A VERY BIG BANG

On one clear day 65 million years ago, the sky suddenly fell in, and 80% of all life became extinct. But this cataclysm also opened the door for humans to inherit the Earth. **Wilson da Silva** gives a blow-by-blow account.

SIXTY-FIVE MILLION years ago, in one catastrophic flash, the Earth changed forever. Without warning, a mountain-sized rock from space crashed through the atmosphere like a giant flaming fireball.

When it struck the ground, the energy released was unimaginable – more than 10,000 times the explosive power of all the world's nuclear weapons exploding in one place, and at one time.

A searing blastwave of wildfire raced through the air for thousands of kilometres, burning any living thing in its path. The shockwave shook the planet like a bell, triggering tsunamis, landslides and volcanic eruptions around the world.

The sky fell dark, temperatures dropped. In the dark and desperate years that followed, around 80% of all the species on Earth became extinct. Among them, the dinosaurs, magnificent creatures that had ruled the planet for 160 million years.

THE ENORMOUS ASTEROID that hit the Earth on that fateful day was a monster: at least 10 km in diameter. As it punched through the sky over what is today the Yucatán Peninsula in Mexico, it was travelling at tens of kilometres per second.

It was so large, and moving so fast, that it didn't just slip through the atmosphere: in a split second, it actually rammed away all of the air above the ancient volcanic island chain of today's Caribbean. The sky filled with an incandescent flash of fury and then, suddenly, the asteroid struck.

At the point of impact, the shallow sea, barely 100 m deep, was vaporised in 100th of a second. The shockwave blasted enormous masses of surrounding water high into the sky, triggering tsunamis in all directions.

In the blink of an eye, the impact gouged a hole 30 km deep into the seafloor, piercing into the planet's molten mantle and instantly digging out a crater more than 100 km wide. Pulverised rock and dust, from the ground and from the incoming asteroid, was blown to 40 km into the sky, past the ozone layer and beyond the stratosphere.

In the blink of an eye, the killer asteroid had come to a stop – striking with the energy of a 100 million atom bombs. But the repercussions were still being felt around the world.

A cataclysmic blastwave generated by the impact radiated from ground zero at 70,000 km/h, or about 20 km a second. As the ring of air grew in diameter and encountered resistance from surrounding atmospheric air mass, it began to slow.

Within 10 minutes, the blastwave had travelled 500 km and wind speeds had fallen to 1,000 km/h – about the speed of sound, but still many times faster than the wildest hurricanes and cyclones on record. An hour later, the widening 'blast ring' had reached a radius of 1,000 km, but was still packing winds of speeds never seen before.

Scientists have calculated that the winds were so strong, that in the southern coast of today's United States and along most of Central America, they would have flattened forests and blown away living creatures – even large ones – up to 1,000 km away.

But the outward blast had also created a vacuum over ground zero: it wasn't long before the winds reversed, crashing back into the impact site at cyclonic speeds.

Meanwhile, the sea at the point of impact would have leaped at least 100 m into the air. Tsunamis generated by the impact headed from ground zero, toward the coasts of Africa, North and South America.

Because the sea at the point of impact was so shallow, the ensuing tsunamis were not as fierce as if they might have been in deep ocean water. Still, by the time they reached continental shores, waves would have been tens of metres high – enough to reach several kilometres inland, washing away forests and drowning creatures in their path. Fossilised evidence of these tsunamis have been found in rocks in Texas (where waves were estimated to have reached at least 50 m high), and boulders the size of cars were washed as far as 500 km away, to what is today Belize in South America.

The whole of the planet would have rung like a bell after the collision. Most of the >>

PHOTOLIBRARY

Artwork showing a large asteroid crashing into Earth.

>> impact force was transferred straight into the ground – an awesome 10 to 13 on the Richter scale, at least 1,000 times stronger than any earthquake on record.

On the opposite side of the globe from the Yucatán Peninsula, in what is today the Indian Ocean off the north-west coast of Australia, the seafloor suddenly heaved up in massive swells. Shockwaves from the impact on the other side of the world, having travelled across the Earth's rocky surface, converged here. Forces estimated at 10 times that experienced in the catastrophic San Francisco earthquake of 1906 were exerted, cracking open fissures and spilling lava.

