A DIFFERENT VIEW OF GEOLOGIC TIME

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If geologic time, the 4.54 billion years since the Earth began, could be reduced to a period of just a single year, the calendar of events would be as follows:

January 1 -- 12:00 A.M. – the earth is formed: a molten sphere, too hot for any liquid water or plant or animal. The **Hadean Era of the Precambrian Eon** is underway. During the 740 million years until the Hadean ends, the earth will cool and form a crust. Gravity segregates the heavier metals that sink and form a core. Volcanoes are the rule of the day. Cooling is continuous and when the temperature drops below100°C. (212°F.), condensed water rains down and creates rivers, lakes and seas in low areas. The earth is pelted by big and small meteorites. One of these, of small planet size, whacks the earth in passing and knocks off a chunk which spins outward a couple of hundred thousand miles and becomes a moon.
February 28 -- 11:50 A.M. – the **Archean Era** begins. Some rocks from this time are preserved until the present. The earth is spinning faster than at present and a "day" is less than the 24 hours we presently experience. The first prokaryotes (single-cell organisms lacking a nucleus) appear. The atmosphere is composed mostly of methane, nitrogen and carbon dioxide which causes the sky to appear red. Banded iron formations (chert/jasper and hematite/magnetite) are being deposited at many places and indicate presence of enough oxygen to bond with iron. Late in the era, proto-continents begin forming up and possibly photosynthesis-capable algae appear on the scene.
June 12—3:56 P.M.– The **Paleoproterozoic Era** arrives and the earth's land surface is still barren of any life. Prokaryotes dominate but about midway through this era, the first possible Eukaryotes (cells with a nucleus) appear. About halfway through the era, what is present South Africa is whacked by a 10 km (6 mile) diameter meteorite leaving the yet visible 250 km (155 mile) wide Vredefort Crater. 150 million years later, another big meteor slams into an area which now is Sudbury, Ontario, Canada, leaving a 200 km (ca. 125 mile) wide crater. The first three hundred million years experience something new: worldwide glaciation – the so-called Huronian glaciation that occurred in three separate glacial events. One result was an increase in atmospheric oxygen from perhaps 0.5 to 0.7% to around 3.5% that oxidized much of the atmospheric methane. Red beds are common and indicate presence of oxygen. Photosynthesis is encouraged and cyanobacteria ("blue-green algae") proliferate forming stromatolites. The increased oxygen oxidizes much of the sulfur in seawater and the first gypsum/anhydrite deposits precipitate. The Columbia mega-continent assembles and breaks-up over a 300 million year time frame during this lengthy era.
August 24 – 12:20 A.M. -- Time marches on! 3.4 billion years have elapsed since New Year Day. The **Mesoproterozoic Era** is here. Breakup of Columbia is complete and the megacontinent of Rodinia is assembled with its parts. Thrusting of assembling continental blocks onto the eastern and southern edges of Laurentia result in the Grenville Orogeny, making the proto--Adirondack and proto--Appalachian Mountain chains. The portion of Rodinia that is now the central United States begins to rift threatening to split the continent. Fortunately this "Mid-Continent Rift" fails to break completely. Single-cell acritarchs are present. During the later Mesoproterozoic, definite eukaryotic cells capable of sexual reproduction are present and stromatolites still thrive.
October 11 – 6:01A.M. – It's the **Neoproterozoic Era**! During the first third, Rodinia breaks up. Acritarchs increase in both variety and numbers. The pieces resulting from Rodinia's breakup have drifted and are clustered around the South and North Pole. The breakup creates the proto-Pacific Ocean known to geology as the Panthalassic Ocean. At the start of the Middle Proterozoic – known as the **Cryogenian Period**, about 750 million years ago, world-wide glaciation begins in both continental clusters and spreads toward the Equator. Nearly the whole earth is covered with ice ("Snowball Earth"). There are at least two separate glacial advances and retreats during the next 215 million years. Glaciation seems to accelerate organic development and by the end of the Cryogenian, acritarchs have become diverse, calcium carbonate absorbing red algae have appeared, dinoflagellates have provided a chemical record of existence, ciliate protozoa such as paramecia are present as are testate (shelled) amoebae and possible fungi have "made the scene." Simple corals, sea anemones and sponges make their first appearance. The land surface however remains barren. The Neoproterozoic winds up with the **Ediacaran (aka Vendian) Period** starting about 630 million years ago. During the next 30 million or so years, tectonic shifting recombines the continents into a mass named Pannotia clustered around the Equator. Acritarchs and stromatolites are decimated, probably by effects of glaciation but other life forms thrive. Additionally, a variety of bizarre, soft-bodied, multicellular animals of uncertain affinity (the Ediacaran fauna) are found in 20 or so locations around the world. Some are obvious worms and others represent jellyfish and other later phyla. The first lichens (a fungus-alga association) are forming on land. Some other life forms would become extinct by the approaching Cambrian Period. Very late in the Ediacaran Period, Pannotia begins to break apart.

Note: This is the first of a series. The next portion will be in the May-June Bulletin.

A DIFFERENT VIEW OF GEOLOGIC TIME

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Part II

November 17 – 1:44 A.M. – The year is late! The **Phanerozoic Eon** is at hand with its opening act, the **Paleozoic Era.** The Paleozoic opens with the momentous **Cambrian Period**. Pannotia completes disintegrating and forms four major continents: Gondwana, Laurentia, Baltica and Siberia along with numerous lesser-sized "islands." Major marine transgressions overtake much of the land surface. Atmospheric oxygen content may be ten percent and enough calcium carbonate has dissolved in the oceans to permit the first hard-bodied animals to form. Primitive brachiopods, trilobites, gastropods, sponges and reef-forming archeocyathids thrive in the shallow seas. Both red and green algae abound. Graptolites show up during mid-Cambrian. The first certain conodonts (the first chordate animals) appear. Tiny jawless fish are swimming in the Yangtze Platform (present south China) that is part of an island arc off the coast of Gondwana. This "Cambrian Explosion" has representatives of every modern animal phylum. Archeocyathids become extinct at the end of the Cambrian.

November 21 – 9:53 A.M. – The **Ordovician Period** arrives. The Gondwana landmass drifts southward from the Equator and will center around the South Pole by the end of this period. Primitive non-vascular plants develop on land but remain close to streams and lakes. Graptolites abound as do conodonts. The variety of primitive fish increases and early bryozoans, crinoids and nautiloids are found. The first eurypterids are creeping about and tentative shark traces are being left on the future Colorado plateau. During the Ordovician, the Taconic island arc smashes into east Laurentia wreaking geologic havoc and building new Appalachian Mountains while tacking modern New England onto the continent. Near the end of Ordovician time, the polar location of Gondwana causes a new period of continental glaciation. The colder temperatures and shallower seas result in deletion of 60% of marine invertebrate genera and 25% of all families. Hard times!

