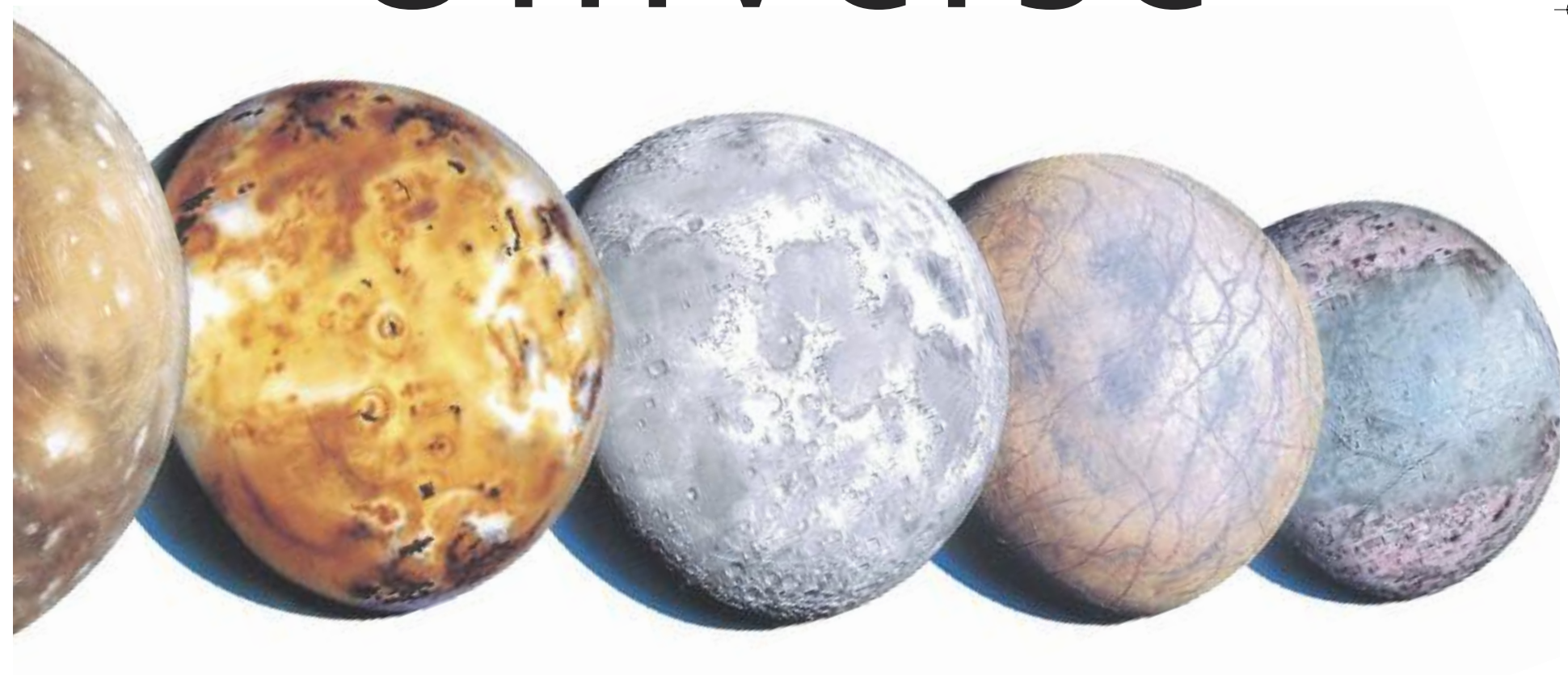


RECORD BREAKERS

Earth and Universe



by Storm Dunlop

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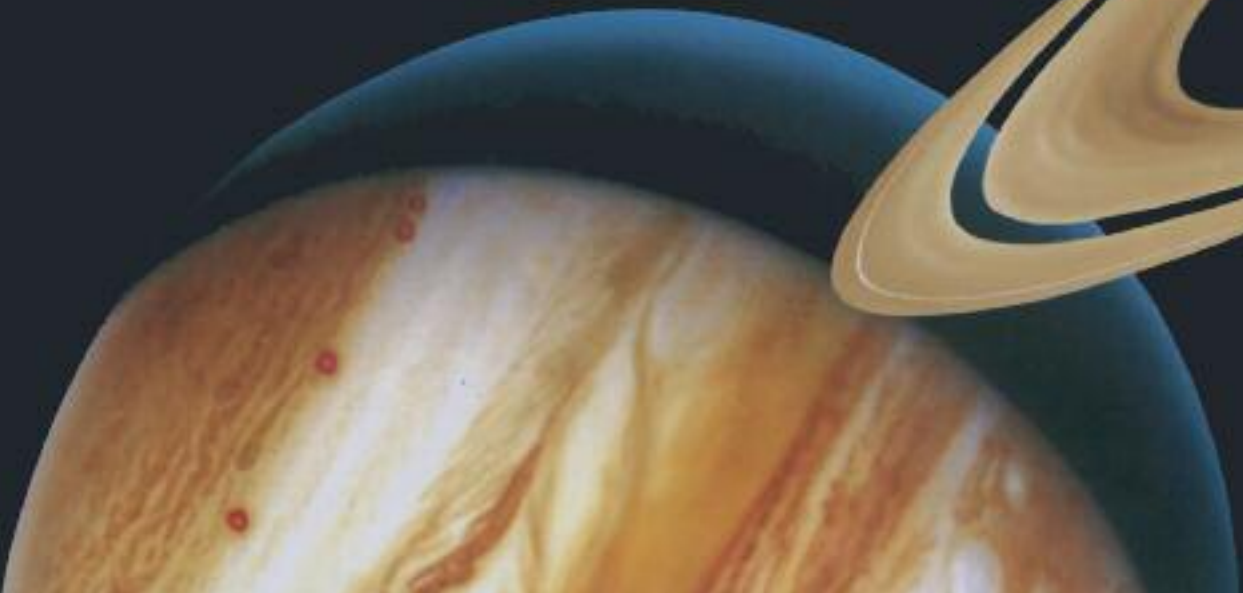
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INTRODUCTION

Imagine a star so gigantic that, even if you travelled in the fastest plane, it would take over 500 years to fly round it. Yet there are other stars, called black holes, so incredibly tiny they are smaller than the ball from a ball-point pen! Even though some black holes are unbelievably distant, astronomers can still detect where these objects are.

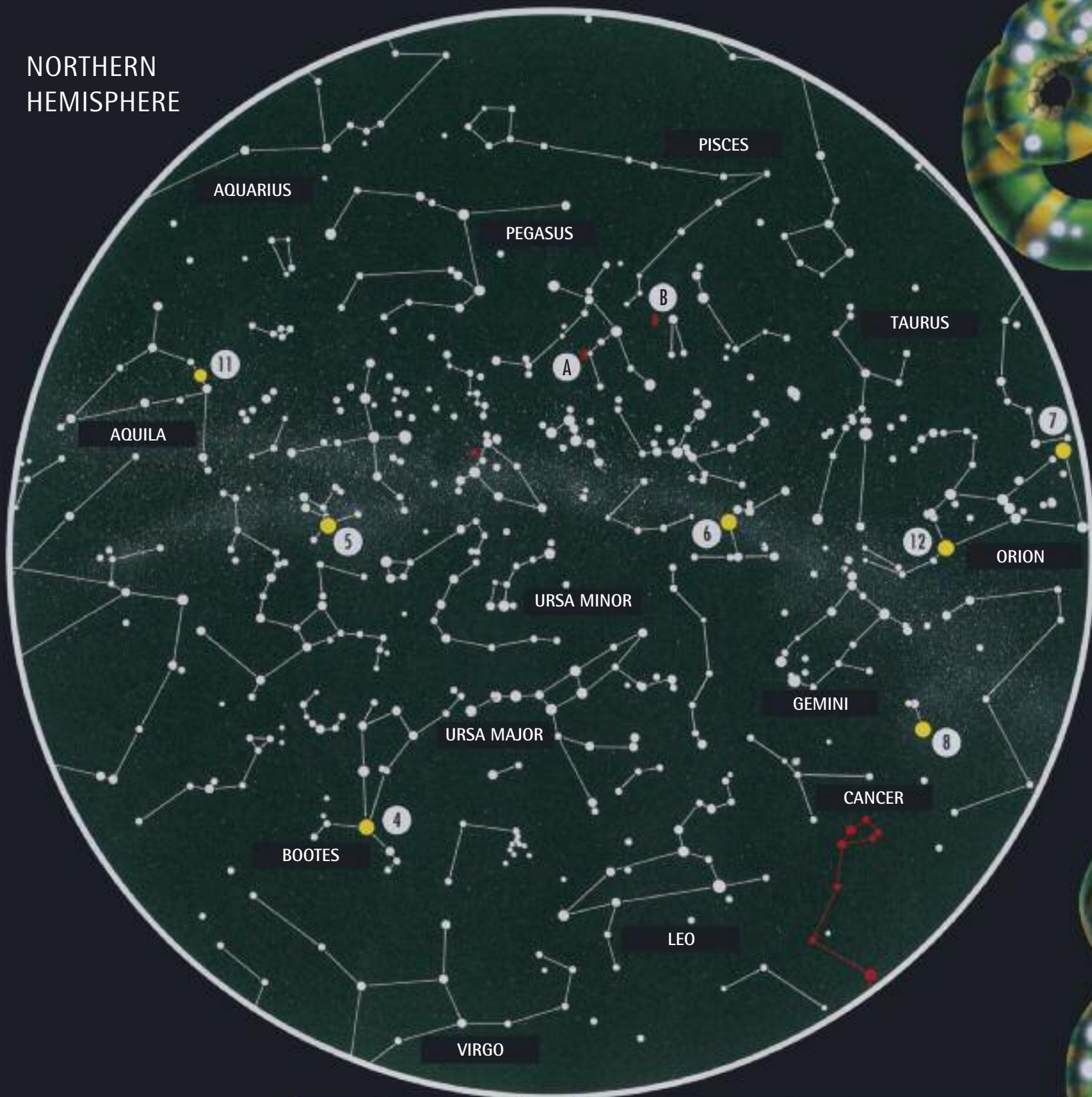
Our own Solar System also contains many astonishing record holders. Tornadoes on Earth are extremely destructive, but winds on Saturn are more than ten times as fast. The swirling storm of the Great Red Spot on Jupiter is twice the size of the Earth itself, while some sunspots can be more than twenty times as large. Venus is so hot that any astronaut who landed there would be immediately incinerated, while Pluto is so cold (below -200 degrees Celsius) its surface is made of frozen gases.

How does Earth's Grand Canyon compare with the giant valleys on Mars? Where is the world's deepest lake, its highest mountain, and its longest river? When did the most powerful earthquake ever recorded occur? Find the answers to these and many more questions in this book.

STARS OF THE NIGHT SKY

A guide to stellar record holders

NORTHERN HEMISPHERE



These two charts show the night sky visible from the Northern Hemisphere (left) and Southern Hemisphere (right). (Over the course of a year, the part you can see varies.) The brighter stars are shown as larger spots. The lines between the stars link those stars together in the same constellation.

THE BRIGHTEST STARS

- 1 Sirius
- 2 Canopus
- 3 Alpha Centauri (Rigel Kent)
- 4 Arcturus
- 5 Vega
- 6 Capella
- 7 Rigel
- 8 Procyon
- 9 Achernar
- 10 Hadar
- 11 Altair
- 12 Betelgeuse

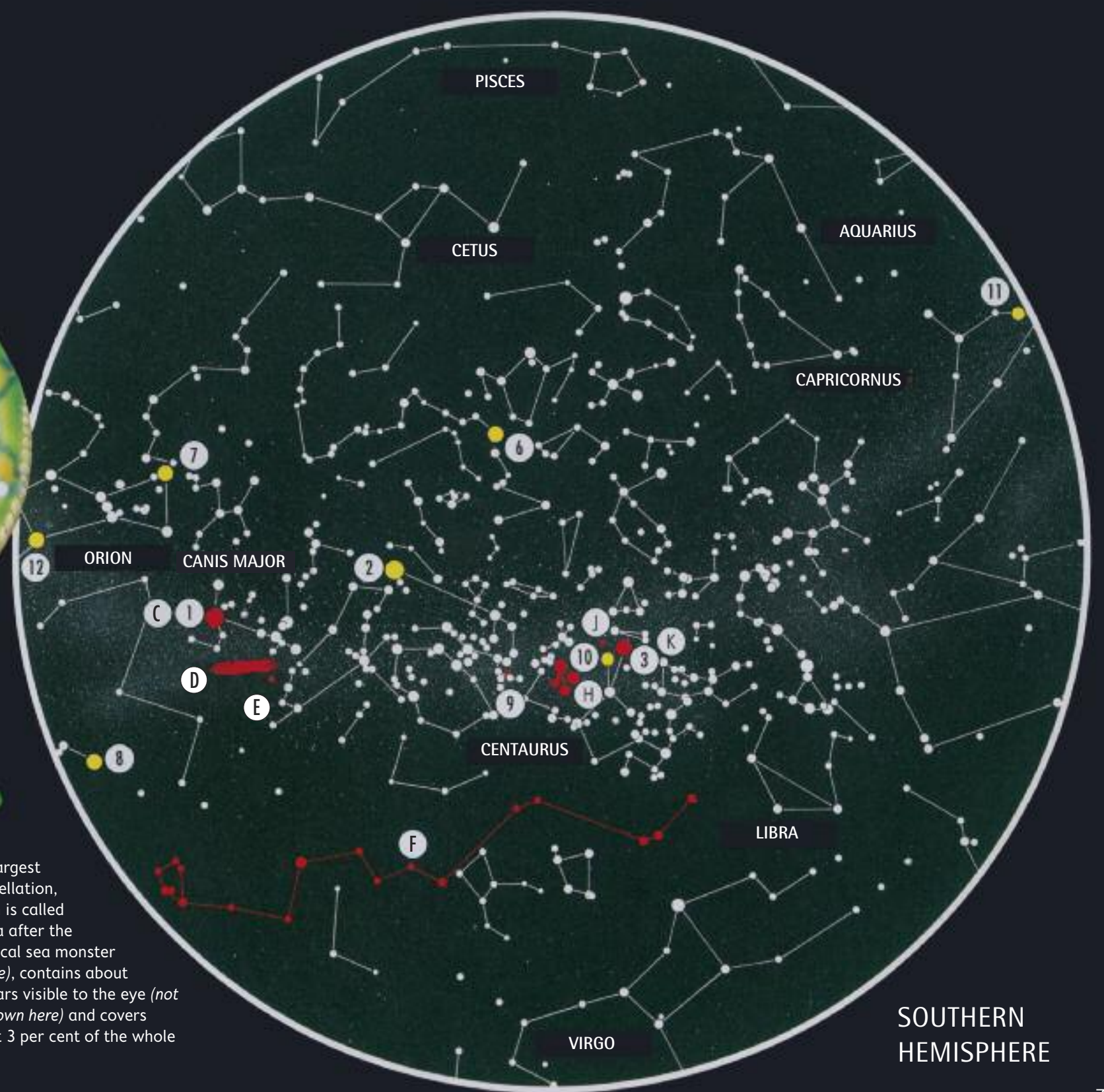
STAR RECORD HOLDERS

- A M31 galaxy Farthest object easily visible to the eye 2.5 million light-years away
- B M33 galaxy Farthest object ever visible to the eye 2.6 million light-years away
- C Sirius Brightest star 8.6 light-years away
- D Canis Major dwarf galaxy Nearest galaxy 50,000 light-years away
- E VY Canis Majoris Largest star 2100 times the size of the Sun
- F Hydra Largest constellation
- G Eta Carinae Most massive star 200 times the mass of the Sun
- H Crux Smallest constellation
- J Proxima Centauri Nearest star 4.2 light-years away
- K Alpha Centauri (Rigel Kent) Second nearest star and nearest visible to the eye 4.4 light-years away



Imagine flying in supersonic jet at a cruising speed of 2000 km/h. It would take nearly 200,000 years to reach the nearest star! Distances in the universe are so vast that we have to use a special measure called light-years. Light moves at 299,792 kilometres per second (it would take the aircraft nearly five-and-a-half days to cover the same distance). In a year, light travels

about 9,460,528,405,000 kilometres, so we can use this distance, a light-year, instead of reckoning in millions and millions of kilometres. Powerful telescopes can detect quasars, central regions of galaxies throwing out enormous amounts of light and heat far out in the universe. They are the farthest objects known. The most distant quasar so far discovered is about 13,200,000 light-years away!



The largest constellation, which is called Hydra after the mythical sea monster (above), contains about 68 stars visible to the eye (not all shown here) and covers about 3 per cent of the whole sky.