It was not a good day to be a dinosaur. In fact, it wasn't a good day to be on the surface of the Earth at all.

ANY LIVING CREATURE within sight of the impact would have died instantly. And they would have been the lucky ones.

Plants and animals within 1,000 km of ground zero would have been swept away, either instantly obliterated by a firestorm, or dashed against mountains and cliffs – and then sucked back into the impact site – or drowned by the tsunamis that followed.

Meanwhile, high above, the hail of boulders, rocks and dust thrown up by the impact would soon begin a slow arc back toward Earth.

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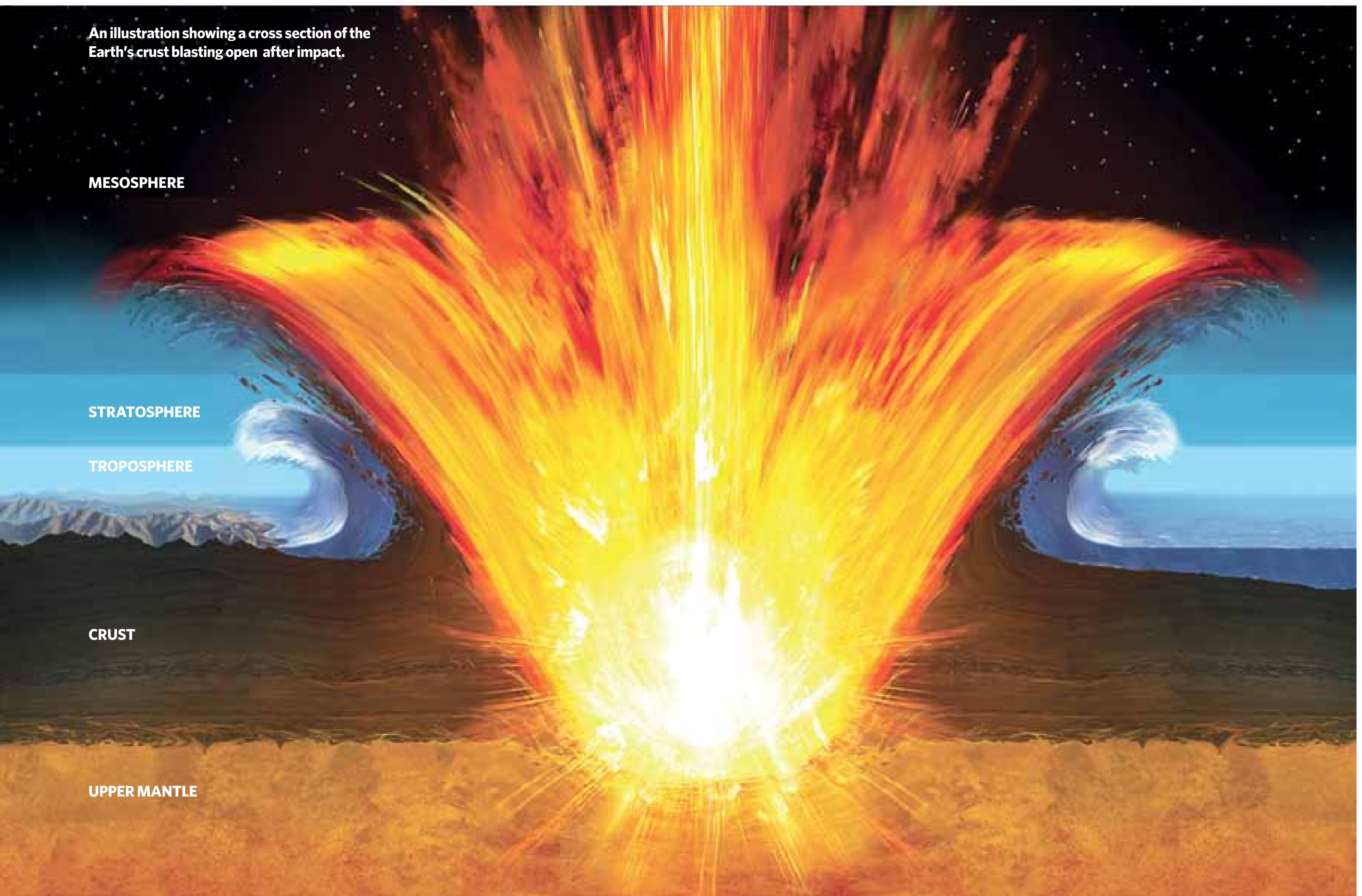
At the centre of the impact, a spike of incandescent molten rock would have blasted high up into the atmosphere, unencumbered by air resistance thanks to the vacuum created by the incoming asteroid seconds before. Below and behind it came a bubble of molten debris with a temperature in the thousands of degrees Celsius.