November 24 – 10:47 P.M. – A month left in the year and the **Silurian Period** is here. The "continents" continue drifting. Another large island arc, Avalonia, bulldozes into Laurentia causing the Acadian Orogeny that raises mountains in eastern Canada and New England. Baltica welds onto Laurentia and a new mega-continent, Laurasia, is formed. The collision starts the Caladonian Orogeny which builds a mountain chain from the future northeastern U.S. through eastern Canada, Scotland and Norway. There is no major extinction but a few important species of conodonts and 52% to 79% of graptolites die out. Penteramid brachiopods which began their "run" in the Cambrian reach their peak. The first true land plants and the first land animals in the form of primitive arachnids and centipedes are up and about. There is a wide variety of crinoids and mollusks and numerous types of jawless fish. Stromatoporoids, possibly a type of sponge, are building reefs.

November 27 – 12:24 A.M. – The **Devonian Period**: the Age of Fishes! Atmospheric oxygen averages 15% by volume and CO_2 starts out of around 2200 ppm (parts per million) (Compare to present-day 380 ppm.) The abundance of CO_2 probably initiated development of plant life. The first ferns, horsetails, seed plants and scale-tree plants grow in the first forests – some 30m (100 feet) high. As CO2 content is absorbed and turned into plant carbohydrates, its atmospheric concentration declines through Devonian time. The first cartilaginous fish (sharks) appear in the seas along with bony fish, armored fish (placoderms) and other fish with jaws, bony lobefish (possible predecessors to land tetrapods) and ammonites. Brachiopods recover in numbers to 200 genera, tabulate and rugose corals, trilobites and bryozoa continue on until late Devonian when a minor extinction of uncertain cause cuts the numbers of brachiopods, trilobites, tabulate corals, acritarchs and completely eradicates jawless fish, placoderms and the by-then ancient stromatoporoids. Crinoids still abound and their cousin blastoids are at their peak. Worldwide climate is mild and the first land-living vertebrates creep about, some dining on the newly ashore arthropods which include wingless insects and the earliest arachnids. The three major continents, Gondana, Laurasia and Siberia, continue to shift positions with Gondwana moving northward toward the Equator and Laurasia. Something, possibly relocation of the land masses causes an large anoxic event in many of the ocean basins and thick black shale deposits form in basins around the world.

November 30 – 11:28 P.M. – The Lower Carboniferous (or **Mississippian Period in the U.S.**). World sea level rises following the Devonian and large areas of the continents are flooded by warm, shallow seas creating lush swamps within large, sluggish deltas. Atmospheric oxygen content is now nearing 35%, a level that accelerates wildfires in the dense forests. CO_2 levels are down to 800 ppm. The increased oxygen probably promotes existence of giant insects and the many amphibians now present. Crinoids, now the most numerous of the echinoderms, and bryozoans both burgeon in the shallow continental shelves and thick beds of limestone accumulate. Single-celled foraminifera, especially *Fusulinidae*, make their appearance. Brachiopods flourish and productid brachiopods make their debut. Bivalves increase in numbers and importance. Nautiloids are becoming common but the trilobites are waning in variety and quantity. Insects are diversifying and some types of eurypterids are coming ashore. The first scorpions (one variety up to 70 cm (28 inches) long) scurry through underbrush looking for food. There are many marine fish and fresh water fish are abundant. Sharks increase in numbers and variety. The most important event among animals is the first appearance of the amniotic egg, which will promote the development and advancement of land animals. Many forms of new plants develop and thrive forming coal deposits as they die and accumulate. The first appearance of lignin in plants occurs during this time. There is volcanism in Europe and parts of Asia bump into and are welded to European Laurasia forming the Ural Mountains. Tectonic activity further elevates the Appalachians and raises extensions forming the Ouachita Mountains. Late in Mississippian time, the seas retreat and vast amounts of sand, mud and gravel erode from the Catskills and form sandstone, shale and conglomerate deposits as far away as present day Illinois.

December 5 – 1:52 A.M. – The Upper Carboniferous (or Pennsylvanian Period in the U.S.). World average climate and atmosphere are probably nearer to that of the present day than at any other time before or after. Vegetation booms and major coal beds are started in many basins around the world. Giant dragonflies zoom about and more than 800 species of cockroaches scurry over the ground avoiding the nearly 100 species of amphibians that range in size from a few inches long to that of large crocodilians and are searching for lunch. The first land snails are present. The first diapsids (reptiles) are present as well as the first synapsids (pelycosaurs), mammal-like reptiles which are considered to be ancestral to mammals. Abundant single-cell fusulinids near the ocean surface are swept up by currents and deposited in coves along coastal areas. At about the middle Pennsylvanian, world climate dries some indicating a cooler climate. The temperature decrease is caused by developing continental glaciers in Gondwana. Resulting glacial advances and retreats cause lowering and raising of sea levels which result in regular cyclic sediment changes in coastal areas. (Geologists call these cyclic stacks of sediments "cyclothems.")

Gondwana and Laurasia are nearly finished colliding and a new megacontinent, Pangaea, is formed. The Alleghenian/Hercynian Orogeny results forming the Allegheny mountains which overprinted the southern Appalachians and formed a range perhaps as high as the modern Himalayas. As collision progressed, mountains were pushed up to the west, resulting in the Arbuckles and Wichita mountains in present-day Oklahoma and Marathon mountains in Texas. The orogeny also stressed a Precambrian weak zone to the north-northwest that yielded to push up the Ancestral Rocky mountains located about where the present Rockies are. The ancestral range, however, is estimated to have been only 10,000 feet high. The Hercynian (European) part of Laurasia was impacted by the east African part of Gondwana which pushed up part of the European Alps, the Caucasus mountains and the Mauritanide mountains in North Africa. This upheaval continued.

