DID AN EXTINCTION-LEVEL CATASTROPHE NEARLY 13,000 YEARS AGO ENGULF EARTH, TRIGGERING THE DAWN OF CIVILISATION?

PREHISTORY DECODED

A SCIENCE ODYSSEY UNIFYING ASTRONOMY, GEOCHEMISTRY AND ARCHAEOLOGY

MARTIN SWEATMAN

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Front cover image courtesy of Alistair Coombs.

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To Alison

Contents

Acknowledgements
Prologue

1 Göbekli Tepe
2 The Vulture Stone
3 The Younger Dryas Mini Ice Age
4 The End of Gradualism
5 The Great Debate
6 Comets vs Asteroids
7 Solving Göbekli Tepe
8 Decoding Çatalhöyük
9 40,000 Years of Astronomy
10 Zep Tepi and the Great Sphinx
11 The Godfather
12 The Origin of Civilisation

Appendix A:
Placement of Patterns on the Vulture Stone
Appendix B:
Latitude and Longitude
References

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Prologue

Thereupon, one of the priests, who was of very great age, said, 'O Solon, Solon, you Hellenes are but children, and there is never an old man who is an Hellene.'

Solon, hearing this, said, 'What do you mean?'

'I mean to say,' he replied, 'that in mind you are all young; there is no old opinion handed down among you by ancient tradition, nor any science which is hoary with age. And I will tell you the reason of this: there have been, and there will be again, many destructions of mankind arising out of many causes.

'There is a story which even you have preserved, that once upon a time Phaethon, the son of Helios, having yoked the steeds in his father's chariot, because he was not able to drive them in the path of his father, burnt up all that was upon the earth, and was himself destroyed by a thunderbolt. Now, this has the form of a myth, but really signifies a declination of the bodies moving around the earth and in the heavens, and a great conflagration of things upon the earth recurring at long intervals of time: when this happens, those who live upon the mountains and in dry and lofty places are more liable to destruction than those who dwell by rivers or on the seashore; and from this calamity the Nile, who is our never-failing saviour, saves and delivers us.

'When, on the other hand, the gods purge the earth with a deluge of water, among you herdsmen and shepherds on the mountains are the survivors, whereas those of you who live in cities are carried by the rivers into the sea; but in this country neither at that time nor at any other does the water come from above on the fields, having always a tendency to come up from below, for which reason the things preserved here are said to be the oldest.

'The fact is, that wherever the extremity of winter frost or of summer sun does not prevent, the human race is always increasing at times, and at other times diminishing in numbers. And whatever happened either in your country or in ours, or in any other region of which we are informed – if any action which is noble or great, or in any other way remarkable has taken place, all that has been written down of old, and is preserved in our temples; whereas you and other nations are just being provided with letters and the other things which States require; and then, at the usual period, the stream from heaven descends like a pestilence, and leaves only those of you who are destitute of letters and education; and thus you have to begin all over again as children, and know nothing of what happened in ancient times, either among us or among yourselves.'

Excerpt from *Timaeus* by Plato, c.428–c.347 BC.

1

Göbekli Tepe

Not far from the border with troubled Syria, hidden under a huge mound of earth, animal remains and debris on top of a round hill, lay an ancient megalithic monument patiently awaiting discovery for 10,000 years. Its burial appears to have been a deliberate act of preservation, achieved in an era of prehistory so early we can hardly imagine. Whoever was responsible, they made a good job of it. Despite being the size of a grand palace, almost nothing could be seen of the enormous monument at all. Thousands of tonnes of earth and debris had been hauled over it, piled high enough to cover it completely. It was a Herculean effort, likely involving hundreds of highly motivated people. They buried it with their bare hands.

You could have walked right over it, distracted by the fantastic view to the south over the Hurran Plain towards Syria, oblivious to the treasure that lay beneath your feet; oblivious to what is undoubtedly the most stunning and important ancient monument ever discovered. It lay unremarked until its location was recorded in an archaeological survey of southern Anatolia, modern-day Turkey, by Istanbul and Chicago Universities[1]. However, all that could be seen of Göbekli Tepe then, in the 1960s, was the very top of some apparently plain limestone blocks just poking above the ground and some high-quality flint tools and artefacts. Thinking it was a much more recent Iron Age cemetery, and therefore of little interest, it was left alone.

Decades later, Professor Klaus Schmidt of the Deutsch Archaeological Institute, an expert on the prehistory of southern Anatolia, came across their report and, intrigued by their findings, decided to take a look for himself. He knew the region was rich in very ancient archaeology. Only a few years earlier he had assisted with excavations at the nearby site of Nevali Çori, itself over 10,000 years old. Perhaps, if he was lucky, this new site might turn out to be even older.

Archaeological interest in this area of southern Turkey had been growing steadily for many decades already. It seemed that wherever they looked, archaeologists uncovered yet another Stone Age settlement that challenged their views about how civilisation began. The sites they discovered were getting older and older, and yet they remained highly sophisticated, pushing back the origin of civilisation to ever earlier times.

The old pre-war view that 'civilisation began in Mesopotamia', in the region of southern Iraq, around 3,200 BC, had long been abandoned. That epoch was now recognised as the beginning of written history, when proper writing systems first appeared together with large city-states. Civilisation, on the other hand, began at a much earlier time in prehistory.

Modern scholarship now links the origin of civilisation to the development of agriculture, as it is thought that the invention of agriculture enabled large settled communities to develop through the intensification of food production, which could in turn support specialists, such as builders, artisans and warriors. And it is the emergence of specialist roles such as these, along with the complex hierarchical social interactions they imply, that today is used to define the origin of civilisation. Without agriculture, it was generally thought that large communities of specialists could not develop.

In fact, Klauss Schmidt's work at Nevali Çori had already borne fruit in this regard. At that ancient site some of the earliest evidence for domesticated wheat, which differs from the wild type by bearing more plump and robust grains, was found. Today, all the evidence points towards the origin of agriculture, and therefore civilisation, occurring in the region near Nevali Çori early in the 9th millennium BC[2].

But it was no longer possible for Klauss to work at Nevali Çori, as it had been submerged by the dammed waters of the Euphrates. So, he was looking out for new sites to continue his studies and further his career as one of the pre-eminent experts in this region. Upon reading the account of buried limestone blocks and flint artefacts at Göbekli Tepe, he knew he had to investigate, as the flint tools suggested a Stone Age, rather than Iron Age, settlement. Perhaps he might even discover another clue to the origin of civilisation at this new site. After all, this was the 'holy grail' for his academic discipline; whoever could solve the riddle of the origin of civilisation would go down in history.

But at Göbekli Tepe he got far more than he bargained for. He got very lucky indeed. For at Göbekli Tepe he discovered, after many years of meticulous excavation, all the hallmarks of a sophisticated civilisation appearing at a time long before agriculture appears in the archaeological record. Indeed, Göbekli Tepe seems to turn the 'agriculture first' idea on its head.

This was a major surprise. The archaeological world was stunned. It was almost as strange as discovering Atlantis. Göbekli Tepe quickly became the most important, interesting and challenging site in the study of antiquity. It tells us that things are not as we thought, and we have probably made some wrong assumptions somewhere along the line about the development of civilisation and its relationship to agriculture.

In fact, we now know the challenge of Göbekli Tepe is much greater even than this. By understanding Göbekli Tepe, truly understanding it, we gain access to so much more than just the origin of civilisation, as great a prize as that is. In fact, we can begin to understand the minds of ancient people stretching back over 40,000 years, to a time deep into the last ice age. A time when the world was completely different, huge animals roamed the land, and humans were supposedly primitive foragers. Indeed, a time when at least three different species of human co-existed on the Eurasian continent[3].

How is this possible? How can we possibly know the thoughts of people over such a vast timescape? Surely, there are no reference points, no similarities at all between us today and the very primitive Stone Age people living in the middle of the last ice age? Wrong. It turns out that Göbekli Tepe is like the first clue in a crossword. Solving Göbekli Tepe provides clues to the next puzzle, and solving that provides more clues, and so on until we arrive at the world's earliest known (or at least the earliest accepted) piece of figurative art, the Lion-man of Hohlenstein-Stadel cave, made over 40,000 years ago by Stone Age people living in the south of present-day Germany[4]. Half-man, half-lion, this extremely ancient ivory sculpture, discovered in 1939, is about one foot tall and displays great artistic skill (see Figure 1). The Lion-man would not be out of place in a modern artist's gallery.

Between Göbekli Tepe and the Lion-man sculpture lie nearly 30,000 years and thousands of miles across Europe. And yet they are intimately connected to each other, and to us today. It seems the people who constructed Göbekli Tepe over 11,000 years ago and the person who sculpted the Lion-man 40,000 years ago had a common understanding of the night sky, and probably shared aspects of the same mythology. And, quite incredibly, we retain some of this knowledge today. It has not all been lost in the mists of time or the fog of war. Some of it has survived, even into modern culture, and continues to be useful.

But this is not all. By solving the mysteries of Göbekli Tepe and the extremely ancient cave art of Europe, including the Lion-man of Hohlenstein-Stadel cave, we also gain a proper understanding of our place in the solar system. Until recently, it was generally thought that Earth was a peaceful sanctuary, protected from the violent whims of the cosmos. We now know that view was a sham, a delusion, and we need to wake up. We have been duped by centuries of misguided scholarship.

This is no idle speculation. The clues are there to be discovered and decoded. And the first clue is found at Göbekli Tepe.

Figure 1. The Lion-man of Hohlenstein-Stadel cave.
(Photo by Oleg Kuchar © Museum Ulm, Germany.)

The Fertile Crescent

Göbekli Tepe is situated at the heart of an ancient region known as the ‘Fertile Crescent’, which lies just to the east of the Mediterranean. In terms of current territories, it comprises north-east Egypt, Israel, Palestine, Jordan, Lebanon and part of Syria on the west side, then south-east Turkey across the North (which hosts Göbekli Tepe), with the Euphrates and Tigris rivers to Iraq on the east side (see Figure 2). The western portion is usually called ‘The Levant’, the northern portion is often called ‘southern Anatolia’, and the eastern portion is normally called ‘Mesopotamia’, where the first cities flourished around 3,000 BC.

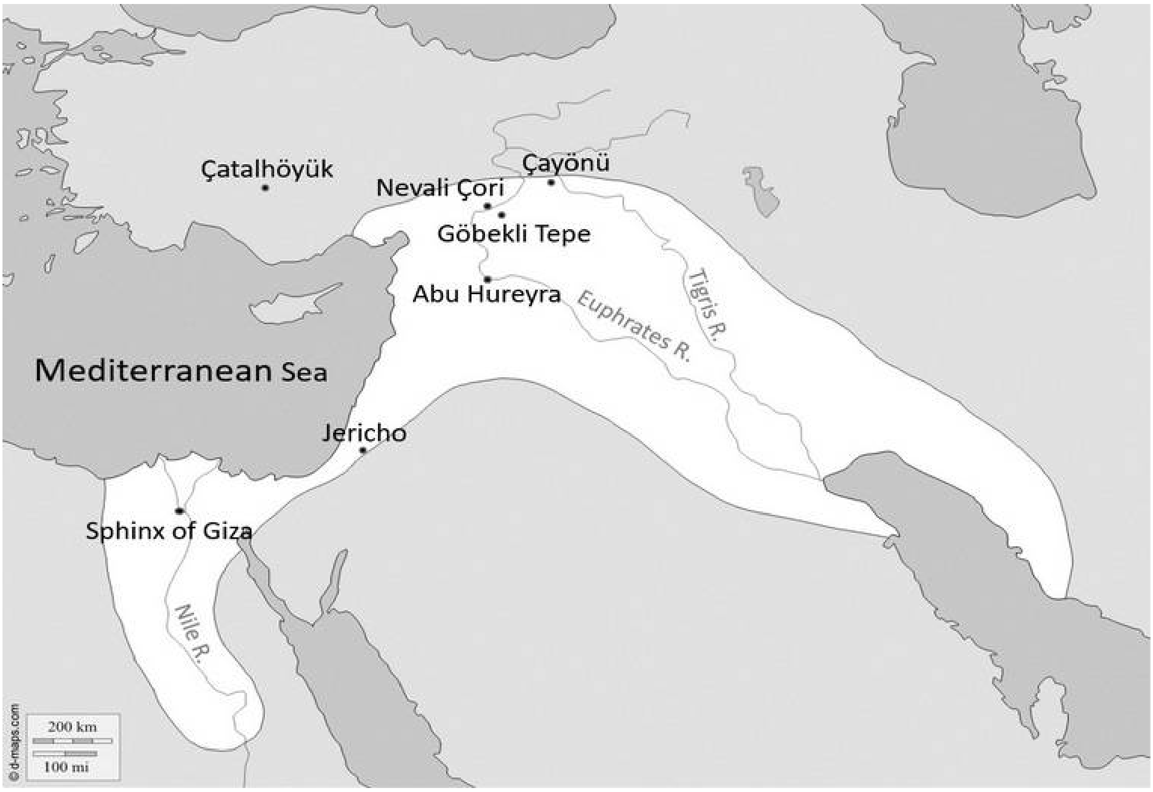


Figure 2. The Fertile Crescent of West Asia

At the time Göbekli Tepe was occupied, many aeons ago, this crescent-shaped region, instead of being predominantly arid, rocky desert as it appears today, consisted mainly of fertile woodland with plentiful flora and fauna. It was a bounteous region where agriculture is thought to have started first on Earth, after an extended period of extremely cold climate known as the 'Younger-Dryas', a kind of mini ice age, that ended around 9,600 BC. Consequently, the Fertile Crescent around the time of the Younger-Dryas period had become a subject of great interest and debate in archaeological and anthropological circles, even before Göbekli Tepe was discovered. Because agriculture appeared here first, this region, it is generally thought, must hold the secrets to the true origin of civilisation.

The archaeological record of settlements in the Fertile Crescent dates back to around 20,000 BC to regions in the south of the Levant in modern-day Jordan and Israel[5,6]. Here, archaeologists have found the charred remains of groups of round huts made from brush and wood, along with stone tools, crafted bone objects, marine shell beads and red ochre. These sites are thought to have been inhabited by a semi-nomadic people, the 'Kebaran', who moved from camp to camp as they exhausted local resources, in tribes of little more than 100 people. As for all the world's people at this time, they are thought to have been hunter-gatherers, collecting food from wherever they found it by hunting wild game, fishing, collecting nuts and berries, and harvesting wild grasses to make flour. Very likely, as all their resources were seasonal, they moved camps with the seasons, following the migrating animals and ripening fruit. But they also made small-scale artworks and decorations from various materials, like little stone plaquettes and ivory daggers engraved with lines and curves.

Then, between 13,000 and 10,000 BC, permanent settlements appeared throughout the Levant, consisting of round semisubterranean huts, about 3 to 6 metres in diameter, constructed with stone foundations, solid floors of crushed gravel and lime dug down into the ground, and higher quality artistry and decoration. These people, the Natufian, were hunter-gatherers too, but they also began to store food[7]. Storage of food was important, because it allowed them to stay in one place across the seasons. They could tough it out through winter. Having settled down, they could begin experimenting with farming by keeping a few wild animals in pens and cultivating plants close to home to supplement their foraging. But their settlements remained very small – they continued to live as tribes of at most a few hundred people.

Once the much warmer and wetter Holocene climate began around 9,600 BC, after the extremely cold Younger Dryas period, early Neolithic (New Stone Age) villages appeared in the Fertile Crescent. People now built their round huts with stone and mud-brick walls, typically entirely above ground within larger and larger communities, signalling the beginning of a long transitional period known as the Neolithic revolution. But it was nearly another thousand years before their experiments in farming led to genetic changes in the plants and animals they managed. Through selective breeding, they eventually developed more productive strains of domesticated cereals and animals, the hallmarks of an agricultural lifestyle[8].

By 8,000 BC they had built the world's first town, Jericho, in modern-day Palestine, with its massive stone city walls, stone tower and population of several thousand. Buildings now tended to be rectangular rather than round, as at Nevali Çori not far from Göbekli Tepe. There is also evidence of cultivation in other regions of the world, namely rice cultivation in China and corn cultivation in Mexico.

But Göbekli Tepe punctures this notion of a simple linear, or consistently upward, trend in cultural development, from the round wooden huts of the semi-nomadic Keberan, through the Natufian stage of hunter-collectors with their permanent stone-built huts and food storage, to the rectangular mud and brick houses of larger Neolithic villages and towns with the beginning of agriculture. For at Göbekli Tepe, at around 10,000 BC, we find the astonishing development of monumental architecture and advanced artistry, unrivalled for millennia afterwards, that hints at a much earlier and much larger settled community of specialists than was previously thought possible at this time. Clearly, civilisation had already begun at Göbekli Tepe, over 1,000 years before proper agriculture appears in the archaeological record. How is this possible?

Strangely, it is still not known who built Göbekli Tepe, as the homes of its builders have yet to be found. According to the site's archaeologists, Göbekli Tepe was not a residence itself, as there are none of the usual signs of daily life, such as food preparation[9,10]. Nor is there any sign of a roof. Instead, Göbekli Tepe appears to have been a 'special' building, an open-air monument that served a particular purpose, other than housing. In which case, where did its builders come from? Where did they live? Until we find their homes, which should contain clues to their cultural heritage, it is difficult to be sure who built Göbekli Tepe.

Its remote location on top of a hill, with excellent views over the surrounding countryside, is also very odd. It would not have been easy to stay there, being far from any known source of water and exposed to the biting cold of winter storms. It must have had a very special function indeed, one of utmost importance to the people who built it, to justify its existence.

Megalithic Pillars

Recent ground-penetrating radar surveys, which can peer beneath the soil without disturbing it, have revealed the amazing extent of the site[11]. It covers over twenty acres, most of which remains unexcavated. But if the currently excavated portions, which comprise less than 10% of the whole site, are anything to go by, we should prepare for more surprises. For the small fraction of the site excavated so far has uncovered a multitude of huge hammer-shaped stone pillars connected by circular or square rough stone walls (see Figure 3). It is as though a dozen Stonehenges were built next to each other on top of a hill. And yet, Göbekli Tepe is well over twice the age of Stonehenge.

Again, how is this possible? How can these immense pillars, some weighing over fifteen tonnes, have been mined, crafted, and dragged into position using only basic stone tools at such an early time? Remember, Göbekli Tepe was built nearly 6,000 years before the wheel or horse-power were supposedly invented. This immense monument, it is thought, was built by the strength and determination of its people alone.

However, perhaps even more impressive than its immense scale and remote location is its astonishing artistry. Many of the stone pillars are adorned from head to toe with intricate carvings of animals and other more abstract symbols, displaying technique far in advance of similar finds at much younger sites. The finely crafted animals are portrayed in a range of poses[12]. From leaping foxes to snarling lions, flying snakes and many tall standing birds, these carvings appear to be telling a story – they appear to be more than just animal carvings. Professor Schmidt, who discovered it, thought so too[13]. He thought these symbols were an early form of proto-writing used to convey a specific type of information. If true, this would push the known origin of proto-writing back by several millennia. The current record is held by early farming cultures of central Europe, around 6,000 BC. Furthermore, he considered Göbekli Tepe to be an early cultic sanctuary, a kind of temple, with the pillars and animal symbols representing deities and a complex mythology. This is how Göbekli Tepe became known as the world’s first temple.

Even more baffling, one of the animal symbols is expertly sculpted as ‘high relief’ directly as part of one of the giant stone pillars. This 3-D figure is not simply attached or stuck on. This requires stonework and artistic skill of great accomplishment. Surely only a trained artist using specialist tools could achieve such a feat, carving a masterpiece out of a single huge block of stone. But again, this was simply not thought possible for this period of prehistory, since it implies a lifetime of dedicated specialisation, and therefore a sophisticated culture. How could such skills have been developed by the simple hunter-gatherers thought to have inhabited the world at this time?

Figure 3. Top: View of excavations at Göbekli Tepe, south-east Turkey, showing enclosures A to D. Bottom: the view south over the Harran Plain (images courtesy of Travel The Unknown).

Over sixty pillars at Göbekli Tepe have so far been excavated, many engraved with animal patterns or more abstract symbols. Curiously, carvings of snakes, usually in threatening postures, are the most common animal motif found so far. Most of the animal symbols share a similar style – that of low relief carving where the stone around the animal shape is chipped away. However, a few pillars are a little different. One pillar has more of an etched style, rather than low relief, and is almost like a 3-D perspective drawing of an aurochs baying – a remarkable achievement for such an early design.

But perhaps the biggest clue to the advanced nature of this culture are the numerous abstract symbols, such as the 'H-symbols', 'V-symbols', and other repeated motifs carved into many pillars. They are clear evidence that at Göbekli Tepe we have a sophisticated culture communicating abstract ideas through an early form of proto-writing. This writing is obviously intended to last – it is communicating from one generation to the next. But communicating what?

What was so important that these people felt they had to organise themselves and spend much of their precious time in unproductive specialisms to communicate their ideas to successive generations? Something very odd is going on here – this is quite unexpected behaviour for a population of supposed hunter-gatherers. The usual sociological explanations of power rivalries do not begin to account for it. Something happened to these people such that they felt compelled to change their way of life, to undertake a grand construction project of the greatest importance. By no means are these people simple hunter-gatherers.

Göbekli Tepe, in the words of one leading archaeologist, 'changes everything'. It breaks all the archaeological rules about what was possible at this early time. However, this sense of confounded, excited discovery was expressed *before* the animal symbols at Göbekli Tepe were decoded by myself and Dimitrios Tsikritsis, a PhD student at the University of Edinburgh, in 2017. Our work was published last year in an academic journal paper which seems to have become known as our 'Fox Paper'[14,15]. But even we didn't know then just how much Göbekli Tepe would change our understanding of the origins of human civilisation and contribute to our understanding of our place in the solar system. Only now are we beginning to recognise the true extent of its meaning. But before recounting how Göbekli Tepe was eventually decoded, and the scientific case that supports this, let's take a closer look at this amazing site.

The excavators currently working at the site, from the Deutsche Archaeological Institute, have so far uncovered four large nearly circular enclosures as well as many smaller square enclosures. Each enclosure is formed by a thick rough stone wall in which the giant T-shaped megalithic pillars are embedded. They are typically arranged evenly around each enclosure, like the hour markers on a clock face, sticking out from the inner surface of the wall. At the centre of many enclosures stands a pair of taller T-shaped pillars, on stone platforms or wedged into sockets in the bedrock.

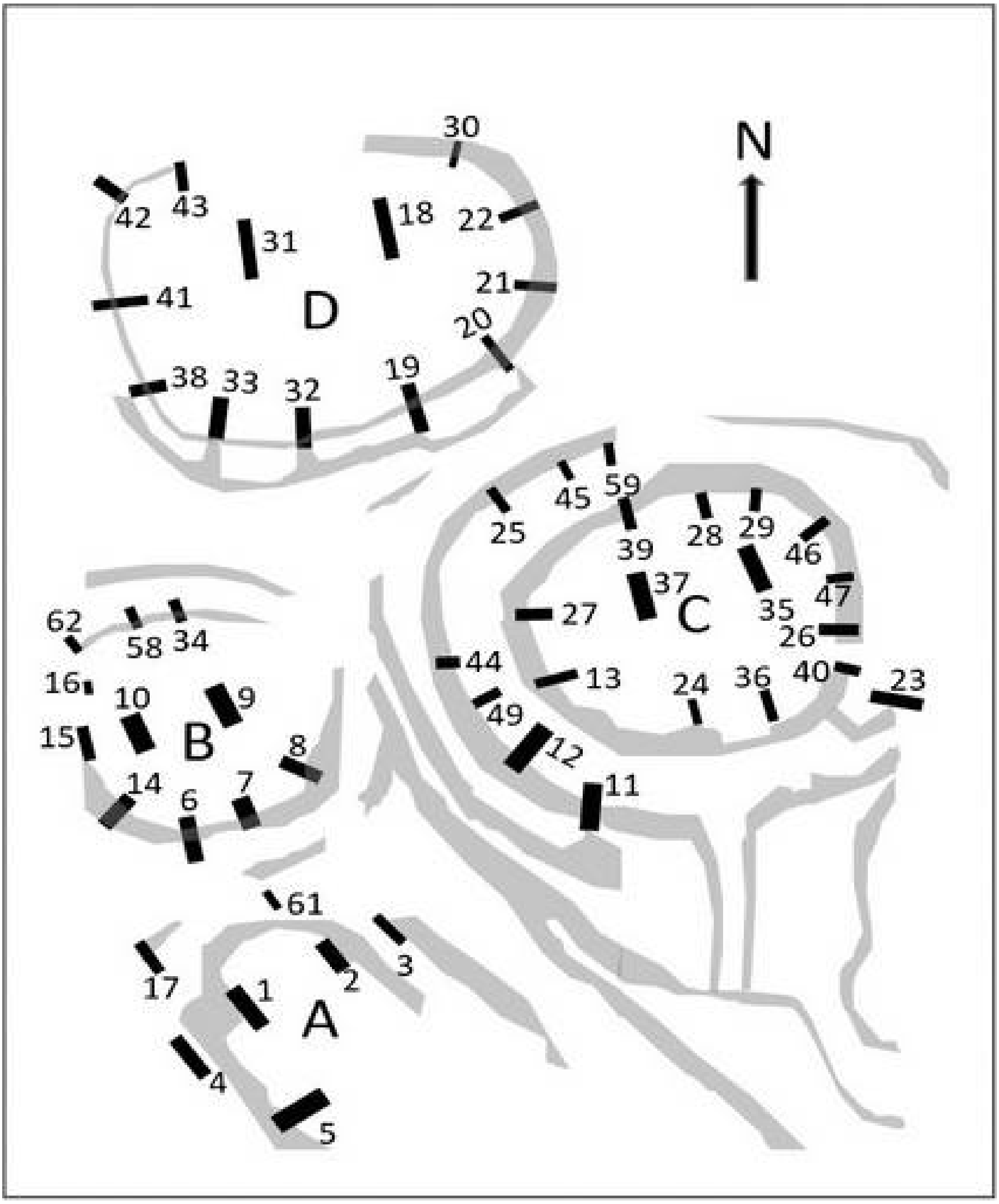


Figure 4. Map of the rounded enclosures excavated at Göbekli Tepe.

The largest circular stone enclosures are the most impressive and, curiously, apparently the oldest. They were built next to each other, with little to no space between one enclosure and the next (see Figure 4). The smaller square enclosures are nearby, forming a separate grid-like pattern (not shown). The ground-penetrating radar survey reveals that other rounded structures, perhaps even larger and older enclosures, remain to be excavated nearby.

Enclosure D, the oldest circular enclosure so far discovered, has eleven large upright T-shaped pillars embedded into its inner surface. The tallest and most imposing pillars yet found, over 5 metres high, stand in parallel near its centre, guarding its secrets like an ominous pair of sentries. They are particularly important characters in our story, with their enigmatic human-like features and fox-like symbolism (see Figure 5).

Figure 5. Left: Pillar 18, one of the tall pair of central pillars at the centre of Enclosure D. Right: Close-up of the bottom of Pillar 18 (images courtesy of Travel The Unknown (left) and Alistair Coombs (right)).

The Vulture Stone, the most important and richly decorated pillar of all, is embedded into the north-west of the enclosure. Striking images of this pillar, dourly labelled Pillar 43 by the site's archaeologists, can be found across the internet. A copy resides in the museum of the city of Sanliurfa, only 15 kilometres from Göbekli Tepe (see the front cover).

The other circular enclosures are similar. Each was completely buried by debris before excavation revealed them in various states of disrepair. Enclosure C is slightly smaller than D, with several interleaved layers of surrounding rough stone wall wrapped about the central enclosure courtyard. These stone walls appear to have been constructed in more than one phase of building, with later constructions modifying earlier ones. The symbolism found in this enclosure is dominated by carvings of boars[16]. The somewhat smaller circular enclosures, A and B, also have notable central pillars with carvings, although many of their surrounding pillars are plain. It was the tops of these central pillars from Enclosure A, just peeking above the surface of the ground, that gave the site away back in the 1960s. Pillar 2 from enclosure A, one of its central pillars, is also important for our story (see Figure 6).

Figure 6: Pillar 2, Enclosure A of Göbekli Tepe (courtesy of Travel The Unknown).

Radiocarbon dating has been used to estimate the ages of these enclosures. This popular type of measurement is used throughout the historical sciences, like archaeology. It can reveal the time since death of once-living things, such as wood or bone. Charcoal samples, which are reliable indicators even though they are burned, taken from the fill that covered the enclosures give dates between the 8^{th} and 10^{th} millennium BC, with enclosure D being the oldest. These ages likely correspond to the dates when these enclosures were buried, not to when they were constructed.

There is only one radiocarbon date measured so far that reliably corresponds to the construction of an enclosure, and that is the date of some wall plaster (that contains some small charcoal particles) from enclosure D which dates to 9,530 BC to within 220 years[17]. This means this rough stone enclosure wall was most likely built between 9,750 BC and 9,310 BC. However, construction of the stone pillars, which are embedded in this enclosure wall, could have occurred much earlier. The same applies to all the large round enclosures; the date of construction of the pillars in these enclosures must predate construction of the walls in which they are embedded, which in turn must be older than the debris used to bury them.

In fact, the pillars might be much, much older than the rough stone walls. One reason for suspecting this is that some of the most highly decorated pillars within Enclosure D are embedded so far into the wall that many of their fine carvings are almost completely covered by it. The Vulture Stone is a good example.

This appears to be an odd thing to do. Imagine the artists of these astonishingly crafted pillars, having spent a great deal of effort with very limited resources under difficult conditions, seeing their creations immediately embedded into a rough stone wall, obscuring their handiwork. They would probably have been quite upset about this artistic travesty. Indeed, we can expect that, having seen one of their fine creations abused in this way, they might be rather reticent about creating more finery if it was going to be treated similarly. Much more likely is that the earliest pillars were constructed some considerable time before the rough stone walls, and perhaps were more or less free-standing originally. Then, at some later date around 9,530 BC, the rough stone walls were built around the pillars. The artists who carved the pillars were no longer alive to object, and presumably the reason for constructing the enclosure walls became of paramount importance. But what was this reason? What changed at around 9,530 BC to cause this change in the design, and possibly the function, of Göbekli Tepe?

One possible interpretation is that one group of people, perhaps a more sophisticated group, made and placed some of the pillars in circular patterns, covered with their 'writing', for a specific purpose and then another group of people occupying the site at a much later time, around 9,530 BC, built the rough stone walls around the pillars. Did the people who built the rough stone walls even know what the circles of pillars had been used for? Could they even read the symbols? We will likely never know. Most of Göbekli Tepe remains buried, and there is a great deal more archaeological evidence to collect. It is entirely possible that even older layers of construction will come to light, and that new discoveries will require the story of Göbekli Tepe's construction and occupation to be retold.

At this stage, though, with the evidence we currently have, it does appear there are important transitions in the architecture, and perhaps usage, of Göbekli Tepe. What do we know of events in the wider world that might explain this? One possibility is massive climate change. One of the most rapid and severe known global climate change events took place around 9,600 BC. For the previous 1,300 years or so, Earth had been enduring a mini ice age, the Younger Dryas period, when average temperatures in the northern hemisphere were lower, by over fifteen degrees Celsius, than today.

But then the northern hemisphere warmed suddenly, climbing quickly towards today's climate within a generation.

Such a massively swift change in climate is almost impossible to imagine – it would be equivalent to moving Rome, which can be unbearably hot in summer, to north of Helsinki, near the Arctic Circle, within a few decades. There can be no doubt it would have had a colossal effect on people at the time. Incredibly, the onset of the Younger Dryas period, at around 10,900 BC, occurred even more quickly, perhaps over the course of just a few years. This amazing rate of climate change would have had a profound effect on plants and animals. Hunter-gatherer populations of the time would have needed to migrate thousands of miles, or adapt to new sources of food, to maintain their way of life.

Interpreting Göbekli Tepe

The discovery of Göbekli Tepe poses important questions about the origin of civilisation. It doesn't seem to fit the popular 'agriculture first' model. But does it completely break existing paradigms, or can they simply be 'tweaked' to incorporate this new information? Is it simply a case of slightly adjusting the timeline for the development of civilisation so that Göbekli Tepe can be shoe-horned in, or does the existence of Göbekli Tepe, with its architectural development seeming to correlate with known periods of rapid climate change, point to a deeper issue that requires a new understanding of the origin of civilisation?

To answer these big questions, we need to understand the meaning of Göbekli Tepe's symbolism. We need to decode it. The animal and more abstract symbols hint at an early form of proto-writing. What does it say? Can it tell us what happened to these people, and why they built these magnificent structures at this time? Can it reveal the origins of our civilisation? What do the site's archaeologists say?

Klaus Schmidt, who discovered Göbekli Tepe, was reasonably adventurous in his views[13] compared to the archaeologists, from the same institute, who now work at the site following his untimely death in 2014. He recognised the central importance of the animal symbols, and due to the portrayal of some rather docile animals, such as sheep and crane, reasoned that they are not intended to represent threatening guardians or hunting conquests.

He noted potential connections with the much later Ancient Egyptian and Sumerian civilisations, circa 3,000 BC, implying a direct line of cultural descent from Göbekli Tepe. For example, the often-threatening snake symbol reminded him of the Ancient Egyptian Uraeus serpent, a symbol of divine power. He also noted the particular importance of fox symbolism at Göbekli Tepe, and suggested a potential connection to the much earlier Stone Age tradition of wearing fox-tooth pendants and necklaces.

But he could not decode the symbols and stopped short of drawing any astronomical significance for Göbekli Tepe, despite the plain fact that Göbekli Tepe was constructed from megalithic stone circles, for which astronomical connections are often proposed, and despite the known importance of astronomy to ancient Sumerian and Egyptian cultures. Schmidt's view was essentially that Göbekli Tepe was a kind of cultic sanctuary, or temple, and therefore represented the earliest clear evidence of organised religion. Furthermore, he suggested it was a 'place of innovation', where religion, agriculture, stone masonry and other specialisms were developed first, before the Neolithic revolution. In other words, it can be viewed as the world's first University.

The site's current archaeologists take a somewhat more conservative view of Göbekli Tepe's symbolism, preferring to focus on the importance of cult and especially feasting[18]. They take, essentially, a sociological approach, fashionable in modern archaeological research, to interpreting Göbekli Tepe, remarking on the importance of social gatherings and feasting, supported by a social hierarchy and level of organisation that was previously not thought to be possible for hunter-gatherer groups. Essentially, they suggest Göbekli Tepe was a kind of cultic ‘beer hall’ or meeting place.

But to my mind, these interpretations don’t go far enough and miss a far more important story. Why would anyone from this period in time, coping with limited resources and extreme changes of climate, waste their precious time building a huge and complex megalithic structure on top of a hill far from a source of water to meet and feast? It doesn’t make sense – they had much more important things to do, such as actually finding food and shelter. The site must have had a very important purpose beyond simply feasting, in their view essential to their continued survival. Schmidt originally suggested that Göbekli Tepe represents the origin of organised religion, and therefore people were driven to build it because of their faith and belief. But faith in what? Animal spirits?

I find this explanation inadequate. The effort and organisation needed to build Göbekli Tepe is extreme. It is a venture that many people, possibly hundreds of people, all agree is vitally important for their continued prosperity, and possibly their survival. This was literally a matter of life and death for them – but what were they afraid of? The site’s current archaeologists suggest there was a ‘cult of the dead’, perhaps as a forerunner to the ancient Egyptian notion of an afterlife[18]. Or perhaps their dead ancestors were revered, and Göbekli Tepe was important in that process. These notions of a ‘cult of the dead’ are beginning to seem more reasonable.

Nevertheless, even though this might be approaching the correct interpretation, I think it still falls short of providing sufficient motivation for building Göbekli Tepe. Perhaps, for the correct interpretation, we should look up to the sky, rather than down at the ground or around at the migrating animals[19]. The sky was undoubtedly far more important to these ancient people than it is to most of us today[20]. We hardly notice the night sky, with all the light pollution and evening entertainment to distract us. But back then, the sky surely played a central role in life. Through looking at the sky one could tell the time of day, and more importantly the time of year, crucial in planning your future, in terms of hunting and having a family. Moreover, knowledge of the changing patterns of the stars and other celestial objects enables navigation and long-distance travel – something we take completely for granted today. And the skies would have been so much clearer then – what else was there to do at night except sing and dance under the stars, telling stories of past events involving heroes and monsters, love, death and tragedy?

It has been suggested by some that the orientations of the tall central pillars of the enclosures are aligned with the setting of Deneb, the pole star of 16,000 BC, in the constellation Cygnus[21]. But, even if the pole star had some mythological status, perhaps the gateway to an afterlife, could it have prompted the extreme behaviour observed at Göbekli Tepe? Certainly, the sky would have captured their attention at night, providing an ever-changing theatre of drama. But would a peaceful sky have provided enough drama to motivate them to build Göbekli Tepe? I really doubt it.

The key to understanding Göbekli Tepe, and presumably also the Neolithic revolution that followed, is through decoding its symbolism. This reveals the true motivations of these people, and how this led to a rapid acceleration of communal living able to support specialists in writing, science, religion, agriculture and construction. To begin decoding Göbekli Tepe, we first need to study the Vulture Stone.

2

The Vulture Stone

Pillar 43, a.k.a. the Vulture Stone, is embedded into the rough stone wall on the north-west side of Enclosure D. It is one of the most artistically decorated pillars yet found at Göbekli Tepe, with, in the main, clearly defined figures of animals together with a headless man and several types of abstract symbol. It is a majestic piece of art that likely predates the enclosure's rough stone wall which is radiocarbon dated to around 9,530 BC. It is also rather large and heavy, being nearly 3 metres tall, 1.5 metres wide and about 0.5 metres thick, weighing in at around 5 tonnes of dense limestone. Since it was revealed to the world in 2006 it has become one of the defining images of Göbekli Tepe[22]. In fact, it is a modern-day 'Rosetta Stone', as it unlocks the meaning of ancient symbols going back over 40,000 years. Quite probably, it is one of the most important artefacts in the world. Let's look at it in some detail.

Starting at the bottom (see Figure 7), we can see the large figure of what appears to be the head and neck of a bird – perhaps a duck or goose – balefully staring back. Above this, is the clear depiction of a scorpion, and above that is the stylised figure of another bird, giving the impression of a vulture, eagle or other bird of prey in flight. This vulture/eagle appears to support a plain circle or ball on its horizontally outstretched wing, which also appears to be at the visual centre of the whole design. To the upper-right of the flying vulture/eagle appears the figure of another bird – this time resembling a bending flamingo gripping a downward wriggling fish in its beak. To the right of that appears a squat 'H-symbol' and a vertical 'I-symbol'. Underneath the flamingo with its fish we can see a rather odd, squat bird-like shape. Lastly, to the left of the scorpion and long-necked bird we can just make out the head and front paws of probably a dog or wolf, although its body is obscured, with perhaps its back legs lower down.

