CONTINENTAL DRIFT, SUPER VOLCANOS, ASTROIDS AND UNDERSTANDING THEIR EFFECT ON SPECIES

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INTRODUCTION

The paper focuses on the science of zoos and aquariums, addressing the need to add more science to the interpretation of animal exhibits that we develop in our zoos. The recent disaster of the tsunami caused by the earthquake off Banda Ache, Sumatra measuring 8.5 (reported as 9) on the Richer Scale on 26 December 2004 followed by earthquakes on 28 March 2005 (Nias Island) measuring 8.7 and 10 April 2005 (Mentawi Island) measuring 6.7 has evoked a sudden interest and concern in the forces of nature and their effects. (Please refer to Annex 1 The Grading of the Richer Scale). My focus in this paper is on the effects of natural disasters on their impact on the evolution of animal species.

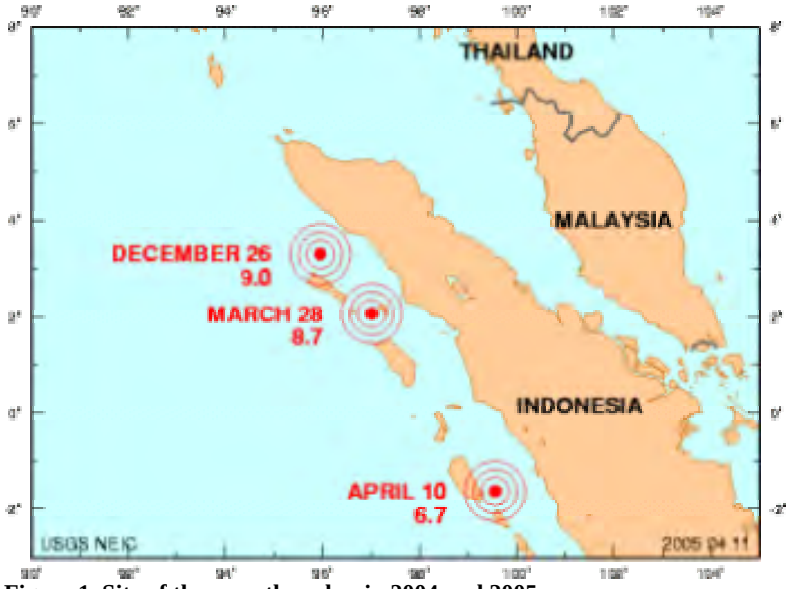

Figure 1. Site of three earthquakes in 2004 and 2005

Zoo designers & interpreters are encouraged to develop new exhibits using examples from the earth's geological time lines and important events in pre-history to make animal exhibits more interesting, scientifically enlightening and exciting. Thus the fact that:

1. India and Australia share the a similar geology since they were once part of the same continent;
2. An asteroid striking earth 65mya[1] probably caused the end of the age of dinosaurs and closed the Cretaceous Period (144 to 65mya);
3. The spread of grassland which commenced in the Paleogene Period (65mya to 25mya) because of drying climatic conditions led to the diversification of grassland fauna;
4. The eruption of the super volcano Toba 75,000ya[2] almost caused the extinction of the human species;

[1] mya= million years ago
[2] ya= years ago

5. The Ice Age opened land bridges for the radiation of mammals and humans;

These are all facts that can be woven into the interpretative fabric of exhibit design and by doing so, not only enhance their educational and scientific value but only offers a potential for adding excitement through special effects.

THE EARTH'S GEOLOGICAL TIME LINES

Figure 2. Pangea and the Panthalassic Ocean

It was not so long ago in geological terms - during the Triassic Period (248–205 mya) that there was only one continent - Pangea. About 200mya Pangea started to break up and continents began to drift. The early dinosaurs and the first mammals appeared during this period. The first Gymnosperms had already appeared in the Carboniferous (375 mya)

Jurassic Period 213–144 Million Years Ago

Figure 3. Luarasia and Gondwana

The Jurassic was a period of continents drifting as Pangea separated into two super continents of the northern Laurasia (North America & Eurasia) and Gondwana (South America, Africa, Australia, Antarctic & India). The continents continued to drift. The dinosaurs became more divers, the first birds & angiosperms appear.