SOUTHERN HEMISPHERE

THE LARGEST VISIBLE STAR

Betelgeuse, the size of 800 Suns

THEY MAY LOOK like tiny points of light in the night sky, but stars can be enormous – sometimes millions of times the size of our Earth. The very largest stars, called supergiants, are unbelievably huge! Betelgeuse, the bright red star in the constellation Orion, is the largest one visible without a telescope. About 1 billion kilometres across, it is 800 times the size of the Sun, our own 'local' star.

Because they are so far away, it is very difficult to measure the sizes of stars. According to latest observations, VY Canis Majoris is the largest known. It may measure up to about 2100 times the size of the Sun.

THE LARGEST STARS

VY Canis Majoris	2100
VV Cephei B	1600
V354 Cephei	1520
KW Sagittarii	1460
Mu Cephei	1420

(times the size of the Sun)



Compared to other types of star, neutron stars are incredibly small. Here (above) one compares in size with the city of New York as seen from the air.

THE SMALLEST STARS

Stars like the Sun are so small when compared with giants and supergiants that astronomers call them dwarfs. A teaspoonful of material from the Sun is as heavy as a spoonful of syrup. After the Sun swells to become a red giant (in about five billion years) it will lose its outer layers. Just the small, very hot, dead core will remain. Called a white dwarf, it will measure about 10,000 km across (roughly the size of the Earth) and be extremely dense. A teaspoonful of white-dwarf material would weigh five tonnes.

The core that remains after a supernova explosion is a tiny star no more than 25 km across, known as a neutron star, the smallest type of star that exists. A teaspoonful would weigh an incredible one billion tonnes!

Supergiant stars are so big that perhaps the only way to imagine just how big they are is to compare them with the orbits of planets in our Solar System (below). Betelgeuse would engulf Mercury, Venus, the Earth and Mars – all the inner planets circling round the Sun. The supergiant VY Canis Majoris would consume Jupiter and Saturn as well!

THE LIFE AND DEATH OF A STAR

Stars are formed when clouds of gas and dust in space (1) shrink to become dense 'blobs' called protostars (2). The same force that keeps us firmly on the ground – gravity – causes this to happen. The core of the new protostar becomes so hot that nuclear reactions (see page 12) start deep inside it. Gas and dust are blown away by a violent 'wind' from the star (3). Sometimes a spinning disc of dust, gas and ice results (4). This may eventually become the birthplace of planets.

The fuel that powers the nuclear reactions lasts billions of years (5). When it runs out, the core collapses and the

outer regions grow into red giants (6). Most stars, including our Sun, are destined to become red giants, but some much heavier ones become supergiants (7).

When its nuclear 'fuel' runs out, a supergiant's core will collapse in a split-second. The outside explodes as a supernova, the greatest explosion known in all nature (8). For a fraction of a second, a supernova will give off more energy than all the billions of stars – in every one of the billions of galaxies – all put together! All that is left behind after the explosion is a dense neutron star (9) or a black hole (see page 10).



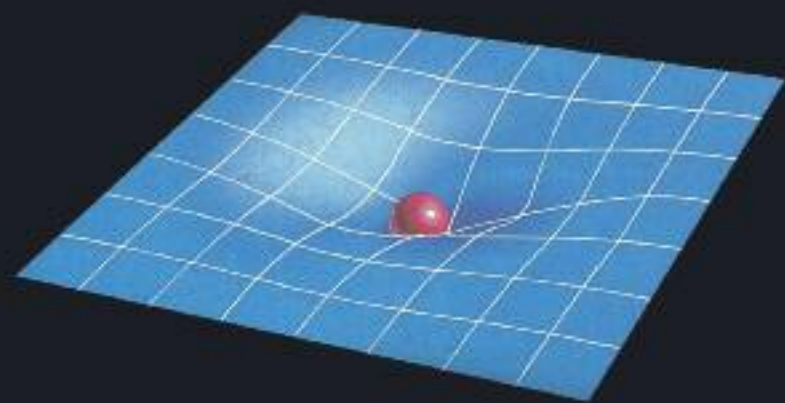
BLACK HOLES

The densest objects in the universe

Completely invisible, black holes are the strangest objects in the universe. Like neutron stars (see page 9) they are all that remains of stars that have blown up in supernova explosions.

All bodies in space have a force of gravity, the force which attracts other things towards them. It is this force that holds stars together, keeps the planets in their orbits around the Sun, and causes all objects to fall to the ground on Earth. To escape from a star or planet, you would have to travel at very high speeds to overcome the force of gravity. A rocket launched from Earth must go faster than 40,320 km/h to escape from the Earth's gravitational pull.

After a supernova explosion, the central core collapses until it is a tiny fraction of the size it used to be. No more than a tiny pin-point in space, it is nevertheless surrounded by a force of gravity more powerful than any normal star in the universe. In order to escape from here, you would have to travel faster than the speed of light: 299,792 kilometres per second!



You can think of the force of gravity being like a ball on a rubber sheet. A star or a planet 'bends' space: anything close by will fall towards them. If the ball got so heavy that part of the sheet stretched into a long, thin tube, you would have a black hole.

In fact, escape would be impossible because nothing can travel faster than the speed of light. That is why these mysterious, invisible objects are called 'black holes': nothing, not even light, can escape from them.

No one has ever seen a black hole, but astronomers believe that they exist because they can detect their powerful gravitational force.

Billions of light years away, an enormous, swirling disc of gas surrounds a giant black hole in the centre of a quasar (see below). The incredible energy blasts two jets of gas out into space.

The pair of stars called Cygnus X-1 almost certainly contains a black hole. We can see a supergiant star (above) circling something invisible with an enormous gravitational pull. The star is losing gas, which swirls down into the black hole.

MASSIVE ENERGY MACHINES

Incredibly powerful, giant black holes, astronomers think, lurk in the centres of galaxies. In some galaxies, such as our own Milky Way, the black holes are fairly peaceful. In others, they are the scene of violent activity. As stars are sucked in towards them, they are torn apart into clouds of gas. Quasars, the most distant objects in the universe are probably the central regions of such violent galaxies. The energy they give out is so great they can still be detected even though the galaxies themselves are too far away to be visible.

THE NEAREST STAR

A shimmering ball of gas

The nearest star to Earth is the Sun itself. A gigantic ball of extremely hot gases, mostly hydrogen and helium, it is big enough to contain nearly 1,400,000 bodies the size of our own planet. It dwarfs even the largest planet, Jupiter. In fact, the Sun contains more than 99 per cent of all the matter in the Solar System. The Sun also provides most of the heat in the Solar System, and thus the warmth that makes life possible on Earth.

The surface, called the photosphere, is in constant motion, like water in a boiling kettle. Its temperature is about 6000°C, but at the centre this rises to an incredible 15 million°C! The core generates all the Sun's energy through what are known as nuclear reactions. At such high temperatures, hydrogen is changed to become helium in a reaction that gives off an enormous amount of energy. (This is called nuclear fusion, the same process that scientists hope one day will drive the world's power stations.)

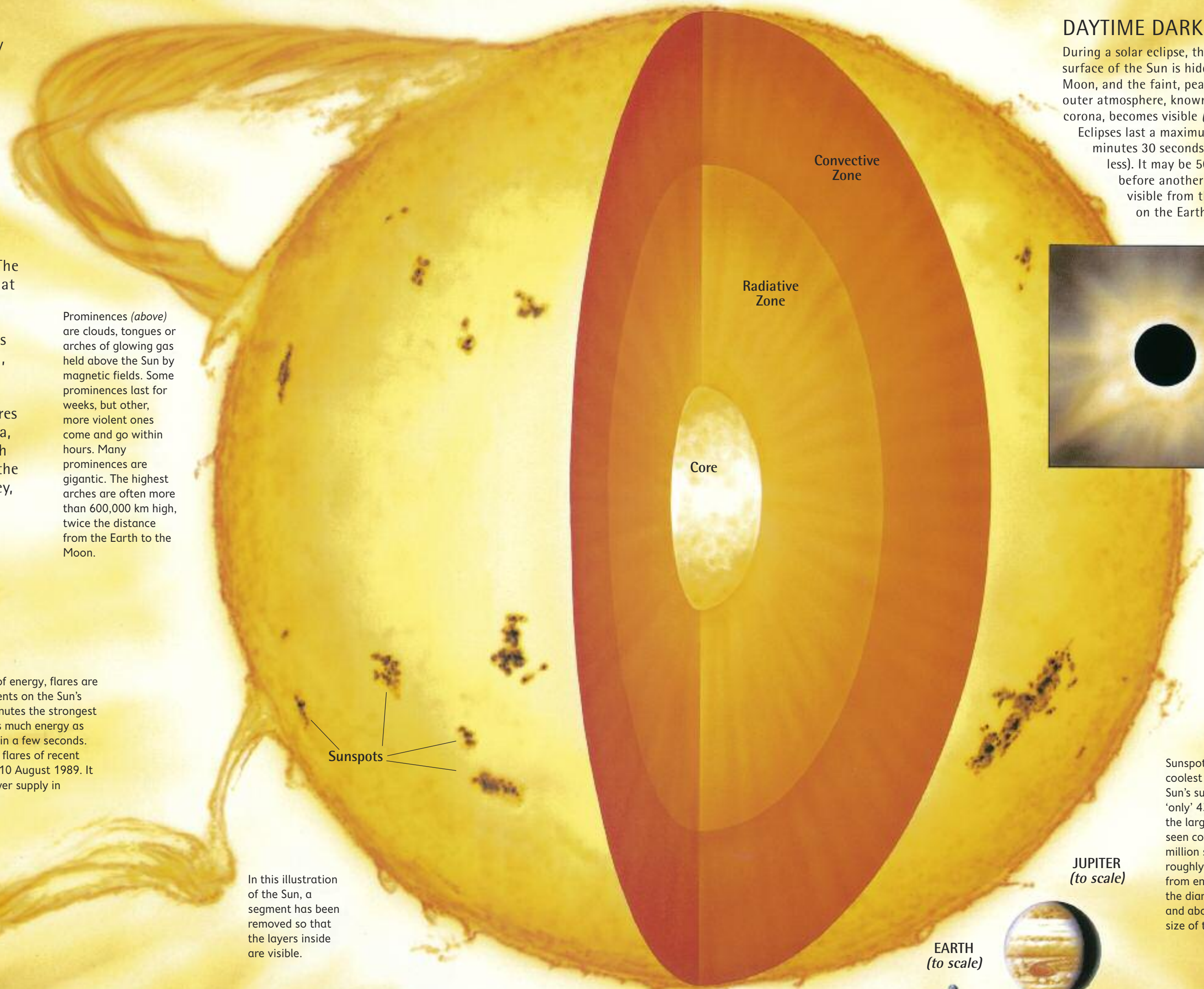
Incredibly, scientists have created temperatures far hotter than at the centre of the Sun. Plasma, produced when gases are subjected to very high temperatures, is the hottest known matter. At the Princeton Plasma Physics Laboratory, New Jersey, USA, scientists achieved a temperature of 510 million°C.

The Sun 'burns' about 4 million tonnes of hydrogen every second, but it is so enormous that, fortunately for us, it will take another 5 billion years before it finally exhausts its supply!

Sudden explosions of energy, flares are the most violent events on the Sun's surface. In a few minutes the strongest eruptions release as much energy as the entire Sun does in a few seconds. One of the greatest flares of recent times happened on 10 August 1989. It blacked out the power supply in Québec, Canada.

Prominences (*above*) are clouds, tongues or arches of glowing gas held above the Sun by magnetic fields. Some prominences last for weeks, but other, more violent ones come and go within hours. Many prominences are gigantic. The highest arches are often more than 600,000 km high, twice the distance from the Earth to the Moon.

In this illustration of the Sun, a segment has been removed so that the layers inside are visible.



DAYTIME DARKNESS

During a solar eclipse, the bright surface of the Sun is hidden behind the Moon, and the faint, pearly-white outer atmosphere, known as the corona, becomes visible (*below*).

Eclipses last a maximum of 7 minutes 30 seconds (usually much less). It may be 500-600 years before another eclipse is visible from the same point on the Earth's surface.



Sunspots are the coolest parts of the Sun's surface: they are 'only' 4300° C. In 1947, the largest group ever seen covered 18,130 million sq km. It was roughly 300,000 km from end to end, twice the diameter of Jupiter, and about 23 times the size of the Earth.

JUPITER (to scale)

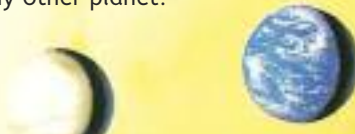
EARTH (to scale)

THE PLANETS

Solar System record holders

Mercury is the smallest planet, and the closest planet to the Sun. It rushes round it in 88 days, the quickest orbit of any planet.

The hottest planet, Venus spins slowly, so it has the longest day. On its orbit, it comes closer to Earth than any other planet.



MERCURY

VENUS

EARTH

MARS

THE INNER PLANETS

MERCURY Diameter 4878 km Day 58.6 Earth days Year 88 days. no moons; bare, rocky surface
VENUS Diameter 12,103 km Day 243 Earth days Year 225 days. No moons; hot, cloud-covered
EARTH Diameter 12,756 km Day 23 hrs 56 min Year 365.26 days. 1 moon; extensive oceans
MARS Diameter 6794 km Day 24.6 hrs Year 687 Earth days. 2 moons; dry, dusty, little atmosphere

Mars is a very cold and dry planet. It has the highest mountain in the Solar System.

Jupiter is larger than all the other planets put together. It spins faster and has the shortest day of all. It also has the most moons (63).

Saturn has the largest rings of any planet in the Solar System. It has the lowest density – even less than that of water.

THE LARGEST PLANETS in the Solar System – Jupiter, Saturn, Uranus and Neptune – are known as the gas giants because, unlike our rocky planet, they consist mostly of gases, particularly hydrogen and helium. Jupiter and Saturn probably have rocky cores, but the others may only have liquid water and methane beneath their gassy exteriors.

The gas giants all have many moons, some of which are larger than Mercury, the smallest planet. The giant planets also all have rings, although except for Saturn's they are very faint. Saturn's bright rings extend for 273,000 kilometres, more than twice the diameter of the planet. They consist of millions of blocks of ice, the largest of which are about 10 metres across – the size of small houses.

Now officially classified as a "dwarf planet", Pluto is mostly made of ice. Its orbit around the Sun is more elongated than those of the other planets, so that some of the time it is actually closer to the Sun than Neptune.

The four, small, inner planets – Mercury, Venus, Earth, and Mars – are mainly made of rock. Between Mars and Jupiter, thousands of asteroids (also called minor planets) orbit the Sun. The largest, Ceres, another dwarf planet, is 1003 kilometres across.

The Sun and planets are illustrated to scale

SUN

SATURN

JUPITER

Uranus was the first planet to be discovered with the use of a telescope.

URANUS

THE OUTER PLANETS

JUPITER Diameter 142,884 km Day 9.8 hrs Year 11.8 Earth years. 63 moons; tiny ring
SATURN Diameter 120,536 km Day 10.2 hrs Year 29.4 Earth years. 60 moons; giant rings
URANUS Diameter 51,118 km Day 17.2 hrs Year 84 Earth years. 27 moons; 11 thin rings
NEPTUNE Diameter 50,538 km Day 16.1 hrs Year 164.8 Earth years. 13 moons; 2 thin rings
PLUTO Diameter 2,324 km Day 6.4 days Year 248 Earth years. 3 moons; mostly made of ice

Neptune is the farthest planet observed by any space probe.

NEPTUNE

Now that other, larger worlds have been discovered, astronomers have re-classified Pluto as one of several dwarf planets.

PLUTO

This diagram shows the planets' relative distances from the Sun.



TO THE CENTRE OF JUPITER

Giant among planets

WITH A DIAMETER more than 11 times that of our own planet, Jupiter – the largest of all the planets – could contain a thousand Earths! Its gravity (the force that attracts other things towards it) is so strong that it often alters the orbits of comets that pass close by (see page 24), sometimes hurling them out of the Solar System altogether.

Jupiter's day is shorter than that of any other planet: just under 10 hours. Because it rotates so fast, it bulges at the equator and measures 8600 kilometres less from

pole to pole. Jupiter has no solid surface: only its small core (with a diameter more than twice that of the whole Earth) is made of rock and metals. Most of the globe is liquid – not water, but a metallic form of hydrogen close to the core and, beneath the clouds near its surface, liquid hydrogen.

Like the other outer planets, Saturn, Uranus and Neptune, Jupiter is surrounded by swirling clouds of gas. Divided into bright zones and dark belts, Jupiter's clouds are separated by bands of high-speed winds. Some reach speeds of 540 km/h. (Saturn holds the record, however, with winds of up to 1800 km/h – faster than the speed of sound on Earth!)