Above all these figures are two rows of nested ‘V-shapes’, and above these at the top of the pillar is a row of three ‘handbags’, each accompanied by a small animal carving, but these are much harder to make out. The left-most handbag accompanies another ‘bent-bird’ figure, although this time without its wriggling fish. The middle handbag is accompanied by a standing or charging quadruped of some type, perhaps a gazelle, goat or ibex, with large horns or ears bent backwards over its body. The rightmost handbag has a downward crawling quadruped, giving the impression of perhaps a frog. Finally, at the bottom of the pillar to the right of the duck/goose is the outline of an ecstatic headless man.

Figure 7. Pillar 43, The Vulture Stone, at Göbekli Tepe. Left: embedded into the rough stone wall of enclosure D. Right: a copy in Sanliurfa museum (both images courtesy of Alistair Coombs).

Now, where should we start with this pillar? How can this group of symbols possibly have any meaning that we can decipher with any certainty? Surely any meaning they once had is now lost to the mists of time? It turns out we can decode this pillar using the scientific method. If we find the patterns on this pillar match other known patterns so well that the probability of the match occurring by pure chance is extremely low, then we have almost certainly decoded them correctly.

Therefore, the first task is to find known patterns that match those in this scene. According to Graham Hancock, a maverick investigator of ancient monuments who eschews the usual academic approach to scholarship, who in turn based his ideas on those of Paul Burley, another maverick, the eagle/vulture and scorpion represent our modern-day constellations of Sagittarius and Scorpius respectively[23]. Hancock also suggested the bending bird with fish symbol might represent Ophiuchus, known as the '13th sign of the zodiac'. In other words, they both thought the animal symbols were star constellations – the same constellations we use today in the West.

Figure 8 shows a side-by-side comparison of the Vulture Stone with these constellations. The scorpion symbol must be at least a reasonable match to the constellation Scorpius, as we continue to use that association today, and I agree with Hancock and Burley that the vulture/eagle is a good match to the 'teapot' part of the Sagittarius constellation. The wings of the vulture/eagle match the teapot's handle and spout quite well, while its head matches the teapot's lid (although the vulture/eagle is slightly rotated). And despite not being in exactly the right place, the bending bird with wriggling fish does, in my view, look a bit like Ophiuchus.

When I first saw this interpretation in Graham Hancock's book, *Magicians of the Gods*, I was intrigued. I had been interested in Göbekli Tepe since its discovery was made public in 2005 because it was such an anomalous ancient archaeological site, and the animal patterns hinted at a great puzzle to be solved. But, despite the obvious scorpion symbol, it hadn't occurred to me to consider an astronomical interpretation, let alone one that used our present-day constellation set. I assumed, much like everyone else, that this was impossible. But the matches he described were already so good, I thought there might be something in it.

Figure 8. Comparison of Pillar 43 with the constellations around Scorpius (left image adapted from Stellarium).

Many might object to this initial step, thinking it is quite impossible that constellations we are familiar with today might be over 11,000 years old. After all, orthodox scholarship tells us that the bulk of the Western constellation set came to us via the ancient Greeks a few centuries BC, with the zodiacal constellations originating with the Babylonians around the beginning of the first millennium BC, or perhaps the even earlier Sumerians. But this issue has vexed scholars for centuries, and the truth is, nobody really knows. The historical (written) record is too dilute and obscure to be certain of where or when the Western constellations were invented. Some scholars have argued that the Western constellation set is likely derived from observers at latitudes in the region of 36 degrees north (to within 3 degrees or so)[24]. This is because if you travelled much further south than this you would be able to see other constellations which are not included in this set. This span of latitudes covers the whole of the Fertile Crescent, which includes Göbekli Tepe at 37 degrees north. So, there is no reason to rule out the possibility that the Western constellation set was used at Göbekli Tepe.

Of course, with only three symbols on the Vulture Stone matched to constellations, the case is hardly convincing. The probability that these matches could have occurred by pure chance, although small, is not small enough. And there could be many other contexts in which a scorpion could appear together with different types of bird. But neither Graham nor Paul went any further with their analysis. They both stopped short of actually decoding this pillar.

To see whether there is anything more in this, to make a convincing case, we need to match many more patterns on the pillar with their respective constellations in the sky. If we keep finding the patterns match up, then we can claim to have decoded the symbols, and we might then be able to decode the meaning of the pillar – its message.

Therefore, we need to compare more of the animal figures on Pillar 43 with the constellations near to Scorpius. So, let's look at Figure 8 again. This view of the constellations around Scorpius is obtained from the very handy and free Stellarium software at a time close to the *setting* of Libra. If you are interested, you can download Stellarium for yourself to check everything I say[25].

The constellations shown in Figure 8 correspond to those we are familiar with today (using Western Lore in Stellarium). The timing of this snapshot is important. If it had been taken shortly after the *rising* of Sagittarius then all these constellations would be upside down. But to get a good match with the animal symbols on pillar 43 we must look at the constellations as they set – as shown.

Below Scorpius in the sky is Libra, normally interpreted today as the Scales if viewed as it rises. But here we are looking at it as it sets. If we had to choose an animal to fit Libra in this orientation we would probably choose a swimming duck or goose – it has the classic 'rubber duck' shape. And a duck or goose does appear to be carved onto Pillar 43 below the scorpion.

And, to the left of Libra in the sky is Lupus, the wolf. On Pillar 43, to the left of the duck/goose is what appears to be the head and front paws of a dog. Now, this particular image on Pillar 43 is mostly obscured – it could be interpreted as, perhaps, several other animals. Nevertheless, its interpretation as a dog or wolf is quite reasonable. At this point, with these symbols identified and in approximately the correct relative locations, the case for this interpretation in terms of constellations is now much stronger.

Ophiuchus, which lies to the right of Sagittarius and Scorpius, has the shape of a peaked archway. But on Pillar 43 we find two animal symbols in the place where Ophiuchus should be – the bending bird with wriggling fish above the odd-looking 'squat' bird shape. Now, based purely on their respective positions we would expect the squat bird to represent Ophiuchus. But this is not such a good fit. It seems to me that the bending bird with fish symbol is a much better fit, although it is not quite in the right place. How should we deal with this apparent inconsistency? We can argue that Ophiuchus *is* represented by the bending bird and fish symbol, and that although its placement is not quite right, it is not too bad. Perhaps the artists were constrained by the shape of the pillar as to where they could sensibly place the animal symbols. And, we can argue that Pillar 43 is, in any case, not intended to be an accurate star map, but is instead only a symbolic representation of the sky, with sufficient accuracy to fulfil its purpose. But then, what does the squat bird on Pillar 43 represent? This is not clear, but we can make it represent any star pattern we like, as there are enough stars in the sky to match to any arbitrary shape. We can effectively ignore it – it will not affect our conclusions.

To see how good the case we have built is now, we need some way of estimating the chance that these pattern matches could have occurred by pure chance. This is how science works. We have a hypothesis – that the animal patterns represent constellations. Now we need to test it statistically. Science uses this same method, known as hypothesis testing, all the time, whether we are developing a new treatment for a disease, or trying to understand the effect of advertising on people's shopping habits, or whatever other proposal we might have. It is the cornerstone of the scientific method. Any hypothesis can be tested – even ones that at first seem ridiculous, like whether the animal symbols at Göbekli Tepe represent constellations. This is the great thing about science – nothing is ever ruled out in advance. It would be unscientific to do so.

A good way to think about this problem is to first consider how many different possible combinations of animal symbols there are for this part of Pillar 43. Suppose you could swap any animal symbol on the pillar with any other animal symbol at Göbekli Tepe. Just for the sake of argument, let's suppose there are one million different possibilities, or different combinations of five animal symbols for this part of the pillar. We'll calculate a better value a little later. Then we can ask the question 'how many of these different combinations are at least as good a match to the constellations suggested as the combination that actually appears on Pillar 43?' This would require us to go through every possible combination and decide whether it is better or worse than the actual one that appears on Pillar 43. Let's suppose, just for the sake of argument, that there are 99 better ones. That means, if we were to replace all the animal symbols on this part of the Vulture Stone with other animal symbols chosen randomly from those present at Göbekli Tepe, that the probability of getting a combination as good as the one that actually appears on it is 100 in 1 million, or equivalently, 1 in 10,000.

If the resulting probability we end up with is very tiny, then we can be very confident that the combination of symbols actually appearing on the pillar was not chosen randomly – instead we can be confident they were placed there deliberately to match the constellations we suspect.

So now, let's try to estimate the number of different combinations of animal symbols that can appear on this part of the Vulture Stone properly. There are at least 13 different animal symbols used on the broad faces of pillars at Göbekli Tepe. I have listed them in Table 1 at the end of this chapter. That means there are at least 13^5 = 371,293 different combinations of 5 animal symbols that could have been placed on this part of the Vulture Stone. Now we need to estimate how many of these are at least as good a match to the constellations around Scorpius as the ones that actually appear on the pillar. In my estimation, the symbols that actually appear on the pillar are the best possible combination – there are no better ones. That gives us a tiny probability of about 1 in 0.37 million of choosing that combination by pure chance. That's a pretty small chance.

However, this is not our final result. We need to take into account two other factors. First, this estimate is biased. The question we should have asked is ‘how many of the different combinations of animal symbols that could have been placed on the pillar match the constellations in *any* part of the sky as well as the ones that actually appear on the pillar?’ Instead, we demanded they match a patch of sky surrounding Scorpius. As this is less likely than finding a match to the constellations in any part of the sky, the probability we calculated was too small. To eliminate this bias, we can simply eliminate Scorpius and the scorpion from consideration. That is, we can take the scorpion = Scorpius as given, and focus only on the other animal symbols around it. This reduces the significance of our statistical estimate by a factor of 13.

On the other hand, we also need to take into account the good match in the relative positions of the animal symbols on the pillar. So far, we have only considered whether the patterns match their respective constellations, not whether their precise placement on the pillar relative to each other matches the relative positions of the associated constellations in the sky. For example, notice how the angles between the scorpion, duck/goose and dog/wolf are very similar to the angles between Scorpius, Libra and Lupus in the sky. It’s uncanny, isn’t it?

Now, this is a more complex type of calculation that I won’t go into here. It is dealt with in Appendix A if you are interested to find out more. But, roughly, I estimate this factor is at least 9. Therefore, these two factors almost cancel out. Our probability estimate is too small by a factor of about 13 because we considered the scorpion, but too large by at least 9 because we didn’t take into account the accuracy with which the patterns are positioned.

This means our final estimate is in the region of 1 in 0.26 million. Although this is an estimate, and not a rigorous result, this is now becoming very interesting. It is approaching the kind of significance on which a strong scientific case can be built. For example, in the field of particle physics, one of the most rigorous scientific disciplines there is, a probability of around 1 in 2 million of a signal occurring by pure chance is needed before it can be announced that a new fundamental particle has been discovered. That was the case for the recent discovery of the famous Higgs Boson in 2012. So, we are not far short of that – only about a factor of 10 out.

However, given the consequences of this interpretation, in that it overthrows centuries of scholarship on the origins of astronomy, even more evidence is desirable. For example, if this idea is correct, then it means the Greeks, Babylonians, Ancient Egyptians and even the ancient Sumerians, probably obtained their knowledge of astronomy from a much earlier culture. It's unlikely that the same constellations using some of the same symbols would have been invented independently in the same part of the world more than once. But there is no obvious evidence of an earlier culture, between Göbekli Tepe and Ancient Egypt or Sumer, with this level of astronomical knowledge. The Sumerians and ancient Egyptians are the earliest known cultures with an interest in astronomy. It would also mean everything we thought we knew about the historical development of science and mathematics might be wrong, since if our understanding of the history of astronomy is wrong, how can we be sure about any of these others?

But there is another issue we need to take into account too. Our estimate of a chance of 1 in 0.26 million that these patterns were chosen by pure chance is based on the view that the best possible combination that could have been chosen actually appears on the pillar. But this is just my opinion – and you might disagree with it. For example, you might think the boar symbol found on Pillar 38 (see Table 1) is a better fit to the Lupus constellation than the dog/wolf symbol that we can only partially see on the pillar. Or you might think the fox symbol is a better fit. Therefore, there is considerable uncertainty in this value of 1 in 0.26 million. Somebody else, looking at these symbols, might think there are, perhaps, 49 different combinations of symbols that are a better match overall than the one actually appearing on the pillar. In which case, our estimate of the significance of this part of the pillar would only be about 1 in 5 thousand. This is no longer so interesting – it is a long way short of the 1 in 2 million chance used by particle physicists.

It's important to realise, when thinking about these statistical calculations, that we are not so interested in how well the animal symbols match the constellations in an absolute sense. Instead, we are considering how well they match relative to all the other options. We are looking for differences between patterns, which is a lot easier than considering how well two patterns match in an absolute sense. Take the vulture/eagle symbol on Pillar 43 for example. This is a fairly good match to the teapot part of Sagittarius. But for our analysis, what actually matters is whether the vulture/eagle is a better match to Sagittarius than the other animal symbols available. It clearly is – I agree with Hancock and Burley on this. Although the eagle/vulture is not a great fit to the whole of the Sagittarius constellation, it does fit part of it quite well. More importantly, it is way better than any other animal symbol (in my view). This is the beauty of this method – differences are easier to spot than absolutes.

So, let's turn to the other symbols on Pillar 43 – can we make the case even stronger by matching the small animal symbols at the top of the pillar, which each stand next to a 'handbag', with other constellations? What do these handbags even mean? Furthermore, if animal symbols in general represent constellations then surely the circle just above the vulture/eagle's wing also represents an astronomical object – but which one?

To make progress with decoding Pillar 43 it will be helpful to first review the well-known phenomenon of 'precession of the equinoxes'.

Precession of the Equinoxes

As we all know, Earth rotates on its own axis once a day, and it takes slightly over 365 days to orbit the Sun. But Earth's own axis of rotation is not perpendicular to its orbit around the Sun. That is, the plane that goes through Earth's equator is inclined with respect to the plane of Earth's orbit around the Sun. So, the Earth is tilted somewhat, currently by 23 degrees, compared to its orbit. This gives rise to the seasons, as well as the solstices and equinoxes.

Because the Earth spins on its axis, it is not perfectly spherical. It bulges slightly at the equator because of the apparent centrifugal forces on Earth's surface as it rotates, which are strongest near the equator. And because the equator is not in the same plane as Earth's orbit, this means there are times in the year when the equatorial bulge nearest the Sun is above the plane of Earth's orbit and other times when it is below it. Gravitationally, the Sun 'pulls' down on this bulge when it is above the plane of Earth's orbit, and 'pulls' up on this bulge when it is below. Rather like a pendulum, this causes the axis of Earth's rotation to 'precess'. In fact, it is exactly like a spinning top; Earth's axis of rotation 'wobbles', albeit very slowly.

A good way to visualise this is to imagine that Earth's axis of rotation points at a star. This is known as the 'Pole Star'. As Earth's rotational axis precesses (wobbles), it begins to point at other nearby stars, which then become the new Pole Star. Eventually, after nearly 26,000 years, Earth's axis of rotation will complete an entire cycle of precession and we will be back to our original Pole Star. The rotational axis will have 'pointed out', or described, a circle in the sky on which all the Pole Stars lie. Today, the Pole Star seen from the northern hemisphere is Polaris in the constellation Ursa Minor. But in 11,000 BC it was Vega in the constellation Lyra, while in 16,000 BC it was Deneb in the constellation Cygnus.

In addition to a very gradual change in the identity of the Pole Star, Earth's axial precession also has other observable consequences. The one that concerns us most is precession of the equinoxes. Imagine you are standing at the North Pole. The Pole Star, currently Polaris, is vertically above you, day or night, while all the other stars appear to trace great circles in the sky with a wide range of diameters as Earth (and you) rotate. You will be closest to the Sun on midsummer's day, the summer solstice, when Earth's axis is tilted most towards the Sun. The constellation observed 'behind' the Sun on this special day in the year in our current epoch is Gemini, as seen from the northern Hemisphere.

But 13,000 years ago, Earth tilted towards a different northern Pole Star, Vega. The summer solstice then occurred when Earth was on the other side of the Sun – halfway along its orbit around the Sun compared to today. The constellation behind the Sun then was Sagittarius. Over the course of nearly 26,000 years, all the zodiacal constellations appear in their respective order behind the Sun on the summer solstice. Of course, we cannot see directly which constellation is behind the Sun, as the stars are not visible during the day. But by observing the stars just before sunrise or after sunset it is possible to work out which constellation the Sun will be in front of.

And, because the summer solstice constellation slowly changes with precession, so does the winter solstice and the spring and autumn equinoxes. They all gradually rotate through the zodiacal constellations – this is known as precession of the equinoxes (see Figure 9).

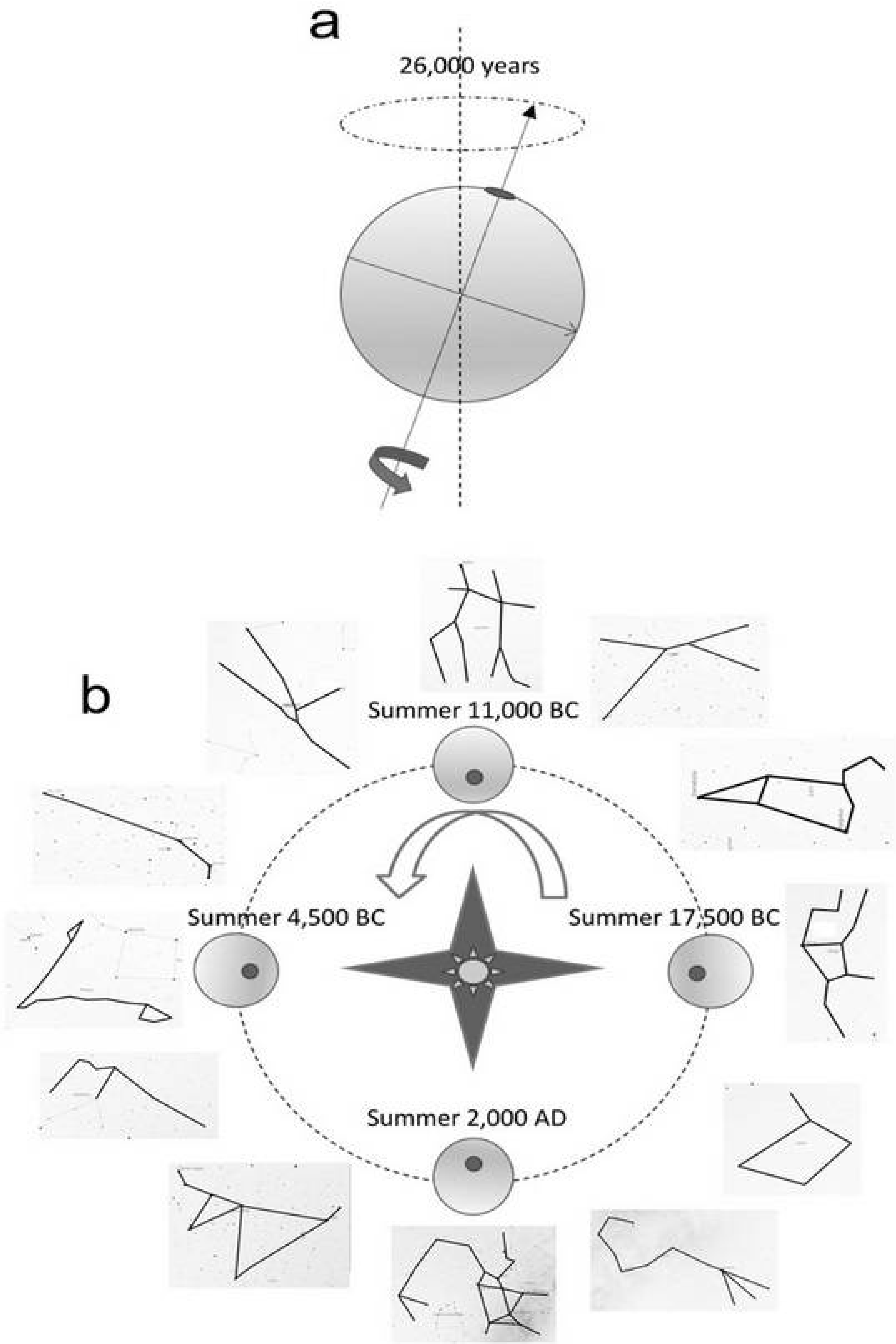


Figure 9. Part a) Earth orbits in the plane of the solar system, but the Earth's rotational axis is at an angle (of 23 degrees) to this plane. This rotational axis precesses, completing an entire cycle nearly every 26,000 years. Part b) Therefore, summer occurs at different points along Earth's orbit around the Sun.

Therefore, by writing down the four constellations corresponding to all four of the solstices and equinoxes, we can encode a date accurate to within, on average, 26,000/48 = 540 years. This means, on average, nearly every 540 years one of the constellations corresponding to the four solstices and equinoxes will change. To write a date with greater accuracy than this using precession of the equinoxes is not so easy – you'd need to draw the Sun's position as accurately as you can relative to one of these constellations on the respective solstice or equinox. So, in principle, if you could measure the position of the Sun and draw it very accurately, you could record a date with an accuracy of one year. Of course, all these calculations are subject to an error of multiples of nearly 26,000 years, since precession is cyclic. The pattern repeats nearly every 26,000 years.

A final remark on precession of the equinoxes. We have so far considered only the four astronomically special days of the year – the solstices and equinoxes. In principle, any combination of days in the year could be used, provided they are not too close to each other. However, there is no point choosing four days in the year at random, because unless someone else knows precisely what days you have chosen, they will not be able to read the correct date. Indeed, a misinformed observer would actually read an incorrect date. No, it is obvious that anyone who is sufficiently knowledgeable to understand how to write a date using precession of the equinoxes also understands that only the four astronomically auspicious dates in the year can be used; the summer and winter solstices, and the spring and autumn equinoxes.

Handbags at Dusk

How does this knowledge of precession of the equinoxes help to decode Pillar 43? Remember the circle resting on the vulture/eagle's wing. Does it have an astronomical interpretation? Hancock and Burley thought it was the sun, and therefore they thought Pillar 43 represented a date using precession of the equinoxes.

Once again, some might be horrified at the suggestion that precession of the equinoxes was known and used by the people of Göbekli Tepe. Conventional scholarship attributes the discovery of precession of the equinoxes to Hipparchus of the Greeks, in the 2nd century BC. But, of course, we can only be sure that this is the latest possible date by which precession had been discovered. We cannot ever know when this phenomenon was first discovered. In fact, de Santillana and von Dechend, while both professors of history at MIT, previously suggested precession of the equinoxes was known many thousands of years earlier, based on a reinterpretation of ancient myths in astronomical terms[26]. Their book, *Hamlet's Mill*, published in 1969, has become a reference work for maverick investigators, like Hancock and Burley, outside of academia who claim civilisation was more advanced in the Stone Age than currently accepted. But this reinterpretation of myth is highly speculative, and their conclusions were generally regarded as crazy by many, perhaps most, within academia.

To see what date is represented by the Vulture Stone, assuming for the time being it is encoded using precession of the equinoxes, we can use Stellarium again. This very handy software allows you to turn back time, to view the positions of the stars and planets in an earlier epoch. In our case, we need to turn back time until the sun appears just above the horizontal wing of the vulture/eagle, as shown on the pillar, on the four different solstices and equinoxes. In other words, when the Sun appears just above the spout of the 'teapot' part of Sagittarius on these special days of the year.

Of course, when you do this you have to take into account precession of the equinoxes. The summer solstice did not always fall on June 21st like it does now, and likewise the winter solstice did not always fall on December 21st. The summer solstice is defined as the day in the year when the sun reaches its highest point, and likewise, the winter solstice is defined as the day in the year when the sun is lowest at its highest point of the day. The spring and autumn equinoxes are defined by the days in the year when the sun crosses the equatorial plane, i.e. the plane in which Earth's equator lies. This means that day becomes longer than night on the spring equinox, while night becomes longer than day on the autumn equinox. When I first looked at this problem I failed to realise this, but fortunately Dimitrios, my co-author of our Fox Paper, was on hand to put me right.

Using Stellarium it is easy to see, when properly taking precession of the equinoxes into account, that the hypothetical date stamp represented on Pillar 43 likely corresponds to one of the following four dates:

- 2,000 AD – winter solstice
- 4,350 BC – autumn equinox
- 10,950 BC – summer solstice
- 18,000 BC – spring equinox

In principle, the date represented by the pillar could be any one of these – we don't know in advance which equinox or solstice was actually used by the people of Göbekli Tepe to write a date. But, we do know, or we think we know, that the pillar is older than the rough stone wall in which it is embedded, which has been radiocarbon dated to around 9,530 BC. It seems very unlikely to me that the people of Göbekli Tepe were interested in dates thousands of years into their future. So, we can certainly rule out 2,000 AD, given by the winter solstice, and 4,350 BC given by the autumn equinox. Of the remaining two dates, by far the closest to the radiocarbon date is 10,950 BC, based on the summer solstice, and I suggest therefore that this is the most likely date.

Hancock, through flawed logic, arrived at the winter solstice date of 2,000 AD, and then suggested Pillar 43 was a warning sent by the people of Göbekli Tepe to us across 11,500 years of an impending disaster, supposedly in 2,030 AD. I reject this idea entirely. It would be impossible for us to make such a prediction, so far into our own future, even today with our advanced knowledge and computing power. Moreover, why would the people of Göbekli Tepe be interested in making such a prediction? I am sure they could not have cared less about matters that far into their future – they would have been much more concerned with their own problems.

But, how precise are these measurements? Surely, we cannot know precisely what date is represented down to the level of individual years? To investigate this issue, we need to find when the sun no longer appears to reside just above the teapot's spout, or the vulture/eagle's horizontal wing. Using Stellarium again, it is easy to show that these dates are only accurate to within about 250 years. In other words, taking the summer solstice as the reference day, the date represented by the Vulture Stone could be anywhere between 11,200 BC and 10,700 BC. Outside of that date range, the sun no longer appears near the position shown on the pillar.

As things stand, there is a probability of around 1 in 0.26 million that these pattern matches are purely coincidental, assuming my view of the pattern matches is correct. But, the possibility that the circle represents the sun, and therefore Pillar 43 represents a date, is pure speculation. More evidence is needed to make a convincing case for this hypothesis.

Therefore, consider the handbags with their accompanying small animals at the top of Pillar 43. As there are three of them, perhaps they represent the other three auspicious astronomical days in 10,950 BC – the winter solstice and the spring and autumn equinoxes. And, perhaps the small animal symbols are their corresponding constellations. This would be consistent with the view that Pillar 43 represents a date using precession of the equinoxes. Perhaps the pillar describes all four special astronomical days in the year? Actually, this idea came from my wife, Alison. I had become stuck trying to figure out what the handbags might represent, but as soon as I mentioned the problem to her, she suggested this possibility. The next morning, I realised the handbag symbols can be interpreted as sunsets, with the semicircle representing the half-disc of the Sun as it disappears below the horizon. This is such a nice fit, it strengthens the case further.

Using Stellarium again to locate the zodiacal constellations for the preceding solstices and equinox gives the following sequence:

- spring equinox 10,950 BC = Virgo
- winter solstice 10,951 BC = Gemini
- autumn equinox 10,951 BC = Pisces

When these three constellations are compared with the three small creatures next to the handbags at the top of Pillar 43, we find they match very well. That is, Virgo at sunset can be interpreted as a downward-crawling four-legged creature. Gemini at sunset can be interpreted as a charging ibex or gazelle with long horns. And Pisces at sunset can be interpreted as a tall bending bird (see Figure 10 for a comparison), i.e.

- Virgo = downward-crawling quadruped
- Gemini = charging horned quadruped
- Pisces = tall bending bird

When I first saw this, I knew intuitively that these fits were just too good to be coincidence. I was stunned. I appeared to have unlocked the secrets of an ancient system of writing used to encode dates over very long timescales using precession of the equinoxes.

But how could I be sure of this? How could I prove this was correct? Might this all just be pure chance, and I was simply seeing connections where there really are none? After all, the timescales involved and the advanced astronomical knowledge required are simply not compatible in any way with the currently accepted view of history and prehistory. However, science allows any hypothesis to be tested. If the evidence supports a particular hypothesis with sufficient confidence, no matter how outlandish it might seem, then that hypothesis must be considered scientifically verified and is worth more than a room full of forceful personalities. Science takes no prisoners and makes no allowance for egos. Only counter-evidence of greater statistical weight can refute it, and there appears to be none in this case. All there is, is the dogma of orthodox scholarship, which carries no statistical weight in a scientific sense.

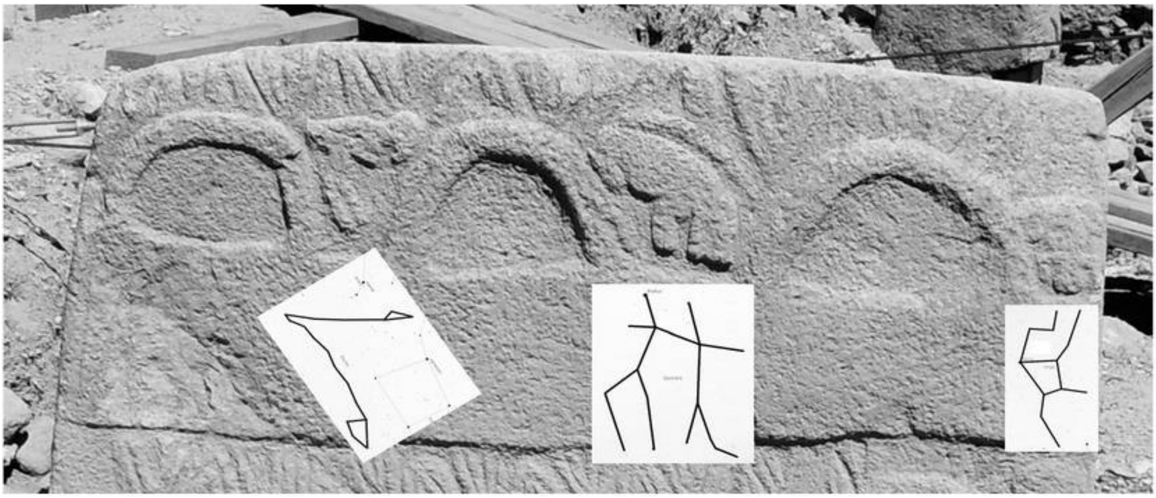


Figure 10 Comparison of the constellations Virgo (right), Gemini (middle) and Pisces (left) with their associated small animal symbols at the top of Pillar 43 (image courtesy of Alistair Coombs).

To test this hypothesis and provide confidence in this interpretation, we can use the same method as before. This time, there are 3 patterns matched to 3 constellations. With 13 animal symbols to choose from at Göbekli Tepe, the total number of different combinations of 3 symbols is $13^3 = 2{,}197$. And in my view, there are two equally good combinations that fit these constellations, Pisces, Gemini and Virgo, the best. One is the actual combination we see on the pillar. The other is the same, except the charging ibex/gazelle is swapped for the lion/leopard symbol found on a pillar in the so-called Lion-Pillar Building at Göbekli Tepe (see Table 1), which to my eye also fits Gemini quite well. Therefore, the chance of selecting one of these two combinations of symbols at random is 1 in 1098. But this is not our final result. The sequence of symbols would work equally well whether it was written left-to-right or right-to-left. This means our final result for this part of the pillar is 1 in 549. This is the probability that the Vulture Stone does not represent a date using precession of the equinoxes. Of course, and once again, this probability estimate is based on my view of the pattern matches between the animal symbols and constellations. You might take a slightly different view.

However, by combining this result with that from the lower panel of the pillar, a composite probability for selection of all the animal symbols on the pillar of 1 in 0.26 million x 549, which is roughly 1 in 140 million, is obtained. This is an extremely tiny probability.

Therefore, if my view of the ranking of the animal symbols against each suggested constellation is correct, there is only a miniscule probability that the patterns on the Vulture Stone can have occurred by pure chance. A probability of 1 in 140 million is so small that it would be irrational to think that this is what has happened. Instead, we should conclude that that the animal symbols were chosen deliberately – they have almost certainly not occurred by pure chance.

To refute this view that the animal symbols represent constellations – the same ones we use today in the West – your view of the pattern matches will need to be very different to mine. Essentially, you will need to find around 140 different combinations of animal symbols that are a better match to the constellations suggested than the one actually shown on the pillar. Then, the probability of choosing one as good as the actual one that occurs would be around 1 in 2 million, and in a scientific sense, this is when doubt in the hypothesis begins to grow.

Pattern Matching

Unfortunately, at this stage, this statistical result is a subjective issue. So, the case I have built for Pillar 43 representing a date is a little shaky. It all depends on how clear the pattern matches are. In an engineering sense, this kind of issue is often referred to as 'signal-to-noise'. In other words, how strong is the signal, the parts of the patterns that match, compared to the noise, the parts of the patterns that don't. There are established methods for dealing with this kind of image noise, but without using them our analysis suffers from some subjectivity, or bias. From a scientific perspective, this is not good enough. Science requires agreement on the measuring process, to ensure that it is unbiased and it is repeatable.

If the patterns we were matching were geometric, like squares, circles and triangles, then there would be no difficulty in identifying them – the signal-to-noise ratio would be very large. We give this kind of task to babies as a game. It's easy. In fact, we use pattern matching all the time – it's a routine part of our lives. You are pattern-matching right now as you read this book. You are matching the letters you see directly now with your memory of how the letters looked in other books. Reading is just pattern-matching. So is face recognition. In fact, your entire visual experience is just pattern-matching. Your brain matches what you see with models of the world that it has developed and encoded in your brain chemistry since birth.

Pattern-matching is now a major research area in its own right, often badged as AI – artificial intelligence. Consider the software on your smartphone that can recognise barcodes and faces. Think about how its camera app can correct for red-eye. Pattern-matching software is now very common with all sorts of applications, from security to product development. It's everywhere, and getting more sophisticated all the time.

In fact, archaeologists use pattern-matching too – they always have done. When an archaeologist looks at a piece of pottery or flint and tries to estimate its age, they are comparing the shape they see directly with lots of examples of the same kind of object they have seen before. They are expert pattern-matchers, and their ability to do this and make useful conclusions is not questioned. It's a required part of their skill set, like mathematics is to a theoretical physicist. So even when there is some subjectivity – like judging whether a piece of flint was actually used as a cutting tool – pattern-matching is allowed in archaeology, despite the uncertainty.

Likewise, matching animal patterns to constellations might seem like a fruitless game, but it is precisely the kind of exercise that must be attempted if we are to decode these symbols and uncover their meaning. There is no alternative. It is how decoding works and many scientific disciplines use pattern-matching routinely.

The problem is only that these symbols are being decoded for the first time. This causes two issues. First, these shapes are not so familiar as constellations, and therefore it is hard to recognise the animal symbols for what they really are. Second, and probably more importantly in this case, the outcome is paradigm-changing as it overthrows the current academic view of the history of science and astronomy. I therefore need to demonstrate a very high level of confidence in this result.

One way of making the pattern-matching process more robust would be to ask a lot of people for their view of the pattern-matches. If lots of people agree, or nearly agree, with my view then in a scientific sense this is good enough. A good statistical case could be built if enough people took part in this test. Alternatively, we could try using an AI or computational method. I don't have the required expertise in this area, but many others do, and I invite them to have a go. So, as things stand, you will need to make up your own mind.

However, I will show later that all this hand-wringing and doubt about pattern-matching is unnecessary. Although, as a scientist, I am honour-bound to bring the flaws in the current case to your attention, I will prove in Chapter 9, in a scientific sense, that my view is correct. So, with this in mind, and in the absence of evidence to the contrary, let's continue with decoding Göbekli Tepe on this basis and see where it takes us. Let's assume, for the time being, that the Vulture Stone does represent the date 10,950 BC to within 250 years, using precession of the equinoxes.

10,950 BC

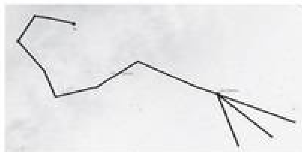
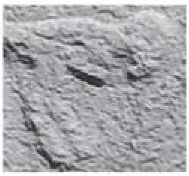
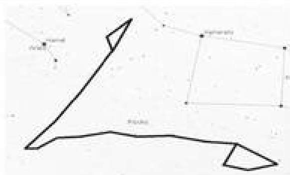
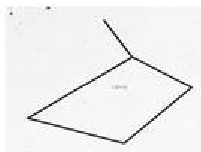
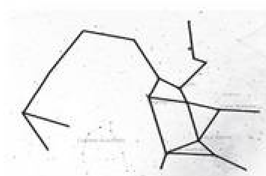
Let's consider this date. It's around 1,400 years older than the radiocarbon date of the rough stone wall in which the Vulture Stone is embedded, 9,530 BC. Very interestingly, 10,950 BC is very close to the onset of the Younger Dryas mini ice age, which occurred around 10,900 BC. Remember, this period of very cold climate lasted for around 1,300 years, and directly preceded what is often called the Neolithic revolution, or the rise of civilisation.

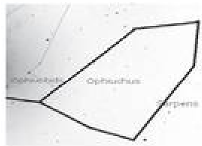
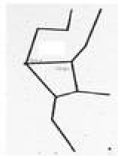
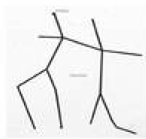
As suspected, it seems the pillars came first, and the rough stone walls were built much later. If the pillars were constructed as early as 10,950 BC, around the beginning of the Younger Dryas period, then it implies civilisation preceded the appearance of agriculture, or at least the appearance of domesticated strains of plants and animals, by around two millennia. The agriculture-first model for the origin of civilisation is then completely busted, and a new theory is required.

But what could this early date refer to? It was surely a very important date to the people of Göbekli Tepe, being written on the most artistically impressive pillar uncovered so far. One that was surely the focus of their attention and deliberately preserved for millennia. Probably, this date encodes the motivation for Göbekli Tepe’s construction. It is such a tantalising clue. And, moreover, what should be made of the ecstatic headless man at the bottom of Pillar 43? Possibly, he indicates the date refers to an event associated with loss of life. But what was it? It’s unlikely to be the death of a single person. Much more likely it refers to a major event, a massive event, sufficient to motivate the building of Göbekli Tepe. It might even hold the secret to the origin of civilisation.

