THE METEORITES

ALSO BY HELEN GORDON AND
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Notes from Deep Time

THE METEORITES

Encounters with Outer Space and Deep Time

HELEN GORDON

Profile Books

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For Greta and Jean

Among the hills a meteorite
Lies huge; and moss has overgrown,
And wind and rain with touches light
Made soft, the contours of the stone.

Thus easily can Earth digest
A cinder of sidereal fire,
And make her translunary guest
The native of an English shire.

C. S. Lewis, 'The Meteorite'

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ARRIVAL

A glint in the blackness. A tear in the fabric of a heavy curtain covering a bright window.

Move closer. The glint becomes denser, finds form. Colours emerge. A blue-white-marbled ball.

Move closer. Land appears, sandy, rose-tinged, burned with gold, covered with pale branching tendrils. The ball becomes a dome edged with electric blue.

Move closer. The soft inky brown of mountains. Rock folded over and over itself like a crumpled silk scarf. A world falling into focus. A body falling through the exosphere, the thermosphere, the mesosphere, the stratosphere, the troposphere.

Move closer. The dark green shadow of a valley. Bright lines of water. Patchwork fields. Arterial roads and grids of houses. A sign: *If you lived here, you'd be home by now*.

Move closer. A car. A horse. A child on a picnic blanket. The land rushes up too fast. Earth flies up like water.

2

CEREMONY FOR A METEORITE

Apart from the villagers, only a few people had been told. The organisers feared that the narrow streets of Ashdon, near Saffron Walden in Essex, would be overrun by enthusiasts. I got lucky. The curator of meteorites at the Natural History Museum (NHM) in London was going to Ashdon and I could tag along.

The 9th of March 2023 was a cold, wet day. In London the curator, Natasha Almeida, selected a heavy grey stone from her collection, wrapped it carefully in layers of plastic and bubble wrap, and placed it in a green rucksack. The stone is one of the oldest objects on Earth. Whether it was allowed out of the museum had been touch and go – the authorities were worried about security; a replica had been arranged as a standby – but eventually permission was granted. Exactly one hundred years earlier, at 1 p.m., the stone had arrived on planet Earth. Now it would be taken – by bicycle, tube, train and finally car – back to its landing site in a field near Ashdon.

Driving into Essex I had the windscreen wipers going and kept switching lanes to avoid the spray of monster trucks roaring along the M11. It was the longest journey I'd taken alone since giving birth to my younger daughter a year earlier.

(A cold, sunny afternoon, a planned caesarean section because there were concerns.) In the rear-view mirror my eyes kept snagging on the empty car seat. I felt a little light-headed. Freedom. Anxiety. The loneliness of being a single body.

Years earlier – how many exactly is unknown but we should be thinking in terms of the millions, the billions – the stone had also separated from its asteroidal parent body. Coming to us from the dark coldness of space, meteorites speak of existences untouched by human experience. Which is to say they are a little like a newborn baby – an arrival from darkness, an existence untouched by human experience. And both meteorites and babies, I was beginning to think, are capable of acts of re-enchantment. The very old and the very young. They alter, however briefly, our perspective, making the everyday world feel at once deeper and stranger, the plainest actions filled with a new significance.

Meteorites draw us to them. Communities coalesce around them. Hunters, collectors, scientists and other enthusiasts. In Essex the Ashdon meteorite had drawn a group of around thirty followers – mostly villagers and members of local geology clubs. We walked alongside the rock as Almeida carried it past thatched cottages and across a series of flat, muddy fields. Rain fell – not heavy but constant. Hands froze. The paper in my notebook turned sodden. The biro wouldn't write. A short grey-haired woman in a blue boiler suit stopped to examine a mound of fresh orange earth by a badger's set. She was from Ashdon museum and searching for evidence of a chapel built by the Danish King Canute to celebrate his victory over the English King Edmund II. Someone suggested that the site of the chapel could be where the meteorite had landed. A sort of cosmic power site.

We gathered on a farm path between two fields. Here, the land was slightly raised. You could see the village in one direction, a farm in another. A wooden post had been set up marking the impact site. Wrapped in sacking, at one o'clock it would be unveiled. The rain came down more forcefully. I was wearing leather gloves, made the mistake of taking one off and – the wetness, the coldness – couldn't pull it back on. We stood around stamping our feet. The organisers – Gerald Lucy of the Essex Rock and Mineral Society and his friend Mike Howgate, also a geologist – checked their watches.