THE GREAT RED SPOT

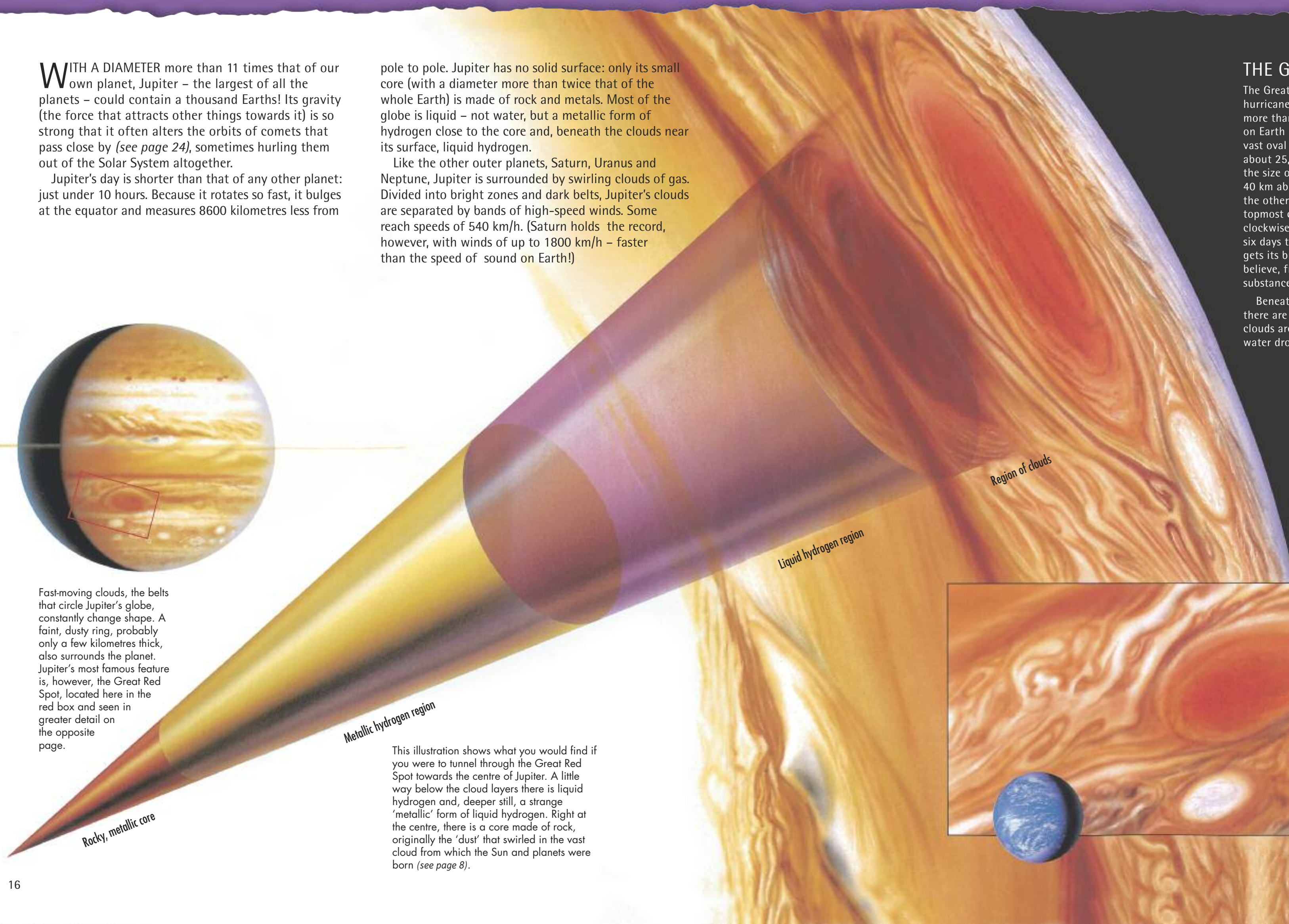
The Great Red Spot is like a giant hurricane that has been raging for more than 300 years (hurricanes on Earth last only a few days). The vast oval of swirling clouds is about 25,000 km across – twice the size of the Earth – and about 40 km above the level of most of the other clouds. The Spot's topmost clouds turn in an anti-clockwise direction, taking about six days to make one full turn. It gets its brick-red colour, scientists believe, from the chemical substance phosphorus.

Beneath the Spot's surface, there are warmer layers where the clouds are made of ice crystals and water droplets like those on Earth.

The Great Red Spot is here compared in size with the Earth, drawn to the same scale (below). The Spot acts as an obstruction to the violent winds that blow round the planet. Other white ovals, like the one visible here, are similar, but smaller, storms.



Fast-moving clouds, the belts that circle Jupiter's globe, constantly change shape. A faint, dusty ring, probably only a few kilometres thick, also surrounds the planet. Jupiter's most famous feature is, however, the Great Red Spot, located here in the red box and seen in greater detail on the opposite page.



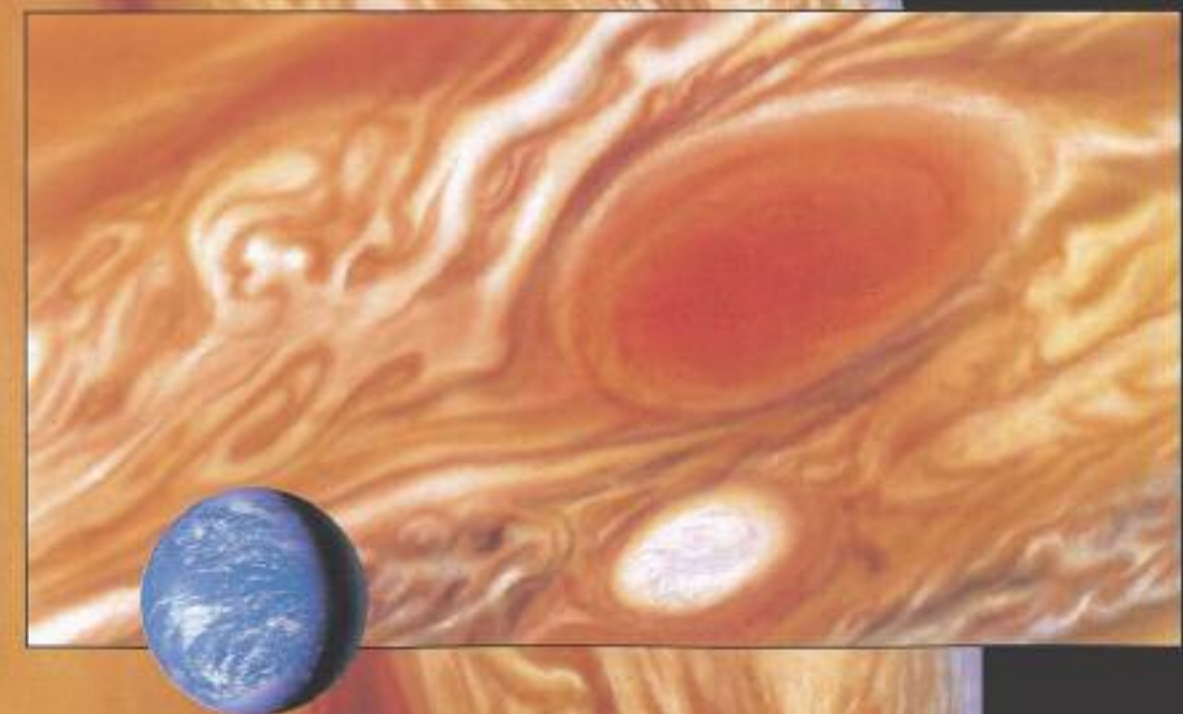
Rocky, metallic core

Metallic hydrogen region

Liquid hydrogen region

Region of clouds

This illustration shows what you would find if you were to tunnel through the Great Red Spot towards the centre of Jupiter. A little way below the cloud layers there is liquid hydrogen and, deeper still, a strange 'metallic' form of liquid hydrogen. Right at the centre, there is a core made of rock, originally the 'dust' that swirled in the vast cloud from which the Sun and planets were born (see page 8).



THE HOTTEST PLANET

Beneath the clouds of Venus

VENUS IS THE NEAREST PLANET to Earth, but no world could be an unfriendlier place to visit! In any case, were you ever to set foot on its surface, you would be immediately incinerated. Venus is the hottest planet in the Solar System: its average temperature of 490°C is easily enough to melt lead. It is even hotter than Mercury, although that planet is much closer to the Sun. This is because Venus's

thick atmosphere of carbon dioxide – so dense that it would crush any person not already burnt to a cinder – prevents heat from escaping.

Most of the barren surface is covered by vast plains, studded with tens of thousands of volcanoes. The mountain known as Maxwell Montes is nearly 12,000 metres high, the second highest in the Solar System after Olympus Mons (see page 20) on Mars.

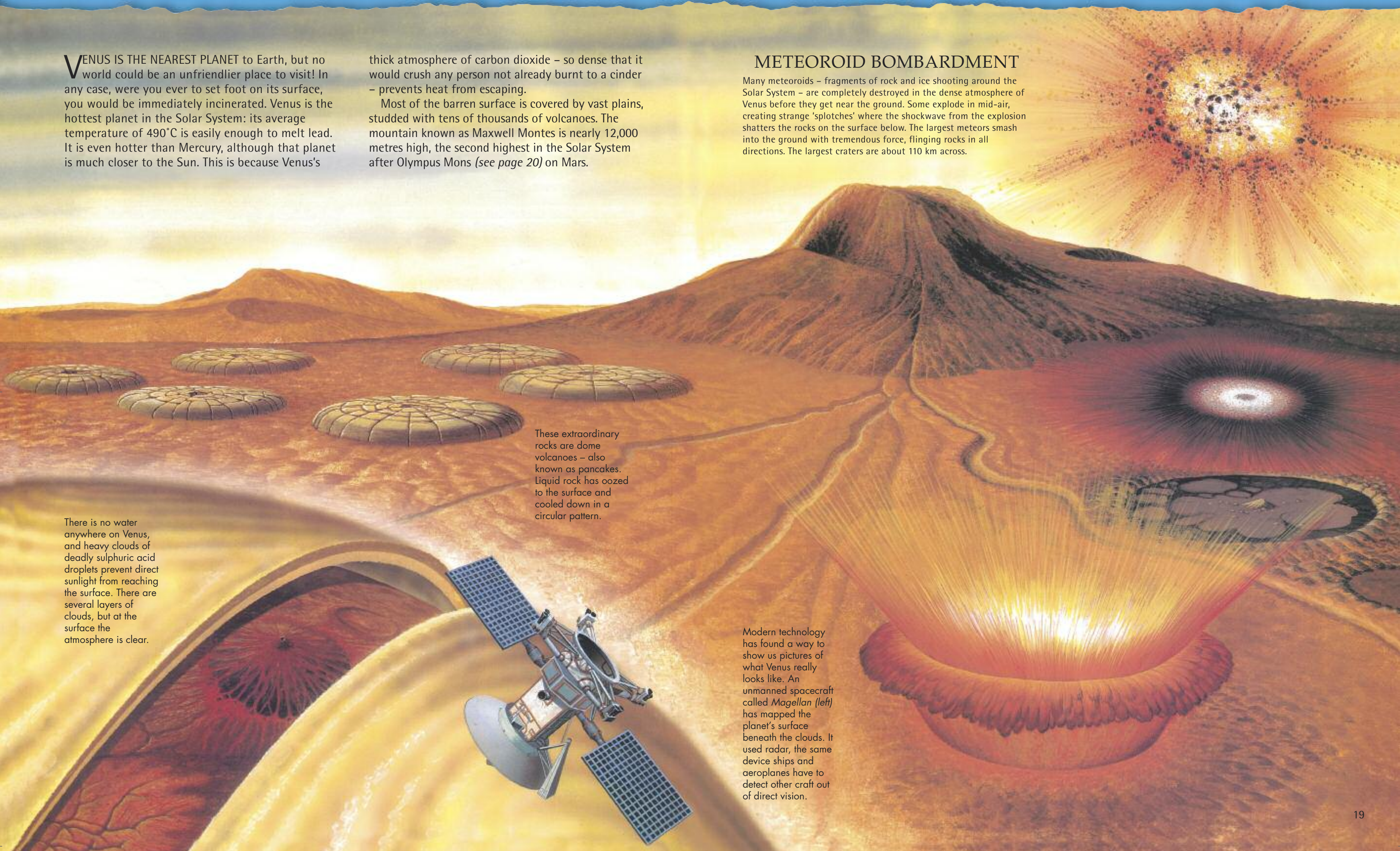
METEOROID BOMBARDMENT

Many meteoroids – fragments of rock and ice shooting around the Solar System – are completely destroyed in the dense atmosphere of Venus before they get near the ground. Some explode in mid-air, creating strange 'splotches' where the shockwave from the explosion shatters the rocks on the surface below. The largest meteors smash into the ground with tremendous force, flinging rocks in all directions. The largest craters are about 110 km across.

There is no water anywhere on Venus, and heavy clouds of deadly sulphuric acid droplets prevent direct sunlight from reaching the surface. There are several layers of clouds, but at the surface the atmosphere is clear.

These extraordinary rocks are dome volcanoes – also known as pancakes. Liquid rock has oozed to the surface and cooled down in a circular pattern.

Modern technology has found a way to show us pictures of what Venus really looks like. An unmanned spacecraft called *Magellan* (left) has mapped the planet's surface beneath the clouds. It used radar, the same device ships and aeroplanes have to detect other craft out of direct vision.



THE HIGHEST MOUNTAIN...

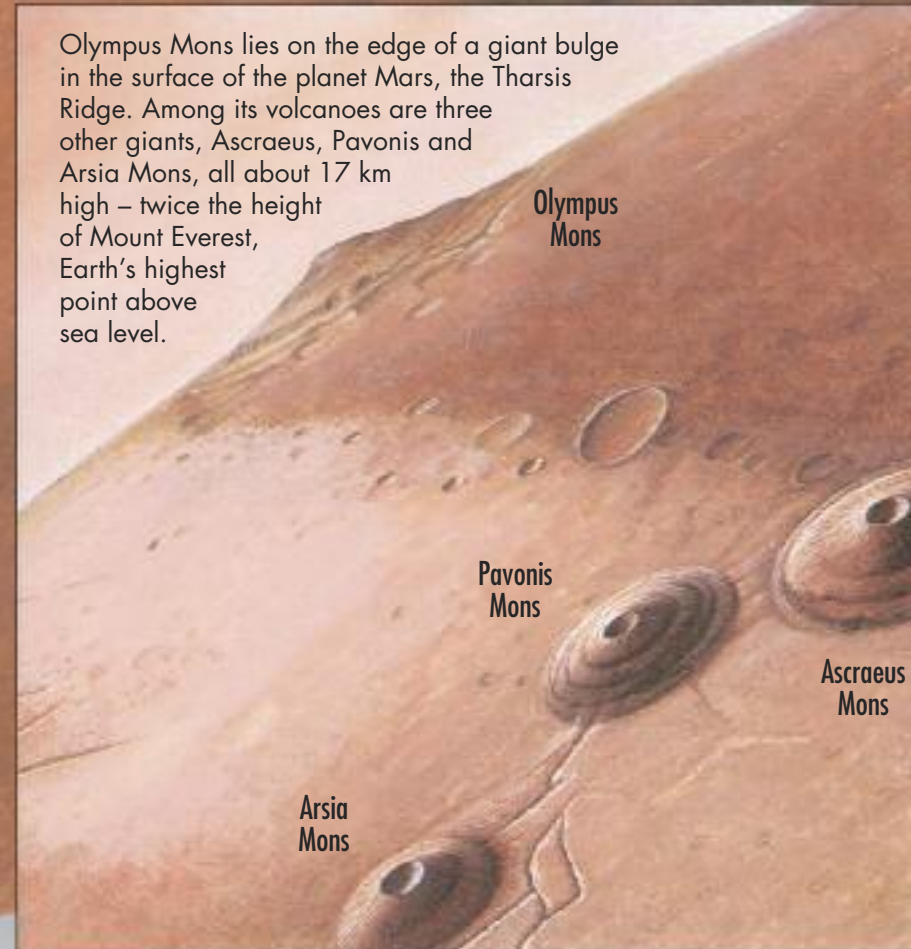
...in the solar system

OLYMPUS MONS, the giant volcano on Mars, towers 24 kilometres above the surrounding land. Nearly three times as high as the highest mountain on Earth and about twice as high as the greatest mountains on Venus, Olympus Mons is the highest mountain in the Solar System.

