 1982 also included some information on the sites. Richard Grieve used a ranking system to describe the state of preservation of the impact structures. After the publication deadline for the ICC papers, I was able to obtain a data set from the Canadian Geological Survey, including Grieve's Earth impact site list from 1998. There was no way to get this data into the Proceedings papers but it was in my presentations at the conference. The 1998 list of Earth astroblemes included 121 points (points without an assigned age figure were thrown out). This data set has the advantage of being very up to date but the disadvantage of there being no information about each site.

The crater numbers were totaled in the ICC Proceedings in a manner that contained an error. Following is a table showing how it was presented for the case of the 1982 data set.

Geologic Column Label	**Evolutionary Age (Ma)**	**No. of Impacts, Grieve, 1982**
Recent	< 1	7
Upper Cenozoic	5 - 1	3
Lower Cenozoic	65 - 5	7
Mesozoic	100 -65	3
Upper Paleozoic	300 - 100	15
Lower Paleozoic	600 - 300	12
Precambrian	> 600	3

Table 1 Data presented as in ICC 98 Proceedings, italics labels are not correct

The Mesozoic, Upper Paleozoic, Lower Paleozoic, and Precambrian labels are not correct for the age periods shown in Table 1 (same for the Norton data set, not shown here). The counts of impact sites in each category are correct for the numerical age ranges shown, but not correct for the Geologic periods shown. The Lower Paleozoic and Precambrian period counts are not quite correct because Geological societies recently adopted a different boundary age between the Precambrian and Cambrian periods than the figure used in the Proceedings. This puts the Precambrian/Cambrian boundary at 550 Million years ago rather than 600. Of course, as young earth creationists we do not accept these ages. But the difference does affect the counts of the astroblemes.

It is important for creationist geologists to look into how Earth impacts are distributed in the Geologic Column. Though there is not a real consensus on some questions about the Geologic Column and the Flood among creationists, this kind of data can shed light on the complex events of the Genesis Flood. The most important point is that impact structures are found in all types of rock and all through the Geologic Column, from Precambrian up. Such data may be counted and presented in a variety of ways, so there is a danger of bias coming through in such a table. After recounting the points with the 1998 Grieve data set, two interesting ways of presenting the numbers follow in Tables 2 and 3.

Geologic Period	**Evolutionary Age (Ma)**	**Grieve data, 1998, 121 points**
Cenozoic	64 - Present	43
Mesozoic	249 - 65	33
Paleozoic	549 - 250	37
Precambrian	> 550	8

Table 2 1998 Earth crater data recounted to correctly correspond to Geologic Periods

Some creationists might argue that showing the data this way shows a bias towards the uniformitarian presuppositions of evolutionary geology. So, I counted the data in another way, breaking down the ages into 12 equal uniformitarian-time periods of 50 million years each. Table 3 shows the data this way from Grieve's 1998 data set. (The data sets mentioned here are available from Spencer, 1998c.)

Evolutionary Age (Ma)	Grieve, 1998, 121 pts.
50 - 0	39
100 - 50	16
150 - 100	12
200 - 150	2
250 - 200	7
300 - 250	5
350 - 300	9
400 - 350	6
450 - 400	5
500 - 450	7
550 - 500	4
> 600	4

Table 3 Earth Impacts throughout the Geologic Column, by equal "time" periods.

Table 3 shows that the greatest number of impacts are in recent strata, which are easier to discover since they are more accessible for study. The accessibility of the various strata is a very important consideration. A paper by Trefil and Raup (1990), uses statistical analysis to determine whether most Earth craters have the same age as the rock they are found in. They conclude that this is the case at most impact sites. This conclusion needs to be reexamined based on young-age assumptions. Small craters are more likely to be eroded before the rock they are found in is eroded. On the other hand, large craters are likely to "survive" even if there is significant erosion around the site. A large impact produces a variety of indicators of impact that may be observed even if the crater rim has eroded away, such as shocked minerals, breccia and deformed strata, magnetic anomalies, and various circular structures in the subsurface rock. Trefil and Raup show statistical data on the percentage of the continental surface which has each geological rock classification available near the surface. Cenozoic and Mesozoic rock are much more common on the surface of the continents than is Paleozoic rock. So, for example, Cambrian rock is less accessible than Cretaceous since it is found over a much smaller area near the surface where we can study it easily. This may imply that the impact structures in the Paleozoic strata were more numerous than the above numbers tend to show, since those strata are less accessible today. This tends to be consistent with what I proposed in my ICC papers.