Lucy said the idea for a marker arose because 'It seemed daft that you'd come here and there was absolutely nothing to see.' Being at the actual location is important, he thinks. 'You can get quite a tingling of the spine when you think somebody at this exact spot did this thing.'

Meteorites are stones or rocks from space that have entered our atmosphere. Most were once part of asteroids – the rocky, airless remnants left over from the formation of our solar system around 4.6 billion years ago. (Much more rarely, they may be pieces of the Moon or the planet Mars. These lunar and Martian meteorites make up only 0.2 per cent of recovered space rocks.) Crashing through Earth's atmosphere at 27,000–90,000 miles per hour – the equivalent of going from New York to Los Angeles in two to six minutes – the surface of a meteorite begins to glow and melt, the rocky body to disintegrate. Usually less than 5 per cent of the original rock makes it down to the ground.

Recovered meteorites typically range in size between a pebble and a fist, and are of modest appearance. A lump of black charcoal. A small grey stone. 'The thing about meteorites is that they can look so underwhelming yet they have this

billion-year history that is so unfathomable,' Helena Bates, another NHM scientist, told me. 'There are all these hidden secrets.'

That meteorites come from space only became generally accepted fact in the nineteenth century, but people must have always been aware of rocks falling from the sky. How could they not? A meteorite enters Earth's atmosphere as a fiercely bright slash of light often accompanied by shattering bangs and explosions. They have been taken for nuclear blasts, divine thunderbolts, erupting volcanoes, the children of gods.

Technically speaking these rocks are known as meteoroids while travelling through space, and meteorites only after they have survived that journey and landed on Earth. A very large meteorite might also be called an asteroid, even after impact. Size-wise there's no official point at which one becomes the other, though the curators at the NHM suggest that a meteoroid is 'typically less than hundreds of kilogrammes in mass and about 1 m (3 ¼ ft) in diameter'. During this book I'll predominantly use the term meteorite for any space rock landing on Earth.

It's also the case that not all meteoroids become meteorites. Meteors – sometimes known as shooting stars – are meteoroids that burn up on entry into the Earth's atmosphere, creating bright streaks of light across the sky. At certain times of the year many meteors can be observed over a period of a few days. These 'meteor showers' are related to the orbits of comets – balls of dust and ice left over from the formation of the Solar System. In the UK we can watch, among others, the Perseids in August, the Leonids in November and the Geminids in December. Small comet fragments are generally too fragile to survive entry into our atmosphere, so though in theory meteor showers could send meteorites down to our

surface every once in a while, no remnants have been definitively traced to them.

Recently I've been watching and rewatching YouTube compilations of Russian dash cam footage from the morning rush hour in the city of Chelyabinsk on the western edge of Siberia on 15 February 2013. The sky is a pale dirty grey, yellow at the horizon. Drifts of snow line the roads. Trees are black cross-hatchings, lone pedestrians reduced to dark shadows. You keep watching for the moment when a glowing golden-white ball suddenly enters the picture, moves across the sky framed so perfectly in the centre of the screen that it's hard not to imagine you're watching the opening of a movie. When the thing in the sky explodes, the screen momentarily whites out.

In another video, not a dash cam this time, the sky is bluer. The meteorite has just passed and white smoke like the contrails of an aeroplane hangs in the sky. You watch for about thirty seconds in silence and then the shock wave hits. I jump every time. The camera shakes. Car alarms go off, shrieking uselessly, and the local dogs begin to bark. Danger. Alert. Danger.

With an estimated diameter of 20 metres – the length of two double-decker buses – and a weight (before entering Earth's atmosphere) of 13,000 tonnes, the Chelyabinsk meteorite sped towards Earth at almost 12 miles a second, shining briefly brighter than the Sun itself before exploding in mid-air. Using the extensive video and camera footage, scientists have calculated that the blast released an energy of 590 kilotons. (For comparison, the atomic bomb dropped on Hiroshima released an energy of about 15 kilotons.) The shock wave generated damaged buildings and shattered windows over an area of 200 square miles. More than 1,500 people were injured, the majority as a result of broken glass, and damage to the city was

eventually estimated at $33m. Scientists believe that the aerial explosion was caused by high-pressure air moving through holes and cracks in the meteorite's rocky body. Had it exploded not in the air but upon impact, Chelyabinsk would almost certainly have been wiped out.

Writing this now I turn from the Chelyabinsk footage and gaze out of the window. Late spring and the swifts are back. The sky is blue and calm. Last year we moved to a suburban house at the edge of London, the city ending officially a mile or so beyond our street. To the south, sheep graze on the common. Northwards, skyscrapers loom. Sunlight glitters on the ivy growing thick and rampant over the walls, the leaning wooden fences that, we hope, will last another year.