Like many volcanoes on Earth, Olympus Mons burst into life at a 'hot spot'. This is a place where a plume of very hot, liquid rock from deep below the surface melts through a planet's outer crust. On Earth, the outer crust is constantly on the move, a fractured armour of 'plates' sliding against, alongside, or beneath each other (see page 32). Hot-spot

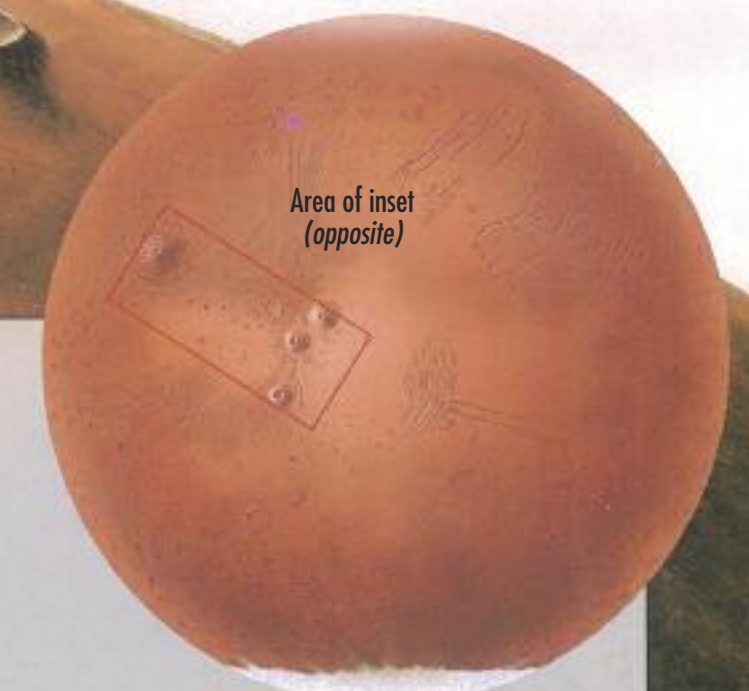
volcanoes – like the Hawaiian Islands in the Pacific Ocean – appear at the surface in different places as a crustal plate wanders over the molten spot.

Unlike the Hawaiian volcanoes, Olympus Mons stayed put above its 'hot spot'. The eruptions and lava (liquid rock) flows have gone on for tens – perhaps hundreds – of millions of years. As each layer of rock cooled, the volcano grew larger and larger. It now measures about 600 kilometres across.



The highest mountain range on Earth, the Himalayas (seen here in cross-section as a grey silhouette) would be completely dwarfed by Olympus Mons – in both directions. Mount Everest, the highest

peak, measures 8848 m to Olympus Mons' 26,400 m! And just five mountains the size of Olympus Mons placed side by side would be roughly as long as the entire Himalaya range (see page 33).



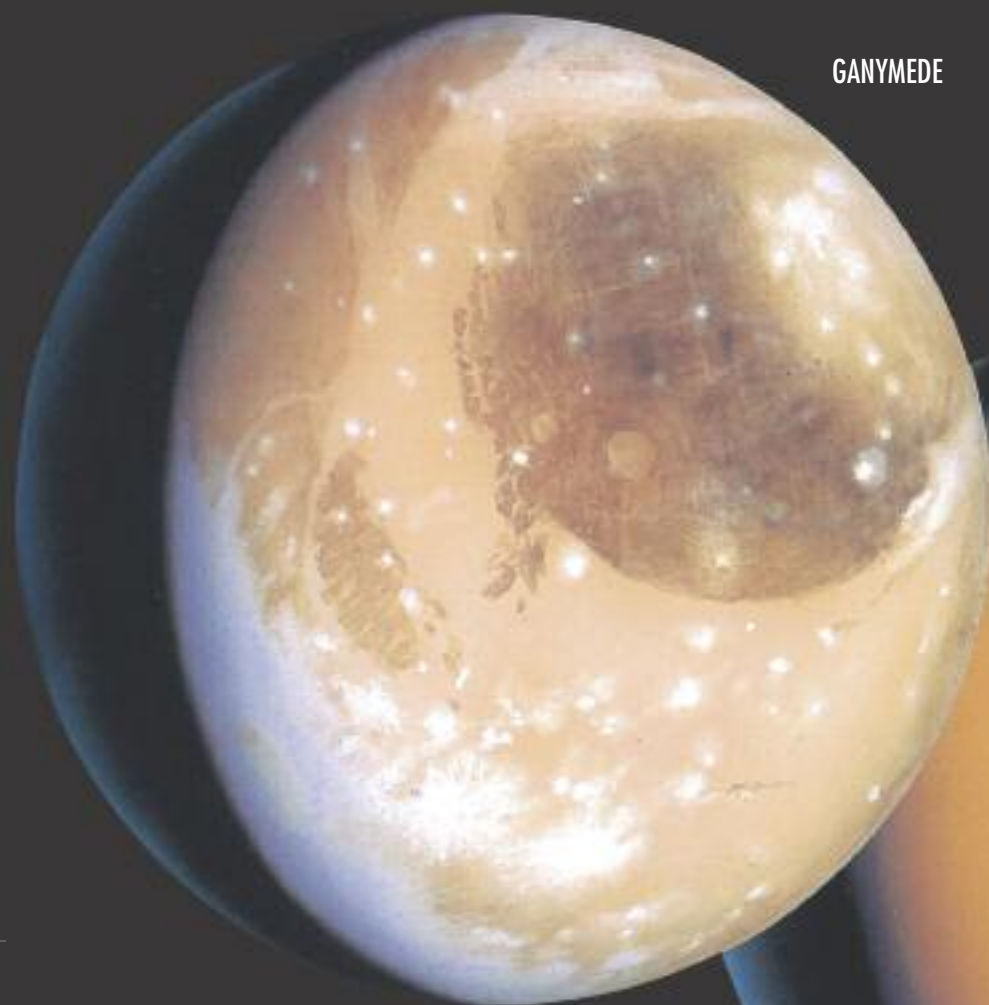
THE RED PLANET

Mars is the red planet. Its colour comes from substances containing iron, similar to ordinary rust, in its surface rocks. Nearly 80 million km farther from the Sun than Earth, Mars is a cold world. Sometimes the temperature reaches the melting point of water (0°C) at the equator in high summer. In winter, it plunges to below -120°C over the poles, which are capped by layers of frozen carbon dioxide and water ice. In the north, an expanse of water ice remains frozen in the summer. It is surrounded by the largest area of sand dunes known in the Solar System, stretching almost completely round the planet.

Now a dry and dusty place, a great deal of water once flowed over the Martian surface. Dried-up river beds are all that remain. One, Vallis Marineris, is a gigantic rift valley (see page 35) about 4000 km long, nearly enough to reach from coast to coast of the United States. Parts of it are about 6 km deep, nearly four times as deep as Earth's greatest gorge, the Grand Canyon (see page 36).

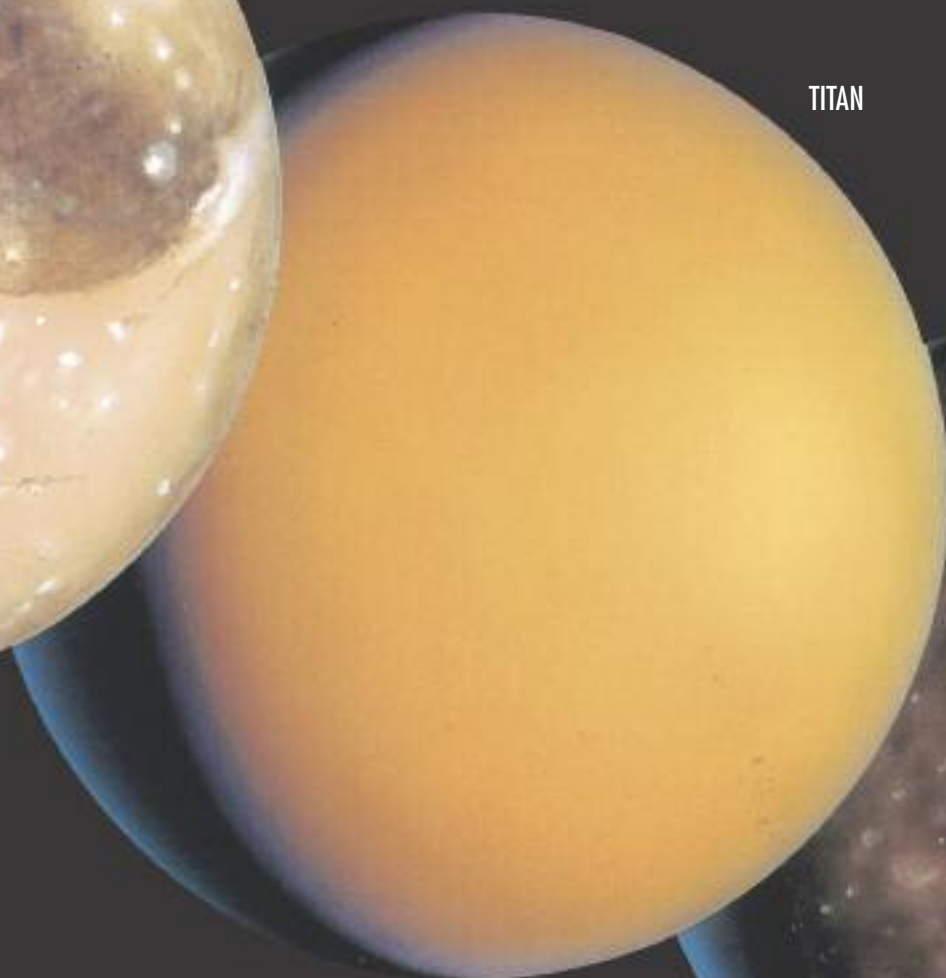
THE LARGEST MOONS

Worlds of ice and rock



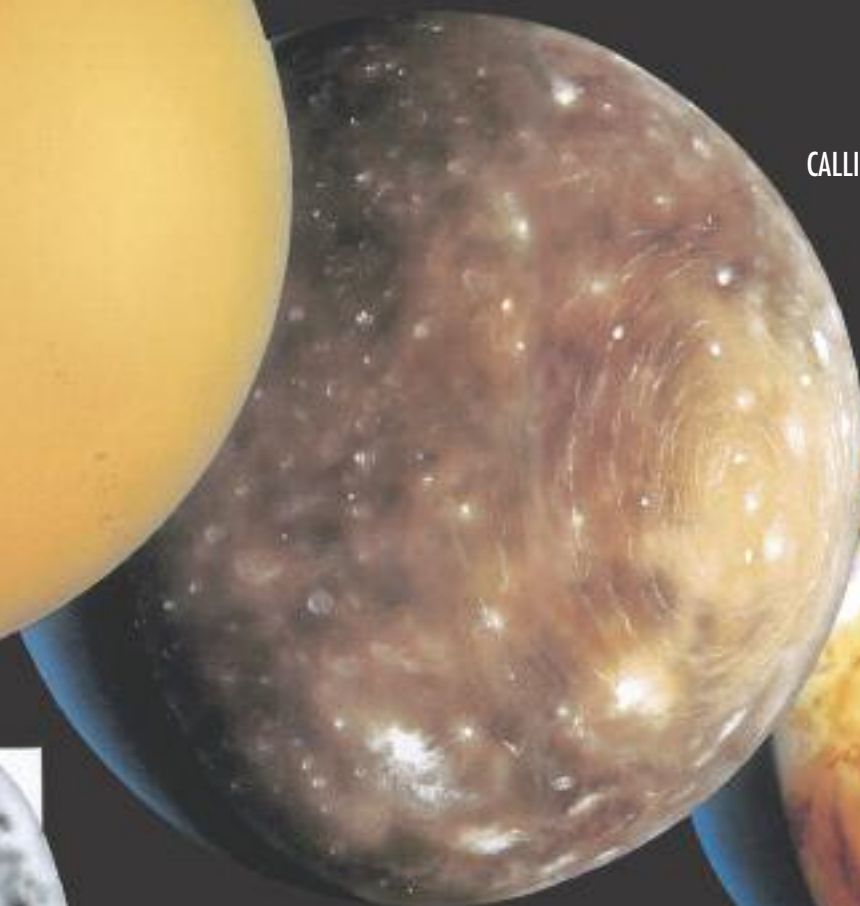
GANYMEDE

Saturn's moon, Titan, 5150 km across, is the only moon in the Solar System with a thick atmosphere (a gas envelope surrounding the globe). Dense clouds permanently hide the surface from the Sun. Recent pictures sent back by the lander *Huygens* show drainage channels and lake beds, both produced by liquid methane.



TITAN

Jupiter's four largest moons are all in the top seven. They are called the 'Galilean satellites' after the Italian scientist Galileo who first discovered them in 1610 (see page 169). Ganymede, the largest of all, is 5276 km across. It has an icy surface, with dark plains and areas showing a strangely 'grooved' pattern, as if someone has clawed away at its surface with a giant fork.



CALLISTO



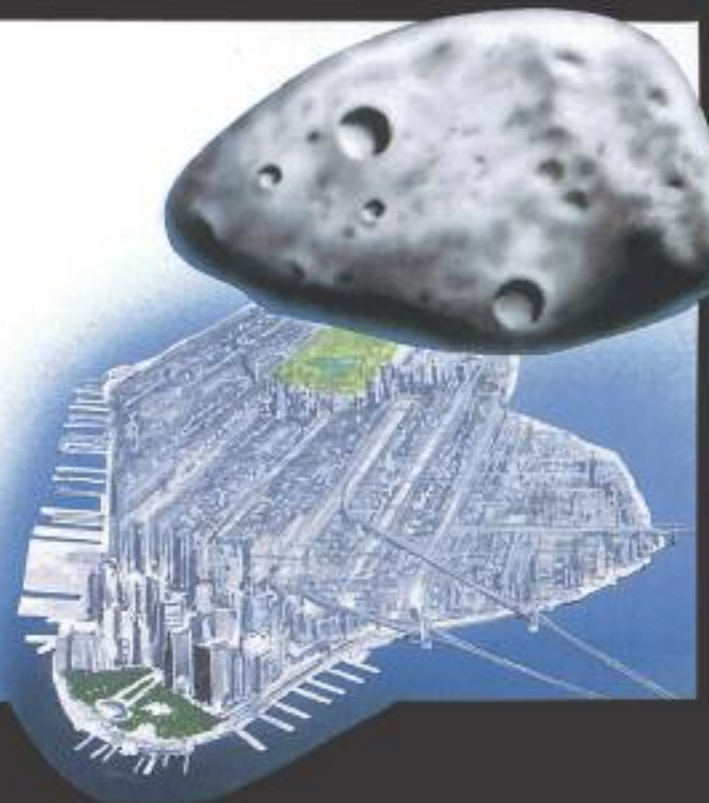
IO



Io's volcanoes erupt liquid sulphur in plumes which sometimes reach heights of 280 km (above). The ejected matter is blasted out at 3600 km/h, faster than a speeding rifle bullet.

THE SMALLEST MOON

The smallest moon (excluding smaller fragments of rock and ice discovered circling the larger planets) is Deimos, which completes its orbit around Mars every 30 hrs 20 mins. Shaped like a giant potato, it is about 15 km long, roughly three-quarters the length of Manhattan Island, New York City (pictured right). It is made of a lightweight rocky material and covered with a layer of dust. Its largest crater, Voltaire, is 2 km across.



Callisto, another of Jupiter's moons, is 4820 km across. For its size it has more craters than any other planet or moon in the Solar System. The largest crater, Valhalla, is 600 km in diameter (about the size of Poland) and is surrounded by 'ripples' about 3000 km across.

Io, Jupiter's third largest moon, is 3632 km across. For its size, it is the most volcanically active body in the Solar System. At any one time, there are seven or eight eruptions in progress. Only the Earth itself has more active volcanoes.

MOON

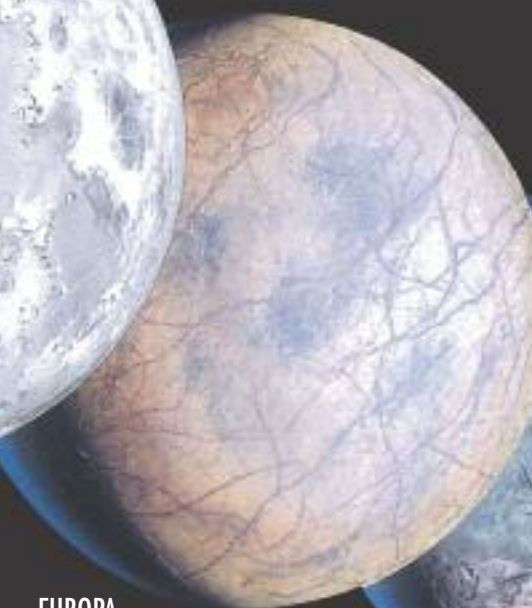
Our own Moon, Earth's nearest neighbour in space, is 3476 km across, the fifth largest moon in the Solar System. It would take 81 Moons to make up a body the size of the Earth.

coming together to form a globe; others are old asteroids that have been 'captured' by a planet's force of gravity (see page 10).

All seven largest moons illustrated here are larger than the dwarf planet Pluto. Mercury, the smallest true planet, with a diameter approximately the same as the distance across Canada and Alaska, is smaller than both Ganymede and Titan.

Europa, Jupiter's fourth largest moon, is 3126 km across. The smoothest body in the Solar System, the largest 'hills' on its icy crust measure only about 300 m high.