It's estimated that nearly 200,000 km^3 of molten rock burst into the sky less than a minute after the impact. Billions of tonnes of solid, molten and vaporised rock were instantly propelled into the upper atmosphere, at velocities ranging from several kilometres a second over ground zero, to hundreds of meters per second at the edges of the crater.

The superheated central plume, or 'ejecta', rapidly ballooned up and out as it arced higher, expanding in all directions atop the Earth's atmosphere. As it climbed, the molten rock came into contact with the icy cold of space, rapidly cooling and becoming solid again.

As the planet's gravity took hold, the now widely dispersed cloud of rock and dust began falling back down, heating up again as it re-entered the atmosphere. All over the world, the skies began to light up as the enormous mass thrown up by the impact – nearly 200,000 km^3 of rock – began to rain down.



An illustration showing a cross section of the Earth's crust blasting open after impact.

JAMIE TUFREY; PHOTOLIBRARY

Some 10 kg of material per square metre began to strike the outer layers of the atmosphere, descending on the hapless inhabitants of Earth at an average velocity of 300 km per minute.

This fiery re-entry would have unleashed a scorching inferno of heat; in a matter of minutes, it would have unleashed 30 times the amount of energy our atmosphere normally receives from the Sun.

Luckily, most of this would have dissipated in the higher altitudes, 60 to 70 km above, as the incoming rocks began to burn up. Only a fraction of this inferno would have made it to the ground, since about half of the heat would have radiated out into space, and the half that radiated back down had to travel through the gases of the lower atmosphere.

Nevertheless, it's estimated that 10 kilowatts of heat energy per square metre still made it to the surface within an hour of impact, enough to heat the soil to 400°C. This would have ignited forest fires on every continent, fires that would have driven the ambient temperature even higher. Any creature in the open would have been grilled to a crisp as the surface of the planet turned into an oven set at 'high'.

How could any living creature have survived this hellish scenario? Scientists believe that cloud cover might have played a part: the 'heat pulse' from the incoming meteors would have vaporised clouds into steam, and the water droplets would have absorbed a lot of this heat. In parts of the world where cloud cover was heavy that day, life may well have been spared. But those living under clear skies were probably burned alive.

In addition, because the Earth continued rotating as these events took place, the curtain of superheated debris that fell back was not symmetrical. An analysis of the likely trajectory suggests that the hardest hit areas (after North and Central America), were those to the west: the Pacific Ocean and Asia, with vast tracts of Europe and the Atlantic Ocean largely spared.

This appears to be borne out by the fact that 'shocked quartz' – grains of quartz with criss-cross patterns that can only be produced by massive shockwaves, such as from asteroid impacts – have been found at many sites dated at 65 million years ago – but few have been found in Europe.

MILLIONS OF CREATURES perished in the horrifying cataclysm that day, 65 million years ago. But millions more – including whole species – were to disappear in the days and months to follow as a long winter shrouded the Earth.


A Titanosaurus watches helplessly as a tsunami caused by the asteroid strike approaches.

The dust thrown up by the impact now circulated in the upper atmosphere, blanketing the Earth in darkness for several months, and in a twilight state for most of a year. This drastic depletion of sunlight starved plants and was enough to collapse a number of food chains and lead to wholesale slaughter of marine plankton floating on the surface of the oceans.