Upstairs in the room that had been our study the baby is sleeping, small hands like fat and dimpled starfish grasping one of my old T-shirts. Her sister is at nursery where, the week before, the staff had buried plastic dinosaurs in the flowerbed for the children to dig up. It's difficult to think of dinosaurs without thinking about the end, about Chicxulub, about a huge asteroid hurtling Earthwards. The after effects of that impact were likely responsible for the extinction of around three-quarters of all species on Earth. Above the garden, high in the sky, I can see a streak of white cutting across the treetops and the red-roofed semis. Everything trembles in a sudden breeze.

The arrival of a meteorite is an awesome, random, strange and – until very recently at least – uncontrollable event. Throughout history we have struggled to make sense of them through our religion, philosophy, arts, entertainments and science – and they have helped us make sense of ourselves.

The Earth is 4.54 billion years old, a little younger than the Solar System itself. Much of what we know about its history

comes from studying the rocks around us. 'We can use radioactive decay to date things, but the only tangible evidence of time passing are the rocks themselves,' the geologist Philip Gibbard once told me.

Rocks are Earth's history book. If you can learn to read them – to see a change of rock type and link that to an ancient climate event, say – then you can build up a history of our planet long before the existence of humans. What plants grew and which animals roamed; what the climate was like; what had been water and what land; where a volcano had erupted or an earthquake cracked the surface of the planet. If I were to dig down in my back garden, for example, I would find soil, then perhaps 100 metres of bright white chalk, then the dark blue-grey gault clay – evidence of a series of warm, tropical oceans that once covered what is now southern Britain.

But there is a problem. Rocks may be Earth's history book, but this is a book where many of the pages are damaged or missing. Where the earliest chapters have been ripped out. This is because Earth – unlike the other planets in our solar system – has active plate tectonics, meaning that the rocky crust is constantly recycled, rocks pulled down towards the molten core of our planet, destroyed then turned into new forms. On the surface we have active erosion, so rocks that avoid being pulled back towards the Earth's core are instead slowly worn down, great mountains eventually becoming flattened plains. The very oldest in-place Earth rocks are thought to be the roughly 4-billion-year-old Acasta Gneiss in the Canadian Shield but these make up only a tiny percentage of all the rocks of the crust – approximately 0.0000003 per cent. Most are much, much younger.

To read the very earliest pages of Earth's history, then, you have to look elsewhere, and at over 4.5 billion years old,

meteorites from asteroids are the oldest objects available for study. These rocks from space have long memories. They provide a window back in time through which we might glimpse the processes that formed and shaped the Solar System, the moons, the planets and our own world. Without meteorites we cannot begin to answer the question, Where did we come from? How did we begin?

One of the earliest written records of a meteor comes from 16 March, 687 BC when Chinese astronomers recorded a night of 'stars that fell like rain' – the Lyrids, the oldest meteor shower to be recorded continuously throughout history. Around 467 BC a stone is supposed to have fallen from the sky at Aegos Potami in the Gallipoli Peninsula. Diogenes of Apollonia suggested a celestial origin: 'In addition to the visible stars, invisible stones also wander through the heavens, having no name. They frequently fall on Earth … like the stony star which fell in flames at Aegos Potami.' It would take another two millennia for the idea of stones from space to be scientifically accepted but eventually his name would be applied to a meteorite group, the diogenites. The earliest recorded meteorite fall from which material still remains is dated to AD 861. The Nōgata meteorite is a 473-g rock now held in a Shinto shrine close to present-day Nōgata. Every five years it is shown to the public, drawn through the streets on a decorated cart.

Historically, meteorites have had a mixed reception among humans. According to the historian Massimo D'Orazio:

> In the Mediterranean area and Asia Minor, during the ancient age, many myths, superstitions and religious cults were associated with stones … thought to have fallen from the heavens … Some of these stones were venerated as a representation of the deity by whom they were sent down

to the Earth, others were considered supernatural gifts made by the gods to some predestined person.

Conversely, others have seen such stones as bad omens. In her book *Meteorite* Maria Golia explains that often among First Nations groups in Australia, meteors, meteorites and meteorite craters were things to be avoided. When a meteorite fell near Tenham Station in Queensland in 1879, for example, the people living there 'were "deadly afraid" of the stones, and covered them with "kangaroo grass" and tree boughs to hide them from the sun, hoping this might prevent further falls'.