Is it possible that Pillar 43 refers to a sudden event at the beginning of the Younger Dryas period – perhaps a terrible disaster? We know of a major volcanic eruption around this time: the Laacher See volcanic eruption in present-day Germany. The magnitude of this volcanic event was similar to the recent Mount Pinatubo eruption in 1991. It was therefore a large eruption, but would it have had a major effect beyond Europe to southern Anatolia, sufficient to motivate the building of Göbekli Tepe, a construction project of extreme endeavour? I really doubt it. After all, the eruption of Mount Pinatubo did not have severe consequences beyond its immediate vicinity.

Perhaps there is another catastrophic event, one that science has so far failed to properly recognise, at the onset of the Younger Dryas that can explain Göbekli Tepe’s anomalously early construction? To find out, we need to investigate the Younger Dryas period more closely.

Symbol	Constellation
 Scorpion	 Scorpio
 Tall bending bird	 Pisces
 Duck/goose	 Libra
 Dog/wolf	 Lupus
 Eagle/vulture	 Sagittarius

 Bending bird with fish	 Ophiuchus
 Crawling quadruped	 Virgo
 Charging ibex/gazelle	 Gemini
 Fox	
 Aurochs	
 Boar	

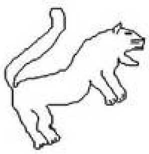
 Ram	
 Lion/leopard	

Table 1: Animal symbol–constellation associations from Pillar 43 at Göbekli Tepe. All constellations are oriented as they set. Notice the scorpion symbol is upside down relative to its constellation (all images courtesy of Alistair Coombs).

3

The Younger Dryas Mini Ice Age

The Younger Dryas period is a kind of mini ice age, about 1,300 years long, that occurred after the end of the last ice age proper, from around 10,900 to 9,600 BC. In the northern hemisphere, average temperatures were about 15 to 20 degrees Celsius lower during this period than they are today.

We know this because in recent decades many ice cores have been drilled deep into polar and glacial ice across the world, revealing a fascinating and complex history for Earth's climate stretching back nearly 1 million years. The annual layers of ice along an ice core, formed by the passage of successive summers and winters, can be counted quite accurately, while temperature can be deduced from the measurement of different forms of oxygen, known as oxygen isotopes, trapped within each ice layer. It is therefore possible to reconstruct a history, or chronology, of Earth's climate that goes right back to the time when the glacier or ice sheet itself began to form, hundreds of thousands of years ago.

For example, the EPICA Dome C ice core, around 3 kilometres long, reveals 800,000 years of Antarctic climate, while the GISP2 ice core reveals over 100,000 years of Greenland climate. Together, they show that the climates of the northern and southern hemispheres have fluctuated massively over this time.

The EPICA Dome C ice core, drilled at one of the coldest places on Earth near the South Pole, reveals that Earth is in the middle of a glacial age, comprising around a dozen different ice ages, each lasting around 100,000 years, one after the other, separated by shorter interglacial periods of around 10,000 years or so. During each ice age average Antarctic temperatures, which are believed to mirror Earth's climate more generally, drop precipitously by around 10 degrees Celsius, before recovering during an interglacial episode. In fact, it appears that ice ages in this glacial period are becoming stronger – the peaks and troughs in the temperature signal are becoming higher and deeper, and ice ages are becoming longer. If it were not for human-caused global warming, we might expect the climate to plunge into another ice age within the next ten thousand years.

Ice ages are characterised by the advance of giant ice sheets, several kilometres thick, from polar regions down to mid-latitudes, and the advance of mountain glaciers. Consequently, as more water becomes locked within ice sheets on land, sea levels drop, by as much as 100 metres or more over the course of an ice age, and vice versa during an interglacial period as the ice melts.

The mechanisms that drive ice ages are still actively debated. Possible reasons include subtle changes in Earth's orbit and axial tilt which affect the amount of solar radiation that reaches the surface, through to major changes in ocean circulation currents, changes in atmospheric composition (greenhouse gases), volcanism, large asteroid impacts and atmospheric dusting by comets. Quite probably, many, or all, of these mechanisms are in play.

From these ice cores it is clear that temperature variations across the northern and southern hemispheres during the last ice age, although following a similar broad trend, are very different in detail. The Antarctic temperature profile, a proxy for southern hemisphere climate more generally, seems to be relatively stable during the last ice age, with only small millennial-scale fluctuations, before recovering to the current interglacial period, known as the Holocene, about 11,600 years ago. The Greenland temperature profile, on the other hand, which is a proxy for northern hemisphere climate, displays sudden and dramatic temperature fluctuations, especially before the Holocene interglacial period in which we now live.

Although the temperature in Greenland during the last ice age appears to be around 20 degrees Celsius lower on average than current Holocene levels, there are frequent large and very sudden upward spikes in temperature of around 10 to 15 degrees occurring every few thousand years, which last for a few hundred to a few thousand years. It therefore appears that the northern hemisphere, or at least the North Atlantic around Greenland, displays what is known as ‘bi-stable’ behaviour, where climate can switch back and forth between two main states. It is quite remarkable that North Atlantic climate can switch so quickly from one state to another. Whilst it is not proven that these massive temperature fluctuations, known as Daansgard-Oeschger events, occurred across the whole of the northern hemisphere, since Greenland ice cores measure North Atlantic temperatures only, the northern hemisphere’s climate nevertheless looks to be extremely erratic before the last 10,000 years of the Holocene period (see Figure 11).

It is difficult for us today to fully appreciate the impact of these dramatic changes in climate. They would certainly shock human populations, as well as the plants and animals they depend on for food. It is quite conceivable that these climate shifts might have driven some species to extinction. At the very least, we can expect these changes to lead to considerable reductions in populations of all manner of species, plant and animal, including human.

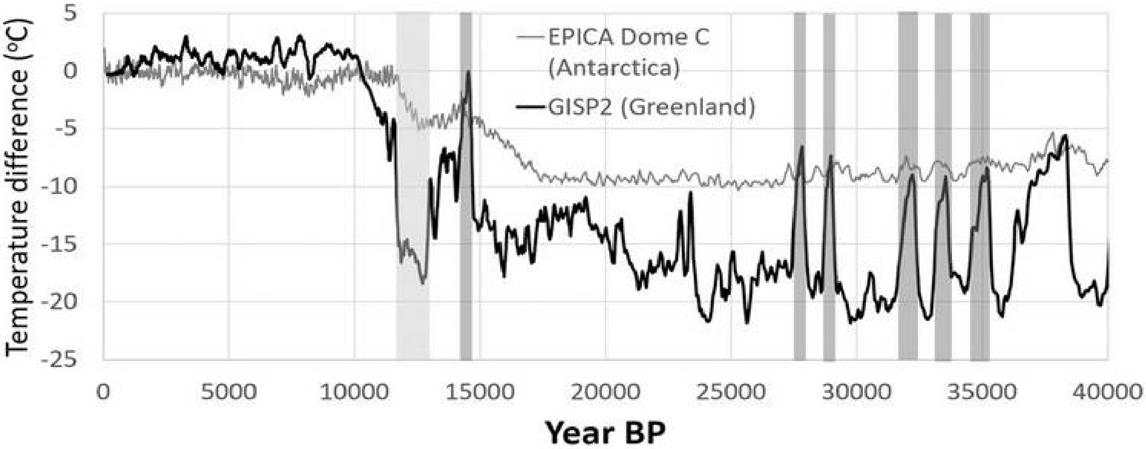


Figure 11. Temperature reconstructions of the last 40,000 years from Greenland GISP2[27] and Antarctic EPICA Dome C ice cores[28]. The light grey band indicates the Younger Dryas period. The dark grey bands indicate Daansgard-Oeschger events. Year BP is the number of years before 1950 AD.

The period we are mainly concerned with – the Younger Dryas – corresponds to the dramatic dip in temperature recorded by the Greenland ice core record, between 12,900 and 11,600 years ago, which led directly to our current Holocene climate. At first glance, it appears this millennial-scale Younger Dryas temperature fluctuation is similar to the preceding ones throughout the last ice age, the Daansgard-Oeschger events. But, this is perhaps not quite the case.

Since their discovery, these Daansgard-Oeschger fluctuations have confounded climate scientists. Naturally, a great deal of research has focused on discovering their causes. Such a massive climate switch, if it happened today, would be utterly disastrous for our modern civilisation. Quite possibly, we would be booted back to the Stone Age. A wide range of studies have been performed, from very large-scale computer simulations of Earth's climate to investigation of glacial deposits, which is the debris left behind by retreating ice sheets and glaciers, and dating of sea level changes. Much of the data is contentious and debated because of problems with interpretation of the radiocarbon dating evidence. But over the last decade, a breakthrough has been made with climate modelling that shows what might have happened[29].

The oceans of the southern hemisphere, being so extremely massive, control Earth's climate to a large extent. They act as gigantic heat sinks, absorbing and releasing prodigious amounts of heat, which they transport around the globe via tremendous oceanic currents. The climate of the southern hemisphere is therefore relatively stable.

However, the surface of the northern hemisphere, having much more land, holds much less heat than the southern hemisphere, which is mainly ocean. Therefore, minor changes in the temperature of the great southern oceans can lead to major changes in the behaviour of the smaller northern oceans. In fact, it appears the main ocean current of the North Atlantic, of which the Gulf Stream is just part, can be switched on and off by the great Southern Ocean. When the North Atlantic current is switched off, the North Atlantic can freeze over all the way down to the Bay of Biscay in France. In turn, this increased ice cover reflects more of the sun's heat back into space, thereby causing a reinforcing feedback mechanism that favours the growth of sea ice cover across the North Atlantic. Greenland, and presumably the rest of the Northern hemisphere, then becomes very cold, quite quickly.

Eventually, because heat from the Southern Ocean is not being dissipated to the North Atlantic, the Southern Ocean warms sufficiently that it switches the North Atlantic current back on. However, warming of the North Atlantic is not immediate, since it is iced over. Only once the ice cover is melted, and the reflective cooling feedback mechanism is broken, can the North Atlantic current be properly switched on, and the northern land masses begin to warm. Breaking of the North Atlantic ice cover, along with the cooling feedback mechanism, is apparently a relatively rapid process once it begins.

This, it is now generally thought, is how Daansgard-Oeschger climate events take place. They are caused by a complex interaction between massive ocean currents, extensive sea ice cover and reflected sunlight. Nevertheless, the initial trigger, i.e. what sets them off, is still a matter of debate. The conventional view is that they are an entirely spontaneous and natural part of Earth's climate system during an ice age. But while this might be the case for some of them, is this always the case? Is it possible that some of them were triggered by something else?

Now let's have a closer look at the Younger Dryas period. If you consider the background trend over the last 40,000 years, in the southern hemisphere a gradual warming trend started about 17.5

thousand years ago leading to the current Holocene climate of the last 10,000 years. Likewise, the northern hemisphere also shows a general warming trend starting around 20,000 years ago, leading to the current Holocene period. The Daansgard-Oeschger events before 20,000 years ago appear to be upward spikes, of 10 to 15 degrees, relative to this background trend in the northern hemisphere. However, the Younger Dryas period, which occurred towards the end the gradual warming trend between the last ice age and current Holocene period, appears to be a downward trough, of around 10 to 15 degrees, relative to the background trend. Possibly, then, the Younger Dryas period involves some of the same mechanisms as earlier Daansgard-Oeschger events, but is perhaps not exactly the same.

Of course, this is not a scientifically rigorous conclusion. But it is a hint (and no more than that) that the Younger Dryas mini ice age is unusual compared to preceding Daansgard-Oeschger events.

If we zoom in and take an even closer look at Earth's climate around the Younger Dryas period, we find the peak of a Daansgard-Oeschger event at around 12,500 BC, presumably signalling rapid de-icing of the North Atlantic, is followed by a relatively swift return to near ice age conditions over the next 500 years. Then there are some smaller oscillations in North Atlantic climate before the dramatic onset of the Younger Dryas period at around 10,900 BC, which takes the North Atlantic nearly back to full glacial conditions. This period lasts for around 1,300 years before another potential Daansgard-Oeschger event reduces ice cover in the North Atlantic, and the transition to the Holocene occurs around 9,600 BC.

These changes in climate are also reflected in the trends seen in sea level rise across this period. Measurements of Mediterranean sea levels[30], obtained by studying the pattern of coastal erosion in the Mediterranean basin below the current sea level, show a significant rise in sea level, of around 20 to 30 metres over the course of several hundred to one thousand years, at about the same time as the peak of the 12,500 BC Daansgard-Oeschger event. Another rise in sea level, of around 15 metres over the course of a few hundred years, also appears at the end of the Younger Dryas period, around 9,600 BC. Each of these surges in sea level can only mean one thing – rapid melting of continental ice sheets. This good agreement between ice core temperature data and sea level rise data essentially proves that these climatic changes actually occurred, and have not been misinterpreted.

These great meltwater pulses, although appearing fairly innocuous in terms of sea level rise, nevertheless correspond to flows of gigantic proportions – measured in millions of cubic metres per second, lasting for hundreds of years running off continental ice sheets, primarily in the northern hemisphere. Such flows dwarf even the largest modern-day river system, the Amazon.

This offers a clue to another contribution to the mechanism for the dramatic Daansgard-Oeschger climate switches seen throughout the last ice age, and also the Younger Dryas period. Dramatic surges in the flow of ice-cold meltwater are thought to be involved[31], possibly through their influence on major North Atlantic Ocean circulation currents.

Imagine the North Atlantic Ocean current as a giant conveyor belt. Warm salty water from the southern oceans drifts northwards and slowly cools. When it bumps into northern continents it stalls and, being cold and therefore denser, it sinks. But, this sinking cold water has to go somewhere, and so an equally strong current of cold water drifts back south along the ocean floor forming our giant conveyor. Now imagine diluting the warm water drifting northwards at the ocean surface with massive amounts of very cold salt-free meltwater running off the northern continents. If the meltwater flow is large enough it will cool the warm surface waters prematurely. At the same time, being salt-free, the meltwater is lighter and more buoyant than sea-water. Both these effects combined, it is thought, could cause the North Atlantic Ocean current to stall and the flow of warm water from the south is then blocked. Like adding an ice cube to a glass of water, the whole northern hemisphere is dramatically cooled.

Therefore, there appears to be a push-push back, or see-saw, effect where heat from the southern oceans switches on a Daansgard-Oeschger event leading to rapid de-icing of the North Atlantic, and warming of the Northern continents. But, once northern continental ice sheets begin to melt, very cold salt-free water running off northern continents pushes back, blocking the North Atlantic current, with ice cover and very cold climate returning to the North Atlantic.

This idea is very nice, but there appears to be some especially unusual climate signals around the time of the apparently special Younger Dryas event. Analysis of North American river sediments reveals a switch in the *routing* of meltwater from the huge Laurentide ice sheet that covered much of present-day Canada at the time[32]. Before the Younger Dryas period began, meltwater running off the Laurentide ice sheet flowed mainly south via the Mississippi, warming up as it travelled over land, before entering the Caribbean Sea. But during the Younger Dryas period it seems that this route was blocked, and instead other routes to the oceans were in play, especially a cold route running eastward into the North Atlantic Ocean.

Early computer simulations of global climate indicated that this rerouting of Laurentide ice sheet meltwater, from the southward-flowing Mississippi to an eastern route, might be sufficient to disrupt the North Atlantic circulation current by itself. This was considered by many climatologists to be a leading candidate mechanism for initiation of the Younger Dryas period, i.e. rerouting of Laurentide ice-sheet meltwater northwards provides a particularly strong perturbation to North Atlantic currents, sufficient to alter global climate. Conversely, it was thought that the southern route opened again at the end of the Younger Dryas period, leading to a restoration of North Atlantic Ocean currents and hence global climate.

In the last few years, however, new climate modelling research has cast doubt on this scenario. It has been found that a switch of Laurentide meltwater routes from a warm southerly exit into the Caribbean Sea to a cold easterly exit into the North Atlantic is unlikely to be sufficient *by itself* to cause the very rapid, prolonged and extreme Younger Dryas climate shift[33]. Additional factors, it is suggested, must be in play, including a major change in atmospheric currents and an increase in atmospheric dust leading to a reduction in sunlight reaching the ground.

This last suggestion lends weight to an earlier extraordinary finding that the climate shifted very suddenly indeed, more quickly than anyone had thought possible, at the onset of the Younger Dryas. By looking at another Greenland ice core (NGRIP) in great detail by measuring changes in different forms of oxygen, as well as changes in wind-blown salt and dust trapped within annual ice layers, it was found that although climate continued to change slowly after this event as colder conditions took hold, there was an abrupt, practically discontinuous, change in climate within one year right at the beginning of the Younger Dryas period[34]. State-of-the-art climate models are unable to explain the scale and suddenness of this finding without invoking some kind of catastrophic event, potentially leading to atmospheric dusting. A massive sub-annual climate shift like this is quite incredible.

Where does all this analysis leave us? It appears the Younger Dryas event is not quite like the Daansgard-Oeschger events earlier in the last glacial period, in that it represents a particularly dramatic and extreme *cooling* relative to the background warming trend. Moreover, it appears that for the duration of the event, cold meltwater run-off from the Laurentide ice sheet was rerouted to a predominantly eastern route to the North Atlantic, rather than the usual southern exit into the Caribbean, potentially causing warm ocean currents from the south to stall. And finally, it appears that additional mechanisms, possibly including atmospheric dusting, are needed to fully account for the extremely sudden (sub-annual) and severe drop in North Atlantic climate at this time.

Overkill, overchill, both, or neither

The Younger Dryas mini ice age lasted over 1,000 years. But it led to more than just a dramatic change in climate in the northern hemisphere. It also coincides with a great extinction event across many continents[35-37] and abrupt changes in human cultures, especially in North America[38-41], but also in Western Asia[42] and China[43], that appear to occur right at the beginning of the Younger Dryas cold period. In North America, we see a transition in the human population from the Clovis culture to the Folsom cultural tradition, right across the continent, while in the Fertile Crescent of West Asia, just to the east of the Mediterranean, a cultural transition from Early to Late Natufian occurred around this time.

The Natufian had already begun to settle down in the Levant, the western leg of the Fertile Crescent. But the Clovis of North America were still hunter-gatherers, who camped wherever they could find food and shelter. They hunted game, large and small, with finely crafted stone-tipped spears, and roamed across the continent, although most of their campsites are found along the eastern seaboard.

According to the best data we have[42], the Natufian transition, from Early to Late, appears to have occurred abruptly in the Levant. Fewer Natufian archaeological sites are found after the onset of the Younger Dryas, compared to before, indicating a catastrophic drop in population. And, in many cases, the Late Natufian appear to have abandoned their settlements and returned to a semi-nomadic lifestyle. But this scenario is not universally accepted – some archaeologists insist the transition was gradual. Regardless, the transition is real, and the evidence is consistent with a sudden event at the beginning of the Younger Dryas Period.

Precisely the same story holds for the Clovis of North America. They too suffered a reduction in population, and the people that followed, the Folsom, used less sophisticated, less well-crafted stone tools. Again, while the transition is generally accepted, its timing and severity are debated. Nevertheless, the best data are consistent with a sudden event at the beginning of the Younger Dryas period[44].

And it should be no surprise that a similar debate surrounds the extinction event at this time that disproportionately affected large animals, known as ‘megafauna’ (adult weight over 45 kilos), across many varied habitats and continents. The scale of these megafaunal extinctions is quite remarkable and not a matter of debate. What is contested by archaeologists and palaeontologists, rather vigorously, is the precise timing of extinction for each species and its primary cause. Even some species that did not become extinct show dramatic reductions, or ‘bottlenecks’, in their populations at this time, just like the Natufian and Folsom human populations.

In northern Eurasia megafaunal extinctees include the woolly rhino and cave lion, while the woolly mammoth, steppe bison and giant deer experienced dramatic population declines. But the pattern of extinctions in North America is much more severe. Here we find extinctees include several species each of mammoth, lion, llama, horse and antelope, as well as the short-faced bear, Jefferson’s ground sloth, the mastodon, species of peccary (a kind of wild boar), moose and musk ox, the American mountain deer, the western camel, the giant beaver, and a sabretooth tiger, among others.

South America perhaps fared even worse. It lost an even higher proportion of its megafauna over the last ice age as a whole, but the dating of their remains is less certain, making comparison with North America difficult. The dating of extinctions on other continents is even less certain, but it appears that Australia was as badly affected as North and South America across the last ice age as a whole. However, if we talk only in terms of megafaunal extinctions confidently dated to around the Younger Dryas event, North America seems to have borne the brunt, at least as far as we can currently tell.

As with the dramatic change in climate, mechanisms are sought to explain these extinctions and cultural transitions. A major problem for all the competing theories is precise knowledge of the timing of the extinction of each specific species. After all, a chance discovery of the remains of an animal can change the accepted extinction date of its species by millennia at a stroke. This problem is known as 'incompleteness' of the archaeological record. The issue here is that archaeologists only sample a very tiny proportion of Earth's surface – they can't dig everywhere. Nevertheless, research using statistical methods indicates the timing of most of the North American megafaunal extinctions of the last ice age is consistent with an abrupt event around the time of the Younger Dryas period[45]. Therefore, it shouldn't be surprising if a catastrophic event at the onset of the Younger Dryas period actually occurred – this scenario is consistent with the megafaunal extinction evidence currently available, although it is far from certain on this evidence alone.

The two main competing theories, until recently, that aimed to explain these extinctions were known as 'overkill' and 'overchill'. Overkill says that humans are primarily responsible for megafaunal extinctions during the last ice age on all continents across the globe through over-hunting. This is because the timing of these megafaunal extinctions on many continents, and the timing of the spread of Homo sapiens in significant numbers into new territories, appears to be so well correlated that it is thought they must be causally related[46]. Opponents of this view, while accepting there may be cases where this is true, especially on small islands, point to its implausibility in general and point out that correlation does not imply causation. With respect to North America, a key obstacle seems to be one of numbers – there were simply not enough people at these times to have made a significant dent in the vast number and range of creatures that became extinct. In North America in particular, the hunting ‘blitzkrieg’ required seems most unlikely[47].

Consider that the Clovis people of North America are thought to have entered the continent little more than a few thousand years before the Younger Dryas period and grown to a population of around one million by the time it happened, and this is difficult to reconcile with the disappearance of so many large creatures over this time across an entire continent. Moreover, the timing of modern human entry to the New World is increasingly disputed. It now seems that humans arrived much earlier in North America, by many millennia[48], than was once thought credible, although the numbers may have been small.

Similar difficulties are encountered in many cases where overkill is postulated – the precise timing of human arrival in new territories and megafaunal extinctions is very difficult to establish with confidence. African megafauna, especially, appear to have been spared, relative to those on other continents. Even today, there remain elephant, rhino, wildebeest, zebra, giraffe, lion, and hippo among other large species in Africa, although it is clear these populations are now at risk.

These facts appear to contradict the overkill theory because Africa is thought to be the continent where modern humans evolved. According to this ‘out of Africa’ model, modern humans, or Homo sapiens, evolved in Africa at least 200,000 years ago, and soon migrated across the whole continent. But we didn’t populate Eurasia until around 40,000 to 50,000 years ago. And yet, despite Africa being our place of origin, of all the continents it has fared the best in terms of megafauna survival. Essentially, Africa appears to debunk the overkill hypothesis. Humans and megafauna have coexisted there for hundreds of thousands of years, seemingly without such intense extinction events as everywhere else.

The usual response of diehard overkillers to the African dilemma is that animals in Africa had developed alongside humans, and were therefore wary of them, whereas animals on other continents were much tamer, and were therefore easy prey when humans arrived on the scene. But this is just speculation which has not been scientifically tested. In any case, given the large number of fierce carnivores that went extinct in North America around the time of the Younger Dryas event, which would have been largely avoided by human hunters, it is probably wrong.

Finally, archaeological evidence for extensive hunting of the megafaunal species that went extinct is lacking – there is a paucity of megafaunal 'kill sites' where archaeological evidence unambiguously points to killing of an animal through human hunting[47]. Actually, the reverse hypothesis appears to hold; there are proportionately more known kill sites of animal species that did not become extinct. Overkill, it seems, is overrated.

Overchill, on the other hand, originally proposed that the ice age itself is the primary driver of these megafaunal extinctions. Supposedly, the extremely cold weather causes large animals, especially, to expire. More recent research indicates that it is not low temperatures per se that led to these extinctions, since there is little evidence of megafaunal extinctions when conditions were coldest during the last ice age. Rather, it appears that rapid changes in climate, which occur more quickly than animal adaptations or mass migrations can cope with, are the main driver of megafaunal extinctions[49]. This makes much more sense.

This view assumes the dramatic climate fluctuations we see over the last ice age, including the Younger Dryas period, are a spontaneous and natural feature of Earth's climate system. And, as you might expect given the temperature signals seen in ice core records, there is plentiful evidence of dramatic changes in habitat around the Younger Dryas period. Moreover, biochemical analysis of animal remains, including their DNA, shows these changes in climate caused severe biological stress on animals at the time[50], such as disease and starvation.

But this idea does not explain why the megafaunal extinctions were particularly severe around the Younger Dryas period, especially in North America.

To explain this observation, both ideas have been combined to produce a more powerful hypothesis. Animal populations severely compromised by rapid climate change, and the changes in habitat that naturally follow, may have been unable to resist the increasingly sophisticated hunting strategies of a growing human population, especially when people moved into new territories where the local megafauna was insufficiently wary of human behaviour. This combined view of climate stress and over-hunting appears to solve many problems with overkill and overchill alone. Megafaunal populations, although stressed by rapid changes in climate, are often able to recover in the absence of human predation. Likewise, megafaunal populations can cope with human predation between rapid climate-change events when habitats are stable. It is an appealing theory.

But even this new synthesis does not solve the whole problem. If we compare South America to Africa, for example, continents covering similar latitudes whose climates were relatively stable (at least compared to northern continents) over the last ice age, we find that South America lost far more megafauna than Africa. Yet Africa had been populated by humans for hundreds of thousands of years, whereas the overlap between human populations and megafaunal populations is difficult to establish in South America. How can this be explained? Simply suggesting the animals in Africa were more wary of human hunters won’t do. It is too speculative an idea, and doesn’t explain the extinction of many fierce carnivores. There is likely another factor, perhaps even a dominant factor, in play that has been overlooked.

And moreover, what of the cultural transitions at the time? Why did the Younger Dryas megafaunal extinction event occur at the same time as changes in human culture across the globe? How can humans have been over-hunting megafauna if their populations crashed as well? Is there a connection between these observations and the apparently special nature of the Younger Dryas climate change relative to previous Daansgard-Oeschger events? Are we missing something? These are important questions to answer. For if we do not understand the behaviour of our precious ecosystem in the past, how are we to reliably predict and control it in the future? They are also hard questions to answer, because precise data on the timing of these extinctions and changes in human culture is difficult to achieve.

It is into this lengthy and intense debate that the Younger Dryas impact hypothesis stepped, in 2007.

4

The End of Gradualism

A significant group of over sixty scientists from fifty-five different universities, known as the Comet Research Group, claim that Earth suffered a catastrophic collision with cometary debris at the onset of the Younger Dryas cold period, around 13,000 years ago[51,52]. They claim it had a dramatic influence on the biosphere, triggering the Younger Dryas period of very cold climate that lasted over 1,000 years, contributing to the extinction of many species of large animal, or megafauna, and leading to an abrupt transition in human cultures on several continents. This is known as the Younger Dryas impact hypothesis.

The evidence they have brought to light is substantial. But they have a major problem – some very vocal and overbearing critics among the scientific establishment. Mainly, these are archaeologists and anthropologists who have been engaged in a great intellectual tussle of their own over many decades about the causes of megafaunal extinctions and cultural transitions at the beginning of the Younger Dryas period. Although this academic community could not agree amongst themselves about if and why these events happened, they are even less agreeable to the notion that they had all been wrong. Their debate with proponents of the Younger Dryas impact hypothesis will be recorded in scientific history as a particularly tough fight.

In 2008 Vance Haynes of the University of Arizona, an eminent professor of archaeology and a specialist in the Younger Dryas period in North America, succinctly summed up the situation regarding a study of nearly one hundred archaeological sites across North America dating to around the time of the Younger Dryas period (the Pleistocene-Holocene transition he refers to)[36]:

> *Of the 97 geoarchaeological sites of this study that bridge the Pleistocene-Holocene transition (last deglaciation), approximately two thirds have a black organic-rich layer or 'black mat' ... with radiocarbon ages suggesting they are stratigraphic manifestations of the Younger Dryas cooling episode ... This layer or mat covers the Clovis-age landscape or surface on which the last remnants of the terminal Pleistocene megafauna are recorded. Stratigraphically and chronologically the extinction appears to have been catastrophic, seemingly too sudden and extensive for either human predation or climate change to have been the primary cause. This sudden ... termination ... appears to have coincided with the sudden climatic switch from Allerod warming to Younger Dryas cooling. Recent evidence for extraterrestrial impact, although not yet compelling, needs further testing because a remarkable major perturbation occurred at 10,900 B.P. that needs to be explained.*

Clearly, the onset of the Younger Dryas period is highly unusual. The 'black mat' he refers to is a layer of sediment that appears across much of North America, usually buried under many metres of overlying sediments and soil (see Figure 12). It can appear as either a horizontal black, grey or white streak, sandwiched between apparently normal layers of earth. Its presence indicates the landscape during the Younger Dryas period was quite unlike what we see today. Instead, much of North America must have been a flooded, damp bog for many hundreds of years, extremely inhospitable for humans and megafauna, but heaven for pond life. A similar layer is found across the Californian Channel Islands off the west coast of America, and another layer, of similar age, occurs in Belgium, where it is known as the 'Ussello Horizon'.

Haynes goes on to say in the same 2008 paper:

No skeletal remains of horse, camel, mammoth, mastodon, dire wolf, American lion, short-faced bear, sloth, tapir, etc., or Clovis artifacts have ever been found in situ within the YD age black mat, and no post-Clovis Paleoindian artifacts have ever been found in situ stratigraphically below it. ... This implies that extinction of the ... megafauna was geologically instantaneous, essentially catastrophic.

Figure 12. The ‘black mat’ at the Murray Springs archaeological site, Arizona (image courtesy of the Comet Research Group).

In other words, the black mat is a boundary layer that separates the world before the Younger Dryas period (with all its megafauna and Clovis hunters) from the world sometime after it (with far fewer megafauna and its Folsom Paleoindian population). Although the date of the top of the black mat might vary by hundreds of years depending on location, it is clear he considers the bottom of the black mat to be an essentially continuous boundary or 'horizon' that signifies an instant in time, at the very start of the Younger Dryas period, when something utterly dramatic happened.

The 'extraterrestrial impact' to which he refers is the hypothetical Younger Dryas impact event that had been proposed a year earlier by the Comet Research Group. That paper, published in the same prestigious journal (*Proceedings of the National Academy of Sciences*, or *PNAS*) by Richard Firestone, a nuclear physicist from the Lawrence Berkeley National Labs, USA, and twenty-five co-authors reads[51]:

> *A carbon-rich black layer, dating to approximate to 12.9 ka, has been previously identified at approximate to 50 Clovis-age sites across North America and appears contemporaneous with the abrupt onset of Younger Dryas (YD) cooling. The in situ bones of extinct Pleistocene megafauna, along with Clovis tool assemblages, occur below this black layer but not within or above it. ... In this paper, we provide evidence for an extraterrestrial (ET) impact event at ... 12.9 ka, which we hypothesize caused abrupt environmental changes that contributed to YD cooling, major ecological reorganization, broad-scale extinctions, and rapid human behavioral shifts at the end of the Clovis Period.*

Let's be clear about what is being said here. Firestone et al. are *not* claiming the comet impact caused the instantaneous extinction of the megafauna or the instantaneous death of nearly a million Clovis people. What *is* being claimed is this proposed impact event *contributed* to, and triggered, the climate change, extinctions and changes in human culture that followed. In other words, it was the primary cause, directly or indirectly, for later events that unfolded over many decades to hundreds of years.

In their paper, they analysed the base of the black mat at many well-separated locations across North America, finding highly unusual chemical signals within this narrow layer of sediment, including an abundance of microscopic magnetic iron grains, unusual forms of carbon or soot, and rare elements like iridium. All of these signals can be interpreted as indicating the occurrence of a cosmic impact event.

In a 2009 follow-up paper the Comet Research Group provided evidence of a layer of 'nanodiamonds' at the base of the black mat[52], at widely separated sites across North America. These microscopic diamonds are embedded within tiny carbon-rich particles, and are thought to form only at extremely high temperatures and pressures, far too extreme to have occurred naturally at Earth's surface. At first sight, the evidence appears overwhelming. And it explains a great scientific mystery, as a massive cometary impact event could potentially explain the strange pattern of megafaunal extinctions observed, as well as the change in climate and changes in human culture, at the onset of the Younger Dryas. This is one of the very nice things about this hypothesis – if it is correct it can potentially explain all the evidence at once.

You might have thought that this breakthrough would have been greeted with great acclaim and many congratulations. But this is not what happened. As already indicated, there instead followed an intense debate fought out in some of the most prestigious scientific journals. One year, the proponents would publish a killer paper, only to find the next year their opponents would publish an equally combative response.

This is only natural. You see, many scientists have worked on problems related to the Younger Dryas period for their entire careers. They know an awful lot about the response of the climate, sediments, megafauna and flora, and human cultures at this time. What is lacking, though, is an understanding of what triggered these responses, and this is where the main debate lies. It has been going on for at least fifty years, without resolution. Therefore, many scientists in this area are quite used to having a big argument – it is how they operate. They have made their careers advancing one idea, while taking shots at all the others. When a new idea comes along, they naturally all take shots at that as well. This is how science works – it is basically one great big bunfight. Ultimately, though, as the evidence hardens in one particular direction, there will be winners and losers.

But in this particular case, while the science is important, the debate is even more interesting because of the way it has been conducted. While proponents of the impact hypothesis have, in my view, behaved impeccably, their opponents have engaged in the scientific equivalent of a shouting match.

In recent years, as their shouting has grown louder and more desperate, opposition to the impact hypothesis has depended, in the main, on challenging the consistency of radiocarbon dates for the geochemical evidence. It has been claimed, several times, and with great force, that the radiocarbon dates corresponding to the different geochemical signals across several continents just don’t agree, and therefore the geochemical impact evidence has been misinterpreted. However, at best, these complaints are caused by misuse of the statistical methods that underlie all science, methods that every scientist should know like the back of their hand.

However, there is an even more fundamental reason for the liveliness of this debate. The Younger Dryas impact hypothesis threatens a scientific paradigm that has existed for over 200 years and was developed by some of science's most illustrious characters. A paradigm that is as important to Earth sciences, like geology, archaeology and anthropology, as Newtonian mechanics was to physics before general relativity and quantum mechanics turned that discipline inside-out at the beginning of the 20th century. This paradigm, known as 'gradualism', is absolutely central to this book, with a backstory going back well over 2,000 years.

Gradualism versus catastrophism through the ages

The idea that the Earth has been subject to tremendous catastrophes within the timespan of human civilisation originates with the earliest myths and religions. All over the world, and for the length of recorded history, cultures have expressed their version of a great fire, or conflagration, and a great flood, or deluge. Typically, they are associated with divine retribution, fire-breathing, flying serpents and sea-monsters, heroic battles and tales of survival. Wherever people have lived, these myths have lived with them.

In Western scholarship, the debate concerning whether these myths have some basis in reality, or instead are imagined, can be traced at least as far back as Plato and his student Aristotle, two of history's greatest philosophers. Plato recounts the destruction of Atlantis and the Phaethon myth thereby promoting catastrophism, while Aristotle argues for unchanging celestial spheres that surround Earth and support the Sun, moon and planets, thereby promoting only gradual changes on Earth, i.e. gradualism.

Plato's 4th century BC account of the Phaethon myth (see the Prologue) is especially notable for the manner of its telling. It recounts a meeting between Solon, a 7th century BC Athenian statesman and ancestor of Plato's, also known as one of the Seven Sages of Ancient Greece, and an Ancient Egyptian priest. The priest tells Solon the story of Phaethon, in which Earth is burned up by an object like the Sun, and emphasises that although this tale sounds like a myth, it is in fact based on real events. The truth, according to the priest, is that the story:

> *... signifies a declination of the bodies moving around the earth and in the heavens, and a great conflagration of things upon the earth recurring at long intervals of time ... and leaves only those of you who are destitute of letters and education; and thus you have to begin all over again as children, and know nothing of what happened in ancient times ...*

Clearly, a series of cosmic impact events separated by hundreds or thousands of years is being described, rather than, say, a series of volcanic eruptions. Even if Plato's account of Solon's meeting is fiction, which is doubtful, it is striking that anyone from this time should have such amazingly good knowledge of this mechanism of destruction. Today, such tales are generally treated with disdain within academia. Plato's catastrophism is generally thought to be no more than a fairy tale.

This modern view of catastrophism developed primarily out of the scientific resurgence in Western Europe after the Renaissance and the Middle Ages. By this time the Catholic Church had adopted Aristotle's geocentric paradigm of the sun, moon and planets supported by harmonious celestial spheres, as it supported the Christian doctrine that only God's will could cause catastrophes on Earth. But Nicolaus Copernicus, a Prussian polymath, challenged the Church's view with his heliocentric sun-centred model in 1543. Thus began the division between science and religion.

Building on Kepler's laws of planetary motion, Isaac Newton, one of the world's greatest ever scientists, published his seminal *Principia* in 1687 in which he described a mechanical universe evolving according to unchanging Laws of Motion and Universal Gravitation. Using his theory, he could provide a unified description of planetary, lunar and cometary motion, finally confirming the

Copernican heliocentric model of the solar system. But while his mechanics supported a view of fixed planetary orbits, consistent with gradualism and Catholic teachings, it also offered a catastrophic mechanism via Earth's interaction with comets. Because these rogue bodies appeared to have almost random orbits in space, it was realised there was at least a small risk that Earth could collide with them. Indeed, Newton's student, and successor to the Lucasian Chair of Mathematics at the University of Cambridge, William Whiston, proposed in 1696 that comets were responsible for past catastrophes, including Noah's flood. Edmund Halley, after whom the famous comet is named, also held this view. These developments should be seen in context. Although a separation between science and religion continued to develop, as the cracks in religious orthodoxy became apparent, many scientists were still very keen to ensure their discoveries and theories were consistent with Christian doctrine. After all, they were living in an age of religious persecution, inquisition, and witch-hunts.

James Hutton, a Scottish scientist often called the 'father of modern geology', advanced the gradualist paradigm further in 1785 through his observations and theories of sedimentation and erosion. He held that Earth's surface changed only very slowly over geological time through processes that are evident today, a concept later called 'uniformitarianism'. This was in contrast to the earlier 'flood geology' that attempted to explain geological observations in biblical terms. But Georges Cuvier, a French zoologist often called the 'father of palaeontology', did not accept the gradualist paradigm. Through his observations of sedimentary strata containing abrupt changes in the fossil record, he proposed, in 1812, a theory of mass extinctions and episodes of catastrophic change at Earth's surface.