But that's not all: the heat pulse of the initial blastwave and the fiery meteor shower that followed ionised atmospheric gases, recombining them into harmful nitric oxides. These mixed with water vapour to form nitric acid, which rained down on the land and sea.

Poisonous metals from the rocks were leached into the rivers and oceans by the waves of acid rain. Scientists have found evidence of large quantities of arsenic, selenium, aluminium and mercury in the soil of the time.

In addition, deep layers of anhydrite, a mineral rich in sulphur, had lain at the base of the Yucatán Peninsula. It's estimated that 100 billion tonnes of this sulphur was catapulted into the air on impact. Some of this fell as acid rain over the years, but >>


The fallout: molten rock raining back on Earth after the impact.

An artist's impression of a mammal that has survived the dinosaur extinction. Its ancestors will one day dominate this brave new world.

>> much of it also crystallised in the upper atmosphere and blocked out sunlight.

Even after the dust from the impact and soot from global forest fires cleared, it's estimated that there was enough crystallised sulphur in the upper atmosphere to block out 80% of the sunlight. This probably plunged Earth into a deep winter for a decade; on land, where a balmy 20°C might have been the norm, temperatures dropped to as low as -20°C.

Many plants, without enough light to photosynthesise, began to die out. Animals that relied on the plants for food began to starve. Predators that fed on the dying herbivores at first feasted on the abundant carcasses, but then they too began to starve.

It was all too much for many species: 80% disappeared in the years that followed, including 90% of all plankton species. Some, like the dinosaurs, had been an unparalleled success for millions of years – until their luck ran out, and they too were shown the door to extinction.

EXTINCTIONS HAPPEN all the time. New species evolve to inhabit an ecological niche and succeed for a while. But the tenure of any species on Earth is not guaranteed, and they can go extinct for any number of reasons: new competitors moving in, a sudden shift in the climate, the onset of ice ages, or catastrophic changes like meteor impacts and supervolcanoes.

In the 4.6-billion-year history of the Earth, there have been five known 'mass extinctions' – concentrated periods of a few years when large numbers of species disappear. The last mass extinction, 65 million years ago, was unusual because of the speed at which species were wiped out.

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It's also famous for claiming the dinosaurs, the undisputed giants of our world. Dinosaurs arose at the beginning of the Triassic period, some 250 million years ago, and by the Jurassic period – 45 million years later – they were in their heyday and covered the Earth. But by the beginning of the Cretaceous, 144 million years ago, dinosaurs began a long and slow decline, for reasons still not well understood. Nevertheless, these magnificent and frightening creatures ruled the planet for another 79 million years … before the unexpected arrival of a giant rock from space pushed them over the edge of extinction.

When palaeontologists dig down to the level corresponding to 65 million years ago, they find massive amounts of fluffy, soot-like carbon deposits – several hundred times anything recorded previously. There seems little doubt that this represents the burnt remnants of sweeping forests and million of animals.

Based on evidence from a number of sites around the world, chemists estimate that the raging fires that followed the impact claimed 100 billion tonnes of organic material. It's calculated that forests and plants accounted for only half of this 'biomass': the rest would have been animals.

Of course, there's always the flipside to any mass extinction: because of the great calamity, creatures that had lived in the shadow of the dinosaurs came to dominate the planet.

No species weighing more than 25 kg made it through the great cataclysm: any large animal would have needed large quantities of food to survive. The larger the animal, the fewer in number exist in nature; there would have been many more possum-like creatures than tyranosaurs. Hence, if a species is few in number, a disaster that kills 95% of that species can push it to extinction. Whereas an abundant species like possums can easily repopulate after a cataclysm; and because they are small, they can survive on less food.

Less than a quarter of all land-based species survived the impact, and half of these were a relatively obscure grouping known as mammals. Small mammals living in burrows could have survived the initial blastwave, and many may have survived the global wildfires.

Being warm-blooded would have also helped them pull through the decade-long winter, and since most were nocturnal, finding food in the year-long darkness would have been no great challenge. Most had opportunistic diets: relying on no specific food group, they ate everything and anything – seeds, roots, insects and meat. Being able to grow their young in the womb, and then caring for them for long periods would have also helped ensure survival of each new generation.