December 6 – 2:31 P.M. - The Permian Period opens with a figurative bang! Laurasia and Gondwana finish consolidating and form one massive continent: Pangaea that is centered over the equator. The remainder of the Pennsylvanian southern icecap melts away as world climate warms. One huge single ocean, the Panthalassa Ocean surrounds the Pangaean mega-continent. Pangaea is shaped like a gigantic letter "C" and three minor continents or terranes:, North China, South China and Cimmeria are strung out between the cusps of the "C" forming a large oceanic gulf, the Paleo-Tethys Sea. Climate was substantially changed by the single continental mass: the interior of Pangaea dried, leaving thick salt deposits and red beds wherever the sea had formerly been. Since several previous continents were incorporated into one, the length of continental shelf was reduced, providing less area for marine invertebrates. Coastal areas remained warm or temperate giving rise to many new species of plants and animals. Conifers, gingkos and other gymnosperms dominate the plant world. Many new insect species including the first beetles creep and fly providing food for new species of amphibians and reptiles. Early on, reptilian, predatory, sail-backed Dimetrodons up to four meters (12 feet) long waddle about riverine flood plains hoping perhaps to nab any Eryops, a predatory 1.5 M. (4.5 feet) amphibian that ventured from its nearby swamp. Vast deserts were created in the interior: areas torrid in the summer and bitterly cold in winter. About half-way through Permian time, during the Guadalupian Epoch, a large extinction event occurred. It may have been caused by a massive lava outpouring: the Emishan traps in the North China craton. Near the end of the Permian Period, several large meteors strike Pangaea; among them one in the eastern area of future Antarctica (Wilkes Land Crater) leaves an approximately 450 KM (300 mile) diameter crater and another in present offshore northwestern Australia (Bedout Crater) leaves a 200 km (120 mile diameter) "hole." During the late Permian, a momentous catastrophe occurs: massive basalt lava flooding in Siberia. During a period of around two million years, two to four million cubic km (480 to 960 thousand cubic miles) of lava and ash poured out of several vents and covered an estimated area of four to seven million square km (1.5 to 2.7 million square miles) to a depth ranging from over 4 km (13,000 feet) in the north to 1000 to 1800 m (3280 to 5900 feet) in the south.

This massive eruption which formed the present Siberian Traps was accompanied by huge outflows of CO_2, SO_2, CH4, Cl, F and water vapor, all of which resulted in greenhouse warming, acid rain, damage or destruction of the ozone layer and an anoxic ocean. These jointly seem to be the cause of the greatest mass extinction known. 90% to 95% of all marine species became extinct: the majority of brachiopds, all reef building cnidarians, most crinoids and bryozoans, the majority of ammonoids, all trilobites, the fusulinids and many other foraminifera and many fish species. Deep water biota were among the survivors. On land, about 70% of life forms were wiped out: several orders of insects, the pelecosaurs, large amphibians, and numerous plants. Atmospheric oxygen declined to 15% and the relative amount of CO_2 increased. Finally, Pangaea began to separate into two continental masses.

Note: This is the second part of a series. The next portion will be in the July—August Bulletin.

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If geologic time, the 4.54 billion years since the Earth began, could be reduced to a period of just a single year, the calendar of events would be as follows: **Part III**

December 9 – 3:50 P.M. – The **Triassic Period** arrives to "save the day!" **A new era – the Mesozoic** shows that life is resilient. Conditions still are less than optimum. Since sea levels were low and the continents were higher, huge deserts and violent sandstorms remain the order of the day. The high latitudes are wetter and allow sufficient vegetation - conifers, gingkos, cycads and seed ferns – to accumulate into future coal beds. The arucaria trees of the present Arizona Petrified Forest are alive and growing. The relatively few surviving Permian life forms had new niches to occupy. The first icthyosaurs and plesiosaurs explored the seas eating what they wished. Some sharks remained to compete with them. The first flying reptiles, pterosaurs, controlled the air and on land, large amphibians and crocodiles and the earliest mammal, probably a meter (3 feet) long monotreme took care to avoid the Coelophysis, an early bipedal dinosaur which grows to be 2.7 meters (9 feet) long, is carnivorous and probably agile and fast. Its smaller "cousin" Eoraptor is about a meter (3.3 feet) long, also bipedal and carnivorous and is a competitor to Herrerasaurus. They and 40 or more other now known Triassic dinosaurs were unknown in the Permian but arose from Permian reptile ancestry. Having suffered extinction of 37% of known Permian species, insects begin a come back and the first representative of grasshoppers probably stayed in the forests to dine on liverworts, ferns and mosses. It is joined by the first wasps, mosquitoes and ants. Sea urchins, ammonites and other mollusks develop anew in the seas along with a newcomer – belemnites. Surviving fish are joined by many new types. Modern colonial corals (Hexacorals) make their debut and build reefs in deeper water. But life is never always rosy. The very size of Pangaea on a sphere contributed to its instability and it began to split. A rift began at the western end of the neo-Tethys Sea and spread westward across the present Mediterranean, following the northwest African coast which was joined to North America. A branch reached into now north central South America. The result is another massive basalt flood which covers a greater area than the end of Permian event. This new catastrophe, for it engenders another mass extinction, creates what geologists have named the Central Atlantic Magmatic Province or CAMP. It seems to have formed fairly quickly, over a period of 580,000 years and spread over 10 to 11 million square km (3.86 to 4.25 million square miles. The Palisades in New Jersey and New York and lava deposits in Nova Scotia were formed then and are matched by basalt beds in Morocco and the western Sahara and by similar aged basalts in Brazil, French Guiana, Surinam and Guinea. Laurasia and Gondwana were again separate and Cimmeria moved northward toward Laurasia. At about the same time, a chain of volcanoes poked out of the sea off the western coast of Laurasia. They would later "drift" into the continental mass and form the early Sierra Nevada chain. While this chaos was ongoing, about 12 million years before the end of the Triassic Period, a 5 km (3.1 miles) diameter asteroid slammed into present day Quebec excavating a 100 km (62 miles) diameter (Manicougan) crater. The CAMP basalt flood created another CO_2 event which is recorded in paleobotanic evidence. An estimated 10^{12} metric tons of gaseous aerosols were injected into the atmosphere. Another devastating mass-extinction ensued! 35% of all animal forms and 20% of marine families died out: most mammal-like creatures, many of the big amphibians, all sizes of dinosaurs (but not all dinosaurs), ammonoids and bivalves were hard hit but enough survived to carry on, many types of land plants, and conodonts (which had been around since the Cambrian) disappear forever. Following the previous Permian extinction, this was a major blow to life on earth and is estimated to have happened during a period of 50,000 years or less.