Today meteorites are hunted and traded across the world. Rock shops sell schoolchildren tiny fragments of outer space. 'Truly something alien that members of the public can have on their shelves,' says Dr Laurence Garvie, of the Buseck Center for Meteorite Studies at Arizona State University. International auction houses such as Christie's sell prized specimens for thousands of pounds, pitching them as something of equal value to the worlds of science, art and interior design. At a high-end rock shop in west London – Venusrox – Matt and Victoria Forster will sell you a polished stony meteorite that 'can help one attune to the energies of the planets and therefore enhance one's inner wisdom'. Alternatively you might be interested in an iron meteorite fragment that promises to be 'a catalyst to spiritual awakening' and, more practically, to 'help develop patience and to see projects through to completion'. (One scientist I know keeps a piece of iron meteorite in his desk drawer. 'I can assure you this does not help me finish projects,' he wrote to me.)

Meteorites are the only direct contact most of us will ever have with the landscapes, the spacescapes, beyond our atmosphere – and right now space seems to be everywhere in a way

that it hasn't been for decades. Matthew Genge, a scientist at Imperial College London, told me he often wondered whether he was one of 'the last generation of Earth-locked scientists'. The meteorite dealer Sean Mahoney of OuterSpacer Meteorites theorised that we're entering a new space age. 'There's a lot of space stuff around like in the sixties,' he said. Elon Musk and SpaceX and Mars missions and Moon missions and asteroid missions. *Star Wars* on Disney. And even if one chooses to tune out most of that, it can't be denied that much of our modern existence relies on satellite systems located in space. We use them for, among other things, communication, weather forecasting, navigation, broadcasting, scientific research, military defence and Earth observation. In his recent book *The Future of Geography*, the journalist Tim Marshall suggests we are at the beginning of a new space race:

> The signs that space is going to be a huge geopolitical narrative of the twenty-first century have been accumulating for some time. In recent years, rare metals and water have been found on the Moon; private companies such as Elon Musk's SpaceX have massively lowered the cost of breaking through the atmosphere; and the big powers have fired missiles from Earth … to test new weapons.

And a new space age is good for those interested in meteorites. 'This is a golden age for the science,' Ashley King of the NHM has said.

Space feels like the future. (And it feels like the future even when it is arguably the past, no human having trodden on a celestial object since 1972.) And perhaps because of this a paradox arises. Though meteorites are so very old, they seem ultimately to speak more to this future than to the past.

'Something,' as Golia puts it in *Meteorite*, 'beyond our grasp yet still within reach … they inspire a striving for discovery, the ever-new.'

The Ashdon meteorite probably began life far, far away in the asteroid belt, a region between the orbits of the planets Mars and Jupiter that is home to millions of rocky bodies which, 4.6 billion years ago, were prevented by massive Jupiter's gravity from forming planets. Vesta, the largest asteroid, measures 329 miles in diameter and is visible from Earth with binoculars. The smallest bodies may be less than 10 metres across. Strange miniature worlds. Tiny rocky landscapes speeding through space. At the point closest to Earth the belt is 1.2 astronomical units, or 111.5 million miles away from us (which is similar to the amount of space between the Earth and the Sun). Incredible, unfathomable distances.

For Ashdon that might have been it. Something like eternity spent with its companions in a circling, orbital dance through the thick darkness of space. But at some point something must have happened to tear the rock from its parent body – perhaps a collision with another asteroid. Now travelling alone, it found itself on a new orbital path – one that would line it up with one of the very peculiar regions that scientists call Kirkwood gaps.

When astronomers began studying the abundance of asteroids in the belt they noticed a series of places where there were hardly any rocks. These became known as Kirkwood gaps, after the scientist who first noticed and explained them, Daniel Kirkwood. For a meteorite, entering a Kirkwood gap is a little like stepping on the head of a snake in a game of Snakes and Ladders. They are locations where Jupiter's gravity has much more effect, pulling passing asteroids out of the belt, their orbits

slowly changing as they travel down through the Solar System until they reach the territories of the inner planets, such as Earth. For us, Kirkwood gaps act as meteorite delivery zones. I've also heard them described as 'escape hatches' – portals that allow a meteorite to leave the endless circling of the asteroid belt.