Cretaceous Period 144–65 Million Years Ago

Figure 4 The six modern continents & India form

During the Cretaceous, most continents were widely separated with the formation and drifting of North America, Eurasia, South America, Africa, Antarctica, Australia and India. During this period the dinosaurs continued to radiate. Flowering plants, mammals and angiosperms radiated and diversified.

CONTINENTAL DRIFT

Continents float like giant icebergs on top of the earth's upper mantle. The uppermost mantle is composed of a rigid lithosphere and below it is a molten asthenosphere. The upper lithosphere is also known as the earth's crust - the cool, outer surface that we see.

There are two types of crust:
1) Oceanic crust (dark, heavy basaltic rock)
2) Continental crust (relatively lighter-colored and lighter - weight granitic rock).

Figure 5 Heavier oceanic crust basalt formations

Figure 6 Lighter, continental crust granite formations

Broken up into a number of distinct, moving tectonic plates, the lithosphere slides in constant slow-motion on the earth's surface. Where plate boundaries converge, this motion causes the lithosphere from one plate to be pushed beneath another, where it is melted and recycled. This movement is known as subduction.

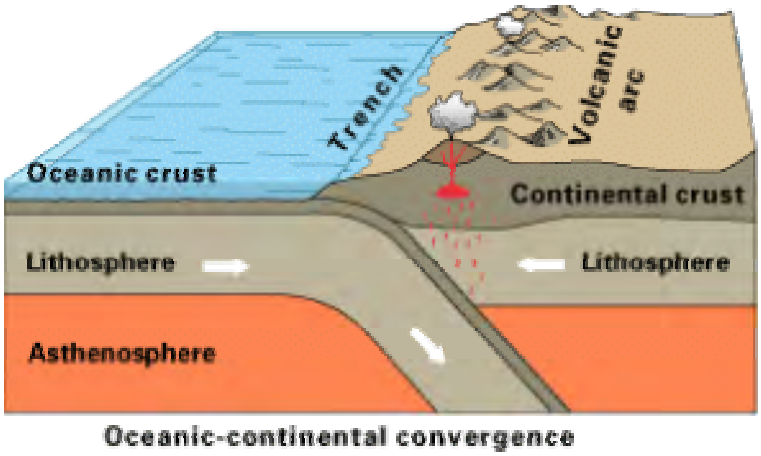

Figure 7 Subduction - lithosphere from oceanic crust being pushed beneath continental crust

Thus the constant movement of these tectonic plates causes the continents to drift.

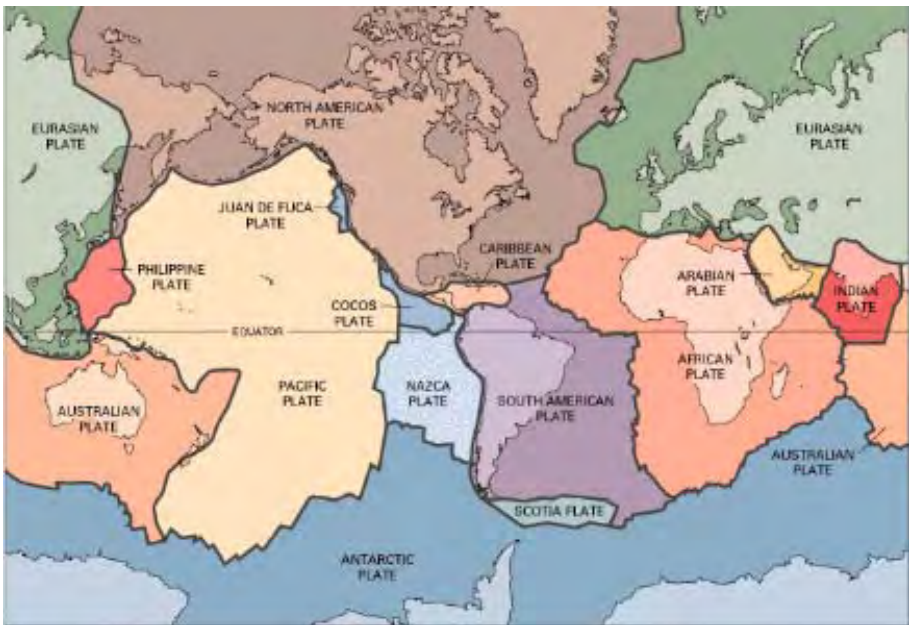

Figure 8 Tectonic Plates of the earth's surface

Subduction and the forces associated with it can create spectacular mountain ranges. This is how the continuous mountain chain around the Pacific Ocean known as the "Ring of Fire" came about - a subduction zone creating magma chambers in the upper mantle, from the tip of South America north to Alaska, then running south through Japan, Southeast Asia and continuing as far south as New Zealand.