Triton, Neptune's largest moon, is 2720 km across. Its surface is the coldest place known in the Solar System: its temperature of -235°C is low enough to freeze oxygen and nitrogen in the air we breathe.



EUROPA



TRITON

HALLEY'S COMET

The brightest short-period comet

THE MOST FAMOUS of all comets is named after the English astronomer Edmond Halley (1656-1742). He was the first to predict that it would return to the night skies every 75-76 years.

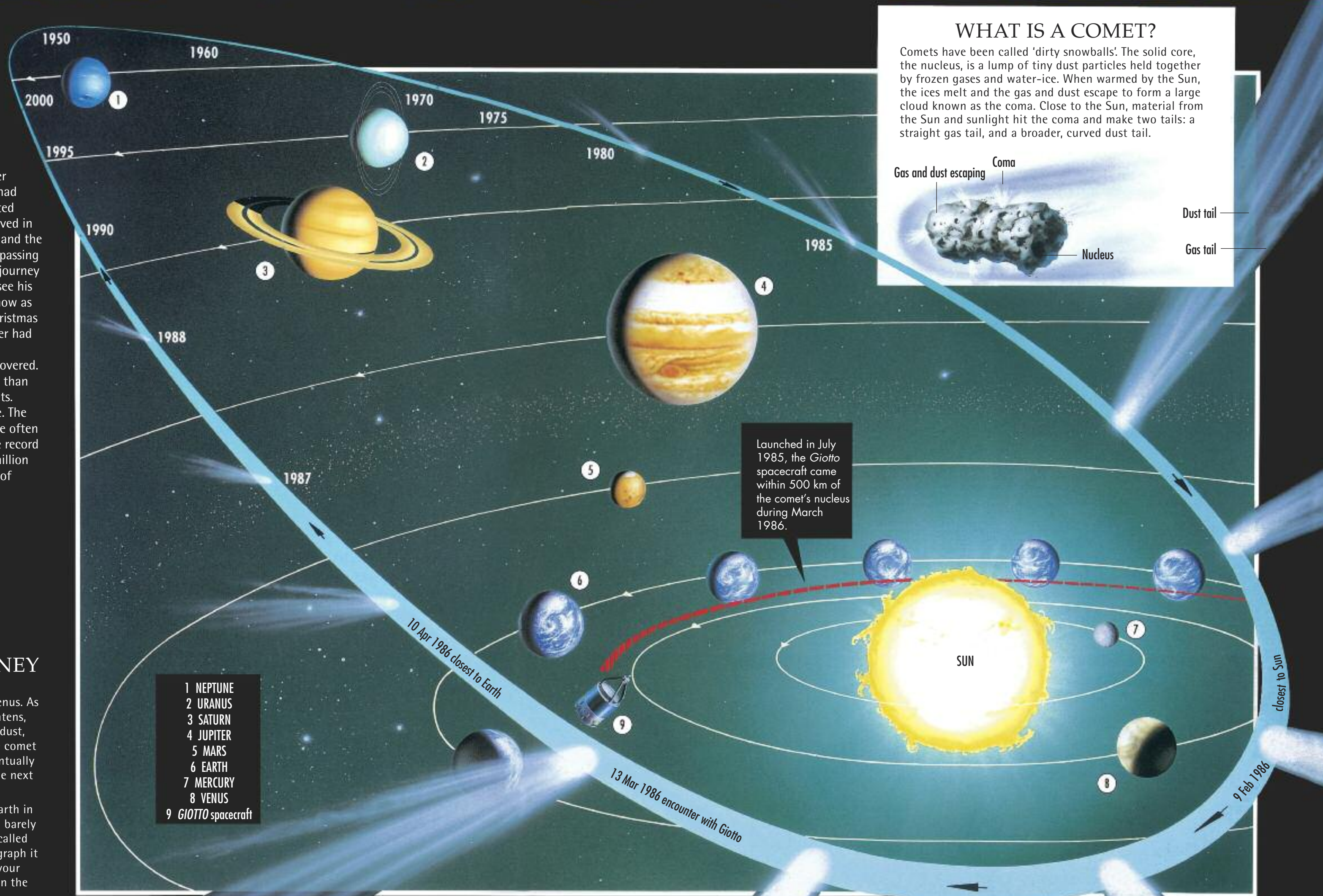
Halley believed that comets, like the planets, travelled round the Sun in elliptical orbits (elongated circles). After examining the records of comets that had appeared in 1531 and 1607, he suggested that they, along with a comet he observed in the skies in 1682, were, in fact, all one and the same. On each occasion, people saw it passing close to the Earth on its never-ending journey around the Sun. Halley did not live to see his prediction come true. What we now know as Halley's Comet was next sighted on Christmas Day 1758, 75 years after the astronomer had seen it.

Thousands of comets have been discovered. Those that complete their orbits in less than 200 years are called short-period comets. Halley's Comet is the brightest of these. The long-period comets (over 200 years) are often more spectacular, with longer tails. The record for the longest tail, measured at 320 million kilometres, is held by the Great Comet of 1843.

A COMETARY JOURNEY

Halley's orbit takes it from just outside Neptune's orbit to just within that of Venus. As it approaches the Sun, it heats up, brightens, and grows a spectacular tail of gas and dust, always pointing away from the Sun. The comet travels away from the Sun tail first. Eventually it fades and its tail disappears - until the next time it nears the Sun.

Halley's Comet last approached the Earth in 1986, but that year it was far away, and barely visible. A remote-controlled spacecraft called *Giotto* did, however, successfully photograph it at close range. You can make a note in your diaries for Halley's Comet's next visit - in the year 2062!

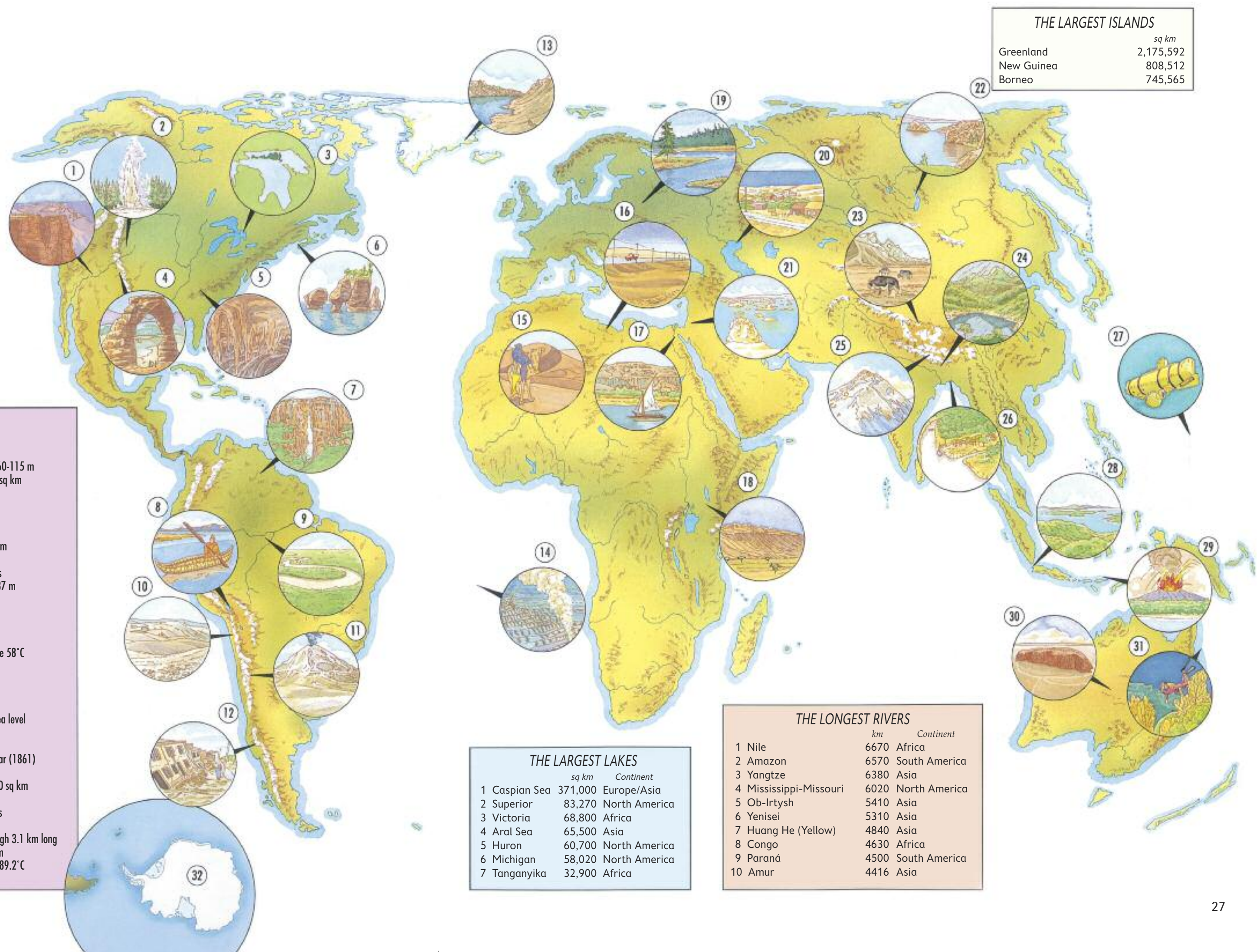


EARTH RECORD HOLDERS

Our home planet

OF ALL THE PLANETS in the Solar System, Earth has the most liquid water, its atmosphere contains the most oxygen and it is the only planet that has any form of life. Without water, life could not have developed, and without plant life there would be no oxygen in the atmosphere. Without oxygen to breathe, no animals could exist.

The oceans amount to nearly three-quarters of the Earth's surface. The largest ocean, the Pacific, accounts for half that area. More than one tenth of the land area is covered by permanent ice, mainly in the giant Antarctic and Greenland icecaps. About a third of the land surface forms the continent of Eurasia (Europe and Asia taken together), the largest land mass.



THE LARGEST ISLANDS	
	sq km
Greenland	2,175,592
New Guinea	808,512
Borneo	745,565

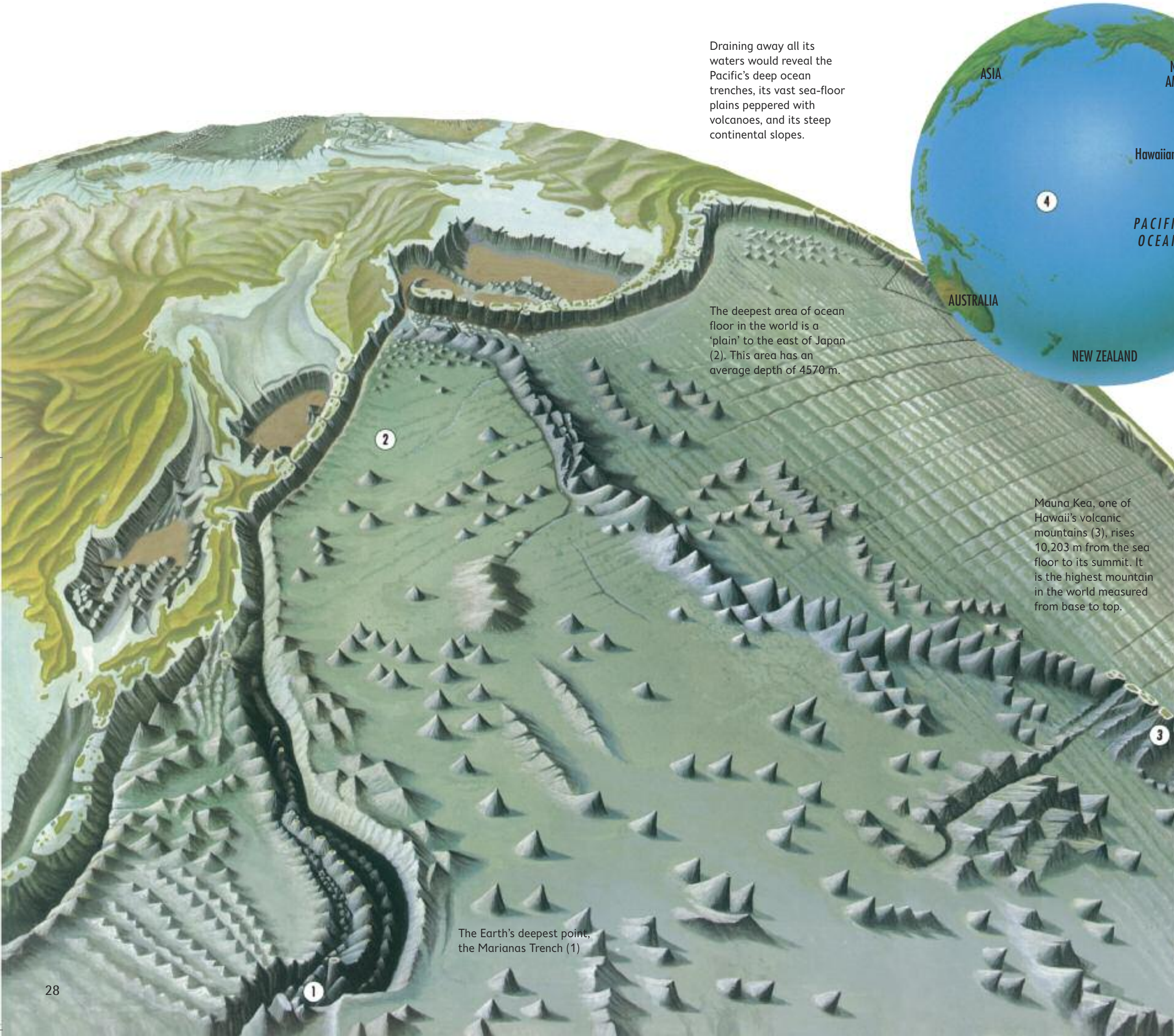
KEY	
1	Grand Canyon, Arizona, USA <i>Longest gorge</i> 349 km
2	Yellowstone National Park, Wyoming, USA <i>Tallest active geyser</i> 60-115 m
3	Manitoulin Island, Lake Huron <i>Largest island in a lake</i> 2786 sq km
4	Landscape Arch, Utah, USA <i>Longest natural arch</i> 88 m
5	Mammoth Cave, Kentucky, USA <i>Longest cave</i> 560 km
6	Bay of Fundy, Canada <i>Greatest tides</i> 14.5 m
7	Angel Falls, Venezuela <i>Highest waterfall</i> 979 m
8	Lake Titicaca, Peru/Bolivia <i>Highest navigable lake</i> 3811 m
9	Amazon <i>Largest river basin</i> 7,045,000 sq km
10	Atacama Desert, Chile <i>Driest place</i> No rain for 400 years
11	Ojos de Salado, Chile/Argentina <i>Highest active volcano</i> 6887 m
12	Valdivia, Chile <i>Most powerful earthquake</i> (1960)
13	Scoresby Sund, Greenland <i>Longest fjord</i> 313 km
14	Mid-Oceanic Ridge <i>Longest mountain range</i> 65,000 km
15	Sahara <i>Largest desert</i> 8,400,000 sq km
16	Al'Aziziyah, Libya <i>Hottest place</i> Highest recorded temperature 58°C
17	Nile <i>Longest river</i> 6670 km
18	Great Rift Valley <i>Greatest rift valley</i> 6400 km
19	Pripet Marshes, Belarus <i>Largest swamp</i> 46,950 sq km
20	Caspian Sea <i>Largest lake</i> 371,000 sq km
21	Dead Sea, Israel/Jordan <i>Lowest point on land</i> 400 m below sea level
22	Lake Baikal, Russia <i>Deepest lake</i> 1637 m
23	Tibet <i>Highest plateau</i> 4875 m
24	Cherrapunji, India <i>Wettest place</i> Recorded 26,461 mm in one year (1861)
25	Mount Everest, Nepal/Tibet <i>Highest mountain</i> 8848 m
26	Ganges/Brahmaputra, India/Bangladesh <i>Largest delta</i> 75,000 sq km
27	Marianas Trench <i>Deepest point on Earth</i> 11,032 m
28	Indonesia <i>Largest archipelago</i> More than 13,000 islands
29	Tambora, Indonesia <i>Greatest volcanic eruption</i> (1815)
30	Uluru (Ayers Rock), Australia <i>Largest fully exposed monolith</i> 348 m high 3.1 km long
31	Great Barrier Reef, Australia <i>Longest coral reef</i> 2027 km
32	Vostok, Antarctica <i>Coldest place</i> Lowest recorded temperature -89.2°C

THE LARGEST LAKES		
	sq km	Continent
1	Caspian Sea	371,000 Europe/Asia
2	Superior	83,270 North America
3	Victoria	68,800 Africa
4	Aral Sea	65,500 Asia
5	Huron	60,700 North America
6	Michigan	58,020 North America
7	Tanganyika	32,900 Africa

THE LONGEST RIVERS		
	km	Continent
1	Nile	6670 Africa
2	Amazon	6570 South America
3	Yangtze	6380 Asia
4	Mississippi-Missouri	6020 North America
5	Ob-Irtysh	5410 Asia
6	Yenisei	5310 Asia
7	Huang He (Yellow)	4840 Asia
8	Congo	4630 Africa
9	Paraná	4500 South America
10	Amur	4416 Asia

THE GREATEST OCEAN

The mighty Pacific



Draining away all its waters would reveal the Pacific's deep ocean trenches, its vast sea-floor plains peppered with volcanoes, and its steep continental slopes.