In a very real sense, the asteroid that wiped out the dinosaurs, and caused so much death and destruction 65 million years ago, opened the way for creatures that would otherwise not exist today. Large mammals such as elephants, bears, gorillas and humans may not have had the chance to evolve if fierce, pack-hunting, swift assassins such as dromaeosaurs had survived.

All of the mammals alive today – from horses to hedgehogs, from walruses to wombats – are descendants of those diminutive mammals that survived the great impact.

Most were little more than scavengers and fruit eaters. But today, their descendants are found in all manner of climates across the globe. With the exception of insects, mammals have a wider distribution and are more adaptable than any other single class of animal. They are the Earth's dominant species … but it took the death of the dinosaurs to bring them out of ecological obscurity and populate the planet.

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Deadly fingerprints

HOW DO WE know so much of what happened on that fateful day 65 million years ago? Like a lot of science, it was long and painstaking detective work.

The idea that something sudden and catastrophic wiped out the dinosaurs goes back to the 18th century, to one of the fathers of palaeontology, Frenchman Georges Cuvier. But most scientists at the time backed a competing school of thought, known as 'uniformitarianism', which argued that all change occurs very slowly over time, such as the erosion of mountains or gradual climate change. This tied in perfectly with evolutionary theories of Charles Darwin in the mid 19th century.

By the late 1960s, a growing understanding of our Solar System led geologists to propose that a large asteroid or a comet may have been the culprit. This was mostly dismissed, even though some of the proponents were leading scientists. And the doubters had a point: it might be a great idea, but where's the evidence?

In 1977, American geologist Walter Alvarez and Italian palaeontologist Isabella Premoli Silva were digging through layers of ancient limestone seabed in Gubbio, northern Italy. They found that the geological layer marking the end of the dinosaur reign, known as the end-Cretaceous, was restricted to a single layer just centimetres thick. Below it, the seas had been brimming with life. Above it, suddenly, 90% of all plankton species had disappeared. But did this thin layer represent a sudden shift, or had it actually been laid down over a long period of time?

Back in the U.S., Alvarez talked to his father, Luis Alvarez, a Nobel Prize-winning physicist, who suggested he test the layer for iridium traces. Iridium is a metal rare on Earth, but common in space. Luis Alvarez reasoned that since we know the average frequency with which meteors fall to Earth today, his son could use it to accurately date how long it took to accumulate that single layer.

To their surprise, they found that the end-Cretaceous layer was very rich in iridium – 30 times greater than layers above and below. To establish if this was just an aberration they tested samples of the same age taken in Denmark and New Zealand. The result was the same. There seemed to be no explanation for the sudden spike in iridium levels, except one: a massive and very sudden meteor strike that blanketed the whole planet with a fine film of extraterrestrial iridium.

The team published their findings in 1980 and it triggered a storm of controversy. But within a few years, similar iridium-rich deposits were found in scores of sites around the world, all dating back 65 million years ago. In this same layer, scientists also began to find shocked quartz. Previously, shocked quartz had only been found in two locations: meteor craters and around the epicentre of a nuclear blast.

Since then, other evidence has been uncovered: fine particles of fluffy carbon deposits – hundreds of times more than anything recorded previously, suggesting planet-wide forest fires.

As the evidence mounted, people began to look for 'ground zero' – the impact site. But while there are hundreds of craters visible on the surface of Earth, none seemed the right age or size.

That was until 1990 when Canadian geologist Alan Hildebrand found magnetic

A tourist examining the thin boundary between Cretaceous and Tertiary rocks.

and gravity depression surveys of the seafloor that indicated there was a 180 km semi-circular depression off the coast of Yucatán in Mexico. Sure enough, drilling samples showed shocked quartz. More importantly, it was exactly the right age (see "Lucky strike" p36).

This was the 'smoking gun' – the impact site, the last missing piece of the puzzle.

The crater was dubbed Chicxulub, named after a nearby Mexican fishing village. Ironically the word Chicxulub, in the tongue of ancient Mayan civilisation of the area, seems to have meant 'tail of the devil' or 'sign of the horns' – an apt name for a killer asteroid.