But Charles Lyell, another influential Scottish geologist, supported Hutton's gradualist interpretation of change. In his three-volume work *Principles of Geology* published between 1830 and

1833, he argued that sudden changes in geological strata, and therefore abrupt changes in the fossil record, were an illusion generated by wholesale erosion of strata over geological timescales. Moreover, catastrophic changes required speculation about forces and mechanisms that are not currently observed, and therefore run contrary to the principle of uniformitarianism.

With a copy of Lyell's *Principles* on board the Beagle, Charles Darwin, the great Victorian naturalist, ventured to the Southern Ocean to find evidence for this theory of natural selection. After his return, a committed gradualist, he published his *Origin of Species* in 1859. This was a decisive move in favour of gradualism. There was now a mutually consistent gradualistic framework, with Newton's mechanical universe that ran like clockwork, Hutton and Lyell's uniformitarian geology, and Darwin's biological evolution. Moreover, observations of comets showed their nuclei were quite small, and there were too few of them to provide a threat to Earth on the timescale of human civilisation. Depending on your point of view, this universal framework either supported the Christian doctrine, since great catastrophes could now only result from God's will, or made it redundant, since there was no need for God at all. In either case, cometary impacts were ruled out, and a chasm opened up between science and religion.

The gradualistic paradigm solidified further well into the 20th century with the discovery of genetics and then DNA. Darwin's theory of evolution through natural selection was now firmly established. Although it still did not demand a gradualistic basis, Darwin's support for gradualism was very influential. That gradual changes in the biosphere were not reflected in the fossil record did not seem to matter. Confirmation of the slow creep of continents in the mid-60s, i.e. continental drift though plate tectonics, provided further support to the gradualistic paradigm, and another mechanism for the diversification of species. Gradualism ruled supreme.

The intervention of Immanuel Velikovsky only served to reinforce this dominance. On the basis of his expertise in Freudian psychoanalysis, and by comparing ancient worldwide myths, in 1950 he proposed there had been major catastrophes on the timescale of human civilisation, and also proposed a revisionist version of history to account for them. By themselves, these ideas were worthy of debate. However, he coupled his theory with a non-physical, or impossible, mechanism – that part of Jupiter had been ejected as a comet, and collided with Earth before being transformed into Venus. While not taken seriously by the academic community generally, his ideas took hold within the public imagination.

But by 1980, it became clear that near-Earth space was, in fact, teeming with asteroids with a wide range of sizes. And impact craters on the moon and inner solar system planets confirmed a similar impact history must hold for Earth, even if craters on Earth remained relatively elusive. Moreover, a new synthesis of Darwin's evolution had recently been developed to account for the abrupt changes seen in the fossil record, which it was now realised were not in fact an artefact of slow geological processes. This was important because it recognised that a complete theory of biological evolution must cater for mass extinctions followed by rapid bursts in evolution. Although great cosmic catastrophes were not thought necessary by most, at the time, to explain these rapid changes, the tide had clearly turned.

Everything changed in 1980 when the geologist Walter Alvarez, with his Nobel Prize-winning father Luis and others, proposed a massive asteroid impact at the Cretaceous-Tertiary boundary that ended the age of dinosaurs, around 66 million years ago. Their evidence was compelling, especially a global iridium anomaly at the geological boundary. Since iridium is a very rare metal on Earth, the discovery of a thin dusty layer of it at the base of a highly visible geological boundary right around the globe indicates only one thing – a massive explosion caused by an iridium-rich extraterrestrial object, a comet or asteroid, that dispersed vast amounts of iridium-laden dust into Earth's atmosphere. When the Chicxulub crater, at 180 km in diameter and 66 million years old, was located off the Yucatan peninsula of Mexico in 1990, the case was practically confirmed. Earth was under threat after all, and catastrophism via cosmic events was revived.

Today, the academic debate has moved on to the causes of major catastrophes and extinction-level events, and, in particular, the relative importance and correlation between cosmic impact and massive volcanism. But the possibility that more recent extinction-level catastrophes could have occurred within the timespan of human civilisation as a result of cosmic impacts is generally thought to be negligible, and usually dismissed.

This, despite the famous Shoemaker-Levy 9 event of 1994 in which a comet impacted Jupiter. This comet, fragmented by Jupiter's tidal forces into a long string of over twenty large pieces, collided with Jupiter to produce many intense surface explosions, each large enough to have devastated Earth's biosphere, over the short space of a few days. I remember the hubbub this event caused in the University of Bristol's physics department where I was a doctoral student at the time. Many powerful telescopes, including the Hubble Space Telescope whose optics had recently been fixed, were trained on the event. Images of the bright fireballs and the blackened spots they left behind on Jupiter's surface, each about the size of Earth, are easy to find on the internet.

Once again, this event challenged the prevailing gradualistic view: here was a massive collision of a comet with a planet of the solar system within our own lifetime. Clearly, these events could no longer be considered exceptionally rare, at least for Jupiter. Gradualistic views were no longer tenable, you might think, as cosmic catastrophism had been proven to occur. But, of course, Jupiter's massive gravity places it at special risk of bombardment and the same risks simply don't apply to Earth. Indeed, one can argue that Jupiter shields Earth from such violent events by ‘mopping up’ errant comets.

To summarise the debate, until the 1970s science had provided the ammunition to separate itself from the catastrophes of myth and religion. But over the next quarter-century a rapid reversal occurred with the realisation that i) the fossil record really does exhibit abrupt extinctions followed by rapid bursts of evolution, ii) near-Earth space contains millions of hazardous bodies, and iii) such catastrophic impacts have been observed on Jupiter in our own lifetime.

Despite all this, the possibility that human civilisation could have been significantly affected by such events is still denied by many to the present day. Although a risk on the timescale of millions of years is recognised, it is generally considered implausible that a global cosmic catastrophe could have occurred over the last, say, ten or twenty thousand years. There are just too few asteroids and comets currently known in near-Earth space to provide a significant threat. We would need to have been very unlucky indeed for an extinction-level event to have occurred so recently.

The Younger Dryas impact hypothesis throws all of that in the air. It challenges the central view of gradualists head on. No longer are cataclysmic cosmic events on Earth extremely rare – according to this impact hypothesis they can happen in our own backyard, within the timescale of the rise of human civilisation even. Darwinian biological evolution still occurs, of course, as does the slow change of landscape on geological timescales. But superimposed on this is the ‘noise’ of violent upheavals, of widely varying magnitude and extent, at irregular intervals, leading to sudden changes in sedimentation, sudden changes in the populations of all manner of animals (including extinctions), and possibly rapid changes in speciation. One might think that catastrophism could easily be accepted as a slight modification to the purely gradual perspective, a simple tweaking of the dominant paradigm. And indeed, this appears to be the case with the largest catastrophes, like the dinosaur-ending one 66 million years ago, which have been accepted. But the possibility that more frequent catastrophes can happen with a wide range of impact magnitudes, and that they are also important, is hard to accept. The reason is that by admitting the more frequent, but less severe, catastrophes can take place, the question that immediately follows is 'Well, which is more important – gradual evolution or violent catastrophe-induced change? Which process has the dominant influence?' This question is anathema to evolutionary biologists who are loath to cede any ground in case creationists try to reoccupy it.

Others can deal with these difficult issues, and, in any case, they are a little premature at this stage. Let's focus on the Younger Dryas impact hypothesis itself, and the great debate it prompted. The full story of this debate is sufficient for a book, or two, by itself. So here I will only cover some of the main twists and turns of this highly charged intellectual spectacle. But before I do go into these details, I should introduce the related topics of the Tunguska Event, and radiocarbon dating, as these play a central role.

The Tunguska Event

Only just outside of living memory, there is an example of the kind of event which is thought to have triggered the Younger Dryas period. When I was young, I remember finding the Tunguska Event of 1908 fascinating. At the time, it seemed nobody had an explanation for why thousands of square kilometres (an area twice the size of Greater London) of Siberian forest had suddenly been flattened, the levelled and burnt tree trunks stripped bare and all pointing in the same direction (at least locally). To all intents and purposes, it looked like an atomic bomb had been dropped on the forest. A real mystery for a young lad to get stuck into.

Of course, the reality is that the Tunguska Event was already known by experts to be caused by an exploding meteorite of some description. Only the details of the event, its precise magnitude and the exact nature of the offending bolide (meteoric fireball) were debated. Was it an asteroid or piece of a comet? The debate still goes on in the research literature, but probably the dominant view now[53-55] is that it was caused by a moderately sized chunk of comet, perhaps as large as 100 metres in diameter, that exploded in an airburst at an altitude of around 8 kilometres. Its downward momentum caused the resulting fireball to target the forest below, like a great blast of dragon breath, without leaving much in the way of a crater. Due to the remote location, it is thought nobody actually died in the event, although eyewitness accounts within the extensive blast range are quite terrifying.

The date of the impact, 30th June, and its apparent direction of travel suggest it was likely caused by a chunk of comet originating from the Taurid meteor stream, one of many such streams we see on Earth. But other evidence is apparently conflicting. A small crater at the bottom of a lake in the blast zone together with signs of meteoric fragments suggest to some that it was instead caused by a stony asteroid[56], rather than a fragile cometary fragment. But at the same time this doesn't rule out a cometary origin, particularly as we know little about the composition of objects from this meteor stream. For example, other reports concerning meteoroid remains after smaller airbursts in recent times thought to be caused by Taurid objects suggest that they have an unusual composition, somewhere between a typical comet and an asteroid[57,58].

The issue here is that large and dense stony asteroidal meteors can punch their way through Earth's atmosphere, and normally explode only when they hit the ground, forming a crater. Cometary meteors, on the other hand, are far less dense and much more fragile, and therefore are unable to penetrate all the way through the atmosphere, unless they are very large, at least several hundred metres across. Instead, smaller comet fragments tend to explode high in the atmosphere, as an airburst.

Altogether, evidence that the Tunguska explosion was caused by a comet fragment from the Taurid meteor stream is rather good, but probably not yet decisive. Its size has been inferred from seismic records at the time of the explosive event as well as computer simulations of the airburst and resulting damage on the ground. At about 100 metres, it represents the largest object known to have impacted Earth in the last century or so. But in the grand scheme of things, it is really quite a small object. There are hundreds of thousands of other objects of at least this size in similar orbits out there in near-Earth space. We are fortunate the Tunguska bolide landed in a remote area, so that human injury was relatively low, and yet evidence of the encounter is accessible. If it had landed over a major city, like London, that city would cease to exist. If, on the other hand, it had happened over the Pacific Ocean, we might not ever have noticed.

At around ten megatons of TNT, the magnitude of the Tunguska explosion is often compared to around 1,000 Hiroshima bombs, or about as large as the most powerful nuclear warhead that ever existed. Collision with a larger object, say 1 kilometre in diameter, would have generated an explosion around 1,000 times larger again, i.e. one million Hiroshima bombs. It's hard to imagine the scale of such an event, but this is the kind of energy scale that has been proposed for the Younger Dryas impact event.

Radiocarbon dating

Radiocarbon dating, invented in the 1940s, is a method of determining when an organism died[59]. It is based on the principle that living organisms continually refresh the carbon content of their bodies, through eating or breathing, until they die. Plants 'breathe in' carbon dioxide via photosynthesis, while animals eat plants and other animals. Therefore, all the carbon in our bodies ultimately comes from the atmosphere, principally in the form of carbon dioxide, and exists as several naturally occurring isotopes, mainly carbon 12 and carbon 13, but also a tiny amount of carbon 14.

While carbon 12 and carbon 13 are stable, carbon 14 is radioactive, with a half-life of around 5,730 years. Importantly, there is a more or less fixed proportion of carbon 14 to carbon 12 in the atmosphere that is regulated by several natural processes, including the atmosphere's interaction with cosmic rays. Therefore, our bodies contain the same proportion of carbon isotopes as the atmosphere, at least as long as we are alive. And because of the carbon 14 (among other elements), we are all radioactive, just a little bit. But, once a living organism dies – when a plant stops photosynthesising or an animal stops eating – the ratio of carbon 14 to carbon 12 within it steadily reduces, due to radioactive decay of the carbon 14 atoms. This ratio can be measured by very sensitive instruments, and then converted into a time since death.

This technique has become a mainstay for historical researchers, including archaeologists and anthropologists, and it earned its inventor, Willard Libby, a Nobel prize. However, it is not without its problems. The main issue is that the ratio of carbon 14 to carbon 12 in the atmosphere has not always been exactly the same – it can vary by small amounts for a range of reasons. This means that the ratio of carbon 14 to carbon 12 within a dead organism does not depend solely on the time since its death – it also depends on the precise ratio of carbon 14 to carbon 12 in the atmosphere at the end of its life, and this ratio is not known with absolute precision. To overcome this problem, radiocarbon dating methods use a 'calibration curve', which converts the uncorrected, or raw, radiocarbon age into a calibrated, or true, radiocarbon age.

Now, these calibration curves are determined by comparing the measured radiocarbon ages of various samples with estimates of their true age determined by other more reliable methods. For example, the true age of dead trees can be determined accurately by counting tree rings, and by matching tree-ring patterns across a wide range of tree samples a chronology based on tree rings can be developed (this is known as dendrochronology). Alternatively, the sediment in lake bottoms can build up in annual layers, known as 'varves', which can also be counted accurately. A calibration curve constructed in this way from counting tree rings and lake varves will become more and more accurate as more and more samples are used to define it.

Importantly, this calibration curve can be used to date the carbon of any sample that was once alive (up to a maximum age of around 50,000 years – the method loses accuracy beyond that). For example, it is not possible to analyse the tree rings in a tiny sample of wood charcoal, yet it can still be radiocarbon dated.

Now, one problem with this approach is that these calibration curves are never straight lines. They always exhibit kinks, known as 'radiocarbon reversals', where it can happen that samples that are actually getting older can be measured as getting younger. These kinks are particularly large precisely around the time we are most interested in, the Younger Dryas period. Even worse, the uncertainty, or error, in the calibration curve is larger around this time. This is because there is a lot of variation in the raw data, like tree rings and lake varves, from the Younger Dryas period used to construct the curve. In fact, the radiocarbon dates of lake varves can disagree with the radiocarbon dates of tree rings by over 500 years at the onset of the Younger Dryas period. This suggests there was a great upheaval in the biosphere at this time[60].

Moreover, and importantly, it is always the case that a raw, or uncalibrated, radiocarbon age will also include a degree of uncertainty in its measurement that must be included in a final calibrated age estimate. That is, we must 'propagate' the uncertainty, or error, in our raw radiocarbon age via the calibration curve through to the true calibrated age.

Consider it this way. Suppose you are driving to a friend's new house for the first time. They give you a postcode which narrows down its location to within, say, 50 metres. Now, you know this small inaccuracy of 50 metres will make little difference to your travel time. Much more important is the distance from your town to theirs, say 100 kilometres, and how much traffic there is. You try to estimate how long it will take you to get there. Do you even consider the 50 metre uncertainty caused by the postcode? No, of course not, in this case it makes no real difference.

For some radiocarbon dating measurements we have the same issue. The uncertainty in a sample's true age can be dominated by the uncertainty in the raw uncalibrated radiocarbon measurement, and not by the uncertainty caused by the calibration curve. Therefore, both types of uncertainty must be properly accounted for in the final estimate of uncertainty of the true age. It is here where opponents of the Younger Dryas impact hypothesis have often come unstuck – they sometimes neglect to do this, and therefore make incorrect conclusions. Considering they are professional scientists, I find this astonishing.

Another key problem with radiocarbon dating is mixing of sediments. Very often, archaeologists like to create 'age-depth' models of the sediment in which they find artefacts. They do this by collecting and radiocarbon dating samples from a wide range of depths in a sediment sequence. They can then infer the age of any artefact from its depth in the sediment. But this presumes there has been no significant turnover or mixing of sediments of different ages. Normally, this is a reasonable assumption, as during quiescent periods layers of soil and sediment build up over time, and therefore the age of sediment increases steadily with depth. However, during a tumultuous period of catastrophic destruction, with rapid changes of climate, as proposed by the impact hypothesis, the possibility for significant ground disturbance is naturally increased, which raises additional problems with radiocarbon dating and development of sedimentary age-depth models.

The overall outcome is that radiocarbon dating should be used with particular caution for Younger Dryas age sediments. Similarly, age-depth models generated from radiocarbon samples should be interpreted with great care for this period.

5

The Great Debate

The debate surrounding the Younger Dryas impact hypothesis encompasses many research areas, from demography (study of populations) to glaciology (study of glaciers). But ultimately, it is not evidence of large animal or human population collapse, or climate change, or glacial debris that will determine whether a comic impact event occurred at this time, as these effects are not 'diagnostic' for such events. These effects might have been generated by other mechanisms. To discover whether a cosmic impact occurred at the beginning of the Younger Dryas period, or the YD 'boundary' as it is known, we should consider the geochemical evidence, which consists of unusual chemicals or materials remaining in the ground, as this is diagnostic.

Normally, a large asteroidal impact will leave a crater, even if the impact occurs into an ocean – the crater will be in the seabed in this case. No crater has yet been confirmed at the YD boundary, although there are a few known structures of interest to the Comet Research Group that proposed this hypothesis. Another clear sign of an asteroidal impact is 'shocked quartz'. These are grains of quartz that are deformed in such a way that only a very high-pressure explosion, like an asteroid impact or nuclear detonation, can explain their presence – they are not created by volcanoes, for example. None has been found within the black mat layer at the YD boundary. The lack of both an obvious crater and shocked quartz has therefore often been used to deny the Younger Dryas impact hypothesis. But this reasoning is incorrect.

As we know, the Tunguska Event left neither an obvious crater nor any shocked quartz, and yet was clearly a very destructive impact event. Instead, the Tunguska explosion is thought to have occurred high in the atmosphere, as an airburst. If the Younger Dryas event involved multiple Tunguska-scale airbursts, perhaps thousands of them, spread across several continents, then it too would leave little in the way of obvious craters or shocked quartz, and yet still lead to immense destruction. Alternatively, an impactor somewhat larger than the Tunguska bolide crashing onto an ice sheet several kilometres thick, like the Laurentide ice sheet that covered Canada at the time, would also neither leave an impact crater in the ground below or generate any shocked quartz. The ice sheet would shield the ground below it, provided the impactor was not too large, and the ice crater formed would then melt away leaving little evidence of an impact in the ground below. This scenario has been suggested by the Comet Research Group. It is entirely possible, even likely, that the largest comet fragments impacted an ocean, in which case a crater could easily have remained hidden. Therefore, the current lack of a confirmed crater or the absence of shocked quartz in the Younger Dryas black mat does not rule out a major impact event.

Instead, to determine whether the Younger Dryas impact event occurred, we should seek the kind of geochemical signals left behind by Tunguska-like airbursts at the YD boundary. Three lines of this kind of diagnostic evidence are the presence of iridium-enriched magnetic grains, nanodiamonds and high levels of platinum group metals, such as platinum itself or iridium, which is also found in abundance at the dinosaur-killing K-T boundary.

Magnetic grains, often too small to see with the naked eye, can be formed from iron, common in asteroids and comets, vaporising at very high temperature, in a massive explosion for example, and then condensing into microscopic magnetic iron droplets, like water condensing as rain. If formed within a cometary airbust they would be flung through the atmosphere for great distances, creating a carpet or layer of fine magnetic grains over a large expanse of

Earth's surface. It is known they can also be created by other mechanisms, such as the burn-up of small meteorites and cosmic dust in the upper atmosphere, as well as heavy industry and internal combustion engines in modern times. However, magnetic grains enriched with a rare metal like iridium, and which under a microscope also display a patterned (framboidal – raspberry-like) surface texture due to rapid cooling (quenching) of the iron, can only have originated from the burn-up of small meteorites or a large meteoric explosion. Therefore, a sudden large peak, or abundance, in a layer of sediment of iridium-enriched magnetic grains with framboidal surface patterns is considered diagnostic of a bolide impact, since other sources should be relatively constant over time.

Likewise, nanodiamonds are thought to form within carbon-rich droplets condensing from vaporised carbon generated by a high-temperature and pressure explosion. Asteroids and comets can be rich in carbon, and a cosmic impact might create the conditions required for the formation of carbon droplets containing nanodiamonds. Alternatively, nanodiamonds are common within some asteroids and comets[61], which means an impact event would simply distribute them over a large patch of Earth's surface. Therefore, a sudden large peak in nanodiamonds within sediments also very likely indicates a comet or asteroid strike.

Lastly, platinum-group metals (like platinum and iridium) are rare in Earth's crust, but not so rare in asteroids and comets. Therefore, an abundance, or spike, of a platinum-group metal within a sediment layer is a very good indicator of an extraterrestrial event. This indicator can be spread very widely around the globe carried within fine dust particles created by the impact explosion. There is really no alternative mechanism for producing a platinum-group metal-enriched layer of dust over a large patch of Earth's surface, other than via a cosmic event like a comet impact, especially if it coincides with an abundance of nanodiamonds and magnetic grains. Importantly, an abundance spike of platinum-group metals has been found in a layer of peat bog at the epicentre of the Tunguska explosion[62].

All three of these lines of diagnostic evidence have been found at the YD boundary by the Comet Research Group, and confirmed by several independent research groups. Independent verification of the evidence by research groups unconnected with the Comet Research Group is crucial. It means the evidence is real, and not mistaken. If other researchers could not find these signals, they must have been doing something wrong.

The presence of iridium-enriched magnetic grains at the Younger Dryas boundary was confirmed at one site, Murray Springs, New Mexico, in 2010 by Vance Haynes and co-workers[63]. A detailed geochemical analysis of these magnetic grains by another research group shows they are not only of extraterrestrial origin, but must also have been formed by a cosmic impact[64]. This is revealed by their chemical composition, with abundant rare metals, and framboidal surface pattern, likely caused by rapid cooling.

The presence of nanodiamonds at the Younger Dryas boundary was also confirmed by an independent research group in 2010, within a thin layer of Greenland ice sheet[65]. The nanodiamond signal is very clear – over a million times background levels, and this time the nanodiamonds are not only embedded within other forms of carbon – they are also found as very tiny individual isolated diamonds, and therefore their analysis is much easier. It was even possible to identify different crystalline forms of nanodiamond, including one that can only form under very extreme conditions, pointing very strongly towards an extraterrestrial impact.

A nanodiamond abundance peak was also confirmed[66,67] in the Ussello layer at Lommel, Belgium, which is thought by proponents of the impact hypothesis to be an extension of the Younger Dryas black mat. And another black mat site in Mexico, within lake-bottom sediments at the Younger Dryas boundary[68,69], was found to contain an abundance of both nanodiamonds and magnetic grains with framboidal surface patterns.

In 2014, the nanodiamond layer at the YD boundary was found by the Comet Research Group to span the Americas through to Europe as far as Abu Hureyra, just south of Göbekli Tepe, in West Asia[70] – see Figure 13. Clearly, this event was huge, and could easily have had global consequences.

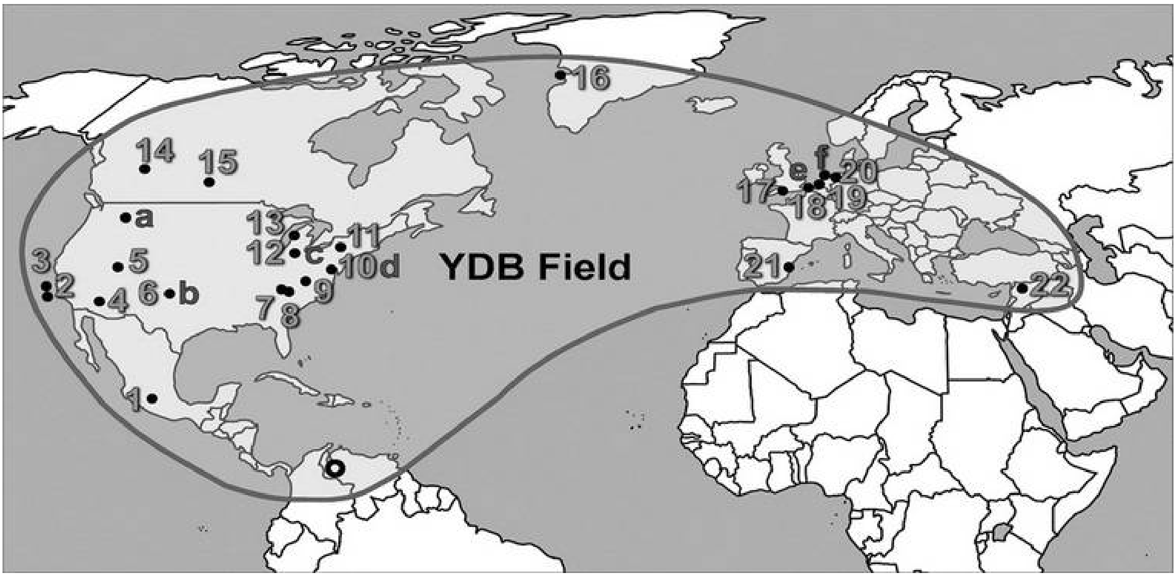


Figure 13. The YD boundary (YDB) nanodiamond field, showing the range of sites at which nanodiamonds have been found (image courtesy of the Comet Research Group[70]).

Regarding platinum-group metals, high-resolution analysis of the GISP2 ice core from Greenland reveals a clear and substantial platinum anomaly occurs around 10,940 BC (according to the ice core chronology) at the beginning of the Younger Dryas cold period[71] (see Figure 14). This shows that the Younger Dryas mini ice age was, very likely, triggered by a cosmic impact – the timing of the platinum spike and the onset of climate change is practically coincident within the resolution of the data. Furthermore, this 2013 work shows that the impactor was platinum-rich, and the platinum signal is sharply defined in time. This means that similar sharply defined platinum layers should occur more widely – perhaps much more widely. This was the ‘smoking gun’ of the Younger Dryas impact and the hunt for a global platinum anomaly began. Soon after this discovery was made, abundance peaks for iridium, platinum and another rare metal, ruthenium, were also found in a sediment core from a lake bed in North West Russia[72] consistent with the Younger Dryas boundary.

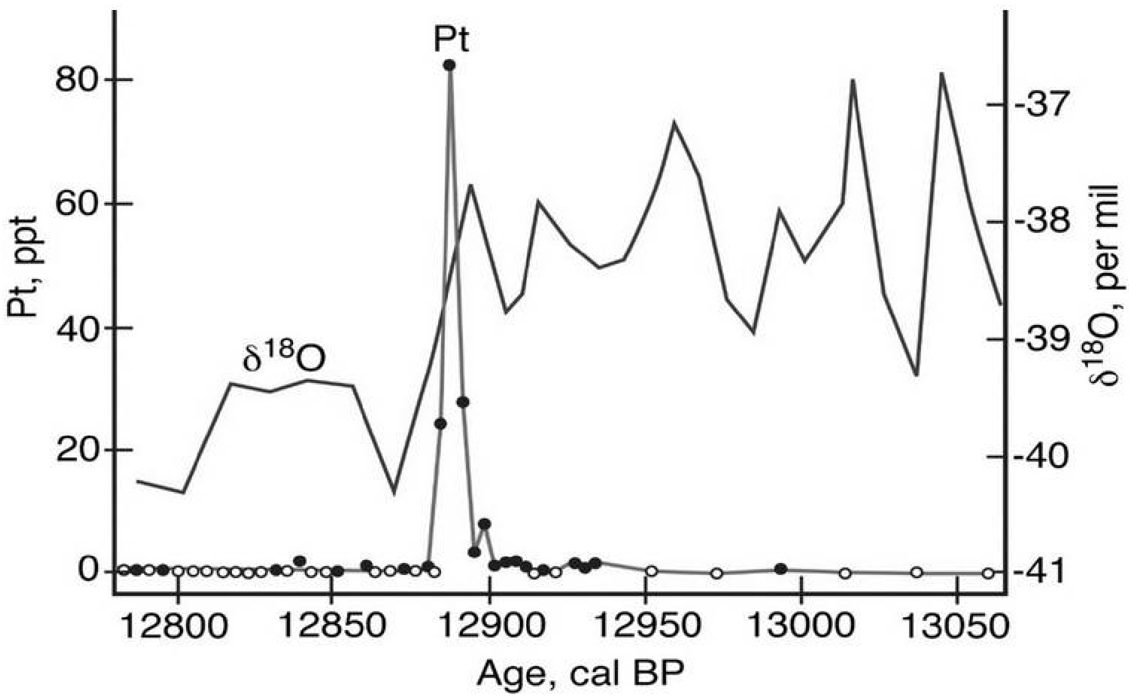


Figure 14. Platinum anomaly and oxygen isotope trace in the GISP2 Greenland ice core. Notice how the platinum spike occurs precisely when the oxygen isotope trace plummets. The date 12,890 cal BP translates to 10,940 BC (adapted from Petaev et al.[71]).

Finally, in 2017, the platinum anomaly at the Younger Dryas boundary was extended to the whole of the North American continent by the Comet Research Group[73]. At several sites, the platinum layer occurs together with nanodiamond and magnetic grain abundance peaks. Like the iridium abundance peak at the dinosaur-ending K-T boundary, this widespread platinum abundance peak essentially clinches the case.

A Flawed Defence

To begin with, soon after the impact hypothesis was published in 2007, its opponents made their own measurements of the geochemical signals at the YD boundary. They published several reports that claimed the signals either did not exist or had been misinterpreted. But finding these signals is a fairly difficult exercise. It requires great care and laborious attention to detail to get the experimental procedures just right, as often these signals are quite weak and, more importantly, difficult to accurately locate in the sediment. Taking a sample of sediment just one inch too high, or too low, relative to the boundary layer, can yield negative results. Likewise, using the wrong method to separate out the chemicals to be analysed from the sediment can also lead to negative results. Therefore, it is quite easy to miss the boundary layer entirely and claim a negative result, and it appears some of the work by opponents of the impact hypothesis falls into this category.

By 2011, before the platinum anomaly was discovered, opponents of the impact hypothesis thought they had enough contrary evidence to refute it. Nicholas Pinter especially, a professor of geoscience from UC Davis, considered the Younger Dryas impact hypothesis dead and buried. With his co-authors, he published a paper glibly titled *The Younger Dryas Impact Hypothesis: A Requiem*. In their summary they state:

> *... none of the original YD impact signatures have been subsequently corroborated by independent tests.*

While this was true for some work performed by opponents of the hypothesis, it was not true more generally, even in 2011. A peak in iridium-enriched magnetic grains had been confirmed at Murray Springs in 2010 by Haynes et al., and an abundance of nanodiamonds had been confirmed at the YD boundary by two other research groups, in Greenland ice[65] and a Belgian black mat[66].

Nevertheless, Pinter et al. continue:

> *... In all of these cases, sparse but ubiquitous materials seem to have been misreported and misinterpreted as singular peaks at the onset of the YD. Throughout the arc of this hypothesis, recognized and expected impact markers were not found, leading to proposed YD impactors and impact processes that were novel, self-contradictory, rapidly changing, and sometimes defying the laws of physics. The YD impact hypothesis provides a cautionary tale for researchers, the scientific community, the press, and the broader public.*

Now these are strong words, and unwarranted. It seems to me that this paper is an overreaction – an attempt to 'brow-beat' the academic community and silence proponents of the Younger Dryas impact hypothesis. It is essentially the academic analogue of shouting, and a signal that gradualism is under threat. Pinter, a hydrogeologist who specialises in the science of water erosion, is no doubt a big believer in this paradigm.

The following year, archaeological researchers from Leiden University confirmed a nanodiamond abundance at the base of the

Ussello Horizon in Belgium, but they did not associate it with the YD boundary because radiocarbon dating of the sediments pointed towards an event slightly after the accepted time of the Younger Dryas event. However, a close look at the size of the uncertainty in their radiocarbon measurements shows that their conclusion is flawed – their data is actually entirely consistent with a Younger Dryas boundary origin[74]. This is poor quality science.

Then, in 2014 after the platinum anomaly in Greenland ice was discovered, the same research group from Leiden published another critical review of the impact hypothesis evidence to date[75]. Once again, they questioned the radiocarbon dating of YD boundary age sediments in various locations, suggesting the data indicates multiple impact events spread out over hundreds or thousands of years, rather than one large event in the space of a few hours across several continents. But, just as before, it is actually quite obvious from inspecting the uncertainty in their radiocarbon dating measurements, which spans many hundreds to thousands of years, that they have got this wrong again. It appears this group of archaeologists don't understand how to properly interpret uncertainty in experimental measurements. In particular, they do not seem to understand how to 'propagate' experimental errors.

Accurate dating of YD boundary age sediments is also the main concern of David Meltzer in May 2014. He is professor of anthropology from the Southern Methodist University, Texas, and a leading proponent of the overchill hypothesis of megafaunal extinctions. His research group analysed radiocarbon dating measurements collected from twenty-nine sites across three continents, stating in their abstract[76]:

> *Proponents of the YDIH state that a key test of the hypothesis is whether those indicators are isochronous and securely dated to the Younger Dryas onset. They are not. We have examined the age basis of the supposed Younger Dryas boundary layer at the*

29 sites and regions in North and South America, Europe, and the Middle East in which proponents report its occurrence. Several of the sites lack any age control, others have radiometric ages that are chronologically irrelevant, nearly a dozen have ages inferred by statistically and chronologically flawed age-depth interpolations, and in several the ages directly on the supposed impact layer are older or younger than similar to 12,800 calendar years ago. Only 3 of the 29 sites fall within the temporal window of the YD onset as defined by YDIH proponents. The YDIH fails the critical chronological test of an isochronous event at the YD onset, which, coupled with the many published concerns about the extraterrestrial origin of the purported impact markers, renders the YDIH unsupported.

Now, this is quite a definitive statement. Despite all the geochemical evidence in support of the impact hypothesis at this time, Meltzer's group, much like the Leiden archaeologists, are adamant that the dates of various YD boundary sites are not in agreement. However, once again, a close look at their data, buried in the 'supporting information' section of their work, shows their calculations are plain wrong. In some cases, they neglected to include the uncertainty in their raw, uncalibrated radiocarbon dating measurements in their final estimate of uncertainty – that is, they failed to propagate the error properly. In other cases, they simply neglect to mention the uncertainty in their measurements at all. As any good scientist knows, a measurement without an estimate of uncertainty is meaningless. This is because, without saying how likely a result is to be within a certain range, it could actually be anything whatsoever – which is meaningless information.

So, the problem is purely one of their own invention. Again, this is poor science that should have been filtered out by the peer-review process and should now be corrected or withdrawn. It seems this kind of mistreatment of experimental uncertainties is commonplace in the archaeological and anthropological research community, and points to a problem in training their young researchers.

Not content with this distortion, Meltzer contributes, the same year, to a highly critical follow-up, *The Younger Dryas impact hypothesis: a cosmic catastrophe*[77]. However, reading beyond the over-assertive title reveals this paper has no new data to offer regarding the three diagnostic indicators of interest to us. Essentially, this paper is another sign of the threat to gradualism, and its proponents are becoming increasingly desperate.

However, in 2015, perhaps prompted by this radiocarbon dating controversy, a proper statistical analysis of Younger Dryas sedimentary sequences is published by the Comet Research Group[78], from which a date for the event of 10,835 BC, to within 50 years at the level of 95% confidence, is established. This means the geochemical evidence is consistent with a single event between 10,785 and 10,885 BC.

At face value, this range of dates appears to be somewhat inconsistent with the platinum spike in the GISP2 ice core discovered in 2013, shown in Figure 14, which is dated to 10,940 BC. But, in fact, this is not the case, as it is known[79] that the chronologies of Greenland ice cores and radiocarbon calibration curves differ by around 70 years at the end of the Younger Dryas period. In other words, the number of ice layers counted in Greenland ice cores differs from the number of sediment layers and tree rings that contribute to the radiocarbon calibration curve by about 70. This difference is caused by problems in precisely identifying ice layers or tree rings in each case. Subtracting 70 from 10,940, or adding 70 to 10,835, according to which chronology you prefer, shows that these dates are actually in very good agreement, within the quoted uncertainty of 50 years. Although there are complaints from some[80] that this contradicts the earlier work of Meltzer et al., as is now clear, that work was itself horribly flawed from a scientific perspective.

This appears to have settled the matter. There have been no further reports since 2015 that dispute the Younger Dryas impact hypothesis on the basis of new physical evidence for these three types of geochemical signal. Meanwhile, evidence in its favour continues to accumulate.

A Series of Unfortunate Events

In their 2011 'Requiem' paper that attempted to debunk the Younger Dryas impact hypothesis, Pinter et al. provided their own evidence concerning magnetic grains. They analysed sediment sequences from several Californian Channel Islands that span over 15,000 years from the end of the last ice age, around 17,000 BC, through to the Bronze Age, around 2,000 BC, each containing multiple layers that resemble black mats. They found high abundances of magnetic grains within all the black layers. Likewise, in July 2012, another research group confirmed that magnetic grains, this time enriched with iridium, are abundant within many different black mats from the south west of the USA and the Atacama Desert in Chile, not just the YD boundary black mat[81].

But, none of these researchers concluded in favour of the impact hypothesis. Quite the reverse. Apparently, according to these authors, iridium-enriched magnetic grain-loaded black mats can occur through normal terrestrial processes, such as filtering by wetland bogs. In other words, a bog, if and when it develops, can concentrate these unusual geochemical signals which, it is claimed, can occur naturally.

This is another excellent example of the uniformitarian principle in action. It is a real problem that continues to infect archaeology and anthropology academics. Explanations for evidence that do not fit their preconceived gradualistic views are automatically discarded. In fact, it is worse than that because these researchers provide explanations that do not fit the evidence. For example, they do not explain what produces these geochemical markers in the first place. They don't just appear out of thin air. And as there are obviously no boggy layers of sediment in Greenland ice, this idea cannot explain the occurrence of nanodiamonds and platinum there.

Clearly, their conclusions are not secure since, logically, it could be the case that there have been many cosmic impact events over this period, each producing the same kind of black mat. In fact, we already know that, because of their chemical composition and framboidal surface pattern, the magnetic grains found at the YD boundary at the bottom of the black mat at Murray Springs could *only* have been formed by an extraterrestrial impact[64]. This important result does not seem to have registered with opponents of the impact hypothesis.