The deepest area of ocean floor in the world is a 'plain' to the east of Japan (2). This area has an average depth of 4570 m.

Mauna Kea, one of Hawaii's volcanic mountains (3), rises 10,203 m from the sea floor to its summit. It is the highest mountain in the world measured from base to top.

The Earth's deepest point, the Marianas Trench (1)



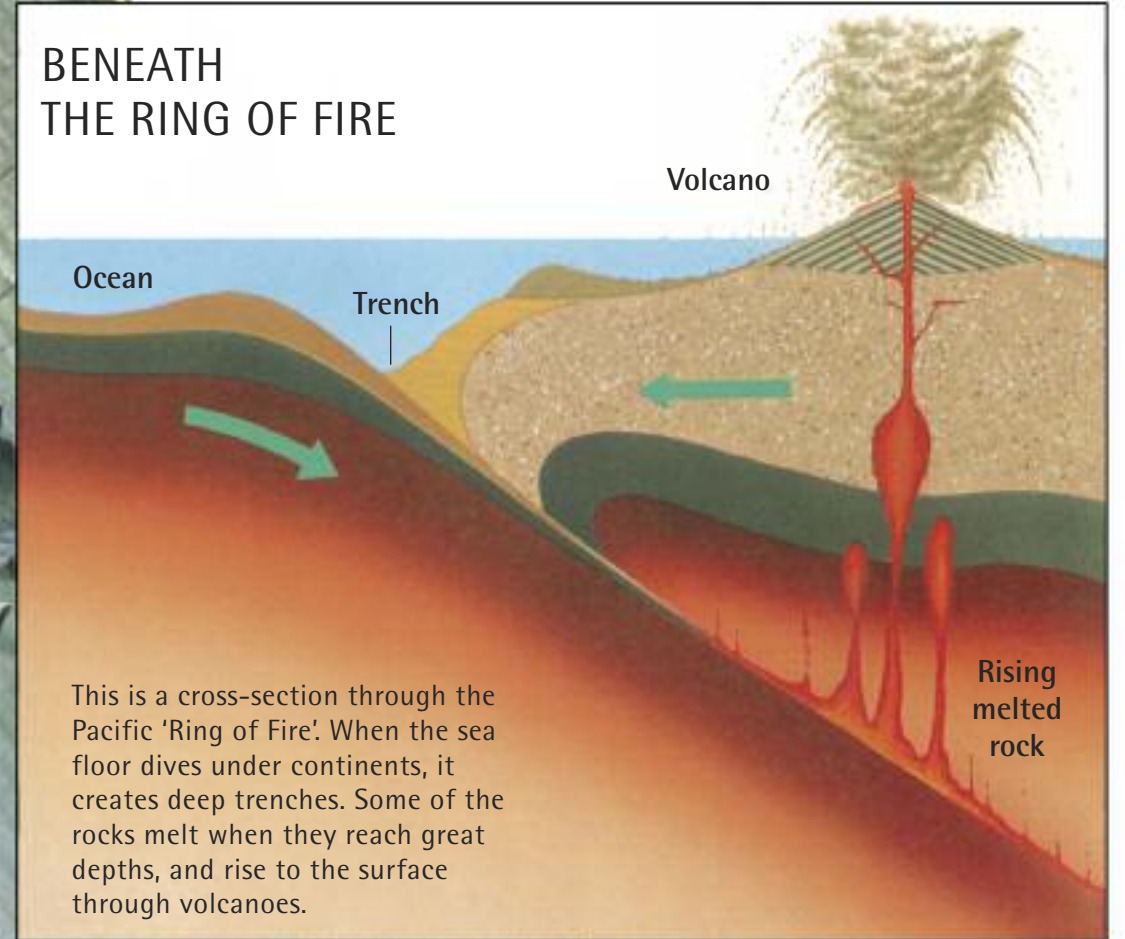
The world's largest atoll, Kwajalein (4), is in the Marshall Islands, in the central Pacific Ocean.

Almost three-quarters of the Earth's surface is water. Of this, nearly half forms the giant Pacific Ocean, which covers an area nearly ten times the size of Russia, the world's largest country. This enormous expanse of water has an average depth of 4188 metres, but in the Marianas Trench the bottom plunges to 11,032 metres, the deepest point on Earth.

Most of the Pacific's sea floor consists of one gigantic plate (see page 32). Where it crashes into other plates next to it, the sea floor is slowly being dragged down into deep ocean trenches – like the Marianas Trench. All around the Pacific (the name means 'peaceful'), the Earth is alive with active volcanoes and repeatedly shaken by violent quakes (see pages 41 and 43). Not for nothing is the Pacific shoreline called the 'Ring of Fire'.

All the small islands scattered across the Pacific started out as volcanoes. Erupted lava quickly cools to solid rock, while repeated eruptions build up a volcano's height until it breaks the surface of the sea. In the tropical waters of the South Pacific, coral reefs grow in the shallows all round an island coastline. Built by tiny animals that grow their skeletons outside their bodies, a ring of coral – called an atoll – can be left just peeping above the waves after the volcanic island it once encircled has sunk back beneath the sea. Some are large enough for people to live on.

BENEATH THE RING OF FIRE



This is a cross-section through the Pacific 'Ring of Fire'. When the sea floor dives under continents, it creates deep trenches. Some of the rocks melt when they reach great depths, and rise to the surface through volcanoes.

THE GREATEST MOUNTAINS

The mid-oceanic ridge

HIDDEN BENEATH THE OCEANS is the world's greatest mountain range. Called the Mid-Oceanic Ridge, it starts in the Arctic Ocean and runs southwards through the Atlantic before bending to the east, winding through the Indian and Pacific Oceans. It ends up near the west coast of North America after a journey of 65,000 kilometres. Some of its peaks are 4200 metres high, but only a few break the ocean waters as tiny islands. Iceland has grown into a large island as volcanoes have erupted over and over again in the same place.

Beneath the Ridge, liquid rock or magma from the hot interior of the Earth rises towards the surface. The sea floor bulges upwards and cracks open. The magma, called lava as it bubbles out of the Earth's crust, seeps into the faults (long cracks) and pushes the rocks further apart. Every year, the faults running down the Ridge grows wider by a few centimetres – about the speed that fingernails grow. Over millions of years the ocean floor itself becomes wider and wider.

There are much longer faults cutting right across the Ridge at right-angles. These break up the sea floor into giant blocks, giving the Ridge a zig-zag shape.



The Mid-Oceanic Ridge forms a continuous chain passing through all the world's oceans. One branch runs up the Indian Ocean and meets the Great Rift Valley (see page 34) in the Red Sea.

VOLCANOES UNDER THE SEA

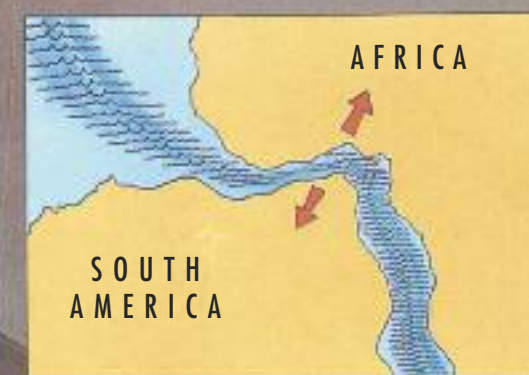
Unlike the violent explosions of volcanoes like Santorini (see page 40), eruptions along the Ridge are fairly gentle. This is because the liquid rock flows easily. Along the centre of the Ridge runs a rift valley, a strip of land between two parallel faults (see page 35). Most of the eruptions happen here, where lava finds its way to the sea floor through the faults.

Sometimes a volcano may erupt for long enough to grow and reach the surface, where it forms an island in the ocean. Bouvet Island in the South Atlantic Ocean, the most remote island in the world – 1700 km from the nearest land – arose in this way.

Deep in the central valley that runs the length of the Mid-Oceanic Ridge, tall chimneys made of solidified minerals, called black smokers, blast hot smoke into the ocean waters. These smokers provide warmth and food for weird crabs, worms and fishes found nowhere else on Earth.

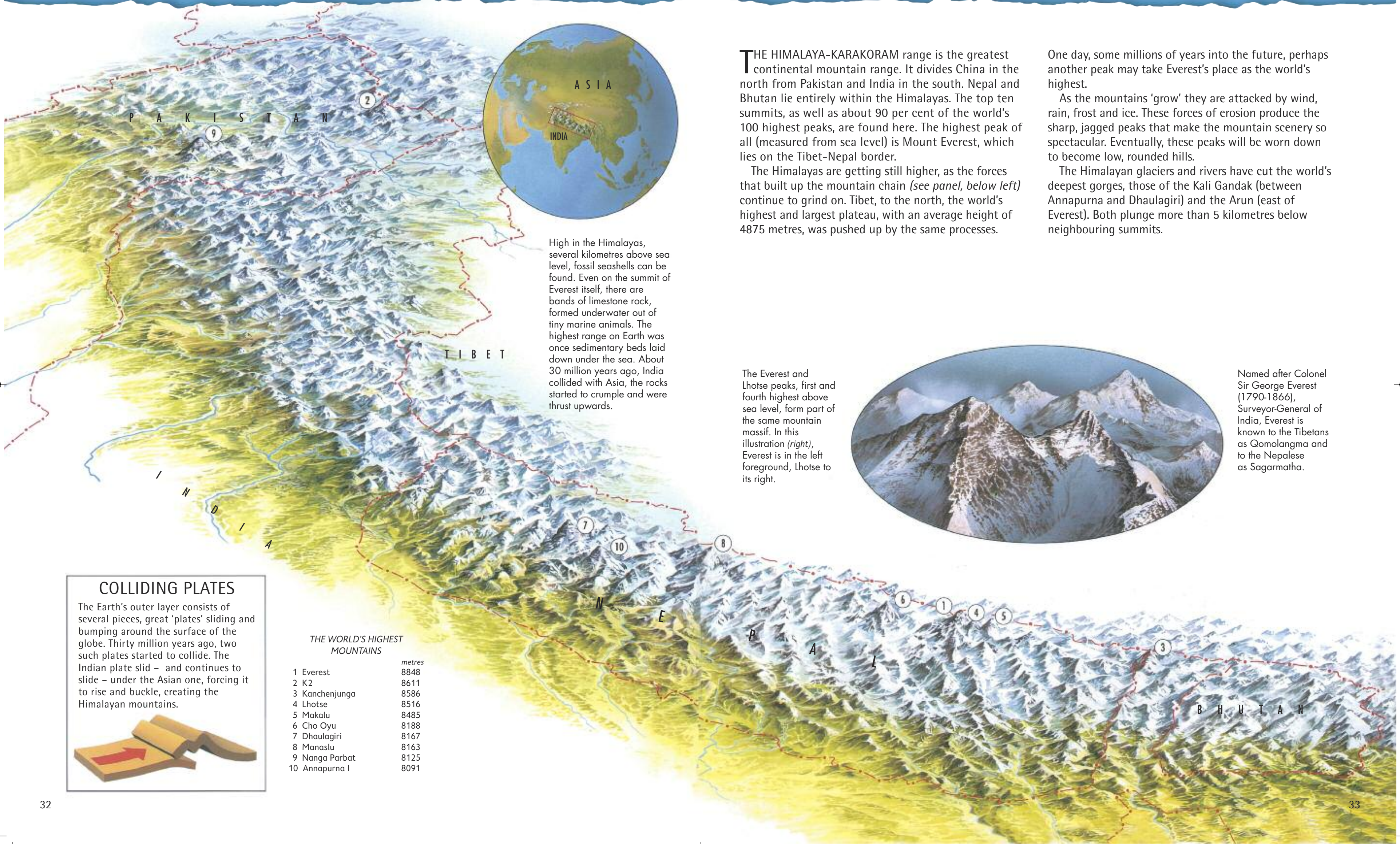
Have you ever noticed that Africa and South America would fit snugly together if you pushed one up against the other? In fact, millions of years ago, they were close

together, both making up part of a single continent. The sea floor opened up between them, and the spreading Mid-Oceanic Ridge pushed them far apart.



THE HIGHEST MOUNTAINS

The towering Himalayas



High in the Himalayas, several kilometres above sea level, fossil seashells can be found. Even on the summit of Everest itself, there are bands of limestone rock, formed underwater out of tiny marine animals. The highest range on Earth was once sedimentary beds laid down under the sea. About 30 million years ago, India collided with Asia, the rocks started to crumple and were thrust upwards.

THE HIMALAYA-KARAKORAM range is the greatest continental mountain range. It divides China in the north from Pakistan and India in the south. Nepal and Bhutan lie entirely within the Himalayas. The top ten summits, as well as about 90 per cent of the world's 100 highest peaks, are found here. The highest peak of all (measured from sea level) is Mount Everest, which lies on the Tibet-Nepal border.

The Himalayas are getting still higher, as the forces that built up the mountain chain (see panel, below left) continue to grind on. Tibet, to the north, the world's highest and largest plateau, with an average height of 4875 metres, was pushed up by the same processes.

One day, some millions of years into the future, perhaps another peak may take Everest's place as the world's highest.

As the mountains 'grow' they are attacked by wind, rain, frost and ice. These forces of erosion produce the sharp, jagged peaks that make the mountain scenery so spectacular. Eventually, these peaks will be worn down to become low, rounded hills.

The Himalayan glaciers and rivers have cut the world's deepest gorges, those of the Kali Gandak (between Annapurna and Dhaulagiri) and the Arun (east of Everest). Both plunge more than 5 kilometres below neighbouring summits.

The Everest and Lhotse peaks, first and fourth highest above sea level, form part of the same mountain massif. In this illustration (right), Everest is in the left foreground, Lhotse to its right.



Named after Colonel Sir George Everest (1790-1866), Surveyor-General of India, Everest is known to the Tibetans as Qomolangma and to the Nepalese as Sagarmatha.

COLLIDING PLATES

The Earth's outer layer consists of several pieces, great 'plates' sliding and bumping around the surface of the globe. Thirty million years ago, two such plates started to collide. The Indian plate slid – and continues to slide – under the Asian one, forcing it to rise and buckle, creating the Himalayan mountains.