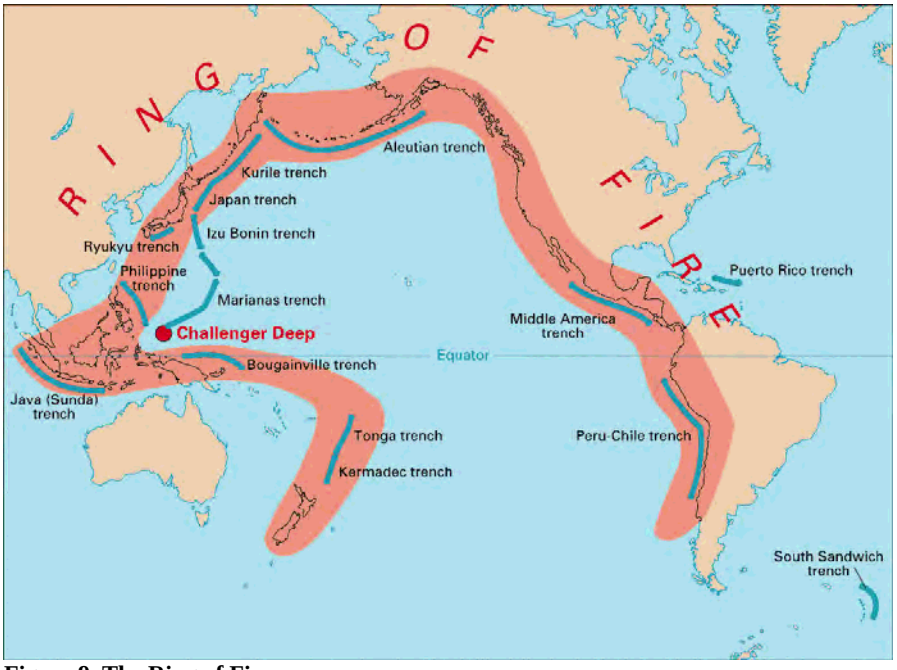

Figure 9 The Ring of Fire

MASS EXTINCTIONS

There have been five major implosions of extinction over the history of the earth:

- The 1st was 430 million years ago (Ordovician) when 85% of all life was extinguished accounting for mainly marine invertebrates and jawless fish. The cause of extinction was probably major habitat change
- The 2nd great implosion of extinction was 360 million years ago (Devonian) when fish, insects and amphibians were at their peak. The cause of the extinction was probably global cooling
- The 3rd implosion was after the formation of Pangea 248 million years ago (Permian) when 95% of all reptiles and amphibians became extinct. The cause of the extinction was probably volcanic activity
- The 4th implosion was 213 million years ago (Triassic) affected the early dinosaurs, first mammals, and marine vertebrates. The cause of the extinction was probably volcanic activity
- The 5th and last happened 65million years ago marking the end of the Cretaceous and the end of the Dinosaurs. The cause of extinction was probably an asteroid impact coupled with volcanic activity especially in India - the Deccan super volcano.

INDIA AND AUSTRALIA SHARE A SIMILAR GEOLOGY SINCE THEY WERE ONCE PART OF THE SAME CONTINENT

It is interesting to note for the joint conference of SEAZA and ARAZPA that India and Australia share a similar geology since they were once part of the same continent of Gondwana.

Figure 10. Movements of India and Australia

Gondwanaland - made up of Africa, South America, Antarctica and Australia - split apart during the mid-Mesozoic Era (150mya), India drifting steadily northwards in the Late Mesozoic (70mya) towards the super continent of Laurasia, commenced to collided with Eurasia about 45mya and eventually suturing about 20mya. The collision did not stop there but penetrated 2,500km inland, thrusting up the high plateau of Tibet (5,000m above sea level) and the Himalayas (7-8,000m above sea level). The initial land bridge at contact 45mya allowed Cenozoic mammals to invade.

Figure 11 The Himalayas – Mount Everest

The presence of almost identical Permian rocks (286 to 245mya) in South Africa, Southern India and Australia coupled with almost identical fossils of land plants and animals also reinforce this close association.