On entering Earth's atmosphere on 9 March 1923, the Ashdon meteorite would have been travelling at around 8 miles per second – which is the equivalent of going from Glasgow to London in under a minute. Passing through the atmosphere it would have been subject to friction, slowing its fall and heating its rocky surface to a melting point of up to 2,000 degrees Celsius. The rapid speed of entry would also have generated shock waves or sonic booms (as heard on the Chelyabinsk footage). Continuing to slow down, the meteorite would have begun to rapidly cool, its molten surface forming a dark glassy coating called a fusion crust. This dark-coloured exterior contrasting with a light-coloured interior is characteristic of most meteorites. Sliced open they can resemble a cross section of a Mars bar or Milky Way.

Also travelling towards Ashdon that day was a 36-year-old thatcher and father of two called Frederick Pratt. Pratt set to work in a wheat field just south of All Saints church, perhaps gathering hazel for use as thatching spars, cutting hedges or clearing out a ditch. Around 1 p.m. he was startled to hear overhead a high-pitched 'sissing' sound.

As a First World War veteran, Pratt's first reaction, we might guess, was alarm. Seeing a projectile racing through the air he assumed that something had been fired from a gun. On impact, he said, the object caused the earth to 'fly up like water'.

The Ashdon meteorite had travelled from more than 100 million miles away to land a mere thirty yards from Pratt. An incredible near miss.

*

Meteorites are very, very rare events. Harvard astrophysicist Avi Loeb has calculated that, 'the chance of a particular house being hit by a kilogram-mass meteorite over a 30-year mortgage plan is a part in 33 million. Statistically, you have to wait for a billion years before your home will be hit by a meteorite.' Each year, worldwide, typically only around ten such rocks are seen in the sky and then recovered, though more do fall. How many exactly is difficult to say. Some studies use cameras to image the night sky and record the number of observed fireballs (a meteorite travelling through Earth's atmosphere); others use the number of meteorites found in desert regions, where preservation is better, the rocks are relatively easy to spot and there are few other sources of terrestrial stones. Current estimates indicate that approximately 5,000 to 17,000 meteorites larger than 100 g – about the weight of a golf ball – fall every year. So few are recovered because many falls are simply never noticed or because the rock lands in the ocean, in remote and inaccessible places, or places that are difficult to search. With its woods, heaths, moors and arable farm land, and with so many other terrestrial rocks and pebbles to confuse the issue, most of the UK, for example, is terrible meteorite hunting territory.

Almost all meteorites (98.2 per cent) are what collectors and scientists call 'finds', where the stone has been discovered by searching the ground, having fallen earlier – in most cases several thousand years earlier. The Ashdon meteorite is an example of the much, much rarer category of 'falls' – meteorites that have been seen to fall from the sky and then picked up where they have impacted on the ground. Pratt had become one of only a small group of people to have such a direct encounter with a visitor from space. (People actually hit by meteorites are, of course, even rarer. The only verifiable documented case

is from 1954 when a woman named Ann Hodges was hit by a meteorite as she napped in her house in Sylacauga, Alabama. Fortunately, the rock first bounced on the floor and Hodges was only bruised by the encounter.)

At Ashdon, the meteorite's first experience of Earth was, I suppose, familiar. Rock meeting rock. Hitting the field, it burrowed itself into the soil to a depth of around half a metre, so that Pratt, hurrying over, could find no evidence of the object. For three days it lay buried, smothered in damp orange mud. There it might have remained, sinking further down into the earth, unnamed, unremarked, becoming over time indistinguishable from the rocks around – an act known as 'terrestrialisation': slowly, through processes of weathering, through the ingress of Earth's water, the corrosion brought about by our planet's oxygen, a meteorite, left alone, transforms into what Harvey Nininger, the great American meteoriticist and collector, called 'something that can no longer be properly regarded as being a meteorite'. In other words, it assimilates.

But then Pratt returned with a friend and a spade and dug up the rock. 'It was an odd shape,' writes Gerald Lucy, 'rounded on one side and the other side irregular – and out of curiosity they chipped off a few pieces to see what it was made of.' Baffled, Pratt took the stone first to the police station at Saffron Walden and then to the other local source of authority: the church. He laid the stone before the vicar and told his story. What was it? He wanted to know. How could this possibly have happened?

The Rev. Francis W. Berry, vicar of the church in nearby Wendens Ambo, where Pratt lived, purchased the stone from his parishioner and, several months later, donated it to the Natural History Museum where, as luck would have it, the Keeper of Minerals, a man named George T. Prior, was also Britain's foremost authority on meteorites.

In June that year Prior travelled to Ashford. A photograph taken by him shows Pratt standing at the impact site. In the photograph the wheat reaches up to the thatcher's knees. Pratt stares out at us, expression guarded, arms held stiffly against his sides as an old summer wind blows through the wheat and lifts up the edges of his jacket.