December 14 – 10:19 A.M. – The Jurassic Period. Dinosaurs rule! Pangaean separation continues as Laurasia breaks apart into North America and Eurasia. By mid-Jurassic time, Gondwana splits into an eastern portion consisting of Antarctica, Australia, Madagascar and India and a western part (Eurasia) comprised of Africa, South and North America, Greenland, Europe and Asia. Later during the Jurassic Period, Eurasia continues to break apart and North America separates. The North China (Sino-Korean) and South China (Yangtze) blocks merge and by Mid-Jurassic time have collided with and joined the eastern Eurasian plate. As the North American plate moves westward over the oceanic plate, great amounts of sediments are bulldozed off the sea floor, pile up, and accrete to North America's western edge. Deep and extensive granitic masses intrude along the west coast. All this activity, part of the Nevadan Orogeny, results in a high, rugged mountain range, the Sierra Nevada. As it erodes during the remainder of the Jurassic, huge amounts of clastic sediments are swept as far eastward as the mid-continent (Morrison Formation: now exposed at surface in Utah, Arizona, etc and is subsurface in western Kansas). By mid-Jurassic time, the early Atlantic Ocean is estimated to have been around 600 km (380 mi.) wide. On the European side, continued splitting from Africa forms the Alpine Tethys Sea, an early precursor to the Mediterranean. In northern Europe, a rift system which started in the present North Sea during the Triassic failed and during the Jurassic, much volcanic activity and basalt flows occur as the underlying mantle warps upward. Most of western Europe lay under a shallow sea. Around 60 varieties of Jurassic saurians have been found. Members of the plate-back Stegosaur clan move about as they wish. Among several varieties of carnivore saurians, the "king" is the Allosaurus which is up to 8.5 m (28.5 ft) long and weighs in at around 5,000 pounds. The Yangchuanosaurus, a meat-eater which roamed in China was of similar size and temperament. Record-setting giant tetrapod herbivores develop during the Jurassic and become extinct at its termination. The ground quivered when they walked: the largest known, Seismosaurus grew up to 45 m (148 ft) long with estimated weight at 55 tons, the Brachiosaurus, Apatosaurus (alias Brontosaurus), Brachiosaurus and Ultrasaurus were a bit shorter and weighed somewhat less excepting the Ultrasaurus whose weight is thought to range from 55 to 130 tons. In the sea, four varieties of marine reptiles are to be avoided: plesiosaurs, mosasaurs, icthyosaurs and big turtles; all top-notch hunters. Brachiopods are reduced in number and type but ammonites, crinoids, sea urchins and belemnites thrive. 67 known genera of siliceous sponges thrive and build reefs in the shallow seas which covered central Europe. Hexacorals and algae flourish and form marine reefs from the equatorial zones to the high latitudes. Early in the Jurassic, something, perhaps a possible large release of methane from volcanoes, wiped out nearly 80% of marine shallow-water bivalve mollusks along with other shallow water creatures. Polar areas were warm and ice free. (At least one known dinosaur, the early Jurassic Crylophosaurus, roamed the Antarctica part of Gondwana.) The land surfaces were home for many other vertebrates and invertebrates: numerous types of fresh-water fish, insects (30 known species of flies), multituberculates (early mammals), mollusks, smaller, non-saurian reptiles and two possible types of birds occupy the hospitable land areas of the world. Deserts were still plentiful however, although some saurians and probably lizards survived in them. As the Jurassic came to an end, several varieties of animals, including the giant saurians, became extinct but the overall demise was far from the extent of earlier mass extinctions.

December 18 – 10:34 P.M. The Cretaceous Period. The end of the Mesozoic is in sight. The early Cretaceous climate continues to be warm and moist like the preceding Jurassic Period. Near the middle of the period, the climate warms as increased worldwide volcanism leads to an increase in atmospheric carbon dioxide and causes global warming. As the Pangaean breakup progressed smaller plates break off of Gondwana and move to new positions. As the Atlantic open between North America and Europe during early Cretaceous, a rift opens to form the Bay of Biscay and separate the Iberian block from present France. The block rotated counterclockwise into the western Tethys Ocean. The Atlantic Rift spread to the south and the African plate began to separate from South America and move northeastward. Also during the Cretaceous, the Apulian (alias Adriatic) plate broke off of Africa and began moving northward toward Eurasia. As it progressed, it will be involved in the formation of the Dinaric Alps (in the Balkans), the Apennines and eastern part of Italy and the southern Alps (much of this activity being post-Cretaceous.) Meanwhile, the Nazca and Antarctic plates are sliding beneath the western edge of South America and consequently pushing up the young Andes Mountains. Early in the Cretaceous, the Farallon Plate (a separate portion of the Pacific Plate) begins to slip beneath the westward moving North American plate. The Farallon contained blocks or "mini-continents" which move with it and with the accreted wedge of seafloor sediments are scraped off the sinking ocean plate and pressed into and "welded" onto the coast. This was the Sevier Orogeny and is the origin of the Coastal Range of California. The pileup of an accreting wedge creates a forearc basin in its forward area and the Great Basin of California was the result. As subduction continues, the sinking plate reaches depths where melting occurs and the lighter, hot, rising magma breaks through the surface, creating a volcanic arc where the future Sierra Nevada Range would appear. During about the same time, the North American plate was moving over a mantle plume (presently located beneath Yellowstone Park) that was melting and injecting granitic batholiths. However, the plate movement was still not exhausted. During the Late Cretaceous, the Farallon Plate was overridden by the westward moving North American Plate and slid beneath at a shallow angle at the base of the crust. This caused the Laramide Orogeny that continued past Cretaceous time and raises the Rocky Mountains along the weakened fault zone that had existed since the Ancestral Rockies of the Mississippian Period. Late in the Cretaceous, Greenland breaks off Eurasia. North and South America are not yet connected. By mid-Cretaceous time, a warming climate and submarine volcanism was displacing sea water onto land. Much of Europe was a shallow sea as was much North America where the Midcontinent Seaway extended from the Arctic Ocean to the Gulf of Mexico in a band a thousand miles wide. Worldwide sea level stands higher than at any time since the early Carboniferous Dinosaurs continued to rule the.earth but the behemoth sauropods of the Jurassic have been replaced a few slightly smaller types. The Ceratopsians appear and the "top dog" Allosaurus was replaced by the equally terrible *Tyrannosaurus rex*. The Pachycephalosaurs debuted and members of the duckbill saurian family assemble and move in herds. The relatively small but deadly Velociraptor and Utahraptor chase and eat whatever they can catch. Armored ankylosaurs and the giant crocodile, Deinosuchus, roam the shore zones and huge marine reptiles such as mosasaurs and plesiosaurs rule the seas. They may have hunted for the Archelons, marine turtles that are 12 feet long and nearly that wide. Many types of modern fish, including rays and sharks, swim in the seas; fresh water fish abound and pterosaurs and the first birds are airborne. The first known ants and termites must have bothered some animals. The first angiosperms or flowering plants were bothered by the first aphids and pollenized if needed by the first butterflies and bees. Many types of modern trees originate during the Cretaceous: sassafras, oak, willow, beech and magnolia to name a few. The grass family makes its first appearance; to proliferate throughout the future. The angiosperms will diversify and spread over the world. Invertebrate marine animals continue from the Jurassic with little effort. The oceans are full of various foraminifera including the first marine diatoms. Coccolithophores, single-celled, flagella-bearing, phyto-plankton covered with geometric scales of calcium carbonate jump from fewer than 100 species in the early Cretaceous to nearly 500 known species during upper Cretaceous times. On dying, their shells disintegrated and the separate plates fell to the ocean floors to form thick beds of chalk in northern Europe, the Sinai and western Asia, the North American Interior Seaway and western Australia among other areas. The Cretaceous Period went out with a bang!