The more logical conclusion, then, is that there have probably been many extraterrestrial impact events at different times and locations across the globe over many tens of thousands of years with a wide range of magnitudes, including the massive Younger Dryas event around 10,900 BC, although none of them appear to have left a crater or any shocked quartz. So, far from providing evidence to dispute the Younger Dryas impact hypothesis, these research groups have actually given it more ammunition. All one needs to do is treat the uniformitarian hypothesis with due scientific scepticism and accept that cosmic airbursts do not necessarily lead to craters or shocked quartz, as demonstrated by Tunguska.

Summary

The decade-long debate described above is probably not over. It is a classic example of how the academic community in general fights against paradigm shifts in understanding. But, the totality of the geochemical evidence found to date is difficult to explain except in terms of a massive cosmic impact event at the onset of the Younger Dryas period. The platinum anomaly at the base of the Younger Dryas black mat is especially important, as it shows the case for the impact hypothesis is correct beyond reasonable doubt. There is no alternative explanation for its appearance, coincident with the other indicators. It has been detected by three independent research groups across North America, Greenland and north-west Russia. It seems likely that it will extend much further than this. Moreover, Greenland ice-core data shows there was only one event of this kind within a few hundred years of the beginning of the Younger Dryas period, and that it occurs right at the beginning of the extreme cooling.

The geochemical evidence for multiple cosmic impact events over the Holocene and the preceding ice age is also very interesting as a potential explanation for some of the earlier Daansgard-Oeschger events and megafaunal extinctions. Indeed, the Comet Research Group has recently discovered that huge mounds of megafaunal remains, often called ‘boneyards’, preserved in Alaskan and Yukon permafrost near the Arctic Circle show every sign of having been wiped out in this way[82]. They found these jumbled animal remains lay heaped and broken within sediments enriched in magnetic grains and platinum, likely resulting from a cosmic impact. Radiocarbon dating provided dates for several distinct catastrophic events between 16,600 and 46,000 BC. Very interestingly, similar boneyards are found in Siberian permafrost.

This begs the question, are there further platinum signals corresponding to these other events in ice cores? Could we generate a global history of cosmic airbursts from analysis of the platinum group metal signatures in ice cores and ancient sediment sequences? Probably, this would be a fruitful avenue of research.

Conventionally, in line with the uniformitarian principle, the Younger Dryas cooling is thought to have been caused by a switching of Laurentide ice sheet meltwater flow from a southern route into the Caribbean to an easterly route (and possibly other routes as well) into the North Atlantic, resulting in a change in important ocean circulation currents. But it appears that, by itself, this cooling mechanism is probably insufficient and the Younger

Dryas cooling likely requires a degree of atmospheric dusting. A cosmic impact event appears to fit this evidence very nicely.

But, before concluding in favour of the Younger Dryas impact hypothesis we need to deal with another line of evidence that has been used to deny it. One particular scientist, Mark Boslough, a specialist in high energy impact physics from Sandia National Labs, New Mexico, is a frequent critic[83-85]. He has claimed, quite bizarrely, it even violates physical laws. Despite clear geochemical evidence now in its favour, he stated a cosmic impact event could not possibly produce such an extensive range of debris (across at least three continents) and yet not produce an obvious crater, being less than 13,000 years old. In particular, he states:

> *No physical mechanism is known to produce an airburst that would affect the entire continent.*

He is assuming here that the event is caused by a single impactor. A single impactor will only explode as an airburst (and therefore not leave a crater) if it is relatively small – too small to affect the whole continent of North America. But while this view is probably correct for a single impactor, it does not apply to multiple Tunguska-like impactors which could be spread across several continents. But on the issue of multiple impactors he states:

> *Moreover, the probability of the fragmented comet impact event specified by the hypothesis is infinitesimal, about one in 10^{15}. The combination of proposed size, configuration and trajectory of the putative impactor is exceedingly unlikely to have occurred together as a single event in the entire history of the Earth.*

Now these are strong and definitive statements from a world-leading expert in impact physics. He is essentially claiming that asteroids and comets don't travel through space together – so it is practically impossible for Earth to encounter more than one of them at the same time. And because even a single impactor of the required size is very rare, the possibility of encountering two or more of them simultaneously is vanishingly small.

But is he right? Is it really implausible that the Younger Dryas event could have been caused by multiple impactors? Do comets and asteroids always travel through space alone as single bodies? And, what has this got to do with physical laws? Are there really too few comets and asteroids to be considered a realistic threat over the timescale of civilisation? What evidence is there for this?

If Boslough is correct, it throws the Younger Dryas impact hypothesis into disarray. Despite all the geochemical evidence in its favour, we would need to think again. The problem is, the evidence fits the impact hypothesis so well, and there doesn't seem to be any reasonable alternative. To address these serious concerns, we need to investigate the astronomical evidence, and in particular, the latest developments in cometary science.

6

Comets vs Asteroids

Did a huge cosmic catastrophe occur around 10,900 BC that wiped out many large animal species, brought the world to its knees, and triggered a mini ice age? Regardless of myths and legends, this question can only be definitively answered by science, based on evidence and logical deduction.

We saw in Chapter 5 that geochemical evidence points very strongly towards this view, although precise details of the event are elusive. It is not clear what kind of object, or objects, caused the destruction, and the impact it had on climate, megafauna, and human cultures continues to be debated. Furthermore, the impact hypothesis has been challenged, mainly by Mark Boslough, on the grounds that an event involving multiple impacts spread across several continents even defies the laws of physics. This view contends that comets and asteroids orbit the inner solar system alone, without any accompanying debris. They cannot team up in pairs or swarms of fragments. This is an odd position to take, since we all know that the Shoemaker-Levy 9 impacts in 1994 on Jupiter were caused by a long train of fragments resulting from the splitting of the parent body. But Boslough denies this can happen within the inner solar system, and therefore to Earth.

If he is correct on this point, then the implication is that the Younger Dryas impact event was likely caused by a single impactor – a single comet or asteroid. But to have caused the massive destruction implied by all the geochemical evidence, it must have been rather large – so large that we should expect to find an obvious crater along with shocked quartz. To date, none have been found.

Then, there is the more general view that even one large impact event is unlikely to have occurred on Earth over the course of, say, the last 10 to 20 thousand years, because there are not currently enough objects of the required size in near-Earth space. The next most recent extinction event thought to have been caused by a cosmic event is the dinosaur-killing impact 66 million years ago. So, how could such an apparently rare event as the Younger Dryas impact event have occurred so relatively recently? And in any case, this proposition contradicts the uniformitarian view that is so popular in academia, even today.

But, notice the assumption here: that near-Earth space has not changed appreciably over the course of human civilisation. Is it true that the number of large objects, i.e. asteroids and chunks of comet, that we observe right now near Earth has been the same for tens of thousands of years? Is it possible there were many more comet fragments, for example, 10 or 20 thousand years ago? What evidence is there for this? How quickly can Earth's cosmic environment change?

The area of research that deals with these questions appears to be rather unpopular. Few are working on these problems. But one group of determined British scientists has made considerable progress, despite a relative lack of interest from research funding agencies. They are led by Bill Napier, an astronomer and cometary scientist, and Victor Clube, an astrophysicist, both formerly professors at the universities of Edinburgh and Oxford. Over the last forty years, their small group of British neo-catastrophists has pioneered a new view of Earth's place in the solar system. Their vision is startling, and a wake-up call for the rest of us.

But before I outline their theory of terrestrial catastrophism, which commonly goes by the name of 'coherent catastrophism', we should review a few basic principles first, namely the nature of minor bodies of the solar system, and their orbits.

Orbits and their Precession

The orbits of solar system planets are not circular. They are all very slightly elliptical, or squashed. Because of this, they all have a specific direction in which their orbits point. If we imagine a line connecting the two most widely separated points of an orbit, and call this the orbital axis, then for any given orbit this line could be pointing east-west or north-south, or any direction in between.

Neither do the planets all orbit in the same plane – the solar system is not flat as a pancake. If we use Jupiter's orbit to define the plane of the solar system, as it is the most massive body (other than the Sun, of course), then all the other planets' orbits are slightly inclined with respect to it. Imagine someone trying to hula several hoops at the same time – planetary orbits are a little bit out of kilter like this.

Nor is any orbit fixed for all time, because every orbiting body in the solar system is influenced by the gravity of every other orbiting body. As there are no exact mathematical solutions to this problem (for three interacting bodies or more) and as there are an unknown number of such bodies in the solar system, we cannot know the precise orbit of any solar system object indefinitely far into the future, just as we cannot forecast our weather on Earth indefinitely far into the future. Orbits are chaotic on very long timescales.

The most stable orbits in the solar system belong to the most massive objects: the major planets, especially Jupiter. These are, therefore, the main gravitational perturbers of the orbits of smaller bodies, and usually it is sufficient to consider only their influence on other solar system objects. By taking the gravitational effect of the sun and these eight planets into account, the position of any other object orbiting the sun can then be forecast, either forwards or backwards in time, with computer simulation methods, just like making a weather forecast.

If only things were this simple. In addition to the gravitational effects of the sun and the major planets, an orbiting body is also subject to non-gravitational forces, such as viscous drag due to dust in the solar system. That's right, space is not entirely empty – it is filled by very low-concentration dust and gas, which drags on any object that moves through it. We do not need to go into the physical details of each type of non-gravitational force – they are many and complex. It is sufficient to know that the magnitude of all these non-gravitational effects combined depends on the body's surface area, whereas gravity depends on the body's mass and therefore its volume. So, for very large bodies (planets and large asteroids) we can generally ignore these surface forces, because gravity wins out. Gravity dominates for large bodies. But, as an object's size decreases, its surface area increases relative to its volume, which means these surface forces come to dominate the smallest bodies, especially microscopic dust.

We therefore know that the orbit a body follows depends largely on its size. A large dense body, such as a huge asteroid, will follow an orbit that is almost perfectly elliptical. But, the gravitational effects of the planets, especially Jupiter, will cause this elliptical orbit to evolve – it will not follow the same elliptical orbit for all time – it will precess. This means the direction in which its elliptical orbit points, defined by its orbital axis, changes very slowly.

Two types of orbital precession are important for our story (see Figure 15). The first is apsidal precession, also called precession of the perihelion. Imagine a flower head at the top of a stalk with one elliptical petal that points in a particular direction. The outline of the petal represents an elliptical orbit. Now imagine this petal slowly rotating around the flower head, even though the flower head is held fixed. This is like an elliptical orbit slowly undergoing apsidal precession, even though the plane in which the orbit resides is fixed. Now imagine twirling the stalk between your fingertips so that the whole flower head, which is inclined, rotates. This is like another kind of orbital precession known as nodal precession, or precession of the longitude. Here, the plane in which the elliptical orbit resides slowly rotates.

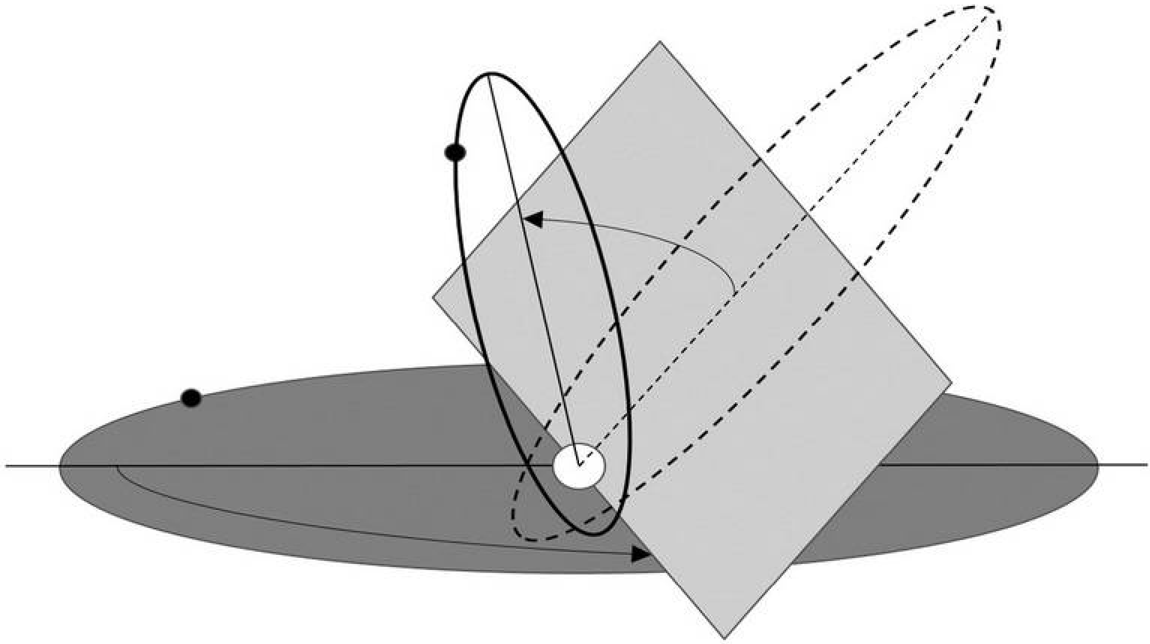


Figure 15. Earth's orbital plane is shaded dark grey. The orbit of an asteroid or comet is represented by the thick black line. Apsidal precession (upper arrow) causes the direction of its elliptical orbit, or axis, to rotate around the Sun within the same fixed plane, shaded light grey. Nodal precession (lower arrow) causes the entire orbital plane, in which the asteroid or comet's orbit resides, to rotate around the sun.

The orbits of smaller bodies influenced by non-gravitational forces are even more complex. They too follow orbits that precess, but due to the non-gravitational forces acting on them they gradually become less elliptical, and more circular. The smallest particles, microscopic dust grains too small to see with the naked eye, are dominated by non-gravitational forces, and so their orbits are quite unstable. Depending on their size, they are either drawn in towards the Sun, where they are consumed, or are driven outward by the solar wind, generated by the sun, towards interstellar space.

Comets

Apart from the sun and its eight planets and their moons, there are a multitude of smaller bodies in the solar system. The most well-known and studied (other than Pluto and its moons) are the asteroids of the main belt that take nearly circular low inclination orbits between Mars and Jupiter. The main asteroid belt, a diffuse orbiting ring of asteroids, defines the outer limit of the inner solar system, comprising the terrestrial planets, Mercury to Mars. There are many thousands of large asteroids in the main belt, yet its total mass is only around half that of Charon, Pluto's largest moon, and nearly one-third of that is in Ceres, the largest main belt asteroid with a diameter of around 950 kilometres. The asteroids are generally distinguished from comets by their composition, with asteroids being mostly dense rock and metal, with some organic compounds and a little ice. They are found mainly within the inner solar system.

Comets, on the other hand, are generally composed of ices (a mixture of many volatiles, including water, carbon dioxide, carbon monoxide, methane, ammonia, etc.) and organic compounds, similar to oil and soot, with smaller amounts of rock and metals. They are like huge fluffy, dirty snowballs found mainly in the outer solar system or beyond.

Comets form in the outer solar system beyond Jupiter where it is cold enough for these ices to condense from the very low concentration of vapour in space, like frost condenses on cold car windscreens overnight. The very outermost comets are thought to form a very diffuse spherical cloud, known as the Oort cloud, which surrounds the solar system out to vast distances, perhaps halfway to the nearest star. Although there could be billions or even trillions of large comets out there, we cannot see any of them from Earth even with our most powerful telescopes – they are just too small and far away. But, we know they must be there, because occasionally they are knocked into the inner solar system, where they can be seen.

If they are only slightly nudged, for example by the weak gravitational pull of a distant passing star or by the viscous drag of an interstellar dust cloud, comets in the Oort cloud can fall into the outer and inner solar systems. Those that, after many thousands of years of drifting inwards, eventually reach semi-stable orbits in the outer solar system, between Jupiter and Neptune, are called Centaurs. Those that enter the inner solar system are called period comets – with short (less than 200 years) or long (longer than 200 years) period orbits. Additionally, some are called sun-grazing comets if they approach the sun very closely. But these comets don't tend to last very long – perhaps only a few thousand years before they decay completely to dust.

The Jupiter family of comets are short-period comets whose aphelion (largest distance from the sun) is not far short of Jupiter's. The aptly named Apollo and Aten objects are those short-period comets that cross Earth's orbit, so that their perihelion (closest distance to the sun) is inside Earth's orbit, while their aphelion (furthest distance from the sun) is outside Earth's orbit. Because of apsidal precession, these orbits will eventually intersect Earth's orbit, by definition. This will happen four times every complete cycle of apsidal precession – twice as the orbit precesses below Earth's orbit and twice more as it precesses above (see Figure 15). Encke-type comets are those specific Apollo objects that have orbits similar to comet Encke, a comet of particular importance to our story.

Not all comets in the inner solar system have orbits that cross Earth's; some remain entirely within Earth's orbit while others remain entirely outside it, although eventually strong gravitational interactions with the terrestrial planets can cause them to become Earth-crossers.

Very rarely, both comets and asteroids can collide with each other, to produce fragments of, generally, a smaller size. The orbits of these fragments will depend on the details of the collision – they can be quite different to those of the parent bodies. Comets can also decay via outgassing if they are close enough to the sun. Typically, comets within the inner solar system, where it is warmer, will outgas, while those in the outer solar system, where it is much colder, will not. Outgassing is just the reverse of the process by which they formed. The volatile ices, warmed by the sun in the inner solar system, evaporate (or more precisely, sublimate) away into space.

The closer a comet approaches the sun, the warmer it becomes and the more gas it releases. As a comet is held together by these volatile ices, when the ice evaporates other particles are also released, mainly dust and larger pebbles. Due to the dominance of non-gravitational forces, the smallest dust particles and gas released do not follow the same orbit as the comet; instead they appear to form the comet's tail which points away from the sun due to being blown outwards by the solar wind. However, larger pebble-sized fragments released by a comet, which are not so strongly influenced by non-gravitational forces, can follow similar trajectories as the comet, only slowly diverging from it over many orbits. In this way, comets can form trails of larger stones and boulders. Observations of short-period Jupiter-family comets show that most of them have trails[86]. To be clear, comet 'tails' and 'trails' are quite different. Their tails are composed of gas and tiny dust particles and point away from the sun, while their trails are composed of pebbles and larger boulders and are spread out along the comet's orbit.

Asteroids, being composed mainly of solid rock and metal, normally have neither tails nor trails, and they reflect sunlight reasonably well. They therefore have a fairly high albedo (reflectivity). Pristine comets arriving from the Oort cloud that have not yet come close enough to the sun to begin outgassing have surfaces mainly composed of ices and organic compounds. They too have a reasonable albedo. As the possibility of detecting a comet or asteroid directly via optical astronomy depends simply on its apparent size and albedo, which determines how much sunlight it reflects into our telescopes, the largest asteroids and pristine comets can be located with careful observations and not a little luck. The smaller or more distant the object, or the lower its albedo, the less chance of spotting it.

Of course, when comets first enter the inner solar system and begin to form a tail as they are warmed, they become much easier to spot, as the tail can be immensely long with a high albedo. In fact, there are even historical reports of large comets passing close to Earth being visible in the daytime[87]. But, if a comet orbits within the inner solar system for a very long time, such as an Encke-type comet, or if one approaches the sun very closely, such as the sun-grazer comets, it can release much of its volatile surface ices and eventually lose its tail. It is thought the remaining organic compounds, along with remaining dust, at the comet's surface can then form a dark and thick layer, like a coating of tarmac or pitch. This surface can have a very low albedo, making these particular 'dormant' comets unreflective and hard to pick out against the night sky, even if they are large. This is not to say the comet is completely de-gassed, and therefore dead or extinct. Rather, the surface layers only are de-gassed and quite unreflective, while the comet's interior can remain in a reasonably pristine state. Quite strangely, dormant and extinct comets can be some of the darkest objects in the solar system[88,89].

As observations of comets have steadily improved it has become clear they can also decay through more sudden and disruptive processes. Outbursts appear to be relatively common for Jupiter-family comets, perhaps occurring nearly every orbit near perihelion (when the comet is closest to the sun). It is generally thought these outbursts are caused by a build-up of gas pressure under the surface of the comet, which can form a consolidated crust, or skin, as it is warmed. Rather like a volcano, or tyre blowout, the pressure can build sufficiently to cause a sudden rupture in the comet's surface, which later heals as its surface cools again when it moves past perihelion. A particularly spectacular outburst from comet Holmes occurred in 2007 near perihelion, causing the comet to brighten massively for many days[90]. Millions of tonnes of gas, dust and larger fragments were ejected at a wide range of velocities (up to 1,000 kilometres per hour for the smaller particles) in the shape of a conical explosion in the general direction of the sun.

It is now known that comets can also undergo splitting, where they disintegrate completely into multiple large fragments[91]. Around twenty individual splitting events have been recorded for Jupiter-family comets within the inner solar system in the last few decades. Although the cause of these splitting events remains unknown, in most cases it cannot have been caused by tidal forces (where a small orbiting body is gravitationally stretched due to one side being closer than the other to a large body, like the sun) since the comets concerned were not close enough to the sun to be disrupted. Although it was Jupiter's tidal force that split comet Shoemaker-Levy 9 before it crashed into Jupiter in 1994, a different mechanism must account for the splitting of Jupiter-family comets within the inner solar system.

For example, Figure 16 shows comet Schwassmann–Wachmann 3 after splitting into several dozen fragments in 2006, and a close-up of one of the fragments taken by the Hubble Space Telescope. The fragment upper left is trailed by a series of smaller fragments. Debris from outbursts and splitting events, like the debris from outgassing, will follow an orbital path depending on its size. The tiniest dust and gas particles form tails, while larger particles will add to, and thicken, the trail.

Very old debris streams that have been decaying for thousands of years can be very broad. Eventually, once the whole stream has completed an entire cycle of apsidal precession, a roughly circular ring, or doughnut, of debris is created which contains within it denser elliptical trails[92], which themselves contain dense nodes or cores that contain the largest comet fragments. Often, it is difficult to distinguish between the large fragments and the 'haze' or coma of smaller debris and dust that surrounds them.

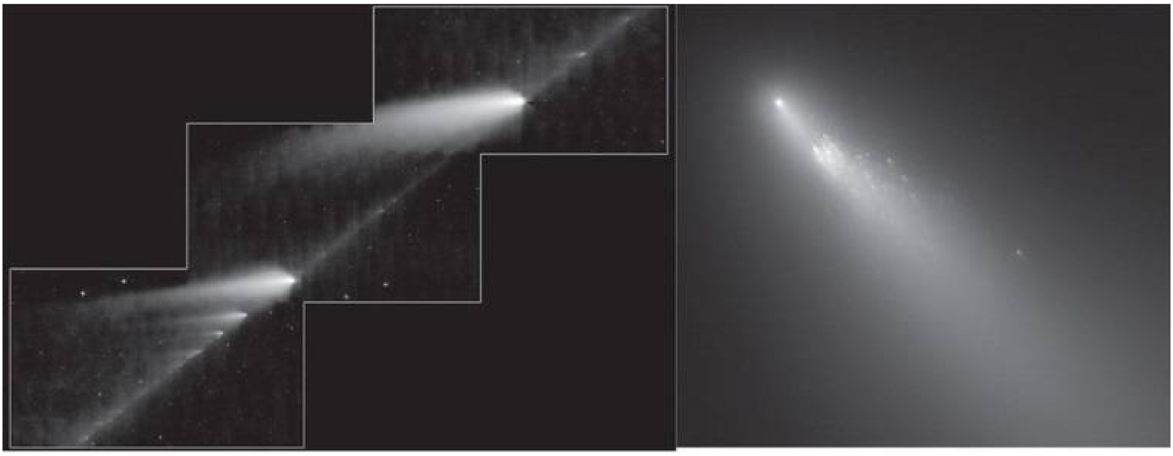


Figure 16. Left: The splitting of comet Schwassmann-Wachmann 3 in 2006, observed with the Spitzer Space Telescope (image courtesy of NASA/JPL-Caltech/W. Reach (SSC/Caltech). Right: Close-up of one of Schwassmann-Wachmann's larger fragments, observed with the Hubble Space Telescope (image courtesy of NASA, ESA, H. Weaver (APL/JHU), M. Mutchler and Z. Levay (STScI)).

When Earth intersects a cometary debris stream a meteor shower is observed to radiate from a specific direction in the sky, depending on the apparent velocity of the stream relative to the Earth at the point of intersection. For a broad debris stream the radiant (i.e. the point in the sky from which a meteor shower appears to radiate) can appear to move across the sky each night as the Earth continues on its orbit. Very many meteor showers are known, including the Piscids, Taurids, Leonids, Orionids, Geminids, and so on. They are observed at different times of year, with a range of intensities, according to when the Earth intersects their particular debris stream.

Each Apollo-type comet can create a meteor stream observable from Earth, because all Apollo-type comets are Earth-crossers. Two notable examples include the Taurid meteor stream, which is thought to have arisen from disintegration of comet Encke[93,94], or from a progenitor comet which ejected Encke's comet as a large fragment thousands of years ago, and the Leonid meteor stream, which is thought to be caused by disintegration of comet Tempel-Tuttle. As denser regions of a comet's debris trail precess, the intensity of a meteor stream observed from Earth can be seen to wax and wane over many centuries.

The gas and smaller particles of dust to which the entire comet will eventually decay, unless it is flung out of the inner solar system via gravitational slingshot around a planet or it collides directly with a planet or large asteroid, will diffuse throughout the inner solar system. Each grain of dust reflects a little light, just like that in a dusty sunlit room, and altogether this dust reflects enough sunlight to be just visible to the naked eye at dawn or dusk under favourable conditions. This spectacle is known as the Zodiacal Dust Cloud, which forms a hazy triangle of light distinct from the Milky Way (see Figure 17). As the dust lies in the plane of the inner solar system, it appears to envelop the planets, which, as seen from Earth, move along a line in the night sky that projects from Earth's surface, known as the ecliptic.

Figure 17. The Zodiacal dust cloud observed with ESO's La Silla Observatory in Chile (image courtesy of ESO/Y.Beletsky).

Until about ten years ago, it was generally thought that the zodiacal dust cloud resulted mainly from collisions between asteroids in the main belt. Because the main asteroid belt is considered a very old structure – as old as the solar system – the zodiacal cloud was thought to be more or less unchanged over the same period. But recently it has become clear that this is wrong. Measurements of many kinds now show it is mainly composed of cometary dust, and that most of this dust must be produced by the decay of comets within the inner solar system. If the dust were mainly asteroidal we would expect to find a higher concentration of dust near the main asteroid belt. But space missions that have traversed the asteroid belt show this is not the case. Also, the dust swept up by Earth is found to be most similar to the dust collected directly from cometary comas by several space missions. Overall, around 90% of zodiacal dust in the inner solar system is thought to originate from Jupiter-family comets that decay entirely within the inner solar system.

With this understanding of how comets orbit and decay within the inner solar system it is easy to counter Boslough's main point. He is quite wrong to suggest small bodies of the solar system always orbit alone. Perhaps he was thinking only of asteroids. Comets, on the other hand, and their trains, orbit the inner solar system in broad bands that generate the meteor streams we see on Earth. Within these broad bands are denser regions, which themselves contain clumps, or swarms of debris. Being an expert in impact physics, knowledge of cometary science is fundamental to his own research, so his position on this is surprising. Quite possibly, his Fellowship of the Committee for Skeptical Enquiry (CSE) had caused him to overreact to the Younger Dryas impact hypothesis and ignore the latest cometary science. The CSE, a private organisation, is dedicated to debunking unscientific claims of the paranormal, UFO kind, and includes among its fellows many famous scientists, such as Richard Dawkins and Steven Weinberg. In general, I support its aims, as I am a strong advocate of evidence-based scientific enquiry. But, for whatever reason, it seems to have become involved in the debate surrounding the Younger Dryas impact hypothesis, which is a long way outside its remit as this debate is proper science. But this just shows how contentious this matter is – any proposal that threatens the uniformitarian paradigm is considered by some to be so ridiculous that it is placed in the same ballpark as ghosts and fairies.

An encounter by Earth with a swarm of small comet fragments can be just as damaging as an encounter with a single large fragment, if similar amounts of energy are released by the collision. Consider, for example, the damage caused by a fierce sandstorm. As the energy released by a cosmic impact depends on the total mass of all the material encountered, it doesn't matter whether the swarm consists of one large fragment or many small fragments. But the details of the encounter will differ, including any geochemical signals, because that energy is released in different ways at different heights in the atmosphere. Very large fragments, over a few hundred metres in diameter, will likely punch through the atmosphere and impact the ground, creating a crater and shocked quartz, while smaller fragments will generally explode as airbursts, leaving a geochemical calling card that depends on their composition and the height at which they explode. Provided these smaller fragments are spread out in a swarm broader than a single continent, then the kind of geochemical evidence so far detected at the base of the Younger Dryas black mat can be expected. Figure 16 suggests this scenario of collision with a fragmented comet train is entirely reasonable.

But what about Boslough's other argument that we must address – are there sufficient large bodies in near-Earth orbits to have threatened Earth over the course of civilisation? How likely is an impact of the size suggested for the Younger Dryas event?

By the 1980s it had become clear near-Earth space was teeming with asteroids that posed a threat to Earth, and some of them were large enough to cause a global extinction event. Also, Alvarez et al.'s 1980 proposal of the dinosaur-killing asteroid had caught the public's attention; the threat from space had become more than just an academic issue. Several astronomy projects across the world began focusing their telescopes on near-Earth space to try and catalogue the threat.

By the early 1990s politics had got involved, with the US administration setting up the Spaceguard committees, tasked to report on the threat of near-Earth objects and what to do about them. David Morrison, formerly a Professor of Astronomy at Hawaii observatory and then a career scientist at NASA, chaired the 'detection' committee. His committee's 1992 report to US Congress was very influential, and set the tone for future debates. It recommended significant funding for a coordinated search effort using new telescopes across the world. The focus was squarely on spotting near-Earth objects in Earth-crossing orbits which, at the time, were thought to mainly be asteroidal.

The 1994 Shoemaker-Levy 9 impact on Jupiter provided much-needed funding impetus, and within the last decade the Spaceguard committee's initial aims have been realised. Their target of cataloguing 90% of near-Earth objects larger than 1 kilometre in diameter in Earth-crossing orbits, considered large enough to bring an end to civilisation if we encounter any of them, has been achieved. More recent plans aim to catalogue much smaller bodies in near-Earth space.

According to the best data we have from Spaceguard-linked searches[95] using advanced telescopes, including some with thermal imaging cameras that can spot even very dark objects by detecting their weak heat signature, it appears an event of the size proposed for the Younger Dryas impact hypothesis is unlikely. From the relatively small number of objects detected larger than 1 kilometre in diameter (there are around 1,000 of them) it seems that the chance of a collision with an object of this size over the last 20,000 years or so is quite low. Not impossible, of course, just fairly unlikely – perhaps just a few per cent.

But this conclusion only considers collisions with single large objects. It neglects entirely the possibility of collisions with comet swarms composed of smaller objects that might not yet have been spotted. And, moreover, it assumes near-Earth space has not changed much over this time. Crucially, we now know that this last assumption is almost certainly wrong. It appears that 20 to 30 thousand years ago, or perhaps more, a giant comet around 100 kilometres across entered the inner solar system, and by now has largely decayed to dust, leaving behind the Taurid meteor complex and comet Encke, as well as many other large bodies in Earth-crossing orbits.

The Taurids

The Taurids are a broad and diffuse meteor stream that, as seen from Earth, occur around early November, radiating from the direction of Aries and then Taurus. It is not currently the most intense or spectacular – there are many other meteor streams that can lay claim to that title. But the latest observations show that it is by far the most massive. It only appears weak because it is spread out so thinly in space, because it is so old. In fact, it has spread so much that the Taurids are thought to be only the main sub-stream of a much broader meteor complex that also includes several other meteor streams, seen from Earth at different times of the year and radiating from different points in the sky.

Although consisting mainly of small grains that create the commonly seen shooting star, the Taurids occasionally throw larger boulders at us that create significant fireballs[96]. These are sometimes called ‘Halloween fireballs’, and indeed, this association might be very ancient. The main night-time streams consist of two broad branches, the Northern and Southern Taurids, which appear respectively just above and just below the ecliptic, which describes the plane of the solar system in which the main planets orbit.

Although the Taurids peak in the direction of Aries/Taurus in November, weaker influx from this broad trail can been seen for several weeks before and after. The Taurids also occur during the summer months, peaking around mid-June, in the daytime from the direction of Taurus and Perseus. These showers, the beta-Taurids and zeta-Perseids, are not usually visible to the naked eye, as they occur during daytime, but they can be detected by radar. They are actually the same Taurid meteor stream as the night-time ones – the different timing and apparent direction being due to Earth intersecting the Taurid stream twice at different points in its orbit[88].

It has long been thought that these main Taurid meteor streams are associated with comet Encke[93,94], which has a similar orbit. Almost certainly, they are the debris produced by fragmentation of comet Encke, or by its parent comet – its progenitor. In its current orbit, Comet Encke is occasionally just bright enough to be observed by the naked eye on a very clear night. Although of reasonable size, thought to be around 5 kilometres in diameter, it currently has only a weak tail, presumably because much of its surface is dormant and not outgassing. Perhaps its surface is mostly covered with a thick and dark crust. Encke, like the Taurid meteor stream more generally, resides in a low inclination orbit with high eccentricity – it is very elliptical. Most importantly, it is a short-period comet whose orbit straddles Earth's. Its perihelion (closest approach to the sun) is close to Venus while its aphelion (furthest distance from the sun) is way beyond Mars – it is therefore also an Apollo object, which makes it a threat to Earth.

As for all small bodies within the inner solar system, Encke's orbit precesses due to gravitational interactions with the major planets, especially Jupiter. Every time Encke is near aphelion, far beyond Mars, it is pushed or pulled a little bit by Jupiter. And the cumulative effect of this, summed over many orbits, is orbital precession. The direction in which its elliptical orbit points, its axis, completes an entire cycle of apsidal precession roughly every 6,000 years. This means that, because its orbit straddles Earth's, their orbits intersect four times every 6,000 years.

Of course, being a small object in the vastness of space, we do not expect a collision between Encke and Earth at these times, since both Earth and Encke can be anywhere along their orbits when their orbits intersect. But on average, if we didn't know in advance where Encke is along its orbit, then four times every 6,000 years there would be a chance they might collide, albeit a very small chance.

But, of course, Encke is not just an isolated comet. Remember, it is probably surrounded by a halo of debris, as for most comets in the inner solar system, that has dispersed along its orbit. And remember too, that Encke is likely to be just one of the largest fragments embedded within a broad meteor complex, the Taurids, that contains thousands, or perhaps even millions, of Tunguska-sized fragments. So, while we do not expect to collide with Encke itself, there is a realistic prospect of colliding with another object within the Taurid meteor stream.

We know this, because we already encounter the Taurid meteor stream on a regular basis – we see the Taurids on Earth twice a year. But currently, we only encounter a weak and diffuse portion of the stream consisting mainly of small grains of dust and larger pebbles. But in time, denser filaments embedded within the larger complex that contain larger objects will undoubtedly precess into Earth's path.

It was because of this periodicity in risk, and the likelihood of multiple impacts with many fragments at once, that the phrase 'coherent catastrophism' was coined to describe this kind of cosmic impact risk[97,98]. There will be certain extended periods when fireball activity associated with Encke and the Taurids is expected to peak.

If any of these fireball swarms are sufficiently large and/or intense they could have cataclysmic consequences for Earth's biosphere. The question, central to this book, is whether this was the cause of the Younger Dryas event?

Encke-like near-Earth Asteroids

A link between the Taurid meteor stream and comet Encke was proposed nearly seventy years ago by one of the founders of modern cometary science, Fred Whipple, a professor of astronomy at Harvard. He originally proposed that at least a portion of the Taurid meteor stream was formed by a fragmentation event involving Encke some 5,000 years ago, with another portion formed by a fragmentation event around 1,500 years ago[93,94].

Then, in 1984 while working at the Royal Observatory in Edinburgh, Victor Clube and Bill Napier suggested that several large apparently asteroidal bodies might be linked with the Taurids[99] – they might be outgassed or dormant fragments of an ancient progenitor comet. Of course, true asteroids cannot be linked with comets since they form in different regions of the solar system. But dormant comets with a thick crust that no longer sport a tail can appear rather like asteroids, and, indeed, it is now suspected that many near-Earth asteroids are actually dormant or extinct comets[100].

Since then, several groups have studied patterns, or correlations, in the orbits of some large near-Earth bodies and meteor streams, and today it is accepted that most, and probably all, meteor streams can be linked with a comet, whether currently active or dormant. In many cases, these meteor showers are linked with an object that is currently designated as an asteroid, because it doesn't appear to have a cometary tail. But these supposed asteroids are almost certainly dormant comets that over many years have fragmented and degassed to produce a meteor stream and corresponding asteroid-like large body. It appears the convention is that these cosmic bodies are classed as asteroids until proven cometary.

But, this consensus has been achieved only in the last few years. Even as recently as 2007, it was still argued by some cometary scientists that most of these large near-Earth bodies associated with meteor streams are more likely to have originated from the main asteroid belt, and are therefore true asteroids. This view was reinforced by the apparent colour of these objects: many seemed to have surface colours resembling main belt asteroids more closely than comets[101]. But the truth is, we simply do not know enough about the surface chemical composition, and hence colour, of dormant comets to confidently assign them to any particular class of object, and therefore we cannot decide their cometary or asteroidal ancestry on this basis alone[102].

The most notable contribution to this line of work for our story is Napier's seminal 2010 paper *Palaeolithic extinctions and the Taurid complex*[103]. In it, he argues that an ancient and very large comet entered the inner solar system, probably over 20,000 years ago, and has since decayed largely to dust, leaving behind the Taurid meteor complex along with a host of large, dormant comet fragments and comet Encke.

He searched the database of all known near-Earth objects, which has been compiled from many Spaceguard-related telescope searches, and selected from it only those objects whose orbits have a similar size, inclination and eccentricity to comet Encke. He then examined the 'longitude of perihelion' of all these objects. Suppose you were to look down vertically at the solar system so that you were no longer aware of the height of any orbit. In other words, suppose you 'projected' all orbits onto the plane of the solar system. You can then choose a reference direction in this plane, with the sun at the centre, and measure the angle the perihelion of an orbit (the point on an orbit closest to the sun) makes with that reference direction. This is the longitude of perihelion of the orbit.

Now, if the objects shortlisted by Napier are unrelated to comet Encke, there should be no pattern, or correlation, in their longitudes of perihelion. They could have originated from any direction in the solar system, and we should find a nearly even distribution of longitudes for these objects. But this is not what he found. Instead, he found that, of the brightest, and therefore presumably largest, twenty of these objects, nineteen of them (including Encke) have similar longitudes of perihelion. I have repeated his analysis using the most up-to-date database of Apollo asteroids, and his conclusion continues to hold (see Figure 18).