Another item of note was brought to my attention by Thomas Fritzsche, who presented an excellent paper at the 1998 ICC on the Chicxulub structure, in Yucatan. This structure has been accepted by many in the scientific community as the impact that led to the global extinction of dinosaurs. Recent seismic reflection sounding studies of the Chicxulub structure have shed light on an interesting controversy over the size of the original Chicxulub crater. Estimates of the transient crater diameter have ranged from 180 to 300

Km. After the impact, slumping and erosion would reduce the observed diameter from this value. The original paper by Luis and Walter Alvarez, Frank Asaro and Helen Michel, in 1980, quoted geologist Richard Grieve as estimating that a 10 Km diameter asteroid would produce a structure 200 Km in diameter. The new seismic data from Chicxulub have revealed that the transient crater diameter was more like 100 Km, and that the shock waves of the impact produced a fault structure that reached all the way into the upper mantle. There is a prominent scarp structure around the Chicxulub impact site at about 195 Km diameter. This was thought previously to be the main crater rim, but based on the new seismic studies the scarp must be considered a ring. This means that the Chicxulub structure is now viewed as a two or three ringed complex crater. Multi-ringed craters can have the rings either outside or inside the main crater rim. Not many impact sites on Earth have been proposed to be Multi-ringed craters. This may the best evidence of such a structure to date on Earth, though they are common on our Moon and Mars. On Earth, where erosion, tectonics, and sedimentation have altered crater structures, it can be very difficult to determine the main crater rim diameter. Hence the controversy over the size of Chicxulub. What is significant to creationists in this is that this new data on Chicxulub significantly reduces the energy of the "dinosaur killer" impact. My ICC papers argue that one large impact, even a large one such as the one at Yucatan, could not cause *global* extinctions of the dinosaurs (Spencer, 1998a). The environmental effects of such an event are not long-lived enough (Spencer, 1998b), and from an evolutionary interpretation of the fossil record, the extinctions took too long to associate them with one impact. The smaller size of the Yucatan impact makes the single-impact extinction hypothesis even less plausible.

Recently published papers by creationists (Faulkner 1999; Froede, 1999; Steele, 1999) underscore that impacts from space are an important piece of the puzzle in a Biblical and scientific understanding of Earth history and the Flood. The events of the post-Flood period, in my opinion, are a very adequate explanation of the extinction of the dinosaurs. It is possible to incorporate a significant number of impacts in our models of Noah's Flood.

Alvarez, Luis; Alvarez, Walter; Asaro, Frank; Michel, Helen; (June 6, 1980), Extraterrestrial cause for the Cretaceous-Tertiary Extinction, *Science*, Vol. 208, No. 4448, pp 1095-1108.

Faulkner, Danny, (1999), A biblically based cratering theory, *Creation Ex Nihilo Technical Journal*, Vol. 13, No. 1, pp 100 - 104.

Fritzsche, Thomas, (1998), The Impact at the Cretaceous/Tertiary Boundary, In Walsh, R E. (editor), *Proceedings of the Fourth International Conference on Creationism*, Technical Symposium Sessions, Creation Science Fellowship, Pittsburgh, PA, pp 553-566.

Froede, Carl R. Jr., and Williams, Emmett L., June 1999, The Wetumpka Impact Crater, Elmore County, Alabama: An Interpretation Within the Young-Earth Flood Model, *Creation Research Society Quarterly*, 36:1, pp 32-37.

Melosh, H. J., (Dec. 4, 1997), Muti-ringed revelation, *Nature* Vol. 390, pp 439-440.

Morgan, Jo; Warner, Mike, et. al., (Dec. 4, 1997), Size and morphology of the Chicxulub impact crater, *Nature* Vol. 390, pp 472-476.

Spencer, Wayne R., 1998a, Catastrophic impact bombardment surrounding the Genesis Flood, In Walsh, R E. (editor), *Proceedings of the Fourth International Conference on Creationism*, Technical Symposium Sessions, Creation Science Fellowship, Pittsburgh, PA, pp 553-566.

________, 1998b, Geophysical effects of impacts during the Genesis Flood, In Walsh, R E. (editor), *Proceedings of the Fourth International Conference on Creationism*, Technical Symposium Sessions, Creation Science Fellowship, Pittsburgh, PA, pp 567-579.

________,1998c, Earth Impacts and Noah's Flood: a resource guide for educators and researchers, Creation Education Materials.

Steele, S. R., (March 1999), The Upheaval Dome Impact Site: Flood Model Interpretations, *Creation Research Society Quarterly*, 35:4, pp 236-237.

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