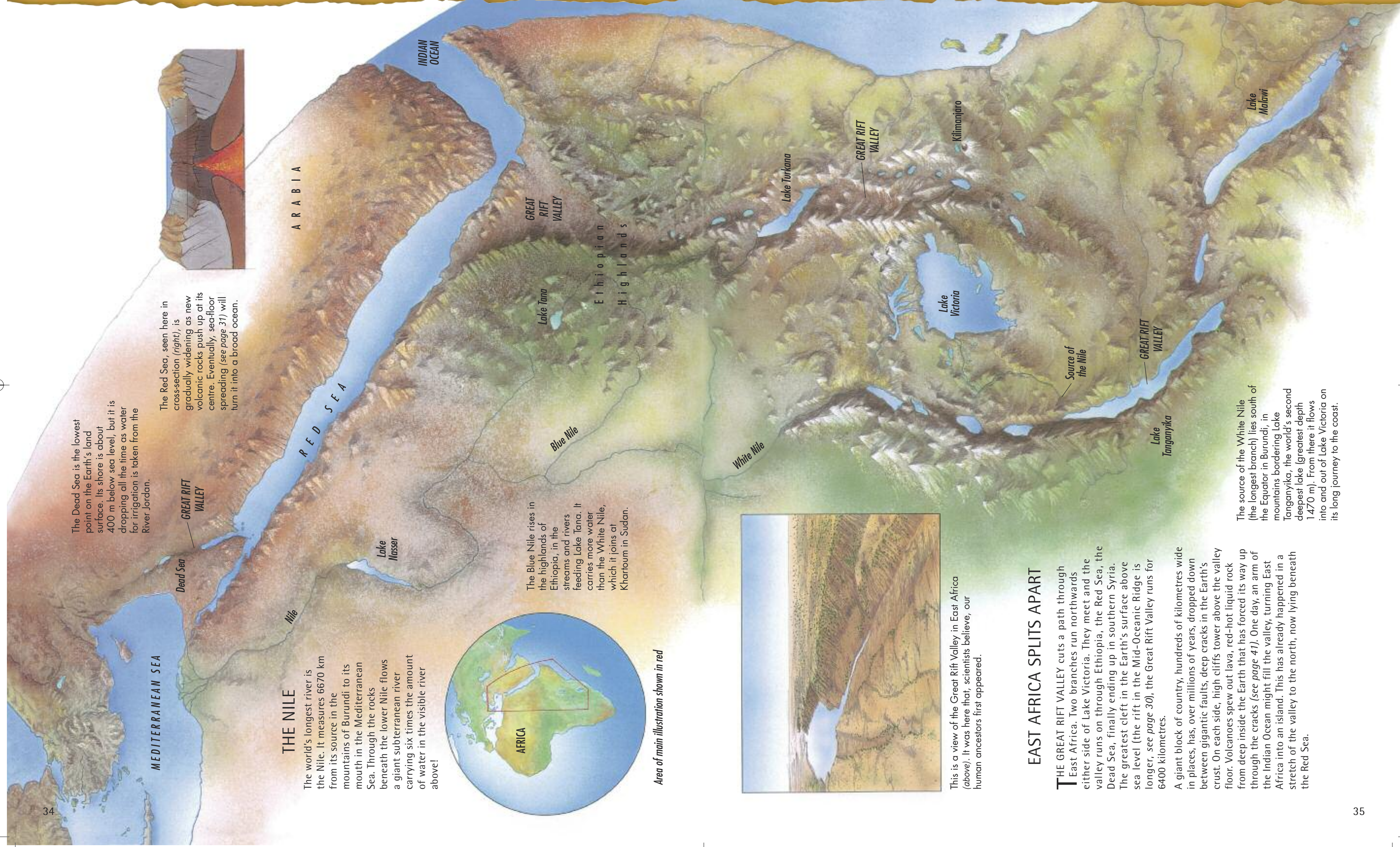


THE WORLD'S HIGHEST MOUNTAINS

	metres
1 Everest	8848
2 K2	8611
3 Kanchenjunga	8586
4 Lhotse	8516
5 Makalu	8485
6 Cho Oyu	8188
7 Dhaulagiri	8167
8 Manaslu	8163
9 Nanga Parbat	8125
10 Annapurna I	8091

THE GREATEST RIFT

And the longest river



The Dead Sea is the lowest point on the Earth's land surface. Its shore is about 400 m below sea level, but it is dropping all the time as water for irrigation is taken from the River Jordan.

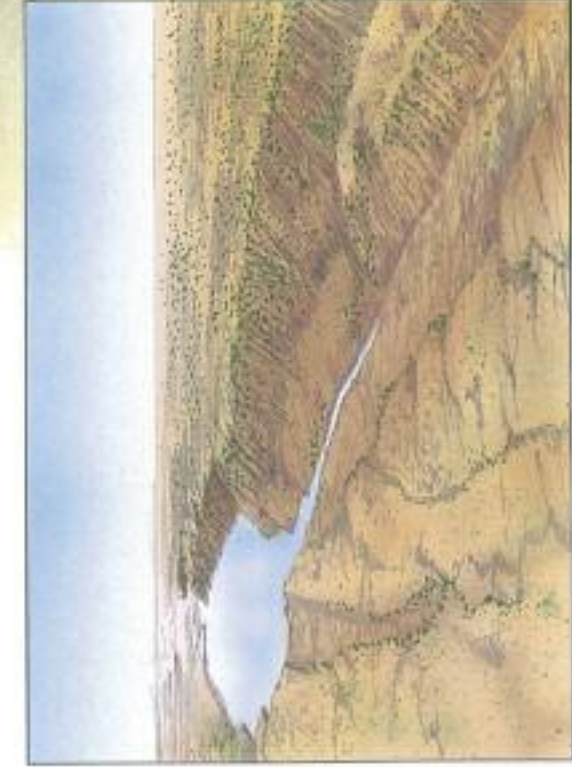
The Red Sea, seen here in cross-section (right), is gradually widening as new volcanic rocks push up at its centre. Eventually, sea-floor spreading (see page 31) will turn it into a broad ocean.

THE NILE
The world's longest river is the Nile. It measures 6670 km from its source in the mountains of Burundi to its mouth in the Mediterranean Sea. Through the rocks beneath the lower Nile flows a giant subterranean river carrying six times the amount of water in the visible river above!



Area of main illustration shown in red

The Blue Nile rises in the highlands of Ethiopia, in the streams and rivers feeding Lake Tana. It carries more water than the White Nile, which it joins at Khartoum in Sudan.



This is a view of the Great Rift Valley in East Africa (above). It was here that, scientists believe, our human ancestors first appeared.

EAST AFRICA SPLITS APART

THE GREAT RIFT VALLEY cuts a path through East Africa. Two branches run northwards either side of Lake Victoria. They meet and the valley runs on through Ethiopia, the Red Sea, the Dead Sea, finally ending up in southern Syria. The greatest cleft in the Earth's surface above sea level (the rift in the Mid-Oceanic Ridge is longer, see page 30), the Great Rift Valley runs for 6400 kilometres.

A giant block of country, hundreds of kilometres wide in places, has, over millions of years, dropped down between gigantic faults, deep cracks in the Earth's crust. On each side, high cliffs tower above the valley floor. Volcanoes spew out lava, red-hot liquid rock from deep inside the Earth that has forced its way up through the cracks (see page 41). One day, an arm of the Indian Ocean might fill the valley, turning East Africa into an island. This has already happened in a stretch of the valley to the north, now lying beneath the Red Sea.

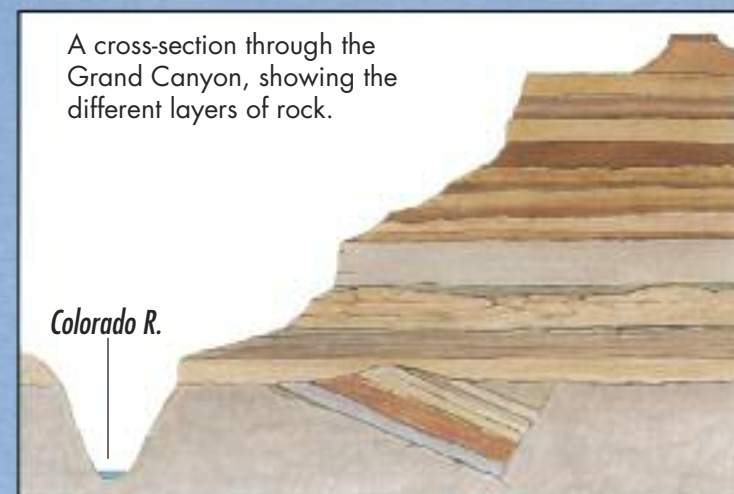
The source of the White Nile (the longest branch) lies south of the Equator in Burundi, in mountains bordering Lake Tanganyika, the world's second deepest lake (greatest depth 1470 m). From there it flows into and out of Lake Victoria on its long journey to the coast.

THE LARGEST GORGE

The spectacular Grand Canyon

THE GRAND CANYON in Arizona is the largest gorge on Earth. It twists and turns across dry, rocky land for 349 kilometres. Averaging 16 kilometres in width and 1.6 kilometres in depth, this vast chasm has been carved by the savage force of the Colorado River and its tributaries. And the process continues today. On a normal day, the river carries off about half a million tonnes of sediment (mud and gravel pulled along by the current). When it is in flood, large boulders are swept downstream.

The Colorado has been at work for millions of years, cutting downwards as the land beneath it has gradually risen higher and higher. Over a period of about 5 million years, the land has increased in height by more than 1200 metres. In the meantime, the Colorado has carved through to rocks buried deep below the ground that once formed the lower slopes of ancient mountains standing 16,000 metres high – twice the height of Mount Everest.



A cross-section through the Grand Canyon, showing the different layers of rock.

HISTORY IN THE ROCKS

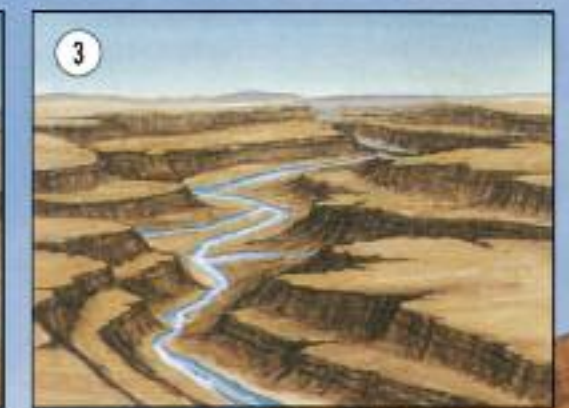
As near a complete display of the Earth's history as you are ever likely to see is revealed on the slopes of the Grand Canyon. As the land lay under the sea for hundreds of millions of years, coatings of sediment have been laid down, one on top of the other like blankets on a bed. Each layer turned to stone, the different types reflecting the climates and life-forms of their age. The oldest rocks of all in the Grand Canyon, found in the deepest part of the gorge, are 1.7 billion years old.



The Colorado River once flowed gently across the desert (1). Then, between 10 and 12 million years ago, the land beneath it began to rise (2). It did so only by about 0.25 mm a year, but the river kept pace with it, cutting a deeper channel to preserve its downward course to the sea. It carved through different layers of rock,



some hard, some soft. The soft rock wore away more easily than the hard, which today stands out as vertical cliff faces (3).



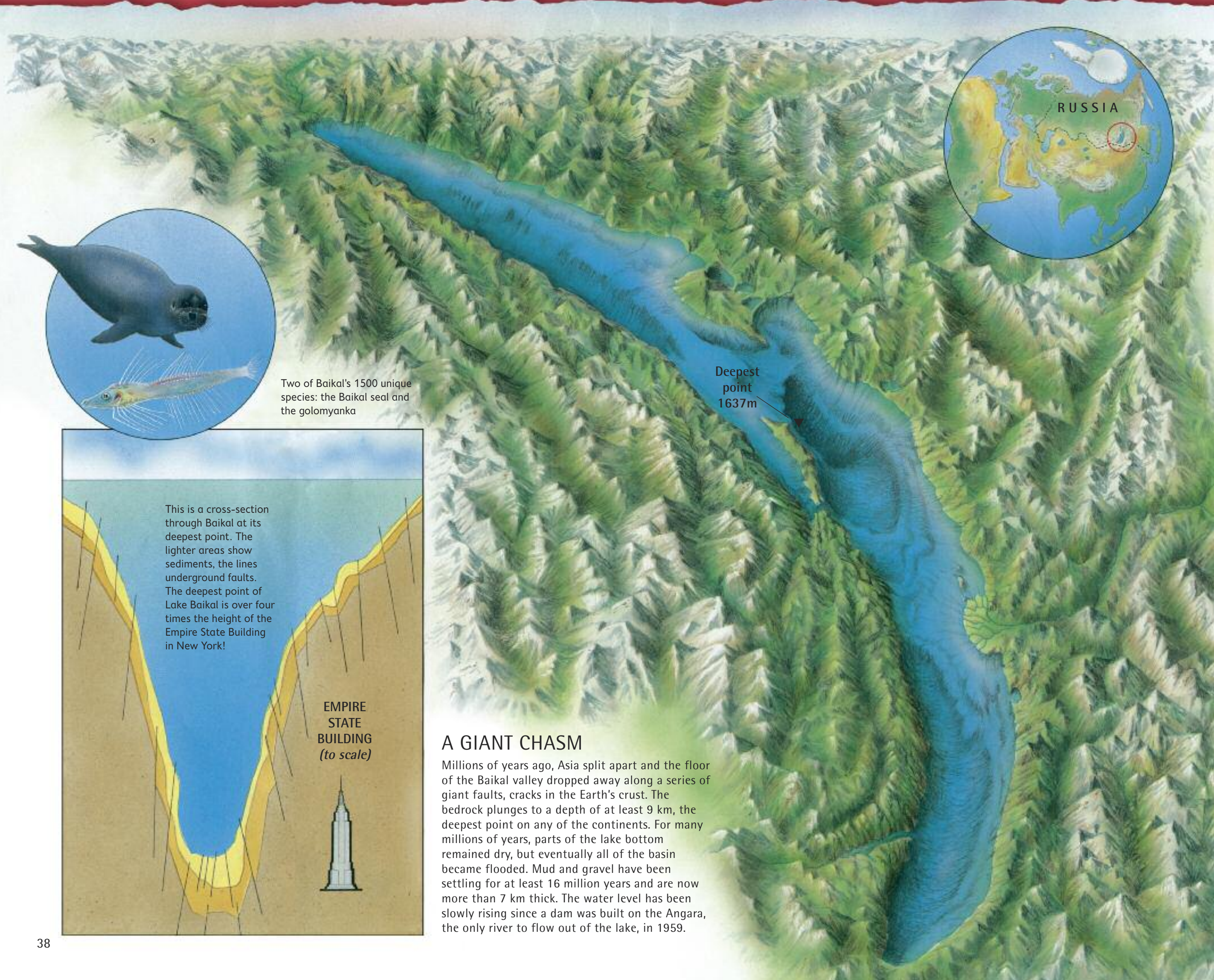
An aerial view (*below*) of the Grand Canyon, and its location in Arizona, USA.



This is a bird's-eye view of the Grand Canyon, showing the arid terrain and characteristic step-like slopes. The Grand Canyon exists only because the climate has always been extremely dry. (The Colorado River's water comes from the distant Rockies.) If there had been more rainfall, most of the softer, upper layers of rock would have been washed away.

THE DEEPEST LAKE

Baikal, blue eye of Siberia



Two of Baikal's 1500 unique species: the Baikal seal and the golomyanka



Deepest point
1637m

This is a cross-section through Baikal at its deepest point. The lighter areas show sediments, the lines underground faults. The deepest point of Lake Baikal is over four times the height of the Empire State Building in New York!

EMPIRE STATE BUILDING (to scale)



A GIANT CHASM

Millions of years ago, Asia split apart and the floor of the Baikal valley dropped split away along a series of giant faults, cracks in the Earth's crust. The bedrock plunges to a depth of at least 9 km, the deepest point on any of the continents. For many millions of years, parts of the lake bottom remained dry, but eventually all of the basin became flooded. Mud and gravel have been settling for at least 16 million years and are now more than 7 km thick. The water level has been slowly rising since a dam was built on the Angara, the only river to flow out of the lake, in 1959.

Lying in the far east of Russia amidst Siberia's mountains and forests, Lake Baikal, the world's deepest lake, is sometimes known as the Blue Eye of Siberia. By area only the ninth largest lake, it is easily the largest body of fresh water in the world. It holds one-fifth of the world total – more than all five of the Great Lakes of North America put together! If all the world's drinking water ran out, Lake Baikal could supply the world's population for a further 40 years.

As many as 336 rivers and streams feed into Baikal, but because most of the surrounding mountains are extremely hard rock, very little dissolved substances find their way into the water. The lake is crystal clear and very pure. Only in the south is there man-made pollution, although this is still very slight.

In the Olkhon Crevice, the bottom plunges to more than 1600 metres below the surface. Here, the average depth of the lake floor lies much deeper than the shores of the Dead Sea (400 metres below sea level), the lowest point on land in the world.

Lake Baikal is probably also the oldest lake in existence, dating back perhaps 25 million years. It has its own special forms of wildlife – hundreds of kinds of creatures living in its waters that are not found anywhere else.