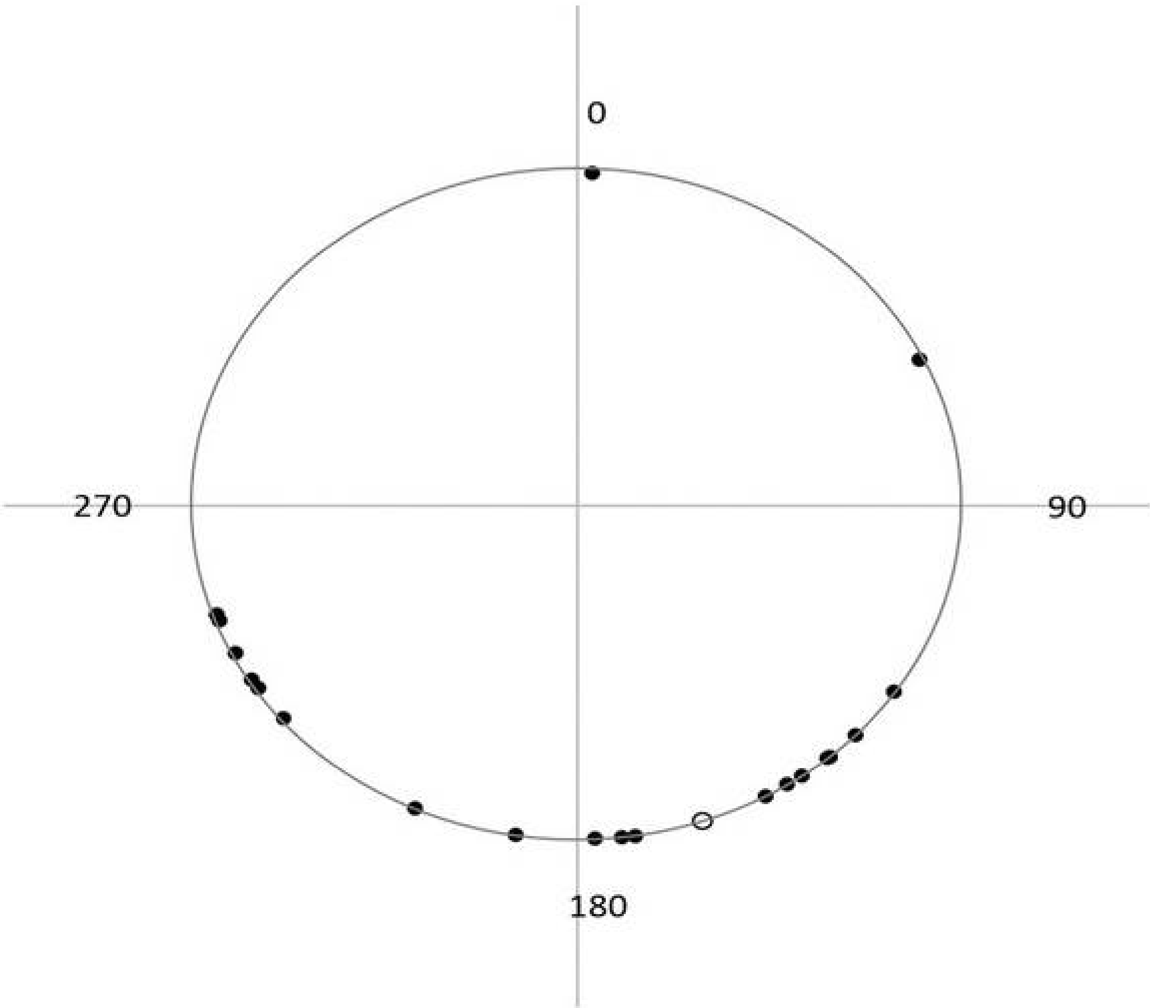


Figure 18. Longitude of the perihelion of the 20 brightest ‘asteroids’ in Encke-like orbits. Although longitude is unconstrained in this search, we see that it is clustered around 190 degrees – indicating these bodies are related. Encke is the open circle at about 161 degrees.

Importantly, the probability of this happening by pure chance, assuming these bodies are unrelated to Encke, is extremely small. In fact, it is easy to calculate that this scenario has a probability of around 1 in 1.6 million of occurring by pure chance. As this is so small, we should instead conclude this arrangement of longitudes has almost certainly not occurred by pure chance, and that most of these objects are 'genetically' related. In other words, they are the fragmentation products of an ancient parent, or progenitor, comet, as this is the only known reason why their perihelia can have similar longitudes.

Furthermore, because Encke is known to be a comet, this implies that most of the eighteen objects in this list are also comet fragments. It is quite satisfying that most of these objects are also associated with major meteor showers seen on Earth, practically confirming their cometary status. We can therefore be very confident that many large bodies in Encke-like orbits are the dormant comet progeny of a larger parent body.

Typically, the large objects featuring in Figure 18 are estimated to be in the range of one to ten kilometres in diameter, with the largest being Hephaistos at around six kilometres. But this assumes they are asteroidal (except comet Encke, of course), and therefore have a high albedo. However, given that they are very likely dormant comet fragments, which will tend to have dark pitch-like crusts with low albedos, they might be substantially larger than conventionally thought.

Centaurs

Having seen that evidence points strongly towards the trapping of a giant comet within the inner solar system over 20,000 years ago, which has since decayed to generate the very broad Taurid meteor complex and lots of dust, we should check how likely such an event is. Because if it is found that this scenario is extremely unlikely, it suggests our deductions are probably incorrect and the evidence has been misinterpreted. We would need to search for other, more likely explanations for the Younger Dryas event.

But, before attempting to resolve this issue, rather than repeatedly referring to this putative giant comet as 'the progenitor of comet Encke' or another cumbersome phrase, let's instead give it a short and convenient name. Celestial bodies are generally named after gods of one sort or another, or is it the other way around? In any case, in the circumstances, it should probably have a name with malevolent overtones. There are plenty to choose from. For the sake of argument, let's choose Satan. It seems appropriate, as Satan and Apollo (or the Greek Apollyon, i.e. Abaddon the Destroyer, the Angel of Death) have been linked in several religious texts.

The existence of the main asteroid belt between Mars and Jupiter has long been known. By the mid-19th century hundreds of asteroids had been discovered, and that figure now stands at hundreds of thousands. So, it is understandable that the cosmic impact threat to Earth originally focussed on asteroids deflected from the main asteroid belt.

Comets, of course, have been known for far longer than this. Chinese records of comet sightings date back to at least the first millennium BC, and ancient Greek astronomers might even have recorded a cometary splitting event[104]. Over the millennia comets have been viewed with fear and dismay by many cultures – they are the 'harbingers of doom'. But modern scholarship generally attributes this attitude to superstition and religious excess rather than a deeper knowledge of their role in the solar system, or ancient lore handed down through the generations.

Despite frequent sightings of comets over the millennia, a good understanding of how comets are formed, and therefore where they come from, is much more recent. By the middle of the 20th century it was realised there must be a reservoir of comets beyond Pluto to account for their regular appearance in the inner solar system. Today, it is known they originate from far beyond Pluto in the Kuiper belt, scattered disc and Oort cloud. These are really different regions of one very diffuse and extended structure; the disc-like Kuiper belt, rather like the main asteroid belt, closer to Pluto, becoming the spherical Oort cloud far beyond the solar system, with the broadening scattered disc in between.

At these great distances, far beyond Pluto, comets are only weakly bound to the sun, and can easily be knocked inwards into our planetary system. Most will simply pass through the solar system on very long-period orbits. But a few will pass close enough to one of the main planets, especially the massive outer planets, to be captured into shorter-period orbits. Those that come to reside eventually between Jupiter and Neptune are known as Centaurs.

The first Centaur discovered, Hidalgo, was spotted in the 1920s, but it was not realised they form a distinct population of solar system bodies until the 1980s. Now there are thousands of Centaurs known over 1 kilometre in diameter, with an expected population of tens of thousands.

Because their orbits cross those of the massive outer plants, their orbits are unstable and they will not remain as Centaurs for long. This means the pool of Centaurs we currently observe must be relatively young, and must also be replenished by other comets falling inwards from the Kuiper belt and beyond. Depending on the specifics of their paths, Centaurs can either impact an outer planet directly, like famous Schumacher-Levy 9, or be flung via gravitational slingshot back into deep space again, or, if we are particularly unlucky, they can be slowed down enough by a close encounter with Jupiter to begin orbiting within the inner solar system. Effectively, Jupiter is the gatekeeper to the inner solar system.

But this possibility has only been realised relatively recently. Napier and Clube, in their seminal *The microstructure of terrestrial catastrophism* paper of 1984, first described the scenario whereby Centaurs can arrive in the inner solar system from unstable orbits in the Jupiter-Neptune region[99]. They specifically identified large Centaurs, or comets, such as Hidalgo (40 km diameter) and Chiron (around 200 km diameter), and suggested one of these is likely to adopt a dangerous Encke-like orbit every few hundred thousand to few million years.

Later, more detailed studies confirmed this scenario by performing orbital simulations for Chiron, one of the largest known Centaurs, finding its orbit to be quite unstable with a significant probability (37%) it had been captured, and then released, from a short-period orbit within the inner solar system in the last 100,000 years or so[105]. The nature of orbital calculations, like weather forecasting and modelling of other chaotic systems, is difficult over such long time periods, and therefore only probabilistic conclusions can be made. Nevertheless, this work suggests that a large fragment of Chiron could have remained in the inner solar system, or that another comet like Chiron could become trapped within the inner solar system in the not-too-distant future. Indeed, the Kreutz group of sun-grazing comets likely originated from the disintegration of a giant comet, around 100 kilometres in diameter, that adopted a sun-grazing orbit within only the last 2,000 years[106]. They are disintegrating so rapidly because they approach the sun so closely.

Although most Centaurs are much smaller than Chiron, there are around ten times as many Centaurs with sizes between 100 and 200 kilometres, than over 200 kilometres. This suggests, if their orbits are as unstable as Chiron's, that we should expect to observe a large (over 100 kilometres in diameter) Centaur adopt an Earth-crossing orbit every 10 to 100 thousand years[102]. It seems Clube and Napier's original 1984 estimate was conservative – the threat is actually greater than they thought.

Given this situation, what should we observe in the inner solar system? What can we expect to see right now? It all depends on the distribution of Centaur sizes, the rate at which comets decay to zodiacal dust within the inner solar system, and the rate at which this dust clears. But, because the mass distribution of Centaurs is top-heavy – most of their mass is in the largest Centaurs – provided large Centaurs fragment and decay faster than they arrive in the inner solar system, which is thought to be correct, we should expect a fluctuating, or flickering, scenario.

In other words, although we can expect a steady trickle of smaller Centaurs to enter Earth-crossing orbits within the inner solar system, these hardly matter. It is the entry of very large Centaurs that dominates everything, from the zodiacal dust we observe to the risk we face on Earth. When a large Centaur becomes trapped within the inner solar system we should expect to see a cascade of fragmentation and splitting events that massively increases the risk of impact to Earth. But as the consumption or elimination of zodiacal dust from the inner solar system is somewhat slower than the process of comet fragmentation, we can later expect this impact risk to reduce substantially, and instead to see a rather massive zodiacal dust cloud remaining in the inner solar system accompanied by a steadily dwindling number of genetically related smaller fragments.

This is precisely what is actually observed right now, and it also explains the apparently higher-than-expected impact rate over the last few tens of thousands of years. Essentially, our modern understanding of the centaur population of comets is entirely consistent with current observations of dormant near-Earth comets and the massive Zodiacal dust cloud.

In fact, it seems the risk to civilisation from the largest Centaurs currently orbiting beyond Jupiter is far higher than the risk posed by all the asteroids currently inside Jupiter's orbit[102]. Clube and Napier pointed this out decades ago, but it seems their warnings have largely fallen on deaf ears. Just as with the Younger Dryas impact hypothesis, their view requires the uniformitarian paradigm to be abandoned, and this was always going to be a tough fight because of the implications for pretty much all of academia. And many people have invested their careers, and millions of dollars of taxpayer's money, in the search for asteroids, and they do not welcome the possibility that they have overlooked the main cosmic threat to civilisation.

Clearly, given the known population of Centaurs, and the nature of their unstable orbits, Satan is unlikely to be the only major demon to have terrorised Earth over the duration of human development, although it is probably the only one since the end of the last ice age. Orbital calculations based on a large sample of the known orbits of Centaurs indicate that Centaurs of all sizes are expected to become Earth-crossers at a rate slightly greater than one per millennium[107], although, of course, most of these will be relatively small. Nevertheless, it is quite clear from all this detailed work that Satan's appearance in the inner solar system in the last 20,000 years or so is not unreasonable, but instead is to be expected.

Clube and Napier's early work in 1984 showed considerable foresight and appears to have been confirmed in almost every detail by the latest cometary science. However, one of their early predictions does not appear to have been borne out. They originally suggested that along with Encke and the Taurids, the progenitor of the whole stream (Satan) likely remains hidden within it, unnoticed due to its dark and inactive surface with very low albedo. But, the latest observations from the NeoWISE mission[95], which uses a space telescope to search for orbiting bodies in the infrared and can therefore spot large comet fragments even if they are very dark, and other Spaceguard surveys, suggests this is unlikely. It appears most of the large bodies in near-Earth orbits have already been found. Despite this, the continuing existence of a large and very dark Satan cannot be ruled out, since every NeoWISE detection is only confirmed when also checked at normal (optical) observational frequencies. If Satan is too dark to be picked out visually, despite its supposedly large size, it might remain hidden still, despite the latest efforts.

Satan

It is now accepted that many, and probably all, of our major meteor showers are caused by fragmenting comets. It is also clear that many large Taurid objects in Encke-like orbits are 'genetically' related to Satan, formerly a very large Centaur, and are responsible for many of these meteor showers.

So, what was Satan like – in particular, how big was he? It is important to know this because the larger the comet, the more fragments it will produce, and the more dangerous it will have been.

There are two main methods for estimating the size of Satan, as it entered the inner solar system. The first involves the zodiacal dust cloud, since it is known that comets that decay within the inner solar system, like Encke, decay into the dust which forms this cloud[108]. By estimating the mass of the cloud, we can infer the size of Satan. The second method involves modelling cometary decay. If we know the rate at which comets decay in the inner solar system, and if we also know how long ago Satan entered the inner solar system, then we can back-calculate its original size based on the size of the remaining fragments. Let's look closely at the zodiacal cloud method first.

If we assume that, say, half of all the current mass of the zodiacal dust cloud resulted from the decay of Satan alone, with the other half coming mainly from other cometary sources, then we can estimate Satan's original size. This is a reasonable assumption because of the correlation in the orbits of Encke and its relatives, and because it is known that most of the mass of the Centaur system is contained in the few largest bodies. The current mass of the zodiacal cloud is consistently estimated to be somewhere between

10 and 100 thousand billion tonnes[102,103,108]. Using this range of values, and an estimate for the density of cometary material of 0.5 grams per cubic centimetre (assuming a 'fluffy' ice-ball with half the density of liquid water), and an estimate that half of a comet's mass is due to dust with the other half being volatile ices, which don't contribute to the zodiacal dust cloud, we obtain an estimated diameter between 35 to 75 kilometres for Satan originally. Adding the current inventory of mass within the Taurid meteor stream makes very little difference to this value.

Now, this is a very big comet – far bigger than any currently known in the inner solar system. But even this must be an underestimate – it is a lower limit. The reason is that over the decay lifetime of Satan some of the dust it produced will already have been lost from the zodiacal dust cloud, either by falling into the Sun or by being blown outwards into outer space by the solar wind. Therefore, to get a better estimate of Satan's original size we would need to know when Satan entered the inner solar system, the rate at which Satan decayed into dust, and the rate at which dust leaves the zodiacal cloud.

What is known about the first issue? When did Satan enter the inner solar system? This is very difficult to know accurately, but we do have a good clue to work with. Recall the remaining large fragments found by Napier that are almost certainly related. If we know how quickly they move away, or disperse, from each other, then we can work out how long ago they separated. This kind of calculation requires detailed orbital simulations using computational methods that take into account both gravitational and non-gravitational forces, since as active comets they will be subject to significant forces due to outgassing. Although there is a fair degree of uncertainty in these types of simulation, because the non-gravitational forces are difficult to know accurately, it has nevertheless been calculated that Satan likely split around 20 to 30 thousand years ago, and possibly longer if these fragments were less active than assumed[109]. Without any cometary activity at all they must have split from each other around 100,000 years ago to achieve the current separation seen in Figure 18. If a lifetime of at least 20,000 years for these comet fragments is considered, it indicates Satan was originally extremely massive, and much larger than the 35 kilometres found so far as a lower limit.

The next issue to consider is the decay rate of comets in the inner solar system. Again, this is a difficult issue, but a recent model, based on observations of the decay rate of small comets within the inner solar system, predicts that the diameters of comets in Encke-like orbits decrease at a rate of about 3 kilometres per 1,000 years[110]. Although this model is relatively recent, it is quite simple, and has only been calibrated by observations of the decay of relatively small comets, up to 10 kilometres in diameter. As Satan would have been much larger than this, we must tread cautiously – it is always dangerous to use models beyond the bounds of their calibration. Other models of cometary decay use a slower rate of 1 kilometre per thousand years. Taking an average view of 2 kilometres per thousand years suggests *each fragment* that split from Satan could have been in the region of 40 to 60 kilometres in diameter when Satan ruptured over 20,000 years ago. If, like Humpty Dumpty, we 'put these fragments back together again' we arrive at a giant comet in the region of 130 kilometres or so in diameter.

Although this is very large, it is quite feasible. Several Centaurs of this size, or larger, are currently known in the outer solar system, including Pholus (190 km), Chiron (230 km) and Chariklo (260 km), although the dimensions of these Centaurs are uncertain. Napier, who is the leading expert on this issue, suggests Satan (he doesn't call it this, by the way) is likely to have been around 100 kilometres in diameter[103]. This is entirely reasonable according to the arguments presented here. Essentially, the current massive zodiacal dust cloud suggests a comet of diameter at least 35 km, and possibly over 100 km, entered the solar system a few tens of thousands of years ago. This view is supported by the very old and broad Taurid meteor stream and the remaining massive zodiacal dust cloud that can be viewed as its fossilised remains.

The fall of Satan

Given that it appears very likely that a giant comet well in excess of 35 km in diameter, and more likely in the region of 100 km in diameter or more, did become trapped in the inner solar system at least 20,000 years ago, what are the expected consequences for Earth?

Again, Clube and Napier first outlined this scenario in their seminal 1984 publication. They suggested the signals of Satan's presence should be observed in the geological record, including in ice cores. Since this time, Napier and Clube's position has hardly changed, and the detailed evidence appears to be converging in their favour.

Coming only a few years after the major contributions of Alvarez and co-workers to the theory of an asteroid impact that killed off the dinosaurs, one might expect their work would have received more attention than appears to be the case, since it provided a potential mechanism for the dinosaur-ending calamity, beyond simply the idea of a huge random or 'rogue' asteroid. But, there appears to be a built-in scepticism towards the notion that comet-induced catastrophes can occur, especially over the course of civilisation. Since this time, Napier and Clube, along with their long-time colleagues, have patiently built their case[97,98] in the face of criticism from some quarters, notably David Morrison at NASA who chaired the 1992 Spaceguard committee. They should be applauded for their gumption, as relatively few among the astronomical community, or even among the specialist cometary science community, appear to have been either as interested or determined as they have been.

David Morrison's reasons for objecting to their theory of coherent catastrophism seem, to me, to be misguided. Perhaps his scepticism is so strong because he is also a Fellow of the Committee for Skeptical Enquiry (CSE), just like Boslough, and to him Napier and Clube's efforts seem too similar to those of Velikovsky, whose name and legacy is like poison within some academic circles. By the time of the 1992 Spaceguard report to Congress, Napier and Clube had already published several papers that described their theory of coherent catastrophism, and two books, *The Cosmic Serpent* and *The Cosmic Winter*, that expanded on their view and attempted to reinterpret historical events in its terms. But the Spaceguard report appears to have ignored their ideas by focusing on the threat from asteroids within the inner solar system. Despite the latest cometary science that suggests the Taurid meteor complex and Centaurs in the outer solar system are a much greater risk, hunting for rogue asteroids in near-Earth space appears to remain NASA's prime strategy.

Even with Clube and Napier's efforts, it has proven very difficult to predict the consequences for Earth of the entry of Satan into the inner solar system. The reason is that the expected number and magnitude of collisions of cometary fragments with Earth over this time depends sensitively on how Satan actually fragmented, and we know so little about this process for giant comets like Satan. For example, suppose Satan only decayed through outgassing. In this scenario, the only large comet fragment produced is Satan himself. Now imagine a different scenario where Satan instead split into 1,000 different large fragments early in his life, which then each proceeded to decay only through outgassing. In this scenario, the probability of a collision with Earth is 1,000 times larger, although the magnitude of any collision event is 1,000 times smaller. Clearly, the fragmentation pathway, or 'tree', is extremely important in assessing the threat to Earth. Although it is likely that Satan split into many major fragments at least 20,000 years ago, beyond this initial splitting we know practically nothing about the detailed fragmentation pathway.

Fortunately, we do know the probability of a collision with any given fragment. A simple formula, derived by the Estonian astronomer Ernst Opik in 1951 (grandfather to Lembit Opik, the former Liberal Democrat MP), allows calculation of the annual impact probability of an object in any Earth-crossing orbit[111], like Encke's. Modern studies based on precise orbital calculations have shown that Opik's formula is pretty accurate under most situations. The value predicted by Opik's formula for an Encke-like orbit is an average collision rate of 1 every 200 million years. This means that if there are 10,000 objects orbiting in Encke-like orbits for 20,000 years, we should expect to experience a collision with one of them over that time. Our main problem, then, is estimating a reasonable fragmentation sequence for Satan.

To date, the most detailed study of the potential consequences of this current period of coherent catastrophism, caused by Satan, is by Napier[103]. He used Opik's formula and a simple model of Satan's fragmentation tree to estimate the likely frequency of impacts of Earth with large comet fragments. His fragmentation model goes something like this. Assume Satan's initial size is 100 kilometres, and that Satan undergoes 1,000 fragmentation events, each producing 10,000 fragments, over 20,000 years. If Satan is depleted after this time, then each fragment is roughly 500 metres in diameter, ignoring losses as dust during fragmentation. Therefore, if we assume a total population of 10,000 of these fragments for the entire lifetime of Satan, i.e. at least 20,000 years, we can expect a collision of Earth with one of them over this time. A fragment of this size is thought to be equivalent, in terms of impact energy, to around 100 Tunguskas, or equivalently 100,000 Hiroshima bombs, i.e. a 1000 Megaton event.

Now, quite probably, this is a conservative estimate because Encke-like comets with diameters around 500 metres are expected to survive for about 250 years[110], according to the estimated rate of cometary decay we are using, gradually turning to dust over this time. In Napier's scenario, a fragmentation event occurs every 20 years. Therefore, the population of fragments is likely to be 250/20 = 12 to 13 times higher than assumed. Consequently, perhaps 10 events of this magnitude, and not just one, can be expected.

Alternatively, suppose Satan undergoes 1,000 fragmentation events, each producing 1,000 fragments, over 20,000 years. If Satan is depleted after this time, then each fragment is roughly 1 kilometre in diameter, ignoring losses as dust during fragmentation. Therefore, assuming a total population of 1,000 of these fragments for the entire lifetime of Satan, i.e. 20,000 years, Earth can be expected to collide with one of them with a probability of 0.1, or 10%, over this time. As before, this will be an underestimate, since each fragment is expected to survive, this time, for about 500 years. This means the total population of these fragments is actually 500/20 = 25 times greater than suggested, indicating that Earth can be expected to collide with one or two of them over the period of 20,000 years. A fragment of this size is thought to be equivalent, in terms of impact energy, to a 10,000 Megaton event.

Considering that Jupiter-family comets seem to undergo frequent fragmentation events, perhaps with each orbit when they are closest to the sun, and that Encke's orbital period is just over 3 years, these kinds of estimates are not unreasonable. They suggest we can expect perhaps 10 events of around 1,000 Megatons, and possibly one or two events of 10,000 Megatons, to have occurred over the last 20,000 years. This agrees with the range suggested by Napier, and is on the scale of that proposed for the Younger Dryas event. Note that although this scenario only takes into account the initial splitting of fragments from Satan, each fragment is expected to split further, and therefore the proposed collision events need not be caused by a single body. In other words, each fragment can actually be viewed as a swarm of comet debris.

This analysis lends strong support to the notion that an event of the size proposed by the Younger Dryas impact hypothesis is entirely reasonable given Satan's presence in the inner solar system, which is itself entirely reasonable given the known population of Centaurs between Jupiter and Neptune. We can therefore be very confident that the view, stated in very strong terms by Boslough, that such an event is extremely unlikely to have ever occurred in the history of the universe (and even defies the laws of physics!) is plain wrong[112]. In fact, the truth is quite the opposite; it would be surprising if no event of this scale occurred over the course of civilisation.

Because the number of comet fragments orbiting within the Taurid meteor stream of a given size increases rapidly with decreasing size, it immediately follows that we can expect many more collisions with smaller fragments. We should therefore expect the archaeological record to be chock-full of encounters with smaller pieces of Taurid debris, which are more likely to have occurred as airbursts. This means we should not be surprised to see geochemical evidence of Tunguska and super-Tunguska-like events at a wide range of depths in sediments, but with a more local extent than the Younger Dryas event, i.e. national rather than continental in scale.

Likewise, we should expect to find numerous but more local effects on the biosphere, such as felled forests with aligned trunks, frequent bottlenecks in animal populations (for which evidence can be found in the DNA of surviving populations), the occasional extinction, and a few cases of civilisation collapse. We should also expect to see major climate change events recorded by ice cores, as well as other geological anomalies such as massive landslides and mega-tsunami. Importantly, all these signals of cosmic catastrophe can occur without the creation of obvious craters or shocked quartz. It seems a new scientific discipline is needed that investigates the effects of collisions with cometary debris, and not just hard, dense asteroids. This view is completely consistent with the evidence for multiple black mats found at different levels in sediments, as discussed in the previous chapter.

7

Solving Göbekli Tepe

I have shown that the famous Vulture Stone at Göbekli Tepe, known as Pillar 43, likely represents the date 10,950 BC to within a few hundred years. This date is written using a symbolic representation of the position of the sun relative to some constellations on the summer solstice, where the constellations are represented as animal symbols in various poses.

Of course, the immediate question is 'What is so special about this date?' It appears this date was tremendously important to the people that constructed Göbekli Tepe, because Pillar 43 is one of the most ornately carved and largest pillars in one of the oldest enclosures yet uncovered.

So little is known about this period of prehistory that at this stage we can only speculate on this question. But one possibility is immediately obvious. Given what is now known about the Younger Dryas impact event, summarised in Chapters 3 to 5, dated by the platinum spike in the GISP2 ice core to 10,940 BC (using the ice core chronology), the most obvious possibility is that Pillar 43 records the date of this event.

This idea is supported by the little headless man with an erection at the bottom of the Vulture Stone who, presumably, indicates the date is associated with death (see Figure 7). Perhaps through decoding more of Göbekli Tepe we can discover if this idea is correct. Therefore, let's turn to other pillars at Göbekli Tepe to see what they reveal.

However, even before doing that, archaeological evidence around the time of the Younger Dryas period in the Fertile Crescent should be re-examined to see if this region was also affected by the

Younger Dryas impact event. While Göbekli Tepe is an ocean and more away from North America where the main physical evidence for the catastrophe has been found, it nevertheless appears that catastrophic effects were also experienced in Western Europe. For example, the Younger Dryas black mat is found in Belgium, where it is called the Ussello Horizon, and a layer of platinum group metals near the YD boundary have been found in a north-west Russian lake bed. But these sites are still thousands of miles from Göbekli Tepe.

The YD boundary is not generally recognised within the archaeological community because catastrophic cosmic events at such a relatively recent time are typically excluded from consideration in archaeological and anthropological research fields in advance. Any evidence that points to their occurrence is almost always interpreted as indicating some other effect in accordance with the principle of uniformitarianism. To be fair, the Younger Dryas impact science is relatively new, and the debate has been contentious, so we should not be surprised if archaeologists in the field are either unaware or uncertain of its veracity.

The most obvious evidence for calamitous destruction at the Younger Dryas boundary in the Fertile Crescent is found at Abu Hureyra, an important Natufian archaeological site in northern Syria, only 160 kilometres south-east of Göbekli Tepe, where some of the first attempts at cultivation of wild cereals have been documented. Here, several indicators of a high temperature fire or explosion, possibly over 2,000 degrees Celsius, in sediment layers corresponding to the Younger Dryas boundary have been found, including microscopic 'impact spherules'[113]. These minute spheres of rock, or silica, appear to be very similar to those found at other Younger Dryas boundary sites in North America, and to others recovered after an atomic bomb test in the 1940s.

Naturally, this evidence is disputed by archaeologists who claim these spherules could have been produced by an ordinary building fire[114]. Also, because spherules like these occur widely at many sites across the Levant, but only where ancient buildings appear to have been burnt down, it is argued that normal building fires were common at this time.

But, of course, this is not logical. It is quite obvious that all such deposits could indicate a widespread destructive event. And in any case, it is hard to see how a modest fire in an ancient building could reach such a high temperature. Temperatures in the region of 500 to 1,000 degrees Celsius are typically reported for large modern buildings and extensive wild forest fires. Overall, the evidence points more favourably to a widespread cosmic event than a building or wildfire. But if this is the case, there should be more extensive evidence of a conflagration, beyond simple building fires, in the Fertile Crescent at this time.

And indeed, there is much more evidence. For example, lake sediments from across present-day Turkey and the Levant[115] have been analysed and show a massive spike in charcoal at a level consistent with the YD boundary according to radiocarbon dating. Essentially, it appears the Younger Dryas black mat continues right across the Fertile Crescent. Of course, this evidence is interpreted by the archaeologists who discovered it in terms of a severe but entirely natural forest fire, possibly encouraged by local people as a means of controlling vegetation, in accord with the uniformitarian paradigm. But this explanation ignores the fact that it is a particularly singular event; no other comparable burning event occurs over the 20,000 years of sediment sampled in these lake sediment cores. There's nothing even close to it – the sediment layer appears as an isolated horizontal black band. And it occurs at a depth in the sediment that corresponds precisely, within the limitations of radiocarbon dating, to the Younger Dryas event.

So, it appears there is real evidence for widespread destruction, or at least a major conflagration, at the Younger Dryas boundary in the Fertile Crescent. Actually, this view agrees with the most recent research from the Comet Research Group. They find evidence, in terms of soot and other indicators of biomass burning within the Younger Dryas black mat, that an incredible 10% of the world's entire land surface was set ablaze by the Younger Dryas impact event[116,117]. A conflagration on this scale would undoubtedly have made a massive impression, and it is easy to imagine that it would provide sufficient motivation for building Göbekli Tepe.

Pillar 18

Now that it is clear the Younger Dryas impact event also affected the Fertile Crescent, other pillars at Göbekli Tepe can be investigated to find support for the idea that the date written on the Vulture Stone refers to this event. After all, there is a level of uncertainty of around 500 years in the date written on the Vulture Stone, and many disastrous events might have occurred during this period sufficient to motivate Göbekli Tepe's construction. Clearly, the Younger Dryas event should be top of the list, but is there any other evidence at Göbekli Tepe that confirms this idea? We know the animal symbols probably represent constellations, so perhaps we can deduce the meaning of some other symbols on Göbekli Tepe's pillars?

At the centre of Enclosure D, which also houses the Vulture Stone, stand two very tall and imposing T-shaped central pillars, Pillar 18 and Pillar 31 (see Figure 4). They dominate the enclosure, being twice as tall as any other pillar, and are engraved with human-like features, including arms and hands. As they lie at the heart of this enclosure, the oldest enclosure yet uncovered, it seems likely that whatever happened here, whatever the date on Pillar 43 refers to, must surely be connected in some way with these two central pillars. They must have been at the focus of events, and are probably telling us what happened – but what do they say?

Recall that Klauss Schmidt who discovered Göbekli Tepe interpreted these two pillars as representing deities, given their imposing scale and anthropomorphic features. But, like other pillars, they are also covered with unusual symbols that might now be deciphered.

Looking at Pillar 18 (see Figure 5 and Figure 19), only the pillar column and base are decorated – the head, assuming the horizontal portion on top is a head, is blank. Several other features are clearly visible along its vertical body: arms with hands nearly clasped at the front above a belt, with what appears to be a large stylised buckle, adorned with apparently abstract H- and C-symbols, although some of the C-symbols are reversed. A necklace under the head consists of a dimpled circle above an upturned crescent but below another H-symbol, which is also dimpled (see Figure 19c). Perhaps the dimples indicate that an attribute of this particular H-symbol is similar to that of the dimpled circle below it. Importantly, a fox is held under the right arm of the pillar, and the pillar appears to be wearing a fox-pelt loincloth.

The symbolism of this central pillar is mainly abstract; the fox is the only animal carved here, but its meaning remains a mystery. This presents us with a cosmic riddle:

What does the fox say?

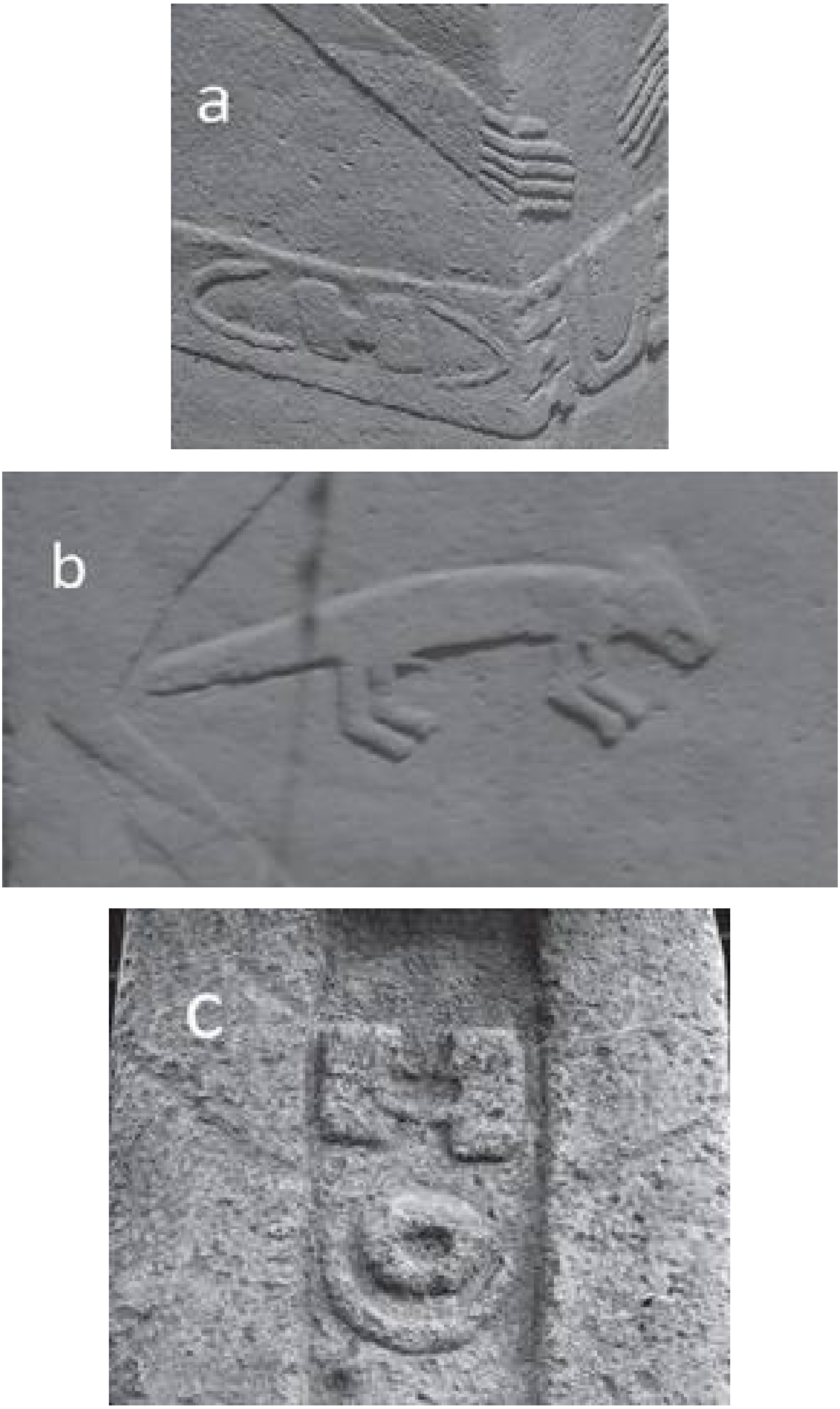


Figure 19. Close-ups of pillar 18, Enclosure D. Part a) shows the belt and belt buckle, part b) shows the fox held under its right arm, while part c) shows the 'eclipse' necklace under the head (images a and b courtesy of Travel The Unknown, image c courtesy of Alistair Coombs).

By decoding Pillar 18, and especially the meaning of the fox symbolism, it might be possible to crack Göbekli Tepe wide open. Does the fox on Pillar 18 also represent a constellation like the other animal symbols? If so, which one? Alternatively, it may well be that for these seemingly special central enclosure pillars a different system of notation was used. But this is unlikely. For the moment, it makes sense to proceed by assuming the fox represents a constellation and see what that reveals.

Clearly, if the fox does indeed refer to a specific constellation, and therefore a particular direction in the sky, it suggests the date carved into Pillar 43 refers to a cosmic event. This is very interesting because the comet fragments thought to have caused the Younger Dryas event would also have appeared to come from a specific direction in the sky, the same as the radiant of the Taurid meteor stream. Does the fox therefore correspond to a constellation along one of the Taurid meteor radiants? To find out, another pillar that features a fox is needed that can be decoded with some statistical confidence.

Fortunately, there is one, and only one, such pillar uncovered so far at Göbekli Tepe – Pillar 2 from Enclosure A.

Pillar 2

Pillar 2 is one of the two central pillars from Enclosure A that gave away the whole site in the 1960s. They were spotted just peeking above the surface of the ground. Starting from the bottom of Pillar 2 (see Figure 6), we see the vertical series of animal symbols: crane, fox, aurochs.

According to my theory, animal symbols on the broad sides of T-shaped pillars represent constellations. So, what does this series of three symbols on this pillar mean? They could, of course, simply represent three unrelated constellations without any additional meaning. But, given the effort required to create these pillars at this time, it is unlikely anything was done simply for decoration. Much more likely, these three symbols have some kind of relationship. The most obvious possibility is that they represent three neighbouring constellations, perhaps in a line. But why would that be of interest to the people of Göbekli Tepe? What is the significance of three neighbouring constellations?