We don't know what happened to Pratt after that. He disappears from the historical record. In the village today nothing is known of any descendants he may have had.

The meteorite, meanwhile, was being examined, classified, catalogued and given a new berth in the museum. It was placed among all the other things that humans have found to be special. Important things we want to preserve from destruction, degradation, the passing of time.

For a while the trajectories of the meteorite and Frederick Pratt had coincided, their orbits come together, and then they separated. Today the meteorite is known and the thatcher has vanished. One kept, one lost.

At one o'clock, amid slightly self-conscious cheering, the wooden post was unwrapped. Almeida checked her bag to see that the meteorite was still safely wrapped up. There was too much rain to bring it out so she set the bag down on top of the proposed impact site. (Though Prior recorded the latitude and longitude of the site, which he gave as half a mile due south of All Saints church and close to what is now a public footpath, it has not been possible beyond that to identify the precise point of impact.) This was the closest the Ashdon meteorite had got to home in one hundred years.

The sky was dark grey now, a band of lighter grey at the horizon line, just above a strip of black trees. Across the fields the farm looked much as it must have done when the current

farmer's forebears first arrived in 1901. Standing there you imagined the farmer's grandparents, great-grandparents. Generations receding into the distance, and the men and women who came before them. Georgian squires, Tudor labourers, medieval clerics, Anglo-Saxon farmers, a Danish king. All treading and retreading the same orange soil.

And long before that – unimaginably long before that – the meteorite had been formed somewhere in the far, cold reaches of space. The light of the stars comes to us from the realm of the meteorites and comes to us, as we learn at school, from the past. We see Sirius as it was nine years before the present moment. We see Betelgeuse as it looked in the late 1500s, long before we were born. The 4.6 billion years the Ashdon meteorite has existed is an amount of time that is easy enough to write but difficult to really comprehend. Humans don't do well with large numbers. There is something unhomely about them. Try to visualise a heap of pebbles. Tens of pebbles are easy enough to imagine but what do a thousand pebbles look like? Could you distinguish between two thousand and three thousand? I have a sense of what twenty-four hours feels like but I have no sense – not emotionally, bodily – of what twenty-four million years would feel like. The brain rebels.

This is the territory not of human time, which is measured in minutes and hours, days and years, but of deep time, which is measured in the thousands, millions and billions. The time of rocks and planets. A scale at which the human perspective becomes less and less useful. Ultimately the Ashdon meteorite's long moment in the dimness of a museum cabinet will form only an infinitesimally small part of its existence, which may go on long after humans have vanished.

Over the last 4.6 billion years – or at least since whenever it was knocked from its original, larger, parent body – the

Ashdon meteorite probably changed very little up until the moment it came hurtling through the skies above Essex. Life on Earth, by contrast, has been shaped and reshaped and reshaped once again. Entire lineages have grown, died, vanished almost without trace, leaving behind only a few enigmatic fossils in the rocks. Landscapes have come into existence only to disappear and be reborn as something else.

Around 250 million years ago the fields of north-west Essex would have been an arid desert. Fast forward 150 million years and that desert would have become an immense, crystal-clear tropical ocean covering most of Northern Europe, visited by dinosaurs and filled with cruising mosasaurs – giant marine reptiles up to 10 metres long with paddle-like limbs and heavy jaws armed with sharp, conical teeth. Time passes. The rock that will become the Ashdon meteorite continues circling through the asteroid belt. In the place that will become north-west Essex, seas come and go. Sometimes land rises up, sinks down into bogs, is inundated with water once more. Many, many lifetimes pass. Around 450,000 years ago the temperature plummeted and for thousands of years the landscape lay beneath a heavy sheet of ice. Then, around 400,000 years ago, the ice began to melt. Early humans, making their way north from Europe, reached Essex – though at first this new species didn't take. Evidence from a later warm period known as the Ipswichian, around 120,000 years ago, shows that there were no humans by then, although there were monkeys, elephants and lions. It is not until around 12,000 years ago that a continuous human presence was established in Britain. We have been in the territory for approximately 0.000000000003 per cent of the Ashdon meteorite's existence.

Another way to visualise it. Stretch your arm out to the side. Now imagine drawing a timeline of the meteorite's life

beginning at the middle of your chin and extending to the tip of your middle finger. On that timeline the crystal-clear ocean, home to mosasaurs and dinosaurs, would come into existence around the middle of your palm. The great ice sheet at the tip of your finger.

Next take a nail file and make a pass over the end of your fingernail. On the meteorite's timeline you've now wiped out all of human civilisation.