Near the end of Cretaceous time, weather changed on earth. Atmospheric temperature increased, many shallow ocean areas became stagnant and atmospheric carbon dioxide increased to possibly eight times that of the present day. The Laramide Orogen began raising land elevation in central North America and the Cretaceous sea drained into deepening ocean basins. None of these changes bode well for life. Volcanism increased and in India (which was still below the equator and separated from Asia), massive flood basalt eruptions began. Named the Deccan Traps, they will erupt for nearly a million years and expel about 1,000,364 km^3 (240,000 $miles^3$) of lava and untold volumes of gases. During the same time frame, an estimated 10 km (6 miles) diameter asteroid impacted the Gulf of Mexico near the present site of Chicxalub on Mexico's Yucatan peninsula. It blasted out bedrock to depths between 15 and 25 km (9 to 15 miles) and made a crater with an outer ring 300 km (186 miles) in diameter. The blast vaporized limestone and gypsum beds sending huge amounts of sulfuric acid and carbon dioxide into the atmosphere. Dust and aërosols blot out sunlight for possibly weeks to months, lowering world temperatures. Tsunamis sweep in all seaward directions depositing debris in Haiti and the Brazos River area of present day Texas. Only 2,000 or 3,000 years earlier, a smaller asteroid had hit the center of present day Ukraine. It made a crater (the Boltysh Crater) 24 km (15 miles) in diameter and 590 meters (1,750 feet) deep. Still at the termination of the Cretaceous, there is evidence of a third asteroid, one 40 km (25 miles) wide struck the Indian Ocean off the coast of India leaving an oval crater roughly 400 by 600 km (370 x 250 miles) in dimension. The result of all this cosmic and volcanic mayhem was another mass extinction wiping out 85% of all species: dinosaurs, ammonites, rudist bivalves, marine reptiles, pterosaurs, many varieties of plankton, many land plants...all gone forever.

To Be Continued: Part IV will be in the September-October issue.

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If geologic time, the 4.54 billion years since the Earth began, could be reduced to a period of just a single year, the calendar of events would be as follows: **Part IV**

December 25 – 5:27 P.M. The Cenozoic Era! (Formerly known as the Tertiary.) Only 66.5 million years until Christmas. The Paleogene Period is divided into three familiar epochs – Paleocene, Eocene and Oligocene (oldest to youngest). As the Paleogene Period began, the world climate was cooler and arid but warmed and became moist as time passed. Atmospheric CO_2 declined and kept the climate from overheating to a "greenhouse" environment as the oxygen content slowly rose. Widespread volcanism continued from the Cretaceous through the Paleogene. Rifting began in western Europe during the Eocene and in the Red Sea and Gulf of Suez in the middle Oligocene. The Red Sea rifting was followed by massive volcanic activity in present Ethiopia and South Yemen. Near the end of the Eocene, the Pyrenees Mountains underwent severe folding.

Continued northward movement of portions of the African plate affected the Alps, Carpathians and Apennine mountains during the late Eocene and again during the late Oligocene. The western European rifting was preceded by crustal thinning with subsequent graben (down-dropped blocks) faulting and scattered volcanism during the Oligocene. Devil's Tower in Wyoming was intruded during the Eocene and Shiprock, a volcanic neck in northwestern New Mexico was intruded in Oligocene time. The Rocky Mountains continued to rise through the Paleogene into the Holocene and volcanism initiated rise of the Cascade Ranges in the Pacific Northwest as terrane blocks accreted to the continent and two adjacent oceanic plates subducted. The Kula plate sank northeastward to lift the Canadian Rockies and the Aleutian chain while the Farallon plate subducted to the east. Its northern part at a steep angle which caused it to melt and surface, forming volcanoes and its southern part at a shallow angle to farther elevate the Rocky Mountains, Colorado Plateau, etc. In Asia, the Indian plate continued its northward trek toward Eurasia and back arc volcanism caused rifting in east Eurasia, separating the future Japan from the mainland and moving it out to sea. At the end of Paleocene time, one of the greatest known sea temperature changes happened: the Paleocene-Eocene Thermal Maximum. Thought to possibly be caused by release of huge volumes of seabed methane, oceanic surface temperatures increased 5° to 8° C (9° to 14° F) and high Arctic sea temperatures increased to about 23° C (73° F) over a period of around 1,000 years. This had a severely negative affect on marine foraminifera and may have been responsible for the end of Paleocene extinction of some land creatures.

In North America, the early Eocene experienced an impact of a 3 to 5 km (1.9 to 3.1 miles) diameter asteroid that struck in the lower end of Chesapeake Bay making a crater 1.3 km (0.8 miles) deep and 137 km (85 miles) in diameter. Another one, possibly a piece of the Chesapeake bolide left its mark on the ocean floor: a 15 – 20 km (9.5 – 12 miles) crater on the ocean floor about 160 km (99 miles) east of Atlantic City, New Jersey. A third asteroid, probably part of a "swarm," struck dry ground at present Popigai in north central Siberia hit sufficiently hard to convert gneissic graphite to diamond, leaving a 100 km (61 miles) diameter crater. Overall, the Paleogene earth was quite active!