According to my analysis of Pillar 43, the Vulture Stone, the little bent bird next to the top left handbag represents Pisces (see Figure 10). Does the tall bending bird on the bottom of Pillar 2 also represent Pisces? When I was first attempting to decode this pillar, I was hesitant to make this connection, because the image of the little bent bird on Pillar 43 is not very clear. It wasn't obviously the same bird as the one on Pillar 2. But then it occurred to me, that they very likely do have the same meaning. What we have here is a system of communication, and for it to work well you wouldn't use different symbols that are similar to each other – as that would just be confusing. More than likely, the tall bending birds on Pillar 2 do actually represent Pisces as well. If they do, we are a massive step closer to finding out what the fox means, since according to the current line of reasoning it should represent a constellation next to Pisces. But, there are several constellations that surround Pisces – how are we to tell which one is the fox? For example, it could be Cetus, Aries or Aquarius, all of whom neighbour Pisces.

To understand this pillar, let's look more carefully at what is going on in the sky near these constellations. Especially, let's consider the radiant tracks of the Taurid meteor stream. Using Stellarium to investigate if any meteor showers radiate from near Pisces, it appears that (see Figure 20), astonishingly, both the Northern and Southern Taurid meteor showers cross this region of the sky from September to December in 2017. In fact, the Northern Taurids take the path: Pisces, Aries, Taurus, while the Southern Taurids take the path: Cetus, Taurus.

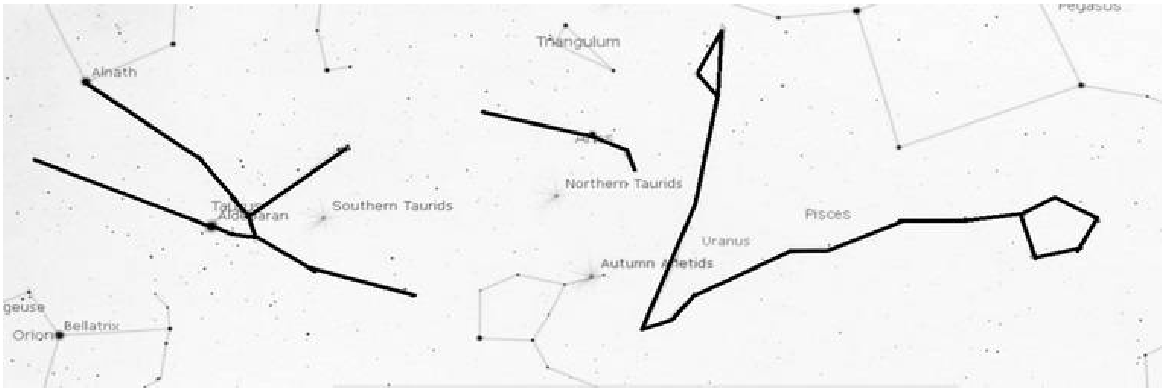


Figure 20. The Northern Taurid meteor stream radiant traces a path from Pisces through Aries to Taurus over the course of several months from September to December in 2017 (adapted from Stellarium).

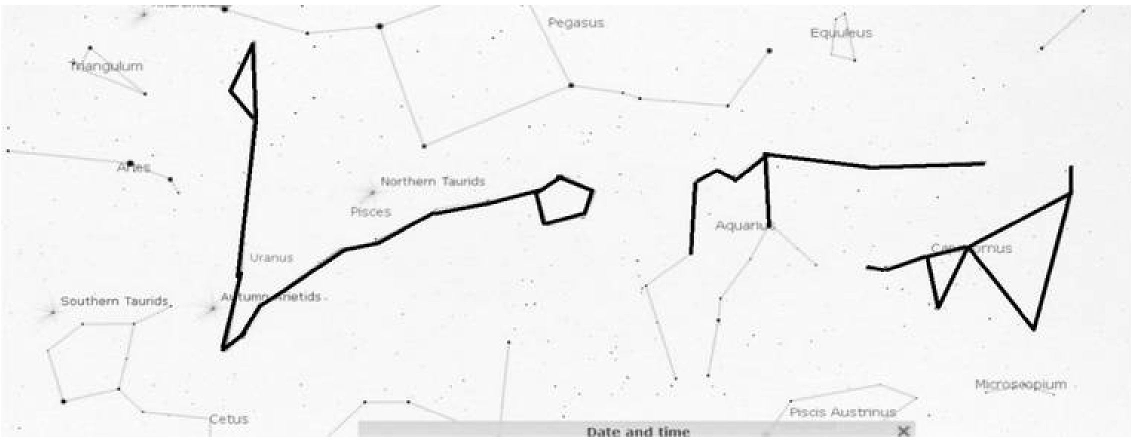


Figure 21. The path of the Northern Taurids at the time Göbekli Tepe was occupied, from Capricornus through the northern part of Aquarius to Pisces (adapted from Stellarium).

When I first discovered this, I remember feeling a thrilling excitement course through me. It was almost shocking. This was just too good. I could hardly believe what was happening. That was the moment I realised this discovery was huge, because it was immediately apparent that the focus of Göbekli Tepe, probably the main reason for its existence, was to observe the Taurid meteor stream – the same meteor stream that is expected, according to the latest cometary science, to be responsible for the current period of coherent catastrophism and the Younger Dryas impact event. The fox is a reasonable fit to the Aries constellation, and obviously the aurochs symbol can be identified as Taurus.

But I quickly realised this could not be correct, as I remembered reading that the Taurids' radiant moved over many millennia. What a blow – my theory must be wrong, despite all the amazing coincidences. Before long I had found again the paper co-authored by David Asher, one of Bill Napier's long-time collaborators, where he discusses the orbital mechanics of comet Encke, which also apply more generally to the Taurid meteor stream[118]. It was clear. The radiant would have moved over the course of 12,000 years. As there is no way Pillar 2 can describe the track of the radiant of the Northern Taurids in 2017, I quickly resolved to contact David to seek the best advice available on the issue.

While waiting for his response, I discovered the correct assignment by going back over the process of logical deduction to find an error. My mistake, it turns out, was my haste in assuming that the aurochs/bull represented the constellation Taurus. Of course, we are very familiar with this constellation, so it is tempting to make this association. But this is an assumption for which there is no independent evidence at Göbekli Tepe. Instead, by looking around the Pisces constellation, which is represented by the crane, the correct associations were immediately apparent to me, and quite beautiful – see Figure 21.

Instead of assuming the aurochs is Taurus, if we look in the other direction along the zodiac we find we can associate the aurochs with Capricornus. Actually, this is quite a nice fit – in my view it is much better than the fit to Taurus. In fact, if we look at all the animal pattern–constellation associations decoded from Pillar 43, we see that they all involve entire wild animals presented in a characteristic pose matched with constellations viewed at sunset. This is somewhat inconsistent with our modern view of Taurus, which only works if we view Taurus as representing just the head and horns of a bull. It therefore actually makes a lot more sense, it is more consistent with our theory, to associate the aurochs with Capricornus – the likeness is quite characteristic of a bull (a modern equivalent of an aurochs) with its hefty forequarters and smaller hind quarters. Of course, making this association implies that at some point in history, the aurochs/bull symbol has been switched from Capricornus to Taurus.

It follows, then, that the fox represents the northern part of our modern constellation Aquarius. Indeed, the fox symbol is an extremely good match to this part of Aquarius. Given the aurochs and fox symbols matched these constellations so well, I knew this was very likely correct. So, I was not at all surprised, and more than a little pleased, when David Asher responded by confirming that the radiant of the Northern Taurids displays nodal precession, or precession of the longitude (see Figure 15). He said it would move along the ecliptic, or the zodiac, towards Capricornus at a rate of about one constellation every 6,000 years or so. Therefore, at the time Göbekli Tepe was occupied, around 12,000 years ago, the Northern Taurids would have taken the path: Capricornus, Northern Aquarius, Pisces, perfectly in accord with our interpretation. Furthermore, Göbekli Tepe is ideally placed to observe these meteor showers, which would have appeared high in the night sky towards the south. Enclosures A to D are perfectly placed.

It is now clear that the aurochs has been decoded correctly, and more importantly the fox very likely represents the northern part of Aquarius, to which it is an extremely good match – see Figure 22. Table 2 summarises these results.

Back to Pillar 18

What does this mean for Pillar 18, the main pillar of interest at the centre of enclosure D? It appears the fox represents the northern portion of Aquarius which was at the centre of the Taurid meteor stream radiant at the time Göbekli Tepe was built. Clearly, this can be interpreted as follows:

> *The fox indicates the Younger Dryas event was caused by the Northern Taurid meteor stream.*

Figure 22. Comparison of Pillar 2 with its associated constellations that describe the path of the northern Taurid meteor stream circa 10,000 BC. Aquarius has been flipped left–right in this comparison (image courtesy of Travel The Unknown).

So, it seems the main motivation for building enclosure D, and presumably Göbekli Tepe as a whole, is to record and remember this most dramatic and destructive of events, and to watch the skies for warning signs of similar events. Göbekli Tepe's purpose has been revealed, and it is astonishing.

Furthermore, by combining this finding with Klauss Schmidt's view that the tall central pillars of Enclosure D represent deities of an early mythology, their meaning is also revealed. Obviously, they are comet gods.

This makes perfect sense. If, as the astronomical evidence suggests, Satan had inhabited the heavens for at least 10,000 years already, it should be no surprise to find a widespread comet cult, especially after the Younger Dryas event. We can expect Satan would have been a wondrous sight to behold. Seeming to chase and harry the planets along the ecliptic plane of the solar system, sometimes vanishing only to reappear in a blaze of glory during close encounters. Frightening and terrible, Satan was also undoubtedly majestic and worthy of worship.

Andrew Collins, another maverick investigator of ancient ruins, in his 2014 book *Genesis of the Gods*, first proposed that the fox and Göbekli Tepe as a whole were concerned with comets and the Younger Dryas event[119]. Graham Hancock took up Andrew's idea in his own *Magicians of the Gods* book published a year later, which, in turn, caused me to fall down my own rabbit-hole. Naturally, their views were strongly rejected by orthodox scholarship and archaeologists in particular. But it is now clear both Andrew and Graham are very likely correct. The main problem with their arguments, the reason why they are not taken seriously by academics, is that their evidence is not couched in scientific terms. They do not provide statistical estimates of confidence to support their findings. Moreover, they have also proposed many other things about antiquity, Andrew in particular, which are preposterous as they disrespect the laws of physics. Because of this, their entire arguments are easily dismissed by those that oppose them. But my theory is cast in much stronger scientific terms and is physically sensible. This makes all the difference.

My hypothesis is that:

Göbekli Tepe was built to remember the Younger Dryas impact event and keep watch on the Taurid meteor stream.

But as a scientist I know I need to take an additional step to provide confidence in this view; the probability that this idea is wrong must be estimated. In other words, what is the chance that these connections could have occurred by pure chance, and I am simply seeing shapes in the clouds?

It is possible to tackle this problem using a similar method to the one used to analyse the Vulture Stone in Chapter 2. There are three potential coincidences at Göbekli Tepe that need explaining, and I need to estimate the probability that each of them could have occurred by pure chance. Multiplying these probabilities together, presuming their independence, will provide an overall estimate of the probability they could have occurred together. We multiply their probabilities together because the conventional view, or 'null-hypothesis', is that there is no connection between these pillars as these symbols are simply thought to represent wild animals, and therefore any combination of animals could have appeared on them.

The three coincidences are:

1. The date written on the Vulture Stone is extremely close to the accepted date of the Younger Dryas impact event.
2. Pillar 2 describes the path of the radiant of the Taurid meteor stream, the same stream that has been implicated by the Comet

Research Group and Clube and Napier's theory of coherent catastr+ophism.
3. Pillar 18, the central dominant pillar of Enclosure D, refers to the northern portion of Aquarius, which would have been at the centre of the Taurid meteor stream, its point of maximum intensity, at the time.

Let's consider each point in turn.

1. The earliest radiocarbon date for Enclosure D is for the mortar of the rough stone wall, at 9,530 BC to within a few hundred years. The date written on the Vulture Stone is 10,950 BC to within a few hundred years, while the Younger Dryas event, according to a Greenland ice core, occurred at 10,940 BC to within 10 years, which is about 10,870 BC according to the radiocarbon chronology. The chance of finding a date on the Vulture Stone that is within 100 years of the Younger Dryas event date, and yet is over 1,400 years before the earliest accepted radiocarbon date, is about 100/1400 = 1 in 14.
2. Pillar 2 has the sequence: crane, fox, aurochs, representing the Taurid radiant path: Pisces, Northern Aquarius, Capricornus. There are 13^3 = 2,197 different possible animal symbol combinations for the three positions on this pillar. In my estimation, the sequence of animal symbols chosen is the best possible – no other sequence of animal symbols, selected from the 13 currently known at Göbekli Tepe, is a better fit to these constellations than the one chosen. The chance of this occurring randomly is 1 in 2,197. As this pillar could be written up-down or down-up without changing its meaning, this becomes 2 in 2,197.
3. The chance of choosing the animal symbol that represents the constellation at the peak intensity of the Taurids, the fox, is simply 1 in 13, as there are currently 13 animal symbols known.

Multiplying all these probabilities together gives a chance of 1 in 200,000, which is a very small chance indeed. A nice result, to be sure.

Of course, this estimate depends on a particular view of how well the different animal symbols fit the constellations suggested. And while this is still a very small probability, indicating the Younger Dryas event was very likely the inspiration for building Göbekli Tepe, it is not small enough to be sure of this. It is not small enough to claim a scientific discovery, for which probabilities at the level of around 1 in 2 million are usually sought. I am about a factor of 10 short of that.

Nevertheless, in the context of the Younger Dryas impact hypothesis and coherent catastrophism, it is a very strong case, and it is certainly strong enough to take forward as a working hypothesis. All the evidence points towards it being correct. In fact, it is the best explanation for Göbekli Tepe's construction yet developed. No other theory for its construction is backed by a statistical estimate of confidence at all – all other theories are based simply on opinion. And this is the key difference between science and non-science, or pseudoscience. If others want to claim their theories for Göbekli Tepe's construction are better than this one, they will need to support their views with estimates of confidence that are better than this. Until they do, this view should be accepted as being the best and most likely possibility.

But, because I cannot yet be completely sure of this hypothesis, although it is clearly a very strong possibility, the search for other evidence at Göbekli Tepe to provide additional support should continue. Let's first look again at Pillar 18, the tall central pillar of Enclosure D. Are there any other symbols on this pillar that might be sensibly interpreted in the context of the Taurid meteor stream and the Younger Dryas impact event?

Consider the belt buckle, consisting of a series of nested 'U' shapes around a middle vertical line, and flanked by a set of 'H' symbols (see Figures 5 and 19a). Collins suggested the U-shapes might depict the bow wave of a comet formed by its coma interacting with the solar wind, rather like the bow wave that forms around the nose of a bullet in flight. Is this a realistic proposal? Quite probably, as Chinese astronomers made similar observations of comets in their *Book of Silk*, circa 300 BC. They had been observing comets and other astronomical phenomena for centuries and recorded many of their comet sightings. They used them to predict future events – a form of astrology. The *Book of Silk* shows twenty-seven drawings of comets, each slightly different. Unsurprisingly, the commonest depiction is of a circle trailing a tail of some description. And very interestingly, some of the tails drawn are practically identical to the belt buckle symbol on Pillar 18.

The H-symbols on the belt buckle are also mysterious. They also appear on the Vulture Stone and other pillars at Göbekli Tepe. Given they occur in several different places without an obvious connection, except an astronomical one, perhaps they simply refer to bright stars? Or maybe they are a kind of notation that indicates these scenes are of the night sky? This is obviously quite speculative. Possibly, we will need to wait for further excavations at Göbekli Tepe before these H-symbols can be properly decoded.

The concave crescent symbols on the belt of Pillar 18 are also curious. In keeping with our astronomical interpretation, they might represent phases of the moon, but this is far from clear. Likewise, the 'eclipse' necklace under the head of Pillar 18. The crescent symbol (see Figure 19c) is likely either representing the moon or an eclipse of the sun. In relation to the Younger Dryas impact, the dimples possibly refer to the obscuring ash cloud generated by an impact sufficient to obscure both sun, moon and stars. It therefore perhaps refers to the cosmic winter generated by the Younger Dryas event.

But this is all quite speculative, and shows that while an astronomical interpretation is easy to find for these abstract symbols, we cannot be sure about any of them as we do not have any statistical support.

The Origin of Ophiolatry

Many pillars at Göbekli Tepe display animal symbols on their broad sides that very likely represent constellations. But the most common animal symbol of all on the pillars, the snake, doesn't appear to follow this pattern. It seems to represent a different kind of astronomical phenomenon. There are several reasons for thinking this.

First, in contrast to other animal symbols, snake symbols have not yet been found alone on any pillar. Instead, they are found in combination with other animal symbols. And given that there is no obvious pattern or sequence of snakes relative to other animal symbols, it seems they cannot represent a specific constellation by themselves.

In fact, although snake symbols are more common than any other animal symbol at Göbekli Tepe (so far excavated), their animal remains are the least common. The fill used to bury Göbekli Tepe contained all manner of debris, from earth and stone fragments to various animal remains. The site's archaeologists recorded all these remains found during excavations – an unenviable task. The most prevalent animal symbols are, in order: snake, fox, boar, crane, aurochs. In terms of animal remains found in the fill, we have in order: gazelle, aurochs, wild ass, sheep, fox, boar[120]. The remains of wild birds (including cranes) are also numerous, but no snake remains have been reported at all. Perhaps this is because snake remains are not very durable? Perhaps – but fish remains have been found. So, it does appear the snake has a special status at Göbekli Tepe, probably representing a different astronomical phenomenon to the other animal symbols.

Collins suggested the snake symbol represents meteors, since they can symbolise the track and sudden deathly strike of a dangerous meteor. I agree. Although snake symbols have been used throughout history to represent a variety of different concepts, including medicine, rebirth and wisdom, the snakes on Göbekli Tepe's pillars are represented in a variety of threatening poses – sometimes descending from above, appearing to attack other animals en masse. Most likely, then, they represent chaos, death and destruction.

In fact, there is some compelling evidence for this view that is difficult to interpret in any other way. On Pillar 33 on the south side of Enclosure D, one broad side shows an array of snakes emanating from the body of a fox, while the other side has an array of snakes emanating from the body of a crane (see Figure 23). All the snake heads converge on the inner narrow face of this pillar. This scene appears to defy straightforward interpretation in terms of normal animal behaviour – why would snakes be emerging from the bellies of wild animals?

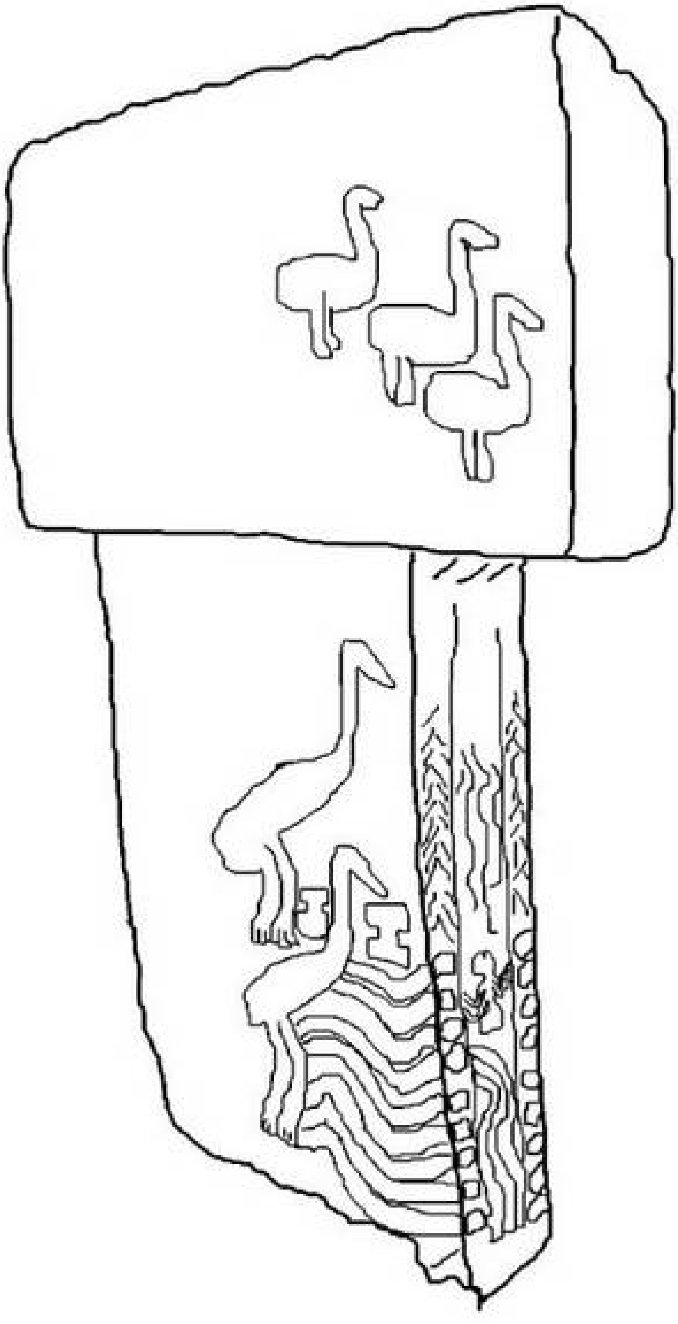


Figure 23. Snakes (meteors) emanating from the body of a crane (Pisces) on Pillar 33. They emanate from the body of a fox on the opposite face.

Probably, these symbols represent abstract concepts, not actual scenes of wild animals, a view reinforced by the appearance of yet more H-symbols on this pillar which, as we have seen, possibly indicate a sky-scene. With our astronomical interpretation the explanation is obvious – Pillar 33 is very likely describing the Northern Taurid meteor stream once again. On one face we have meteors (snakes) radiating from the northern asterism of Aquarius (the fox), while on the other face they radiate from Pisces (the crane). They are actually a very good representation of meteor showers. In astronomical terms, the difference between these scenes amounts to just a few weeks as the Northern Taurid radiant moves across the winter night sky.

Now, this is really interesting. Remember, following Klauss Schmidt's reasoning, the tall central pillars seem to represent deities – probably comet gods according to the evidence here. So, the other symbols here probably have an astronomically related mythological interpretation too. And we know there is a very long history of snake, or more properly serpent, worship (ophiolatry) across the world, stretching back to the earliest historical records.

In Western Europe we have the dragon, or wurm, and the Norse Jormungandr, while in India and Indochina there are the Naga (serpents) and other serpent aspects of many different gods. In Judaism and Christianity, we have Satan represented as a serpent in the Garden of Eden and a great red dragon in the Book of Revelations. In ancient Greek mythology we have Python, who was defeated and cast down by Apollo, while Typhon (the serpent) was vanquished by Zeus. In ancient Sumer, Tiamat (the serpent) is slain by Marduk, while in Ancient Egypt the god Set, often represented with the head of a fox, slays the chaos serpent Apep, said to have a head of stone.

There are many more examples of serpent worship by ancient civilisations in the Americas, from the horned serpent of many North American tribes through to Quetzalcoatl (literally the 'plumed-serpent') of the Aztecs in Central America, who is likened to Viracocha of the Incas in Peru. Is it possible these cases are all inspired by the Taurid meteor stream? Is it even possible they are not separate inventions, but related to a very early mythology that spread across the world at a time when the Americas were connected to Eurasia by the Beringian land bridge, between north-east Siberia and north-west America, during the ice age when sea levels were over 100 metres lower? This is perhaps not so crazy as it sounds. After all, our giant comet (Satan) likely entered the solar system over 20,000 years ago, and perhaps double that. That would certainly allow sufficient time and opportunity for a worldwide serpent mythology to develop.

In fact, the roots of ophiolatry have concerned scholars for centuries[121]. Why are serpents represented in seemingly disparate mythologies and cultic practices, even those separated by vast oceans, far more often than any other animal? Their preponderance requires some explanation. Carl Sagan[122], the well known astronomer and Balaji Mundkur[123], a professor of biological sciences from Connecticut, both suggest it is because humans, and other primates, have a deep-seated psychological fear of serpents – one of their few predators. This is the typical view of psychologists.

Göbekli Tepe clearly demonstrates there is more to it than that. The serpent has likely symbolically represented comets and meteors for a very long time indeed. Clube and Napier, in their first book *The Cosmic Serpent*, made a similar argument[124], as have others before them.

Why Göbekli Tepe?

Göbekli Tepe appears to have been built in response to the Younger Dryas event, a cataclysmic event that changed the course of prehistory. We can be very confident, although not quite certain, of this. Why? What was their purpose in building it? How did they gain from it?

We can hardly imagine the carnage on this terrible day. Those not blasted to pieces by immense airburst explosions would need to avoid the mega-tsunami that inundated coastlines on many continents and the intense global conflagration. The few lucky enough to survive the initial onslaught would need to struggle through near-total darkness, perhaps for several years, as the soot and dust cleared from the atmosphere. Temperatures would have plummeted without sunlight, and the food chain would have collapsed, leaving starving, frightened, sickly creatures desperate for food and clean water.

The event no doubt altered the environment and caused great loss of life and suffering. But the construction of Göbekli Tepe could not change that. So why build it? This is a very interesting question about human nature, and therefore there are probably many answers. In simple, but vague, terms, Göbekli Tepe must have satisfied emotional, intellectual and social needs at the time. These perhaps included the need to understand what happened, why it happened, and how to prevent further occurrences. Also, the desire to remember, to warn future generations, and the desire to come together for mutual support through these difficult times. Perhaps too a desire to pray to the sky-gods and thank them for deliverance. We see similar reactions to today's major natural disasters.

But whatever their precise motivations, their written testimony was surely designed to last for as long as humanly possible. By covering the whole site over before abandoning it, thousands of years after it was first constructed, they ensured their proto-writing survived for nearly 13,000 years. It is amazing to think we can now read witness accounts of this terrible event. Incredible to realise these people were really no different to us today, except in the level of their technology.

We can also be very confident that precession of the equinoxes was known for centuries, and probably millennia, before this event – otherwise the date on the Vulture Stone could not have been written. And, just as amazingly, they were using the same constellations we continue to use today in the West, although many of their symbols were different.

Remember, de Santillana and von Dechend, professors of the history of science from MIT, through comparison of a wide range of mythologies, suggested they are best interpreted as stories involving astronomical objects, and these in turn implied knowledge of precession of the equinoxes at least several millennia before the Bronze Age[26], before 3,000 BC. Their work continues to divide opinion, but it appears they were not only correct, but also rather conservative in their hypothesis, as Göbekli Tepe shows, almost certainly, that many of the same constellations were used in prehistory as today, perhaps as far back as the end of the last ice age.

Why astronomy was considered so important at this very early time is an interesting question. One potential answer is that the giant comet, Satan, would probably have been highly visible in its early incarnation, perhaps even before the end of the last ice age, especially during periods of fragmentation. Perhaps they had already experienced its destructive effects before the great cataclysm of the Younger Dryas event, and therefore astronomy and the early form of writing linked with it developed principally to communicate to potentially sceptical generations that followed that a great truth about the ordering of the world was known, and that this truth was important for their continued survival.

Is it possible this knowledge trickled down the ages from Göbekli Tepe through to later civilisations in the region, such as the Sumerians, Egyptians, Akkadians, and Babylonians, and finally to the ancient Greeks and thence to us today? What happened in the intervening years, between the 9th and 4th millennia BC, is an issue I deal with in the next chapter.

In fact, it appears today's Western set of constellations that involve whole animals in specific poses has survived, more or less intact, from this very early time. We still use the scorpion (Scorpio), and wolf (Lupus), but the bull/aurochs must have moved from Capricornus to Taurus in more recent times. It is tempting to assign other whole-animal constellations that we currently use to their corresponding animal symbols at Göbekli Tepe. For example, perhaps the sheep/ram represents Aries and the lion/leopard represents Leo. Although these associations might eventually be found to be correct, they are no more than speculation at this stage.

The symbolism encoded on Pillar 43, including the date stamp, the 'sunset' icons and the 'H-symbols', clearly demonstrates an early form of proto-writing existed by around 9,530 BC, and possibly as early as 10,950 BC. This form of symbolic representation, or communication, exhibited at Göbekli Tepe is far more advanced than was considered possible by many scholars for this time. But perhaps it should not be so surprising. Many repeated symbols can be found at even earlier Palaeolithic rock and cave art sites across Europe, dating from 40,000 BC[125]. These abstract squiggles, including small serpent-forms and dots, probably represent a widespread form of symbolic communication, and are not just random scrawls, although their meaning remains unknown. Very likely, some are astronomical and might be forerunners of the symbols seen at Göbekli Tepe.

Can Pillar 2, which describes the path of the radiant of the Taurid meteor stream, even be used to inform our astronomical knowledge? It suggests the Taurid meteor complex, and the large bodies orbiting with it, were already well dispersed 13,000 years ago, since the breadth of the meteor stream, spanning three zodiacal constellations according to Pillar 2, is similar to that observed today. It shows that Satan must already have been very old, otherwise there would be much less dispersion. Therefore, an estimate for the age of the Taurid complex[109,126], in the region of 20 to 30 thousand years, as discussed in Chapter 6, is entirely reasonable, although an even older age cannot be ruled out. In turn, this implies Satan was truly a giant, because the earlier he entered the inner solar system, the larger he must have been. We still cannot be more precise, but an initial size far in excess of 100 kilometres is a distinct possibility. This means encounters on the scale of the Younger Dryas event are entirely to be expected over Satan's lifetime. A completely consistent picture is obtained. It also suggests other calamitous events should be seen in the geochemical and archaeological records over at least the last 20,000 years, consistent with the multiple black mats found in America, as discussed in Chapters 5 and 6.

There is little room left for doubt – Göbekli Tepe's ancient code has been cracked. With this interpretation, a long-lost proto-script has effectively been discovered, and it has provided key insights into the life and motivations of people from this time. It can also be used to corroborate the latest astronomical and Earth science evidence for the Younger Dryas impact. I have attempted to list some of the key implications of these findings here, but the ripples of this new understanding will no doubt feed into many areas of investigation about our past.

In many ways, Clube and Napier have been here before, back in the early 1980s[124]. They first developed some of the ideas presented here, even though the scientific basis at the time was much less secure, and Göbekli Tepe was still hidden. One can wonder how they could have achieved such outstanding foresight? One possible answer is that they accepted the accuracy of many sources of historical evidence – evidence that is usually dismissed as the delusional ravings of mad-people, or simply as myth, by conventional scholars. Over time, the scientific evidence has come towards them. But they were not the first to make this suggestion. We know that William Whiston, the Lucasian Chair of Mathematics at Cambridge and Isaac Newton's successor, made a similar suggestion back in the 17th century, and there have been several others since.

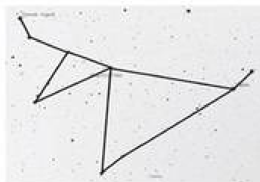
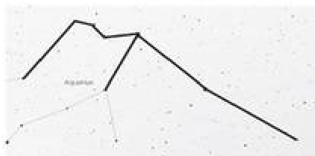
Symbol	Constellation
 Aurochs	 Capricornus
 Fox	 Northern Aquarius

Table 2. Animal symbol – constellations deduced from Pillar 2.

8

Decoding Çatalhöyük

If you read our Fox Paper, which presents the foregoing case for interpretation of Göbekli Tepe, you might have noticed that all the images of Göbekli Tepe are sourced either from Alistair Coombs, an independent writer, or Travel The Unknown, a travel company that visits Göbekli Tepe. The same is true of this book. I would have preferred to use photographs of Göbekli Tepe from the research literature, but, unfortunately, this was not possible. Despite contacting the German Archaeological Institute, who hold the rights to all images of Göbekli Tepe published in the research literature (because they hold access rights to the site) several times, they would not allow free use of their images in our Fox Paper. Now, this is unusual practice for any academic researcher or institution. Normally, we let each other use images we have made for research purposes freely, and only charge for their use in commercial settings. By not allowing us free use of their images, they were, in effect, attempting to suppress our research. This is quite bad behaviour.

I submitted our Fox Paper in late 2016 to the journal *Mediterranean Archaeology and Archaeometry*. It received three peer reviews. Two of the reviewers were content to debate the merits and problems, as they saw them, with the paper and we were able to respond to their comments satisfactorily. However, the third reviewer's reaction was quite different and very revealing. This reviewer was quite clear that under no circumstances should our work be published in any journal, ever. No sensible reasons were given. Now, this reviewer clearly did not like our paper. In fact, he/she thought we must be delusional. But this is not enough to prevent publication. The reviewer’s task is to provide good reasons why an article should or should not be published, or what changes should be made before publication can occur. For example, they should point out any factually incorrect information or mistakes in the methodology or calculations. To give no reasons at all, except to offer an opinion of our mental health, is no longer following the scientific process, or indeed any academic process. As a scientist, I found this astonishing.

Quite clearly, that reviewer did not understand, or want to understand, the statistical arguments in our work, and was determined to protect the existing paradigm by attempting to suppress our research. The normal academic process of providing evidence and reasoned arguments against our work had been aborted by a knee-jerk reaction.

I am not actually very surprised by this attitude. It is the kind of response expected to ideas that are very challenging to mainstream scholarship, as these undoubtedly are. If this reviewer’s research, indeed if an entire field of research, is founded on a particular paradigm, and that paradigm is questioned, then it can be tempting for some people to try and protect it from assault. They might feel they are acting for good reasons, because they actually believe the existing paradigm is correct. But this is not sufficient grounds to react in the non-academic way they did. The end result is that this particular reviewer achieved nothing. They did not put forward any counterarguments and therefore we did not need to respond to them. In fact, by responding in such apoplectic terms, they sabotaged themselves since I doubt the journal editor paid much attention to them either.

The Orthodox Church of Archaeology

By this point, with these two examples or poor academic practice, it was clear there is a particular research community, which I will call here the ‘Orthodox Church of Archaeology’, that will use almost any (legal) means at its disposal to protect what they see as the truth. This is very bad for science. Their view of the truth is based on an unswerving adherence to the uniformitarian paradigm, applied to the timescale of human civilisation. That this paradigm is based on shaky foundations is not something they understand or are willing to consider. Perhaps this is because they have not kept up with the latest science. For example, I am quite sure the apoplectic reviewer and the people with whom I corresponded at the German Archaeological Institute were not familiar with any of the research I have summarised concerning the geochemical and astronomical evidence for the Younger Dryas event. Hopefully, this book will go some way towards changing attitudes. But it can take time for a new paradigm to become accepted. Clube and Napier have been trying for decades already. Of course, I am not implying all, or even many, archaeologists belong to this Church. But, clearly, some do. It suggests the scientific method, which depends fundamentally on the statistical analysis of measurements, is not adequately appreciated within some corners of this community. This view is further supported by the failure of some leading archaeologists and anthropologists to properly analyse radiocarbon dating data in their contributions to the Younger Dryas event debate (see Chapter 5).

This matter seems to cut to the heart of the archaeological discipline which appears, in very general terms, to have an identity crisis. Early archaeologists of the 19th century were essentially bounty hunters. But by the middle of the last century archaeology had become an academic subject, with departments in many universities across the world. But since then there has been a conflict within the archaeological discipline between those that think archaeology should take a more scientific approach by focusing on the collection and analysis of data, and those that prefer an interpretive approach based on, frankly, whatever the current interpretive fashion is.

Put simply, there seems to be a dilemma as to whether archaeology is a science or not. The problem for any academic discipline with taking an unscientific approach is that it can become more like a religion, with undue reliance on authority figures, rather than evidence.

The site's archaeologists responded to our Fox Paper with their rebuttal in the same journal[127]. Now, at last, they were playing the game as it should be played by seriously debating the evidence. They provided five key reasons why they thought our work was wrong, summarised below:

1. They suggested the enclosures at Göbekli Tepe probably had roofs, which would have limited its use as a star observatory.
2. They considered it very unlikely that the constellations we use in the West today would be similar to those used by the people of Göbekli Tepe nearly 13,000 years earlier.
3. They highlighted the millennial-scale gap in their dating of enclosure D at 9,530 BC, obtained from a radiocarbon measurement of its mortar, with our suggested date of 10,950 BC, as being unlikely.
4. They suggested they already had an interpretation for Göbekli Tepe based on communal gatherings, with the animal symbols representing different communal groups. Moreover, they thought our interpretation of animal patterns as constellations is limited – the messages they express are likely more complex than we think.
5. They suggested our selection of pillars was arbitrary.

However, these reasons could not be substantiated with any scientific evidence, by which I mean any physical or statistical evidence that can be quantified. These are therefore just their opinions. Scientifically, such opinions carry zero weight – they are irrelevant in a scientific sense. We could easily counter their opinions with our own response published together with their rebuttal, summarised as follows:

1. Their view that Göbekli Tepe's enclosures were roofed was supported by citing a book written in German. Fortunately, my co-author Dimitrios could read German, and after spending an entire weekend ploughing through it he realised there was actually no evidence in it at all for roofs at Göbekli Tepe, such as post holes, posts or any other feature. In any case, even if Göbekli Tepe was roofed at some point in its history, this has no bearing on its use an observatory at another time.
2. There is no way to quantify the view that it is unlikely that we continue to use some of the same constellations used 13,000 years ago. It is entirely a matter of opinion. Moreover, they could not point to other pillars at Göbekli Tepe for which our interpretation of the animal symbols as constellations leads to inconsistencies.
3. We acknowledged the gap in these dates. There is no way to quantify how unlikely this gap is. It is therefore just opinion that it represents a problem. Much remains to be excavated at Göbekli Tepe, and it is far too early to claim this gap is a problem. Older enclosures might yet be uncovered.
4. Their interpretation in terms of communal gatherings based on animals does not carry an estimate of confidence. So, it is not scientific. It is just their opinion. In any case, their interpretation is not inconsistent with ours. It can be viewed as being complementary. And, interpretation of animal symbols in terms of constellations is not limiting. In fact, this kind of iconographic script is consistent with the known origins of writing, such as Egyptian hieroglyphics and Sumerian cuneiform.
5. As described in Chapters 2 and 7, our choice of pillars is necessary to solve Göbekli Tepe and make a strong statistical case. No other choice of pillars is possible in this sense. If

> Göbekli Tepe consisted of millions of different pillars, all with different combinations of animal patterns, then their argument would likely hold. But there is only one pillar with eight different animal symbols, including the easily recognisable scorpion symbol, from which a strong statistical case can be made (Pillar 43), and only one pillar with a fox combined with one of the symbols on Pillar 43 (i.e. Pillar 2). These are therefore a necessary, not arbitrary, choice of pillars. Our approach is essentially the same as solving a crossword puzzle.