It is postulated that first marsupials appeared in North America approximately 80 million years ago. Towards the end of the Late Cretaceous, marsupials started appearing in South America and by the Eocene (55mya to 35mya) had radiated into Europe, North Africa and reached Asia by the Oligocene (35mya to 25mya).

South America parted company with North America in the Eocene, effectively blocking the rapid radiation of placentals in North America at this time from spreading to South America. During the Eocene, marsupials reached Antarctica, which was attached to South America and Australia at this time. Marsupials could follow a belt of *Northophagus* vegetation[3] all the way around from southern South America, across Antarctica into southern Australia. The first marsupials appear in Australia in the Oligocene via this route. Australia parted company from Antarctica in the Miocene, effectively isolating the marsupial fauna there.

To complicate this marsupial issue, in 2003, fossil bones of the earliest known marsupial *Sinodelphys szalayi* - were uncovered in China, forcing a major rethink of the origins of marsupials, as the fossil has been dated to 125 million years ago. This is 50 million years older than the previous oldest marsupial skeleton, and sheds doubt on the prevailing theory that marsupials originated in North America. Marsupial fossils have not - as yet - been found in India.

[3] Trees belonging to the family of the Nothophagus, such as: low deciduous beach tree, evergreen beach tree and the high deciduous beach tree

Figure 12 . Artist impression of *Sinodelphys szalayi*

AN ASTEROID STRIKING EARTH 65MYA CAUSED THE END OF THE AGE OF DINOSAURS AND CLOSED THE CRETACEOUS PERIOD

There have been five great Implosion of Extinction over the past 500 million years which have wiped out between 75 to 95% of all species on earth. Each have been caused by some catastrophic event be it the eruption of a super volcano, the strike of a large asteroid, climatic change – like the Ice Age or the like. The 5th and latest implosion happened 65mya during the Cretaceous Period (144 to 65mya); when Laurasia & Gondwana were separated, continents were drifting and dinosaurs & flowering plants had radiated. It is thought that this implosion was caused by a large asteroid some 10km in diameter that hit the Yucatan peninsula in Mexico leaving a 180km diameter crater.

Figure 13 Site of asteroid strike

It is postulated that trillions of tons of debris was thrown into the atmosphere and enormous tsunamis and high winds were started. The blast would also have started a chain reaction of earthquakes and volcanic activity. In the weeks that followed a cloud of debris was carried over large distances by the post blast high winds. This will have caused months of darkness and a decrease in global temperatures followed by global warming and acid rain. On the land the effects of the impact on the flora and fauna would have been devastating, especially on the large animals which would need large food supplies and on the dinosaurs which would need sun light to keep warm.

It is postulated that the Indian Deccan super volcano (not a violent eruption but releasing huge amounts magna) erupted during the same period releasing 2,000 cubic kilometers of magma[4] (basaltic flow) which covered 1.5 million square km. It formed the Deccan Traps - Deccan Plateau. Although not violent the volcanic gasses released in the process may have played a role in the extinction of the dinosaurs.

Figure 14 Deccan Traps, india

There is mass extinction ended the Cretaceous Period and the dinosaur dynasty ends.

THE SPREAD OF GRASSLAND LED TO THE DIVERSIFICATION OF GRASSLAND FAUNA

Vegetation at the beginning of the Eocene (56 to 35mya) was very much forests of gingko and conifer (Gymnosperms) trees with ferns, reeds, horsetails and cycads.

[4] In comparison the 1980 eruption of Mount St. Helens produced 1 cubic km of volcanic material

Figure 15 Jurassic Forest - typically of gingko and conifer (gymnosperm) trees with ferns, reeds, horsetails and cycads.

Various groups of small forest mammals filled the vacuum left by the mass extinction of the dinosaurs and gradually evolved to fill the various ecological niches open to them. Due to continental drift the vast inland seas in North America and Eurasia dried up exposing large areas of flat land which was gradually colonized by grasses. The changing environment was reflected by new adaptations from the forest-living mammals to life on the grassy plains - the future prairies, steppes, pampas and savannas.

Figure 16 Steppes

Life on the plains presented a whole new set of problems. For the first time animals could see for miles around them, fundamentally affecting both predators and their prey. The herbivores learned to hide safely in large numbers and began to grow bigger, whilst meat-eating carnivores had to become fast moving masters of disguise.