Extinction of the saurians left the many surviving Mesozoic mammals without much competition other than themselves. Many became predecessors to modern mammals. Small and medium sized insectivores filled the forests. Multituberculates, survivors from the Mesozoic, were possibly marsupials which thrived and reached their peak of diversity during the Paleocene. Ranging in size from that of a mouse to a beaver, they survived through the Eocene and finally disappeared in the early Oligocene. Oreodonts, sheep-sized artiodactyls (even number of toes) which have been described as "generic grazers" roamed western North America in great herds during the Eocene and Oligocene. The early through middle Paleocene epoch saw the origin of the first true carnivores, small generalized weasel-like mammals. The creodonts were also carnivorous mammals which appeared during the Paleocene in the northern hemisphere and in Africa. They ranged in size from that of a domestic cat to the *Sarkastodon*, an Eocene form that weighed in at an estimated 800 kg (1760 pounds). They are divided into two families, one cat-like and the other dog-like although cats and dogs did not evolve from creodonts. Creodonts survived into Miocene time. Condylarths filled an important niche. They were likely survivors from the Cretaceous and expanded in type and numbers during the Paleocene; surviving through the Eocene and disappearing in the Oligocene. They were herbivores and are thought to be ancestral ungulates (hoofed mammals). A well-known member was *Hyracotherium*, formerly known as *Eohippus* or the "dawn horse," a terrier-sized, forest dwelling animal ancestral to the modern horse. An ungulate unique to North America, *Uintatherium*, was a large plant browser ranging from 3 to 4.5 meters (10 to 15 feet) in length and weighing an estimated 4,500 – 5,400 kg (5 to 6 tons). Shaped rather like a modern rhinoceros, it carried three pairs of horns on its head and had two protruding saber-like upper teeth presumably used to rake up water plants. True rodents are first found in the late Paleocene and rapidly diversify through time. Several varieties of more or less modern birds evolved and by mid-Paleogene time, representatives of vultures, eagles and pelicans were extant. An unusual bird was *Diatryma*, four species of which roamed Northern America during the Paleocene and Eocene. Not capable of flight, it stood up to 2.4 meters tall (8 feet), weighed perhaps 175 kg (385 lbs) and sported a solid upper beak 23 cm (9 inches) long and 16.5 cm (6.5 inches) high. It probably was a predator or possibly a scavenger. Other animals included crocodilians, turtles, amphibians squamates (snakes and lizards) and of course, a variety of modern insects. Many types of sharks and other fish occupied Paleogene seas and primitive members of the whale family made an early appearance in Eocene North African seas. One notable whale was the Basilosaurus, an updated mammalian replacement for the Cretaceous mosasaur. Up to 21 meters (70 feet) long and equipped with long tooth-filled jaws, it may have been the top marine predator of its day which was over by the end of the Eocene. Grasses were beginning to take a greater hold on the land during Paleogene time but forests with trees and shrubs were dominant land plants: black walnut, magnolia, palm, chestnut, fig, cycads and grapes flourished with other angiosperms. Pines developed with other conifers and ferns and horsetail rushes filled the moist areas. Cacti made a debut in dry zones. After a 43.5 million year run, the Paleogene Era came to an end. Modern geography was shaping and modern life forms coming onto the world stage.

December 28 - 6:53 P.M. The Neogene Period! A new world! Or is it? Many things look familiar but there are a lot of museum quality animals roaming about. If we omit the Quaternary Period from the Neogene (as some scientists do) the Miocene or lower Neogene constitutes 86.5 % of Neogene time ... from 23 million to 5.3 million years ago. Coastal marshes as far north as modern Maryland harbored crocodilians while the giant *Carcharadon megalodon* – a far greater white shark than those of the present – ruled the sea. It was joined by its cousins which included most types of presently living sharks. Primitive deer, antelope, horses, seals, walruses, various members of the dog family including the "bear dog," a bear-sized canine are present during the Miocene and bears proper split off from the canid group during this time. Likewise, varieties of the elephant family, edentates (armadillos, anteaters, glyptodonts, etc.) and ground sloths roamed the earth. The perissodactyl group included a variety of horses, tapirs and rhinoceroses including the 5.2 meter (18 feet) (at the shoulder) tall *Baluchitherium* that found a home in Asia during the early Miocene. A fourth of known Miocene vertebrates died off near the end of that epoch or during the early Pliocene but 75% of the families have modern-day representatives. By late Miocene, the fauna of Eurasia and probably Africa were homogeneous: abundant families of bovines, dogs, cats (including saber-tooth varieties), mustilids (weasels, ferrets, etc), primitive bears and hyenas filled the land. Most of the modern bird families were airborne by the end of the Miocene and one non-flying "terror bird," *Titanis*, lasted until near the end of the Pliocene. It was a 2.5 meter (8 feet plus) predator that stalked the North American Gulf Coast.

World climate during the Miocene was warm and humid. Palm trees grew in present northern Siberia and Wyoming. The climate cooled as time passed and by the end of the Miocene, it became more arid and an icecap began to spread in Antarctica. During this time and during early Pliocene, many varieties of plants shifted to more amenable climes and were replaced by grasslands. In turn, grazing animals and their predators increased. Ancestral species of bison, possibly originating in India, migrated into Europe and North America (via a Bering Strait land bridge) during the late Pliocene and evolved into more modern types of the genus during the following Pleistocene. During the mid-Pliocene, movement of the Nazca Plate raised the Isthmus of Panama and for the first time, North and South America became connected, allowing faunal movement between the two. The first appearance of primitive hominids occurred in the lower Pliocene of Africa with the presence of *Ardopithicus* which was followed about two million years later by Australopithicines in the upper Miocene.

The Neogene world continued to be tectonically active. The Red Sea opened during the Pliocene and pushed the Arabian plate into the central Iranian microplate to create the Zagros Mountains. India continued its northward push into the Asian Plate, resulting in compressing some of Asia eastward and increasing elevation of the Himalayas and Tibetan Plateau. On the western end of the Alpine-Himalayan orogeny, the floor of the Alboran Sea in the western Mediterranean rose and compressed land on its north and south sides to cause folding and stacked thrust faulting to both sides creating the Rif Mountains in modern Morocco and the Betic Ranges on the Spanish side. During the Late Miocene about six million years ago, collision of the African Plate and the Iberian portion of the European Plate resulted in closure of the Strait of Gibraltar with consequent isolation of the Mediterranean. The sea dried and evaporite deposits up to two km. (1.25 mi.) thick accumulated in some areas. The Nile and Rhone rivers cut deep canyons and formed great alluvial fans on the arid Mediterranean floor and some African fauna migrated to former islands which became accessible on foot. About 700,000 years later rising sea levels, caused by a bit of global warming and ice melting in Antarctica, combined with renewed tectonic activity allowed reintroduction of ocean water across the Gibraltar barrier. A trickle over the 200 km. (150 mi.) barrier soon became a deluge and the Mediterranean basin was refilled in a little more than two years, resulting in an approximate drop of 10 cm (3.9 in.) in world sea level. Elsewhere in the world, Miocene and Pliocene volcanic activity thought to be caused by a mantle plume spilled some 184,000 km^2 (113,000 mi^2) of basalt lava in the Pacific Northwest and adjacent British Columbia. Some of the deposits are up to 1,850 m. (6,000 ft.) thick. Along the Pacific-North American coast, the Farallon Plate nearly completed subduction beneath the North American plate which continued its western trek aver the Pacific plate, As it over rode the East Pacific Rise (where the Pacific plate had struck the western edge of the Farallon), two transform margin faults were created: the San Andreas and the Queen Charlotte faults. The Pacific Plate was to move northward along the San Andreas and subduct to the north at the Queen Charlotte; both actions causing a history of devastating earthquakes. The Farallon Plate having been over ridden by the westward moving North American Plate was not finished. It seems to have leveled out its descent toward the mantle and broke apart in some areas. Some parts sank while others adhered to the bottom of the crust. These Late Miocene-Early Pliocene actions along with increased heat from the mantle stretched the overlying crust causing it to rupture and allow large blocks (grabens) to fall, forming the Basin and Range Physiographic Province. Upper mantle upwelling of uncertain causes (but possibly related to the Farallon Plate) occurred from Late Cretaceous time and accelerated during Miocene and Pliocene to lift the Colorado plateau from sea level to the current average elevation of 1,800 m (6,000 ft). A final but not yet completed effect of the Farallon Plate may have been the opening of the Rio Grande Rift, a potential continent-splitting opening that extends from north central Colorado to Chihuahua, Mexico and the Big Bend of Texas. Opening during Oligocene time and continuing through the Miocene and Pliocene, it is responsible for volcanic fields along its route. Rifting at present has slowed to 2mm per year