Back in the village hall Almeida finally uncovered the stone. 'It's really a pleasure to bring the Ashdon meteorite home to such a welcoming crowd,' she said. The meteorite – streaky grey exterior; sandy black-speckled interior – is around the size of a grapefruit and shaped a little like a muffin that has risen well in the centre: what is known as the meteorite's cone. The middle of the cone is smooth but a series of etched lines flow outwards from the centre point like the rays of the sun. These were caused by white-hot molten rock cascading backwards as the meteorite sped through the air, heat and movement fixed in stone. Collectors call this type of specimen 'oriented' because you can see the direction of travel. 'Even though I'd seen photographs I didn't realise how beautiful it is,' Lucy told me. 'Holding it and seeing the shape and form of it was really something. I felt quite emotional about it.'

Like Earth rocks, meteorites can vary immensely but there are three main types: iron meteorites, which are almost completely made of metal; stony-iron meteorites, which have nearly equal amounts of metal and silicate; and stony meteorites, which mostly have silicate minerals and are most similar to rocks found in the Earth's crust and mantle. Each group can be further subdivided depending on the minerals, structure and chemistry.

Ashdon is a stony meteorite. Representing the majority of recovered meteorites, these are subdivided into achondrites (for examples, the diogenites) and chondrites, of which Ashdon is one. The primary material difference is that almost all chondrites contain tiny glassy beads known as chondrules – rounded particles around 1 millimetre in diameter consisting largely of the silicate minerals olivine and pyroxene. Most also have iron-nickel metal grains floating around alongside the chondrules, whereas achondrites have typically lost their iron metal.

The chondrites are further subdivided into three classes based on their chemistry and petrology: carbonaceous chondrites, enstatite chondrites and – the most abundant – ordinary chondrites, such as Ashdon. These constitute around 86 per cent of all known meteorites. Why do so many arrive here? It could be that this type of rock comes from a region of the Solar System that is gravitationally favourable for delivering meteorites to Earth. Alternatively their prevalence could be due to the relatively recent break-up of a few favourably placed parent bodies. Whether ordinary chondrites are distributed throughout the Solar System in similar amounts is unknown. It is entirely possible that from a less anthropocentric viewpoint they are actually a great deal rarer than we think.

The Ashdon meteorite is officially classified as an L6 ordinary chondrite. L is shorthand for low-iron (there are also LL – low-iron, low-metal – and H – high-iron – groups). The 6 refers to the degree of metamorphism the meteorite has undergone, how much it has been altered or modified by water or heat. A type 6 is a meteorite that has experienced temperatures just short of melting. Somewhat incredibly, the glassy chondrules trapped within its body are likely melted pieces of the solar nebula – the large disk of dust and gas that once swirled around our developing sun and from which our solar system was born.

'If you ever visit a meteorite conference and want to see some arguments, go to the chondrule formation session,' Paul Savage, a cosmochemist from the University of St Andrews, told me. Despite their prevalence in the meteorite catalogue, despite their ubiquity in the early Solar System, where they would become the building blocks of all the planets, chondrules remain deeply mysterious. No one can agree how exactly they formed. Friction? Impact? Radiative heating? Lightning? There are many potential mechanisms to generate them, but there is apparently no one mechanism that completely explains all of their physical and chemical properties. As another scientist wrote in an article in the *Journal of Geophysical Research*: 'One of the best ways to make friends within meteoritics, and one of the best ways to make enemies in meteoritics, is to propose a new mechanism for the formation of chondrules.'

Viewed in thin sections through a microscope, chondrules are beautiful. Mosaics of glowing jewel-like blobs and geometric shapes that recall the work of Gustav Klimt or perhaps Wassily Kandinsky's concentric circles or Paul Klee at his more abstract. Nineteenth-century geologist H. C. Sorby called them 'droplets of fiery rain'. Touch one of these former droplets – a chondrule in an ordinary chondrite such as Ashdon, say – and you are in contact with the raw materials from which, to take the very, very long view, you and everything round you originally came.

Sitting at the dining-room table with my laptop I pause and listen. No sounds from the room upstairs where the baby is asleep. Downstairs, in the middle of the rug, our older daughter's train set has been laid out. A circular wooden track. Small black engines with red chimneys chugging endlessly past wooden trees the height of daisies and little blue- and red-roofed wooden houses, vaguely Dutch in appearance. With my

children the world had expanded, sure, but it had also shrunk. Miniature houses and trees. Quarter-sized spoons and bowls stacking up in the sink. Shoes that nestled in the palm of my hand. With the two of them a trip through the woods to the playground could take all afternoon in the planning of it, the execution, the recovery.