In the Miocene (24mya to 6mya) some animals adapted special teeth to eat the grass that evolved. Many spread across the continents when Africa, Eurasia and North America joined. Representatives of modern mammal groups became the dominant vertebrates. Horses, pigs, true carnivores, rhinoceroses, elephants and camels roamed the colliding continents. Only Australia and South America were isolated continents and unique grazers evolved there.

Adaptations to eating grass

There are presently two Orders of Ungulates: Perissodactyla (odd-toed ungulates e.g. horses) and the Artiodactyla (even-toed ungulates e.g. cud chewing ruminant antelope).

To obtain nutrition from grass a herbivore must use its teeth to break through the cellulose cell wall and form symbiotic relationships with bacteria to breakdown the cellulose (which, unlike the ungulate, can produce an enzymes to digest it). To protect themselves, some grasses evolved silica into the cellulose cell wall, a hard crystalline mineral that will abrade teeth quickly.

The ungulates evolved structural adaptations to deal with grass, cellulose, silica and the open nature of the habitat where they would obtain their food.

Molars became larger, premolars became more like molars and offered large rough surfaces for grinding down cellulose walls. The amount of tooth protruding through the gum became much greater, i.e. the teeth became taller, dealing with the abrasiveness of the silica in the grasses by allowing for more wear. These teeth evolved to expose - on the tooth top surface - enamel, dentine and cement - materials offering different resistance to wear. This means that the teeth wear unevenly maintaining an uneven surface of depressions, separated by sharper edges.

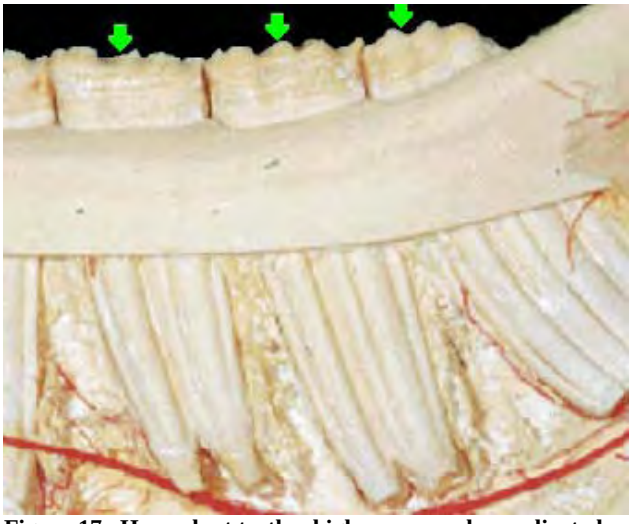

Figure 17 Hypsodont teeth – high crown and complicated enamel folds to increase durable component exposed

The ungulates also developed a symbiotic relationship with micro-organisms: they evolved a special chamber in the gut in which they keep bacteria and ciliate protozoa. They house these organisms at the right temperature and supply them with food and water; the micro-organisms use

their enzyme cellulases to break down the ingested plant material which the ungulates also absorb.

A prairie offers no place to hide from predators thus the ungulates evolved abilities for running away from predators: primarily limbs with a long stride length and the weight of the body was supported entirely by hoof-clad toes.

THE ERUPTION OF SUPER VOLCANO TOBA 70,000 YEARS AGO ALMOST CAUSED THE EXTINCTION OF THE HUMAN SPECIES

The 'Out of Africa' Hypothesis

The last glacial period was apparently caused by the eruption of the super volcano Toba 70,000ya. The six year long volcanic winter and 1000-year-long Ice Age that followed may have decimated Modern Man's entire population. Man's population size fell to about 10,000 adults between 50 and 100 thousand years ago. The survivors from this global catastrophy would have found refuge in isolated tropical pockets, mainly in Equatorial Africa. Populations living in Europe and northern China would have been completely eliminated by the effects of the 1,000 km³ of ash which was thrown into the atmosphere - so much which it blocked out light from the sun all over the world. Global temperatures plummeted by 12ºC.