To the south, the Pacific Plate continued subducting beneath the Andes ranges, pushing them ever higher and creating a string of volcanoes. In the southwestern Pacific Ocean, the Australian plate, now independent of Antarctic, continued a northward path where during the Late Miocene, collision with the Asian plate caused the eventual uplift of the New Guinea Highlands to elevations ranging from 4,038 m (13,248 ft) on the east end of the island to 4,509 m (14,793 ft) on the west end. Tectonic activity elsewhere in the world continued through the Neogene but its description remains beyond scope of this story. Increasingly high mountain ranges, raising of the Central American isthmus and the isolation of Antarctica all contributed to changes in ocean and air currents and brought down world temperature by the end of the Pliocene. Antarctica became ice covered and ice was forming in the Arctic and some areas farther south. Many Neogene species of the dog, cat and horse families became extinct along with the giant megalodon shark and European crocodilians to name a few.

December 30 – 10:15 A.M. The Quaternary Period. It is 2.6 million years ago and the beginning of the **Pleistocene Epoch,** the latest "Ice Age." The most recent 10,000 years of the Quaternary is the **Holocene Epoch** which also is occasionally labeled the Anthropocene because of human-made changes to the earth (and, in the author's opinion, the vanity of the human race). The Quaternary is in many ways a rerun of the past: shifting continents, bolide impacts, volcanic catastrophes, extinctions and new families of biota. Pummeling of the earth from outer space continued when near or at the Pliocene-Pleistocene time boundary, a bolide struck in present southern Tajikistan and excavated the 52 km (31 mi) diameter Karakul Crater. Early in the Pleistocene, around 900,000 years ago, the 13 km (8 mi) diameter Zhamanshin Crater was made in Kazahkstan; the Bosumti Crater, a 10.5 km (8 mi) feature in Ghana, Africa was made 1.07 million years ago; the 1.18 km (1.9 mi) diameter Barringer Crater in Arizona is 49,000 years old; an ocean impact around the year 1443 on the New Zealand shelf is recorded by the Mahuika Crater which measures around 20 km (12 mi) in diameter and is 153 m (502 ft) deep. It produced devastating tsunamis, leaving beach sand at an elevation of 220 m (722 ft) above sea level on Stewart Island, New Zealand. More recently in June, 1908, an object estimated by NASA to have weighed 220 million pounds (99,790 mt) exploded at an altitude of around 28,000 ft (8,534 m) above Tunguska, Siberia laying waste to a vast area below.

Volcanoes are associated with plate tectonics or hot-spots and have affected the earth's topography and climate since its beginning. Major volcanic eruptions during the Quaternary have also made their mark, covering huge areas with ash, darkening worldwide atmosphere and creating sharp, though temporary climatic changes. According to the Smithsonian Institute, between 1,300 and 1,500 volcanoes have erupted on the earth's surface during the past 10,000 years (Holocene time). The first of 183 historically documented Holocene eruptions was in central Turkey about 6,200 B.C. There are perhaps a million young volcanoes on oceanic floors. Estimates of active volcanoes during the entire Quaternary are not readily available but the number must be great. Some of the significantly climate-affecting volcanoes are: the Yellowstone Caldera in Wyoming erupted in the Early Pleistocene, about 2.1 million years ago. It spewed approximately 2,450 km^3 (588 mi^3) of ash into the atmosphere and left a caldera 100 x 50 km (62 x 31 mi) leaving ash deposits which can be found in the subsurface strata of the Mississippi Delta and which blanketed much of middle America. The Valles Caldera located in the Rio Grande Rift zone of New Mexico blew out an estimated 600 km^3 (145 mi^3) about 1.15 million years past during Middle Pleistocene time. The Long Valley Caldera in California covered much of western North America with 600 km^3 (145 mi^3) of ash when it violently erupted 759,000 years ago. Its "crater" a 17 x 32 km (10.5 x 18.5 mi) feature offers signs of renewed activity. The Atitlan Caldera in the Guatamalan Highlands erupted 84,000 years ago, ejected 270 km3 (65 mi3) of tephra (ash, etc) and blanketed Guatamala with tephra deposits 200 m (656 ft) thick in some areas. An estimated 700 kilotons of elemental bromine was released into the atmosphere with the eruption. At present, the caldera contains three active volcanoes. The greatest known surface volcanic event during Holocene time may be the Toba eruption which occurred on the island of Sumatra approximately 74,000 years ago. Its 2,800 km^3 (670 mi^3) of ash covered Southeast Asia, India and the Indian Ocean as far as Africa. The ash was accompanied by an estimated six billion tons of sulfur dioxide (SO_2).