During lockdown, when my older daughter was two, three, four months old, my husband and I used to joke that it was as though the whole country was on maternity leave with us. I was on my own this time, more or less. Sometimes I could sit happily watching the baby move a spoon in and out of a yogurt pot. Other days I found myself googling long-distance walking trails or staring down the hillside to where the train line ran past toy-strewn lawns back into the city.

Stepping out into my own back garden – toy-strewn – I squint up at the blue sky that, in the daytime, acts as a sort of cover separating us from the stars. Nothing to see here, the sky says. You'd be better off paying attention to your gardens, your houses, your rugs and dining tables. Then when the cover is removed at night we're often asleep, or else fitfully awake, nursing a baby with the curtains tightly drawn.

I try to imagine peeling back the blueness to reveal the blackness beyond. The home of the meteorites. The place from where Chelyabinsk, Ashdon, and all the other cosmic rocks had come to us. I try to remember that the Earth is also a planet hanging in space. That we are not just inhabitants of London or Berlin or Manchester, of the United Kingdom or France or Nigeria, but also, though it doesn't occur to us often, Earthlings. I try to imagine all the space above me. To consider myself on the surface of something. A loosening of gravity, the momentary feeling that at any moment everything could float upwards and away.

Amid the incessant daily business of now – the dishes in the sink, the brimming inboxes, the rubbish that needs taking out again already, the morning commute – meteorites remind us that there are other larger, stranger scales to measure ourselves against – that of deep time, of years counted by the thousands, millions, billions – and of space, which goes on, we are told, expanding away from us for many billions of light years. Ancient visitors from far beyond the edges of our skies, meteorites challenge our reflexive anthropocentrism, call out the smallness of our existence – as individuals, as a species – but they also enlarge us, returning to us a sense of ourselves as beings situated among stars.

3

THE FIRST IRON

Around 5,000 years ago in Egypt, someone strung two strands of beads around the neck and waist of a dead boy and sealed him away in a sandy tomb. What did they expect? That the beads would go with him into an afterlife? That they would lie forever undisturbed in the darkness? Not, we can assume, that a British Egyptologist called Gerald Wainwright would open up the grave, make a series of careful notes and drawings, and then carry away the boy's possessions – among them a copper harpoon, a fish-shaped palette for blending make-up and the necklaces.

On Mondays the Petrie Museum of Egyptian Archaeology is closed to the public. Outside, students from UCL stood in groups chatting, drinking coffee. It was a bright autumn day, still warm but the leaves were starting to yellow. White clouds scudded across the blue sky. The year turning. In the silent, low-ceilinged basement gallery, dog-headed gods and smooth-cheeked golden masks gazed impassively from their cabinets. Row upon row of figurines, stone tablets, earthenware pots. Things now removed, as far as was possible, from the changing seasons, the messy business of daily life. I had come to see three of the beads once worn by the boy. The curator brought them

out to me in a box. You could barely even guess that they *were* beads – just three lumpy, blackened cylinders each around 1.5 cm long.

'Predynastic Egypt can be a bit of an acquired taste,' the scientist Diane Johnson had told me. This is the stuff that came before the more famous golden mummies and hieroglyphs. 'The beads look like nothing but they are probably the rarest thing I've encountered in my life in a museum. You might see lots of people at the British Museum crowding round the Rosetta Stone and oohing and aahing but they really ought to be crowding round the Gerzeh iron beads. Everyone should tremble in their presence.'

I didn't tremble but I was nervous about touching the beads. The curator said that I should try not to handle them too much. I hadn't intended to handle them at all, contenting myself with holding up the box they were in to get a better view, but eventually I couldn't help myself. The Gerzeh iron beads were discovered in 1911 in a cemetery near the village of el-Gerzeh, forty miles south of Cairo, and date from 3400–3100 BC. (For context, this means that by the time of, say, Tutankhamun, these beads would already have been regarded as antiquities.) For a moment I had an impulse to pick up a bead, to press it hard between my fingers. It was like the feeling you get sometimes on the top of a high building, the temptation to take that step over the edge. Reaching out, I nudged the thickest bead with the tip of my nitrile-gloved finger. I was now touching the earliest known man-made iron object anywhere in the world. Here was the beginning of iron manufacture, the beginning, ultimately, of the Industrial Revolution, the internal combustion engine, and all that would mean, both for humans and the planet we live on.

Back in 1911, however, the iron beads presented Wainwright