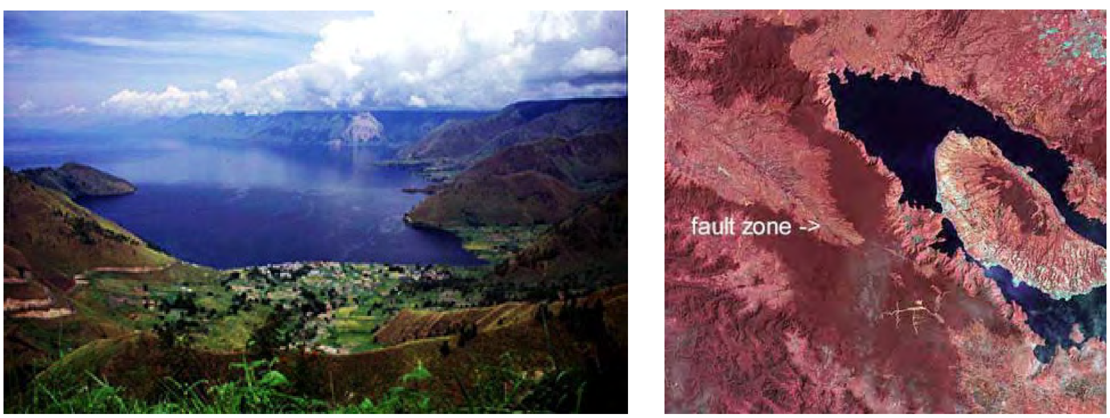

Figure 18 Lake Toba's water filled caldera, 100km by 30km which contains Samosir island. Note the fault zone

What is a super volcano

Super volcanoes are the most destructive force on this planet. They lie dormant for hundreds of thousands of years as a vast reservoir of magma builds up inside them before finally they unleash their apocalyptic force, capable of obliterating continents.

Super volcanoes differ from normal volcanoes in many ways. The stereotypical volcano is a towering cone, but super volcanoes form in depressions in the ground called calderas. When a normal volcano erupts lava gradually builds up in the mountain before releasing it. In super volcanoes the magma never reaches the surface but instead begins to fill massive underground

reservoirs. This continues for hundreds of thousands of years until an eruption occurs, which blasts away a huge amount of ground, forming a new caldera.

There are super volcanoes in the Indonesia, USA, South America and New Zealand. The Yellowstone Park in the USA is a super volcano caldera which erupts with a near-clockwork cycle of every 600,000 years. The last eruption was more than 640,000 years ago – thus we are overdue for a massive eruption soon!

Also according to Professor Ray Cas[5] Toba sits on a fault line running down the middle of Sumatra - just where some seismologists say another earthquake might strike following the series of three earthquakes mentioned earlier. Those quakes occurred along fault lines running just off Sumatra's west coast and created seismological stresses which could hasten an eruption.

Figure 19 Sumatran Trench and Fault

THE ICE AGE OPENED LAND BRIDGES FOR THE RADIATION OF MAMMALS AND HUMANS

The Pleistocene (1.5 to 0.1mya) is best known as the "Great Ice Age," when ice sheets and other glaciers encroached and retreated during four or five separate glacial periods. At its peak, almost

[5] Monash University's School of Geosciences

30% of the Earth's surface was covered by glaciers and parts of the northern oceans froze. Large variations in sea level of were caused by the growth and melting of global ice sheets.