The input of huge volumes of sulfates, carbon dioxide and various gases from erupting volcanoes caused a cooling effect in the earth's atmosphere and subsequently on its surface. This would be a cause, most likely a minor one, of the most severe and lasting phenomenon of the Holocene: the Pleistocene glaciation or "Ice Age". Volcanic eruptions, however, would have a short term effect on climate – a few years. The Pleistocene ice age lasted about a million years; so primary causes were long term events. World climate was cooling somewhat during Late Pliocene time and the cooling continued into the Pleistocene. Orbital and axial vaiations (Milankovich effects), the connection of North and South America by the Isthmus, earlier closing of the Tethys Sea and continued tectonic plate movements were adequate to alter ocean currents and together with continuing tectonic movement raising mountain ranges ever higher (Alpine-Himalaya, Andes, etc) all combined with fluctuating output of solar energy to cause worldwide temperature changes of a few degrees. There were at least four major advances and retreats of ice sheets in North America and six or seven in Eurasia. In South America, the Antarctic ice cap expanded over the southern Andes and Patagonia. In mountainous areas (Southern Alps in New Zealand, Rockies, Himalayas, Alps, etc) mountain glaciers advanced and coalesced on foothill zones and adjacent prairies. At some periods, up to 30% of the earth's surface was covered by ice that in certain areas exceeded 3,900 m (13,000 ft) thickness. The great static weight of ice caused the crust beneath it to buckle and squeezed the underlying aesthenosphere downward and outward hundreds of meters. Following retreat of the ice caps, the land surface slowly "rebounded" – an effect still continuing in Scandinavia, Canada and other previously ice-buried areas of the world. The evaporative loss of water making all the ice resulted in lowered world sea level of around 140 m (459 ft) causing much wider coastal plains or steep escarpments to sea level in non-frozen areas.

During summers, melt-water flowed from the leading edges and from beneath ice caps carrying huge amounts of crushed bedrock (called rock flour) into drainage streams. Winter brought arid conditions; and winds blowing off high atmospheric pressure cells above the ice caps mobilized the previous summer's dust and moved it in the prevailing wind direction. As it blew over low areas such as basins and valleys, the wind velocity slowed and the dust dropped out. Settling, the dust formed non-stratified layers which are termed loess. Loess deposits which occur downwind from the world's formerly glaciated areas range in thickness from a few inches to typically less than one hundred feet. The Illinois Geological Survey has noted that about 30% of North America has loess deposits atop bedrock. In north central China, the Loess Plateau however is typically 300 m (1,000 ft) thick and blankets around 380,000 km^2 (147,000 mi^2). All that loess is not glacial in origin however. Lower parts are pre-Pleistocene and were caused by aridity induced by the rising Himalaya Range that cut off rainfall from the south and replenishment of large lakes to the west. The loess creates huge dust storms in modern China and loads the Yellow River with silt.

As the ice caps formed and moved southward (in the Northern Hemisphere) the biotic zones were forced southward. As the climate cooled, crocodilians died off in Europe and moved south in North America. The giant megalodon sharks died out as did many horse and cat species. "Fuzzy" mammals arrived and remained during the Pleistocene: wooly mammoths, wooly rhinos, musk ox and yaks. Giant deer, cave bears (AKA short-face bears), saber-tooth cats, hippos, and others populated non-glaciated areas. Excepting the yak in the high Himalayas, musk oxen in Ellesmere Island and elsewhere in the far Arctic and pygmy mammoths on Wrangel Island off the Chukchi Peninsula , all would become extinct by the end of the Pleistocene. Extinctions in North and South America include the mammoth, mastodon, camel, horse, ground sloth, giant beaver, glyptodon, giant bison, saber tooth cats, dire wolf, American lion and short-face bear. The pygmy mammoths of Wrangle Island survived into historical time, the last survivors dying around 1650 B.C. Other similar mammoth fossils, dated at around 3690 B.C were found on St. Paul's Island in the Alaskan Pribilofs.

Several types of primitive bipedal humanoids appeared in Africa during the Late Pliocene and Early Pleistocene. By Middle Pleistocene, some 1.8 million years ago (37 minutes on the time scale of this paper), *Homo erectus*, generally considered to be the ancestor of modern humans, Heidelberg Man, Neanderthals and Denisovans (a 2010 discovery in Denisova Cave in the Altai Mountains of south central Siberia) was on the scene. All the preceding are members of the genus *Homo*, with Heidelberg man preceded by *Homo*

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erectus and followed in time respectively by Neanderthal and Denisova man and in the Late Pleistocene by modern man or *Homo sapiens* sapiens. Another Late Pleistocene representative of the *Homo* genus is *Homo floresiensis*, a pygmy or dwarf hominid discovered on the Indonesian Flores Island in sedimentary deposits ranging from 95,000 to 17,000 years. Ongoing debate concerns whether floresiensis is a *Homo erectus* descendent made small by "island dwarfism" (such as the Wrangel and St. Paul's Island mammoths) or descends from some other hominid branch such as the *Australopithecus* group. The Flores man is known to have made and used stone tools and to have hunted and eaten pygmy elephants that also were resident on the island.

December 30 – 3:44 P.M. The **Holocene Epoch** or last 10,000 years of earth history has experienced an ongoing general warming period which may represent another interglacial period or the final departure from the last round of continental glaciation to be followed by return to a warm, ice-free planet such as that of the early Paleogene. Tectonic plates continue to move and will again reshape Earth's geography given sufficient time. Volcanoes continue to create chaos … the Smithsonian Global Volcanism Progam reports 5,337 historical eruptions and the Arabian and Indian Plates continue to push northward causing violent earthquakes from China to Turkey. And lurking in space are asteroids and comets with known orbits that mathematically intersect the Earth's orbit. It probably is only a matter of time until another Chicxalub or Shiva incident happens and causes still another mass extinction. Which politicians or scientific groups will be blamed for that? It's nearly New Year's Eve! There are a only few more hours to decide before the year ends – 99.9% of time has passed. The answer to such a trivial question must wait until next year.

This essay covers only part of the significant events that have shaped the modern earth. The time periods and their durations named in this essay are taken from the *International Stratigraphic Chart* published in 2006 by the International Commission on Stratigraphy and the Precambrian portion of the periods and duration from a chart published in 2009 by the Geological Society of America.

There are between 500 and 700 references used for information contained herein. I have chosen not to list them because of their quantity. The references used are taken from internet sites hosted by the U. S. Geological Survey, the British Geological Survey, the Canadian Geological Survey, the Illinois Geological Survey, the Geological Society of America, The Geological Society (London), Smithsonian Institute, the National Geographic Society, the American Museum of Natural History, the Norfolk Museum (England), Journal of Geophysical Research, Quaternary Research, the Paleontological Research Institute, many North American and British universities. Textbooks include: *Vertebrate Paleontology*, 3rd ed.. By A.S Romer, *Microfossils* by M.D. Brasier, *Glacial and Pleistocene Geology* by R.F. Flint, *Basin and Range* by John McPhee, *Frozen Earth: Explaining the Ice Ages* by R.V. Fodor, *Roadside Geology of New Mexico* by H. Chronic and *Introduction to Historical Geology* by R.C. Moore. No non-documented or "esoteric" internet sites were used. Interested readers are advised to consult an internet search engine such as "Google" or "Ask" by entering the names of subjects or terms used in this essay.

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October, 2011