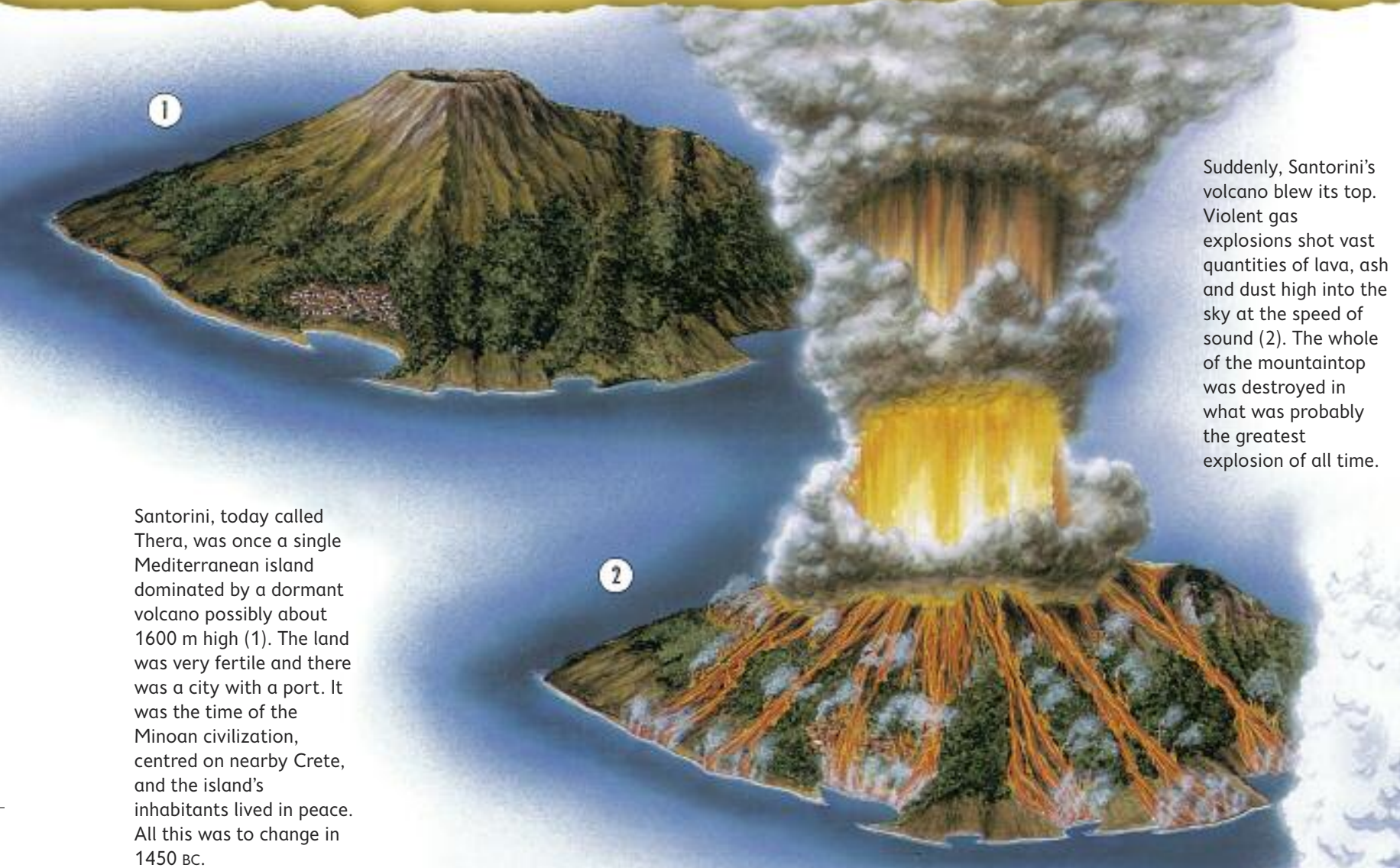
These include the Baikal seal, which lives 3000 kilometres away from its nearest relatives on the shores of the Arctic Ocean.

A CLIMATE OF ITS OWN

Crescent-shaped Lake Baikal is about 620 km long and about 74 km at its widest. Baikal lies close to the centre of the Asian continent. There are extremely cold winters and hot summers. The enormous amount of water in the lake causes the surrounding area to have milder winters and cooler summers than other parts of Siberia. Even so, about 3 m of ice covers Baikal in winter.

THE GREATEST EXPLOSION

A volcano blows



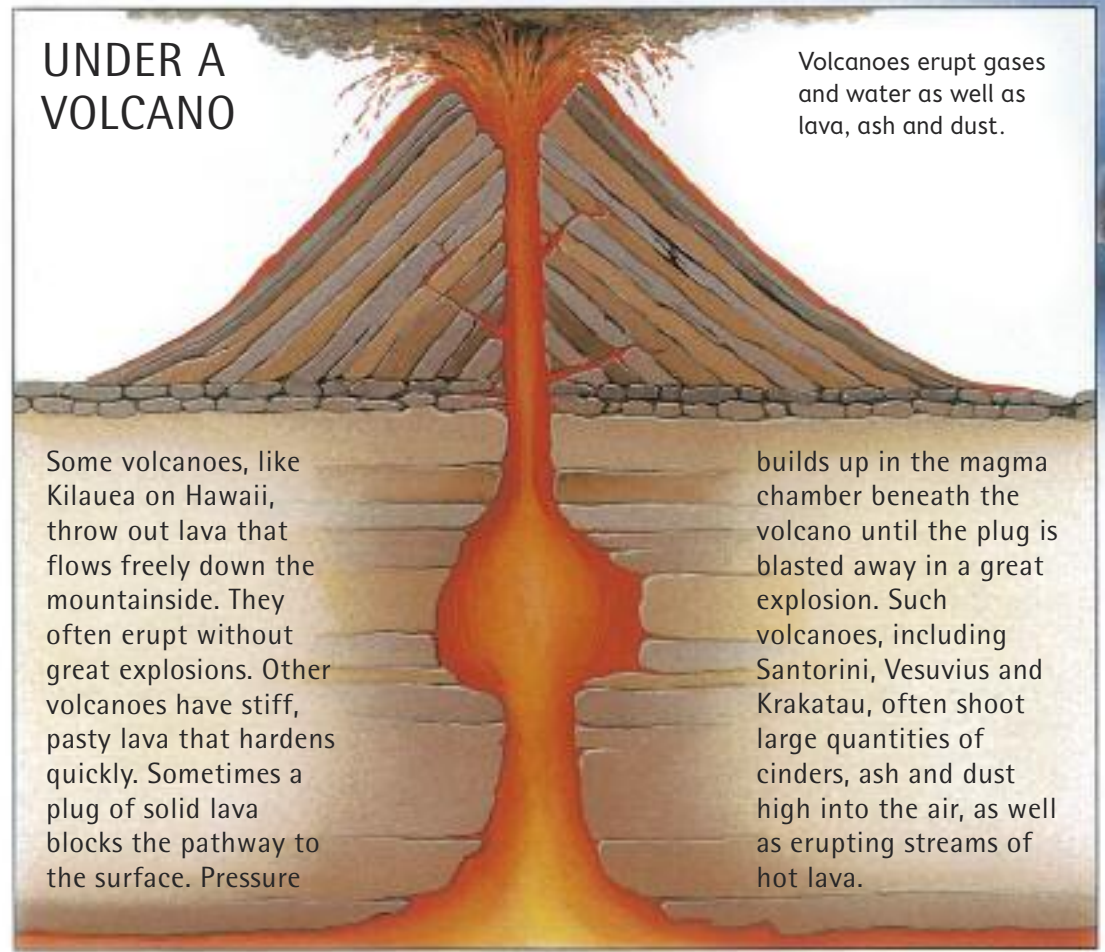
Santorini, today called Thera, was once a single Mediterranean island dominated by a dormant volcano possibly about 1600 m high (1). The land was very fertile and there was a city with a port. It was the time of the Minoan civilization, centred on nearby Crete, and the island's inhabitants lived in peace. All this was to change in 1450 BC.

Suddenly, Santorini's volcano blew its top. Violent gas explosions shot vast quantities of lava, ash and dust high into the sky at the speed of sound (2). The whole of the mountaintop was destroyed in what was probably the greatest explosion of all time.



Volcanic eruptions, the most powerful explosions on Earth, are incredibly destructive. During the eruption of Krakatau in 1883, about 20 cubic kilometres of rock (nearly the entire exploded mountain) was blasted high into the air. The noise of the explosion, the greatest in modern times, was heard 5000 kilometres away in India, China and Australia. Probably three times as much was ejected during the eruption of Santorini around 1450 BC.

Greater still was the eruption of Tambora, on the island of Sumbawa in Indonesia in 1815, when about 160 cubic kilometres was blasted away. Pulverized rock was hurled at least 50 kilometres high into the Earth's atmosphere. Dust blankets drifted around the globe, shutting off the Sun's rays and causing temperatures to drop. The year after the Tambora eruption, 1816, was known as 'Eighteen hundred and froze to death'.

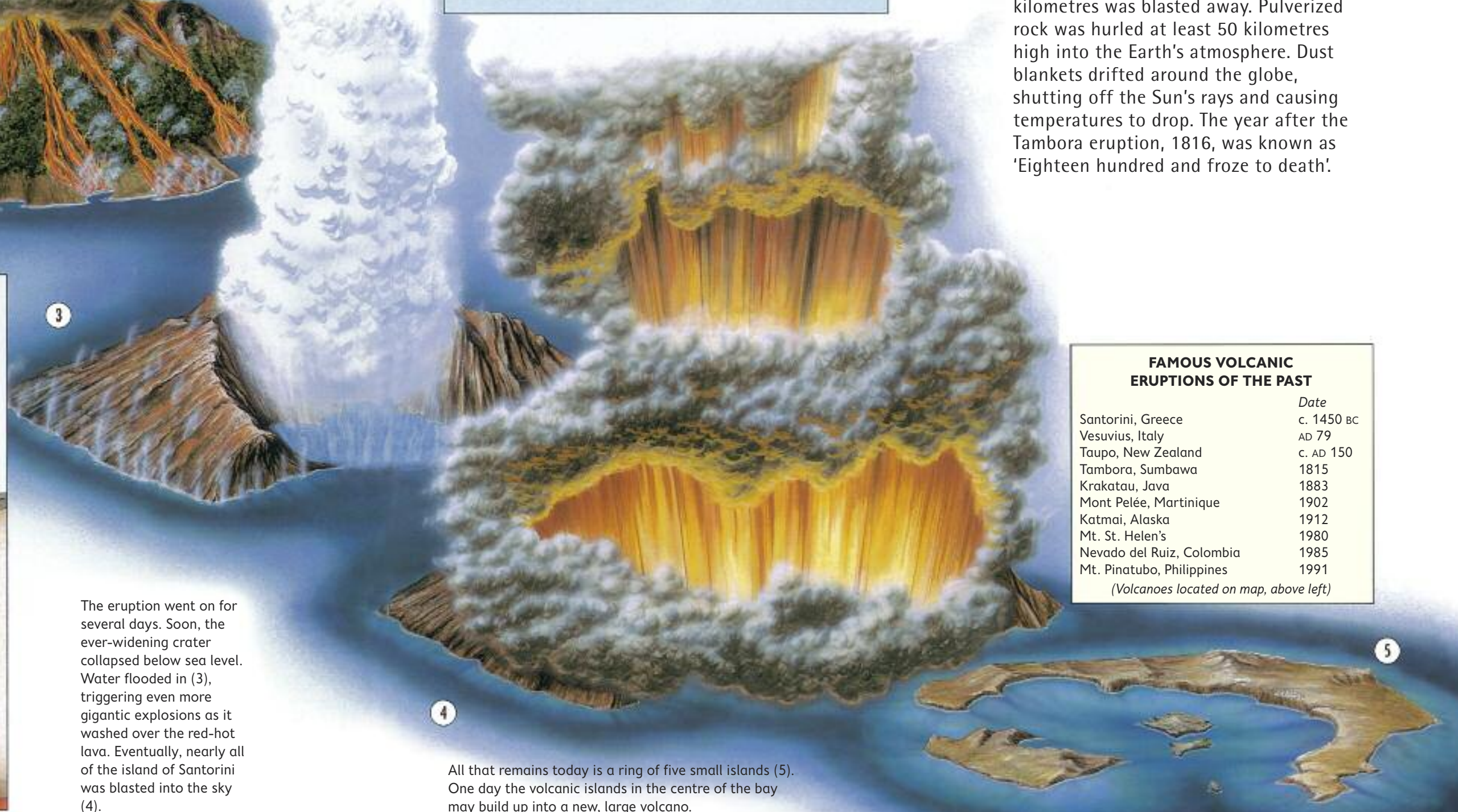


UNDER A VOLCANO

Volcanoes erupt gases and water as well as lava, ash and dust.

Some volcanoes, like Kilauea on Hawaii, throw out lava that flows freely down the mountainside. They often erupt without great explosions. Other volcanoes have stiff, pasty lava that hardens quickly. Sometimes a plug of solid lava blocks the pathway to the surface. Pressure

builds up in the magma chamber beneath the volcano until the plug is blasted away in a great explosion. Such volcanoes, including Santorini, Vesuvius and Krakatau, often shoot large quantities of cinders, ash and dust high into the air, as well as erupting streams of hot lava.



The eruption went on for several days. Soon, the ever-widening crater collapsed below sea level. Water flooded in (3), triggering even more gigantic explosions as it washed over the red-hot lava. Eventually, nearly all of the island of Santorini was blasted into the sky (4).

All that remains today is a ring of five small islands (5). One day the volcanic islands in the centre of the bay may build up into a new, large volcano.

FAMOUS VOLCANIC ERUPTIONS OF THE PAST	
	Date
Santorini, Greece	c. 1450 BC
Vesuvius, Italy	AD 79
Taupo, New Zealand	c. AD 150
Tambora, Sumbawa	1815
Krakatau, Java	1883
Mont Pelée, Martinique	1902
Katmai, Alaska	1912
Mt. St. Helen's	1980
Nevado del Ruiz, Colombia	1985
Mt. Pinatubo, Philippines	1991

(Volcanoes located on map, above left)

THE GREATEST QUAKE

The great Chilean quake



GIANT WAVES

Sudden movement of the sea floor during earthquakes creates waves that race across the oceans at about 700 km/h. When they approach land, they rear up to great heights (*above*). Called tsunamis, they can result in massive destruction. On 26 December 2004, a tsunami surged ashore in Indonesia, Thailand, Sri Lanka and India. Waves of up to 30 m high caused devastation and claimed the lives of 283,000 people.

This is a cross-section 'model' of the region affected by the 1960 earthquake in Chile. Here, the Pacific Ocean floor is gradually plunging beneath the South American continent. A sudden jolt (marked by the 'explosion' on the illustration) sent judders across a wide area and resulted in the devastating earthquake.

Most major earthquakes occur around the 'Ring of Fire' (the coastline of the Pacific Ocean, *see page 29*). Others happen in places where plates (*see page 32*) are pushing against one another: in central Asia and around the Mediterranean Sea.



SOME GIANT EARTHQUAKES

	Date
Lisbon, Portugal	1755
Concepción, Chile	1835
Assam, India	1897
San Francisco, USA	1906
Valparaiso, Chile	1906
Messina, Italy	1908
Gansu, China	1920
Tokyo, Japan	1923
Valdivia, Chile	1960
Anchorage, Alaska	1964
Guatemala	1976
Tangshan, China	1976
Mexico City, Mexico	1985
Spitak, Armenia	1988

ON 22 MAY 1960 a giant fault, some 600 kilometres long, deep beneath the ground in western South America suddenly slipped about 20 metres. A vast area of land in southern Chile was violently shaken for nearly four minutes. In the town of Valdivia, buildings were reduced to rubble. The ocean floor dropped away, causing the sea to rush away from the shore, then return in several giant waves, 10 metres high, which smashed into the shore and flung ships far inland. It was the most powerful earthquake ever recorded.

A smaller tremor about ten minutes earlier had sent most people rushing into the streets. This saved many lives when the main quake came, although around 5000 people were killed. This is a small number when compared with the most deadly earthquake of recent times. A quake which occurred on 28 July 1976 killed about 750,000 people in Tangshan, China.

The force of earthquakes is often described on the Richter scale: the larger the number, the worse the earthquake. The Chilean earthquake measured 9.5, and the Tangshan one, 7.8.

In the Chilean earthquake over 400,000 houses were destroyed in minutes as the ground rocked beneath them. Giant cracks and holes opened up in the surface and split the foundations of buildings. Afterwards, Valdivia and a vast area of the surrounding countryside had sunk by nearly 2 m.



THE MOST VIOLENT STORM

The deadly tornado

THE ATMOSPHERE, the envelope of gases that surrounds the globe, can be extremely violent. Hurricanes (otherwise known as cyclones or typhoons) are destructive circular storms where wind speeds sometimes reach 300 km/h. Even more powerful, although the damage they cause usually only affects a narrow strip of land, are tornadoes. A twisting column of air with wind speeds of more than 400 km/h (the highest wind speeds on Earth), a tornado completely destroys everything in its path.

Ordinary thunderstorms are also incredibly powerful. Every day around the world there are 44,000 thunderstorms; every second there are 100 lightning strikes, each with a force of 100 million volts or more. The amount of power generated daily by such storms would be enough to supply the whole of the United States – twice over!



The tallest clouds are giant cumulonimbus (above), which, in the tropics, may reach 20 km into the sky from their bases at around 500 m above ground level. Currents of air shoot up inside them at 160 km/h or more, and can keep hailstones weighing as much as 500 g suspended in the air! Clusters of cumulonimbus clouds can produce raging thunderstorms and torrential rain, and may, in some parts of the world, spawn destructive tornadoes.

TRI-STATE TWISTER

Each year, the United States is hit by about 1000 tornadoes. The most devastating 'twister' of all, later called the 'Tri-State Tornado', took shape on 18 March 1925. Travelling at about 100 km/h, it lasted for three-and-a-half hours and left a 350-km trail of destruction across the states of Missouri, Illinois and Indiana (right). It killed 689 people, injured 1980, destroyed four towns and made 11,000 people homeless. Eyewitnesses reported that it looked like a giant upside-down cone with lightning darting through it. All the while, there was a thundering roar like a freight train passing close by.



In November 1970 a cyclone hit the low-lying Ganges delta in Bangladesh (above). Violent winds and surging waves claimed the lives of maybe up to half a million people. In terms of lives lost, it was the worst disaster caused by a storm ever recorded.

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