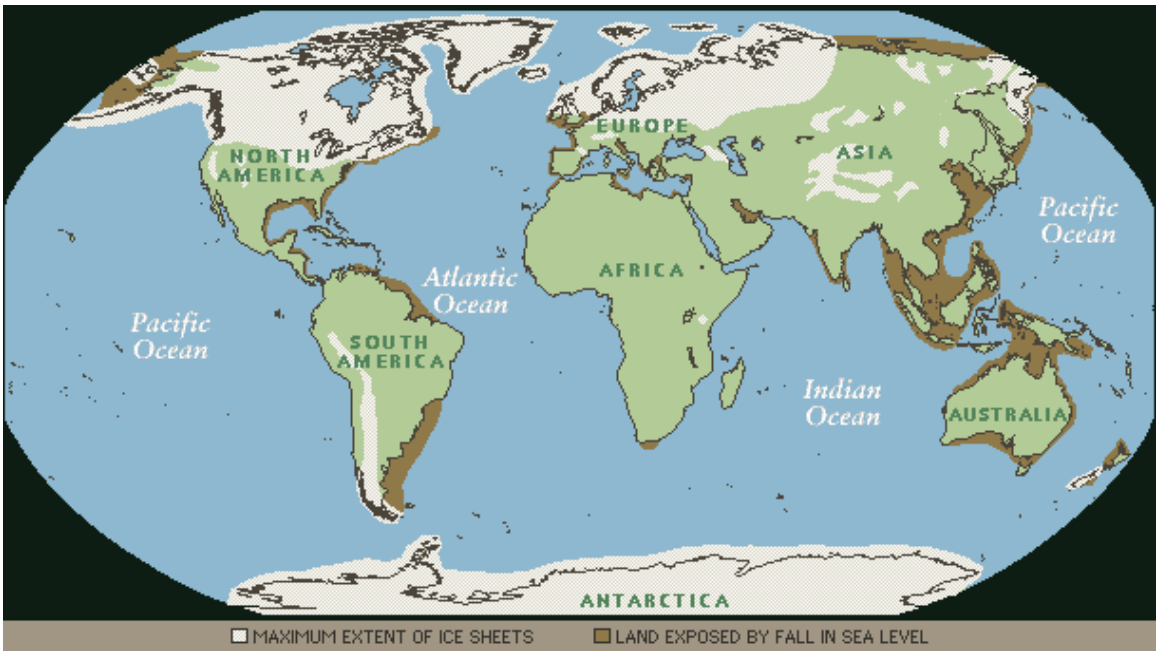

Figure 20 The Ice Age - Pleistocene 1.5 to 0.1mya

During the ice age, the supercontinent of Africa-Eurasia and the Americas was formed, connected by the Bering Land Bridge. Another land bridge connected Australia and New Guinea then, and they formed the continent of Sahul.

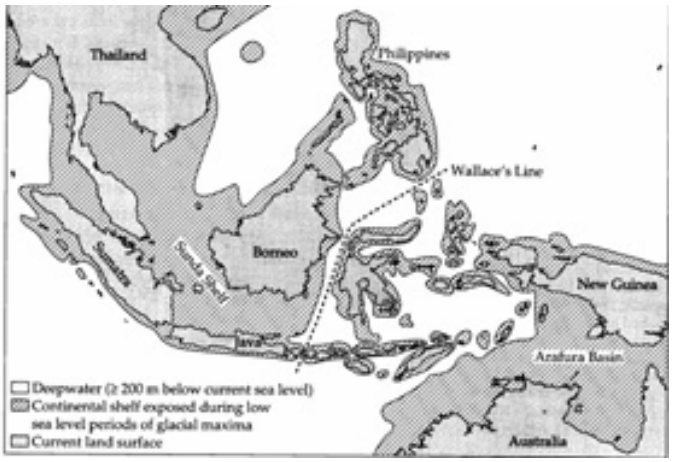

Figure 21 Land bridge connecting Sahul with Eurasia

Thus there was a 3-continent world during the ice age: Africa-Eurasia-America, Sahul, and Antarctica. These connections were made possible because of three factors: Continental drift and connection i.e. North & South America; ice sheets connections i.e. Bearing Straits; and the lowering of the ocean levels by up to 100 metres because of water being locked as ice i.e. allowing land bridges from Eurasia through South East Asia to Sahul (New Guinea to Australia).

.Figure 22 Dymaxion map of the world – unfolded. Note the potential land bridges

Major Extinctions of Large Animals

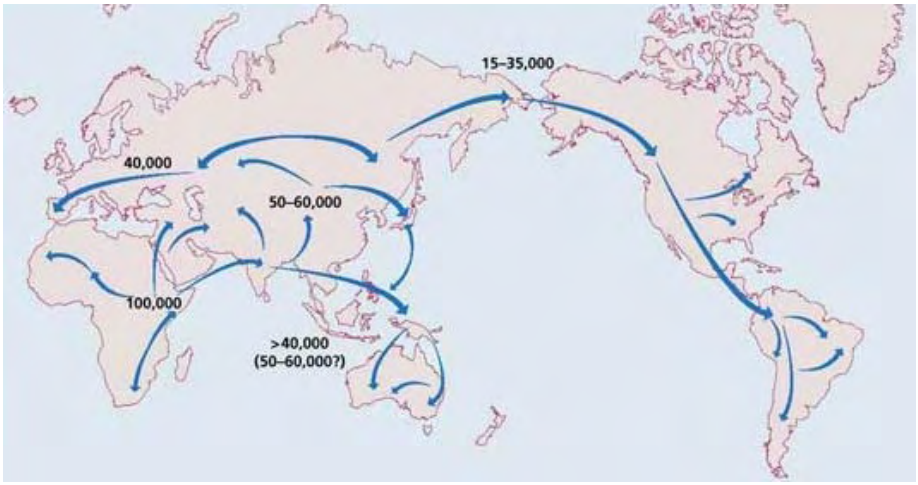

Figure 23 Man's spread over the world

Major extinctions of large as well as small mammals and birds coincides with man's arrival in various continents and islands around the world, as follows:

Continents/Islands	Years Ago (ya)

Africa		100,000
West Asia & Central		60,000
Australia		50,000
South Europe	40,000	
North Europe		15,000
North America		11,000
South America		10,000
West Indies		4,000
New Zealand	900	
Madagascar		800

It is postulated that as man evolved in Africa, the mega-vertebrates that evolved with him evolved *learnt* to avoid /develop a healthy respect for him. Thus, Africa still retains about 70% of the mega fauna that was present 50,000 ya. The mega fauna of other continents did not fair so well, having not evolved a healthy respect for him and thus being extremely vulnerable to being hunt. Some examples of species that were present and became extinct after man's arrival are As follows:

In Eurasia man also arrived 40,000ya and such giants as the Wooly Mammoth becomes extinct 11,000ya, the Wooly Rhinoceros 10,000ya and the Irish elk becomes extinction 9,000ya.

In Australia man arrived about 50,000ya and such maga-vertebrates like Genyornis (Demon duck), Megalania (Giant ripper lizard) and Diprotodon (a huge wombat) become extinct about 25,000ya. The Thylacine (Tasmanian wolf) became extinct in 1930.

North America is known as the Ice Age Serengeti because of its abundance of mega fauna. Man arrives 15,000ya and the American mastodon and, Short faced bear, the cheetah and the Saber toothed cat became extinct 12,500ya and Columbian mammoth, the Western camel and the American lion became extinct 10,000 ya, Saber-tooth cat. Species like the camel crossed over to Eurasia & South America and the cheetah crossed to Eurasia and Africa.

The land bridge between North and South America was formed some 3mya, with movement of animals gradually occurring. Man arrived across the land bridge 10,000ya. The Giant armadillo (Glyptodont) became extinct 10,000ya and the Giant ground sloth (Megatherium) became extinct 8,000ya.

Prior to the development of ocean going canoes, man spread across the globe on land bridges. However the Polynesian seafarers arrived in New Zealand 900ya and the 11 species of Moa became extinct by 1600 AD. Similarly, seafarers arrived in Madagascar and the largest bird ever to have lived Elephant bird became extinct in 1700 AD.

CONCLUSION

It is so essential when planning an exhibit to think of a good story line. For the primary purpose of zoo is to deliver messages about conservation - we are story tellers and need

to tell the story well. The story of extinction has never seriously been told and ironically extinction was only *discovered* about 200 years ago!

Richter Scale

Annex A

Richter Magnitude	TNT for Seismic Energy Yield	Example (approximate)
-1.5	6 ounces	Breaking a rock on a lab table
1.0	30 pounds	Large Blast at a Construction Site
1.5	320 pounds	
2.0	1 ton	Large Quarry or Mine Blast
2.5	4.6 tons	
3.0	29 tons	
3.5	73 tons	
4.0	1,000 tons	Small Nuclear Weapon
4.5	5,100 tons	Average Tornado (total energy)
5.0	32,000 tons	
5.5	80,000 tons	Little Skull Mtn., NV Quake, 1992
6.0	1 million tons	Double Spring Flat, NV Quake, 1994
6.5	5 million tons	Northridge, CA Quake, 1994
7.0	32 million tons	Hyogo-Ken Nanbu, Japan Quake, 1995; Largest Thermonuclear Weapon
7.5	160 million tons	Landers, CA Quake, 1992
8.0	1 billion tons	San Francisco, CA Quake, 1906
8.5	5 billion tons	Anchorage, AK Quake, 1964
9.0	32 billion tons	Chilean Quake, 1960
10.0	1 trillion tons	(San-Andreas type fault circling Earth)
12.0	160 trillion tons	(Fault Earth in half through center, OR Earth's daily receipt of solar energy)

GEOLOGICAL TIME SCALE **Annex B**