More importantly, the site's archaeologists did not dispute our statistical case. As our case is very strong, in the region of 1 in 100 million of being wrong, by not disputing it they left themselves in an untenable and irrational position. That is, it is irrational to accept this statistical case, as it is so strong, but not accept our conclusions. Unless anyone can find a significant flaw with the methodology used to obtain these statistical estimates, our hypothesis should be accepted as scientifically verified. So far, nobody has claimed to have found a flaw in our statistical case, at least in the research literature.

Despite rejecting the archaeologists' point about the improbability of the continuity of the Western constellation set between Göbekli Tepe and today, I knew this was an interesting question. Although I did not doubt that these constellations must have been passed down the generations somehow, I was curious to learn how this could have happened. The current lack of evidence for this is intriguing. It was another puzzle to be solved.

Possibly, I thought, this is simply another symptom of the incompleteness of the archaeological record, and the evidence will be found eventually. But, there is also another explanation. It could easily be the case that the evidence has already been found, but has been misinterpreted. This would not be surprising at all. In fact, a quick search of the internet reveals animal symbols painted on all sorts of ancient artefacts, from pieces of pottery and stoneware to ancient rock art. These animal symbols are everywhere – and they are often very similar to the ones at Göbekli Tepe. So, perhaps evidence for the continuity of the Western constellation set is hiding in plain sight?

I was musing on this idea, trying to find where to start, when, quite serendipitously, Alistair Coombs contacted me. Alistair is pursuing a PhD in the School of Divinity at the University of Canterbury, Kent, and is also a keen researcher in ancient mythology and its astronomical basis. Remember, he supplied some of the photographs for Göbekli Tepe. He too had been on the lookout for evidence to support our case at Göbekli Tepe – looking for examples of similar animal symbols.

Alistair already knew about the ancient site of Çatalhöyük, also in southern Turkey, about 400 kilometres west of Göbekli Tepe, and remembered seeing a symbol from Çatalhöyük similar to the down-crawling quadruped we had decoded at the top right of the Vulture Stone. According to our interpretation, this represents Virgo. He didn't know it at the time, but Alistair was just about to set in motion a series of connections that would lead, eventually, to the 40,000-year-old Lion-man statuette found in Hohlenstein-Stadel cave, southern Germany.

Alistair pointed me in the direction of a book by Mary Settegast, called *Plato Prehistorian*[128]. Mary is another independent writer especially interested in the prehistoric period between the end of the last ice age and beginning of the Bronze Age, the exact same period I had begun to look at for evidence of continuity of the Western constellation set. Her book describes her theory of Plato's Atlantis. Rather than the usual literal interpretation of an advanced civilisation destroyed by a cataclysm, Mary thought it might refer to the migration of people from the Atlantic coast of Europe to the Near East during some prehistoric age. She highlighted the similarity of the symbolism between these regions, even though they are separated by thousands of years and miles. But it was the 'bear-goddess' symbol from Çatalhöyük on the front cover of her book, which looked just like our Virgo symbol at Göbekli Tepe, that had caught Alistair's attention.

Çatalhöyük

Situated high on the Konya Plain, Çatalhöyük is thought to have been the first Neolithic town in Turkey, with a maximum population possibly as high as 8,000[129]. Its ruined remains take the form of a 'tell', or mound, covered over by earth and sediment to form a small round hill. Radiocarbon dating has established that its lowest occupation layers date to around 7,200 BC, with final occupation layers dating to around 6,200 BC. It is therefore a lot younger than Göbekli Tepe, and forms a bridge in time between the likely origin of Göbekli Tepe (11th millennium BC) and the beginning of recorded history (4th millennium BC). It provides a fascinating window into the life of the earliest farmers. By this time, 7,200 BC, agriculture had spread throughout much of the Fertile Crescent and Turkey, but had made few inroads beyond that.

Çatalhöyük was the Göbekli Tepe of its time, in the early 1960s. Back then, when it was first discovered and excavated by James Mellaart, a Professor at the British Institute of Archaeology in Ankara, Çatalhöyük stunned the world with its size and symbolic complexity, which, as for Göbekli Tepe more recently, was thought to be impossible at such an early period in prehistory. Mellaart and his small crew, at breakneck speed, uncovered level after level of compact domestic living spaces, all built on top of the rubble of the level below[130].

After a hiatus of around thirty years, excavations at Çatalhöyük resumed in 1994, now directed by Ian Hodder, formerly of the University of Cambridge but now at Stanford University. His approach was very different to Mellaart's, preferring meticulous detail over the glory of rapid discovery. Assisted by a large crew, sometimes numbering over one hundred, the painstaking process of delicate archaeological surgery continued to reveal extraordinary finds, such as a seal stamp that looks like an excellent depiction of a comet (see Figure 24).

Figure 24. Seal stamp possibly depicting a comet (Image courtesy of Ian Hodder[131]).

Altogether, Çatalhöyük is a curious place. Over thirteen levels of habitation have been discovered covering over 30 acres and 1,000 years of prehistory. Each level consists of a dense patchwork of rectangular houses, thrust together without pathways between. It seems that people walked over the roofs of other houses to get to their own, entering via a roof-hatch and ladder to dark, windowless rectangular chambers. It could have been designed by Picasso during his cubist phase. There are occasional courtyards, but these were probably refuse and waste dumps, or middens, and not recreational. Life at Çatalhöyük appears to have been very claustrophobic.

Why Çatalhöyük was built in layers, each one on top of the ruins of the level below, is unknown. But there seem to have been frequent house fires. One of the later layers was consumed by an especially fierce fire that even carbonised bone and melted jewellery on corpses buried several feet below the ground[128]. It marks an apparent decline in Çatalhöyük's fortunes – the beginning of the end.

But the most impressive and interesting aspect of Çatalhöyük, and the one that concerns us, is its animal symbolism and oppressive religion. Life at Çatalhöyük appears to have been dominated by ritual, with religious tokens and shrines commonplace. Rather than a central place of worship, like a modern church, it appears each house had its own shrines, each meticulously maintained. What would each day have brought these people? Perhaps the routine of daily worship in cramped, dark chambers, followed by toil in fields, and then further rituals before the dark descended.

The symbolism at Çatalhöyük takes several forms. First, there are numerous and varied wall paintings depicting huge animals apparently being hunted or baited by people dressed in leopard skins. Other wall paintings depict geometric patterns, or rows of hand symbols, and one even appears to depict the eruption of a local volcano. In addition to the paintings, numerous small animal parts, such as bear claws, are embedded into many of the walls.

But the most spectacular, puzzling and important aspect of Çatalhöyük's religious symbolism are the large reliefs and displays, or shrines, covered by dozens of layers of plaster, applied annually, that feature in many rooms. Most importantly, for our story, these shrines comprise only four types, according to which animal is displayed; aurochs, ram, leopard or 'bear-goddess'. No other type of shrine has been found[129].

The last type of shrine symbol, the bear-goddess, is unusual in that it was initially thought to represent a splayed lady, or Earth-goddess, giving birth. Certainly, this was Mellaart's original interpretation, and it led to the growth of a 1960s Goddess Cult focused around Çatalhöyük[132]. Feminist groups, inspired by the apparent matriarchal society at Çatalhöyük, argued for a return to the more peaceful, egalitarian society presumed to exist in these ancient times.

But a more recent find, another seal stamp, strongly indicates this splayed figure is of a bear with a stubby tail, and not a lady giving birth at all. Figure 25 compares this seal stamp with the down-crawling symbol on the Vulture Stone at Göbekli Tepe and another stone carving found in the fill at Göbekli Tepe and now on show at Sanliurfa Museum. They are all clearly very similar; they all exhibit a splayed shape with head, legs and paws pointing forwards – rather like a bearskin rug spread on the floor.

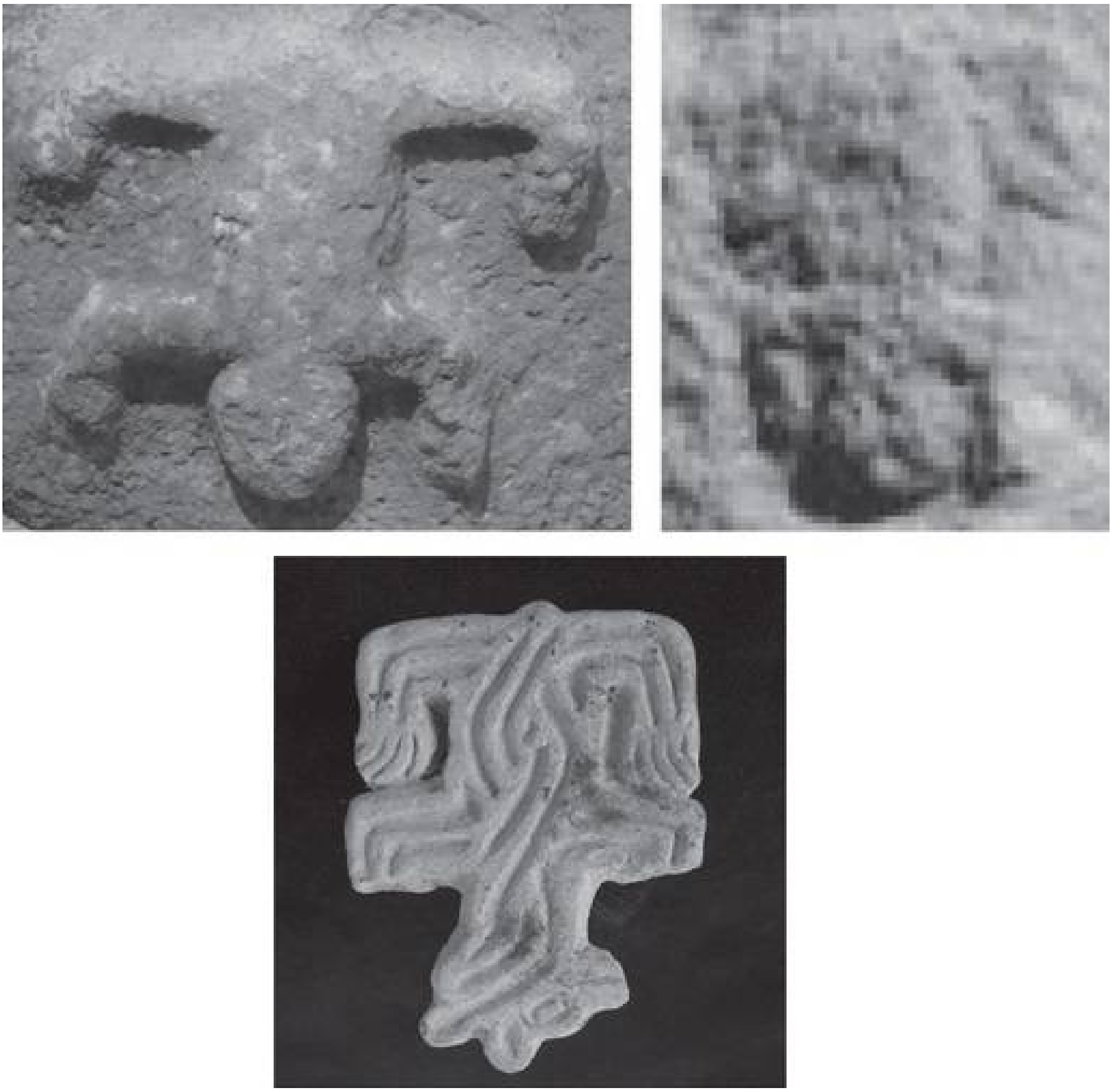
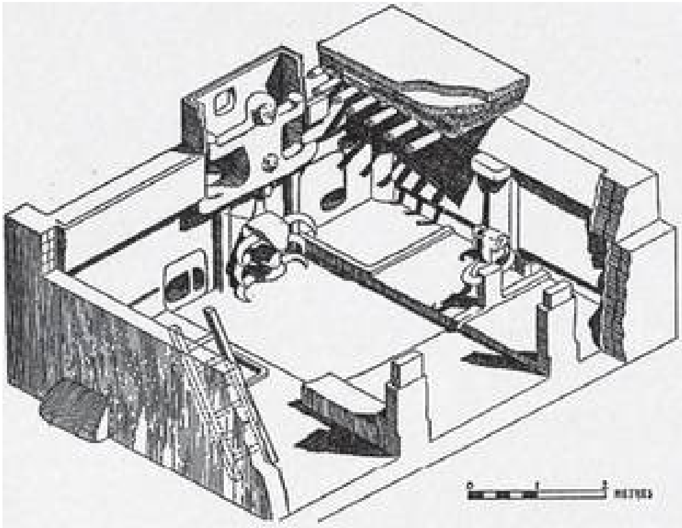


Figure 25. Comparison of ancient Anatolian down-crawling quadruped symbols. Left: a symbol on display at Sanliurfa museum, recovered from Göbekli Tepe. Middle: the symbol on the top right of the Vulture Stone at Göbekli Tepe representing Virgo. Right: a seal stamp recovered from Çatalhöyük. (Right image courtesy of Ian Hodder, the others courtesy of Alistair Coombs.)

But are they the same symbol? How can we know? The truth is, we can't know for sure. But this is another one of those occasions when we can assume they are the same, and see where it takes us. Through decoding Çatalhöyük by assuming this shrine symbol actually represents Virgo, as at Göbekli Tepe, it might be possible later to test this association statistically using the scientific method.

Figure 26 shows drawings of two of the shrines Mellaart discovered at Çatalhöyük. In one room we find three types of shrine together. A large bear symbol hangs over several bucrania (aurochs skulls), while a ram's head is displayed on another wall. The other room has a leopard shrine, with two leopards facing each other. The human face on the bear's head in Figure 26 is Mellaart's interpretation – the faces of these bear reliefs are normally damaged beyond recognition. Notice also the hemispherical bump in the middle of the bear's belly. This was originally interpreted as a pregnancy, but now that this splayed figure is thought to represent a bear, it likely represents something else. But what?

Because of their symbolic prominence and interpretation as shrines, these spaces were clearly very important in the lives of these people. There has been a lot of speculation about their meaning. But, despite the enormous resource poured into these excavations over the last few decades, they remain an enigmatic puzzle. Until now.



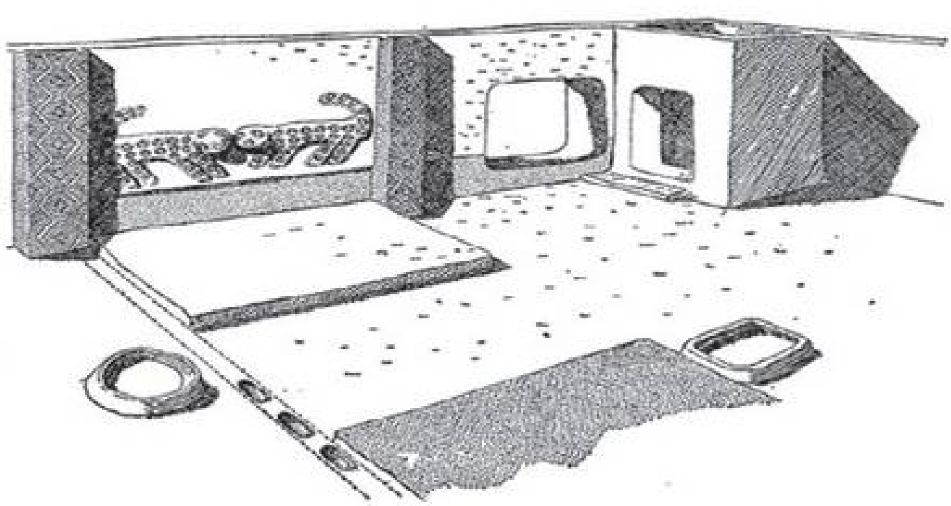


Figure 26. Artist’s impression of shrine rooms at Çatalhöyük. Left: a shrine room with aurochs’ heads, rams’ heads, and a splayed bear symbol. Right: a shrine room with twin leopards. (Images from Mellaart[130] courtesy of Alan Mellaart.)

The parallels with Göbekli Tepe are immediately obvious. Four types of large animal relief situated in shrines, one with a circle in its middle. Obviously, we should examine whether these animal symbols correspond to the four auspicious dates, the solstices and equinoxes, for the period when Çatalhöyük was occupied.

Taking a representative date of 7,000 BC, corresponding to earlier occupation levels of Çatalhöyük, we find using Stellarium that the corresponding constellations are (see Figure 27):

- Summer solstice at 7,000 BC = Virgo
- Autumn equinox at 7,000 BC = Capricornus
- Winter solstice at 7,000 BC = Aries
- Spring equinox at 7,000 BC = Cancer

As already noted, the bear symbol looks like the Virgo symbol at Göbekli Tepe, and, amazingly, the summer solstice in 7,000 BC is Virgo. It appears Alistair was right. We can also now deduce that the circle in the middle of the bear's tummy at Çatalhöyük represents the sun on the summer solstice, just as the circle on the Vulture Stone represents the sun on the summer solstice. They are using the same logographic writing system.

On Pillar 2 at Göbekli Tepe, Capricornus was represented by an aurochs. Once more, we have a perfect match with the aurochs' heads in Çatalhöyük shrines. We have not yet deduced an animal symbol for Aries at Göbekli Tepe. However, there are two known, but as yet unassociated, animal symbols remaining at Göbekli Tepe to choose from: the lion/leopard and the ram (see Table 1). Clearly, given that today Aries is associated with the ram, and the ram appears at Göbekli Tepe and in Çatalhöyük Shrine rooms, it is likely that Aries = ram. It appears, then, that this zodiacal symbol has survived intact across at least thirteen millennia from Göbekli Tepe to today.

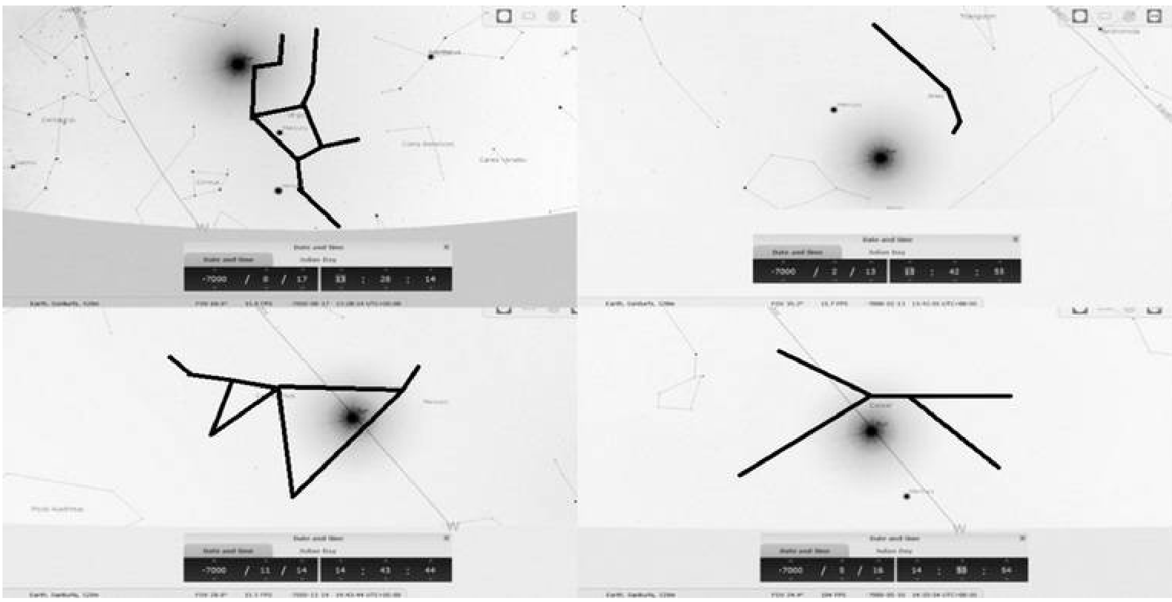


Figure 27. Summer solstice (Virgo, top left), autumn equinox (Capricornus, bottom left), winter solstice (Aries, top right), and spring equinox (Cancer, bottom right), at 7,000 BC, as seen from southern Anatolia (adapted from Stellarium).

The constellation remaining is Cancer, which has also yet to be assigned to any animal symbol. The only symbol remaining at Göbekli Tepe to choose is the lion/leopard, while at Çatalhöyük the remaining shrine symbol is the leopard. Clearly, we can make the association Cancer = leopard. And, indeed, Cancer at sunset in Figure 27 can be viewed as a running or pouncing leopard. Moreover, to make absolutely clear the association of the leopard symbol with Cancer, in Çatalhöyük shrine rooms two leopard symbols are often placed facing each other, reflecting the symmetry of the Cancer constellation at sunset. Everything fits perfectly, and we have been able to resolve two more animal-constellation associations (see Table 3).

But how secure are these animal-constellation associations? Is there any doubt in them? The probability of finding the symbol for Virgo (bear) and Capricornus (aurochs) in these shrines purely by chance is not small enough to be very confident I have got this right. So, these matches could all be coincidence. And, of course, today we associate the lion symbol with the constellation Leo, not Cancer. We use the crab symbol for Cancer. If the lion/leopard symbol used to be used for Cancer, then it must have switched places over the millennia, like the bull has apparently switched from Capricornus to Taurus.

From a scientific perspective, the case cannot be decided on this evidence alone. Much more evidence is needed to be certain. However, I can at least make a hypothesis that the same system for recording dates, in terms of animal symbols representing the constellations corresponding to the solstices and equinoxes, is used at Çatalhöyük as at Göbekli Tepe. But, the search for other animal symbols from ancient archaeological sites should continue to see if they also line up.

Tell Zeidan

One example that adds further support to our hypothesis is the site of Tell Zeidan in Syria. Excavations, led by Professor Gil Stein of the University of Chicago, had only just begun at this tell in Syria in 2009 when they were interrupted by the war. We can only hope this site survives the ongoing destruction.

Fortunately, one of the first things the excavators did was obtain a radiocarbon date for the site. Like Çatalhöyük, Tell Zeidan appears to be the remains of a large town, with layer upon layer of occupation lasting for nearly 2,000 years, from around 5,800 BC to 4,000 BC[133,134]. It therefore provides another temporal bridge, this time between Çatalhöyük and the beginning of recorded history at Sumer and Ancient Egypt, circa 3,000 BC.

Taking a representative date of 5,000 BC for Tell Zeidan, according to our hypothesis we should find special emphasis, in the form of religious symbolism or shrines, on animal symbols representing the solstices and equinoxes at this time. Once again, using Stellarium, we find:

- Summer solstice at 5,000 BC = Virgo
- Autumn equinox at 5,000 BC = Sagittarius
- Winter solstice at 5,000 BC = Pisces
- Spring equinox at 5,000 BC = Gemini

If we convert these constellations to the animal symbols of our zodiac, using Table 1, we find:

- Summer solstice = bear
- Autumn equinox = eagle/vulture
- Winter solstice = tall bending bird
- Spring equinox = charging ibex/gazelle

In the few years of excavations at Tell Zeidan, only a few finds displaying recognisable animal symbols have so far been recovered. The first is a seal stamp in the form of an ibex, or perhaps a stag (see Figure 28a). Second is a piece of pottery displaying what has been interpreted as an ostrich (see Figure 28c). Although excavations to date are too limited to ascribe these animal figures with any religious or cultic property, they are nevertheless consistent with our interpretation. The ibex/stag on the seal stamp at Tell Zeidan is very similar in general form to the symbol representing Gemini at the top middle of the Vulture Stone at Göbekli Tepe, shown in Figure 28b. Although the symbol on the seal stamp in Figure 28a appears to sport antlers, and therefore might be a stag, the apparent antler ‘branches’ might simply result from the method and style of inscription displayed across the whole scene. Therefore, at this stage we should leave open the possibility that this symbol represents any quadruped with a large pair of horns or antlers, such as an ibex, stag or gazelle.

Whether the bird symbol found on the pottery shard truly represents an ostrich or another species is difficult to determine. Nevertheless, this animal symbol is consistent with our interpretation of tall bending birds representing Pisces at Göbekli Tepe. Clearly, the limited finds recovered from Tell Zeidan so far are also consistent with our interpretation of Göbekli Tepe.

Of course, it could be that I am cherry-picking pieces of data to fit my hypothesis. This is known as confirmational bias – we tend to notice and emphasise those coincidences that agree with our preconceived notions. As a scientist, I have to accept this is a possibility. However, given all the preceding evidence, from Göbekli Tepe through to Çatalhöyük, and now Tell Zeidan, I doubt this. Nevertheless, I still cannot make a rigorous scientific conclusion from these apparent coincidences, so the hunt for more evidence to support this case should continue. I can at least claim a potential breadcrumb trail by which this knowledge has survived, all the way from Göbekli Tepe to us today. It seems to have been alive and kicking in the Near East throughout the Neolithic period.

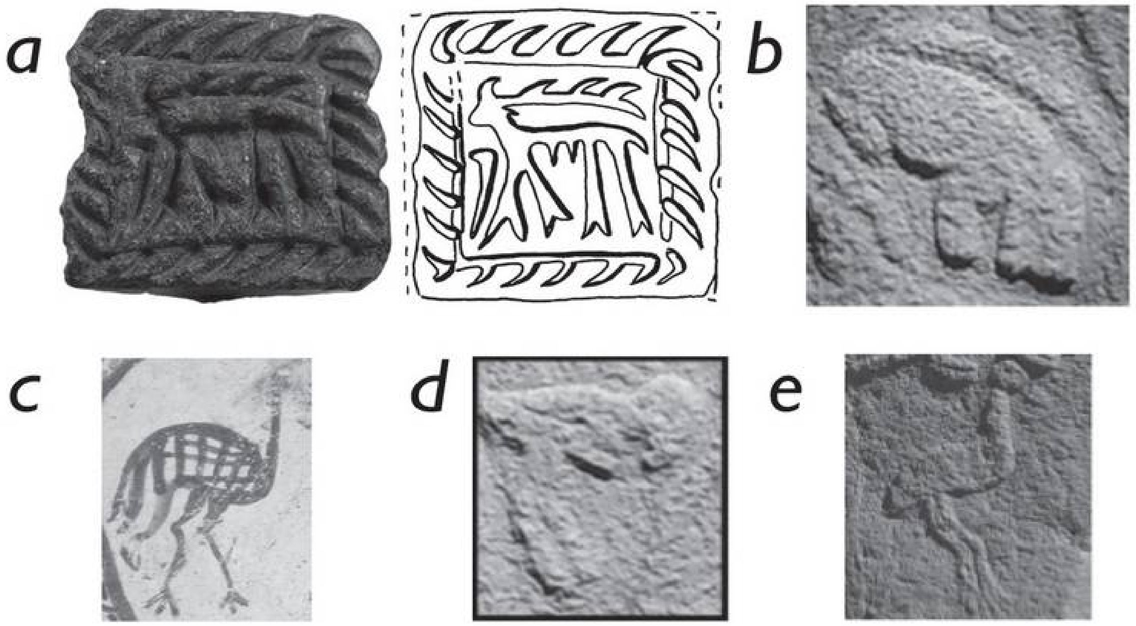


Figure 28. a) Ibex/stag/gazelle seal stamp found at Tell Zeidan, b) Gemini symbol on Pillar 43 at Göbekli Tepe, c) pottery shard with supposed ostrich recovered from Tell Zeidan, d) Pisces symbol on Pillar 43 at Göbekli Tepe, e) Pisces symbol on Pillar 2 at Göbekli Tepe. (Images a and c courtesy of Gil Stein, University of Chicago. Images b, d and e courtesy of Alistair Coombs.)

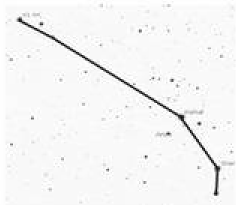
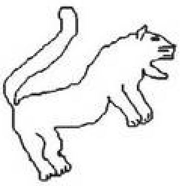
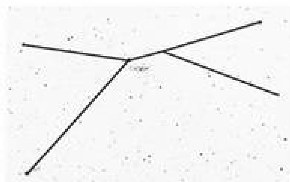
Symbol	Asterism
 Ram	 Aries
 Pouncing lion/leopard	 Cancer

Table 3. Animal symbol – asterism associations deduced from Çatalhöyük.

9

40,000 Years of Astronomy

When I first decoded Göbekli Tepe with Dimitrios' help, we soon realised the animal symbols used there were very similar to those used to represent Ancient Egyptian deities, as well as those found in ancient Palaeolithic (Old Stone Age) caves across Europe. It seemed to us that this was likely more than just coincidence. Mary Settegast makes a similar observation about the similarity of Western European ice age cave art and the art found at Çatalhöyük in southern Turkey in her book *Plato Prehistorian*[128].

To appreciate the potential connection to Ancient Egypt, consider the Ancient Egyptian deities revered at the ancient city of Heliopolis, one of the oldest cities in Egypt near present-day Cairo. Here, a group of nine deities, known as the Ennead, were worshipped above all others during early dynastic eras. They form the basis of a creation myth.

Initially, there is Atum, the sun god and creator of all other things. Atum sired his offspring, Shu and Tefnut, from his own seed. Shu, a male god of the air, is often depicted wearing an ostrich feather, while Tefnut, a rain god, is often shown with the head of a lioness. In turn, Shu and Tefnut sired Nut and Geb, the next generation of deities. Nut, goddess of the stars, is often represented by a cow, while Geb, god of the earth is frequently shown with a goose on his head. In their turn, Nut and Geb had four offspring, Osiris, Isis, Set and Nephthys, which completes the Ennead. Like Shu, Osiris is often depicted with ostrich feathers on his head, Isis is sometimes associated with a scorpion, Set is often shown with a fox head, and Nephthys is frequently depicted with a hawk's head. Each of these animal symbols are among those found at Göbekli Tepe, with the ostrich taking the place of the crane as the tall bending bird, as at Tell Zeidan, and the hawk replacing the eagle/vulture on the Vulture Stone.

But, of course, this could all be just coincidence, as there are so many Ancient Egyptian deities to choose from, most with at least one kind of animal associated with them. However, now that we have established a potential route through which the mythology of Göbekli Tepe might have reached Ancient Egypt, via the Fertile Crescent across thousands of years, connections between them should not automatically be viewed as coincidence. Particularly as the Ancient Egyptians, like the Sumerians of Mesopotamia, are thought to have been rather keen on astronomy.

Having seen how the constellations depicted at Göbekli Tepe might have percolated through prehistory and then history, via the Ancient Greeks, to us today, let's now try to go backwards in time to discover just how old this knowledge is. As the Vulture Stone at Göbekli Tepe demonstrates that precession of the equinoxes was already known by around 11,000 BC with sufficient confidence that it was used to memorialise the Younger Dryas event, it seems very likely there should be earlier examples of this kind of knowledge, perhaps by several millennia. This is the kind of timescale needed to establish through astronomical observations that this regular precessional motion of the sky occurs.

Given the strong similarity with the animal symbols found in many European ice age cave paintings, which include bison, lions, ibex, and bears, let's look all the way back to the end of the last ice age, before 13,000 BC, to see how strong these connections really are.

Several hundred cave systems in Western Europe alone are now known to contain remarkable ancient cave art. Although some of them have been known for hundreds of years, their provenance and extreme age has only been confirmed in the last fifty years or so, largely through radiocarbon dating methods. Many thousands of individual paintings among these caves are known, a high proportion being of animals.

Probably the most famous such cave is Lascaux in the Dordogne region of France. The animals displayed there are very similar to those displayed at Göbekli Tepe, but there are also a few additions, including many horses, several stags, and a single rhinoceros. Unfortunately, it has not been possible to radiocarbon date this art because the paints used in this specific cave are not made using organic pigments. Nevertheless, estimates of its age range from around 17,000 to 13,000 BC[135].

In reality, Lascaux is just one particularly splendid example among many. Indeed, Chauvet cave is much more extraordinary given the extreme age of its paintings, being around 20,000 years older than those of Lascaux and yet displaying a similar level of artistry. In fact, Chauvet's extreme age continues to be controversial. Experts in the stylistic analysis of these artworks maintain that they are simply too similar to those at other caves for there to be such a large difference in age across them. But, this is just opinion. Radiocarbon measurements taken directly from pigments used to make the paintings demonstrate beyond any doubt that the art of Chauvet Cave really is this old[136-138].

Until now, the purpose of this art was unknown. There has been a great deal of speculation about their potential religious or cultic significance, mainly because there is little evidence of any habitation alongside the artworks, just as at Göbekli Tepe, and many of the artworks can only be reached after lengthy journeys and contortions in the dark through narrow cave passages. Some suggest the art is a product of drug-induced hallucinatory experiences of tribal shamans[139]. To my mind, the paintings seem far too accomplished for this. Indeed, Picasso is rumoured to have said, 'After Altamira all is decadence,' after viewing that spectacular cave in northern Spain. Naturally, it is often suggested, as for Göbekli Tepe, they simply depict wild animals. But this is hardly a satisfying explanation. Why go to the trouble of painting wild animals deep inside a cave? For what purpose?

Werner Herzog's wonderfully illuminating documentary *Cave of Forgotten Dreams* tells the story of Chauvet Cave. It is situated against the stunning backdrop of the Pont d'Arc, a natural stone bridge formation over the Ardèche river in southern France. His crew were granted permission to film inside the actual cave system – a rare opportunity as they had been closed to the public for many years due to concerns with potential contamination. This is a real problem for many of these caves. Lascaux Cave had previously suffered from a fungal infection that attacked the artworks, thought to have been caused by a change in humidity levels due to millions of visitors. These days, visitors to Lascaux can see only a replica cave system, although it is very accurate.

Herzog's documentary makes it obvious why Chauvet was chosen by these ancient people. The cave is every bit as spectacular inside as the scenery outside. Stalagmites and stalactites create an alien world of darkness, while the expansive cavern walls glitter like the night sky when torchlit, the perfect canvas on which to bring an astronomical mythology to life. Truly, it is a Palaeolithic cathedral. That this was a place of worship is clear. A bear-skull altar at the centre of one large cavern was perhaps the focus of their rituals. What these ceremonies were like, we can only imagine. But animal bones – fox, bear, eagle – all the species we are familiar with from Göbekli Tepe and Çatalhöyük, are strewn across the floor.

Along with cave paintings, there are also some rare examples of ice-age carvings, or sculpture, found in other European caves. In terms of animal figurines, probably the most famous of these is the Lion-man statuette found in 1940 buried in Hohlenstein-Stadel cave, in southern Germany (see Figure 29). Carved from mammoth ivory 40,000 years ago, it shows excellent technique[4]. Not far from that cave, another lion head, of approximately the same age, also carved from mammoth tusk, was found in Vogelherd cave, along with a stash of other extraordinary pieces, including a horse figurine thought to be about 35,000 years old (see Figure 29).

Much has been written about these Palaeolithic figurines, detailing their discovery, history and, in the Lion-man's case, painstaking reconstruction. But we are mainly interested here in their symbolism. They are clearly very similar to the ice-age cave paintings in France and Spain and roughly contemporaneous with some of them. A connection between them is easy to make. And, given the similarity of the artworks in France and Spain to those at Göbekli Tepe and Çatalhöyük, some of which are only separated by a few millennia, could there also be a connection with the animal symbols at these sites? Did these people all use the same system for representing the solstices and equinoxes? Are we actually looking at an extremely ancient and widespread system for recording astronomical observations that has survived almost intact to the present day?

Figure 29. Left: The Lion-man of Hohlenstein-Stadel cave (by Olag Kuchar © Museum Ulm, Germany). Right: horse figurine from Vogelherd cave (by Juraj Liptak, © MUT).

Not for the last time, many people might be horrified at this suggestion. To some, it is simply inconceivable that people at such an early time were capable of sophisticated astronomical observations such as those required to record precession of the equinoxes. It would mean we have made no progress in our cognitive abilities in 40,000 years. And, if we were capable of such feats then, why did it take another 30,000 years for civilisation to begin? What prevented us settling down to begin the process of technological innovation 40,000 years ago?

But, as before, science allows any hypothesis to be proposed, even one which breaks the norms of scholarship by 38,000 years, as Hipparchus of the Ancient Greeks is supposed to have discovered precession of the equinoxes in the 2nd century BC. And, in any case, there is no problem in principle with this idea – it doesn't break any known laws of physics or biology. All it requires is a massive shift in our understanding of human development. But, perhaps it should not be so surprising. Along with these figurines, excavations in the German caves have found the remains of ancient musical instruments. For example, the shards of an ancient bone flute were found in the sediment of a cave not far from these figurines, presumably of a similar age[140]. Remarkably, it uses a modern pentatonic scale – we would find the tunes it played very recognisable. If people at such an ancient time could make and play instruments, and make such marvellous artworks, then why could they not also perform sophisticated astronomy?

Decoding the Shaft Scene

But how should we proceed to analyse all the information available from these caves? There are hundreds of them, and we don't yet have a complete zodiac. We are missing animal symbols for the constellations Taurus and Leo. Today, they are represented by the bull and lion symbols, of course, but we know that at Göbekli Tepe and Çatalhöyük the aurochs/bull represents Capricornus and the feline symbol represents Cancer instead. Therefore, we can't also associate the bull with Taurus and the lion with Leo. Instead, we should seek independent evidence from these ancient artworks to complete our zodiac, presuming it remained intact across nearly 30,000 years from Hohlenstein-Stadel cave to Göbekli Tepe.

I struggled with this problem for a little while before stumbling upon the solution. All the time, I was drawn back to the Shaft Scene at Lascaux, probably the most famous cave art of all (see Figure 30). This well-known scene is quite separate from all the other artwork at Lascaux, being situated at the bottom of a deep shaft, suggesting it has a special status. It is also apparently unique among these ancient cave artworks in that it depicts a man seeming to fall in a manner suggesting injury or death – reminiscent of the headless man on the Vulture Stone at Göbekli Tepe.

Another clue to the significance of the Shaft Scene is the particularly striking image of the bull or aurochs, apparently pierced by a spear. It also seems to be dying, given its entrails are hanging underneath. Normally, this scene is interpreted as a hunting scene, with perhaps the bull killing or injuring the man. But why would it be located down the bottom of a deep shaft in a relatively inaccessible position within a dark cave? Its interpretation as a hunting scene makes no sense. Surely, the event depicted is much more significant than a simple hunting trip. If we have learned anything from Göbekli Tepe, it is that these artworks were not trivial – they were fundamental to the lives of these people – of sufficient importance to demand their creation. And what about the duck or goose sitting on a stick to the left of the dying man? What possible meaning could it have? It just looks weird.

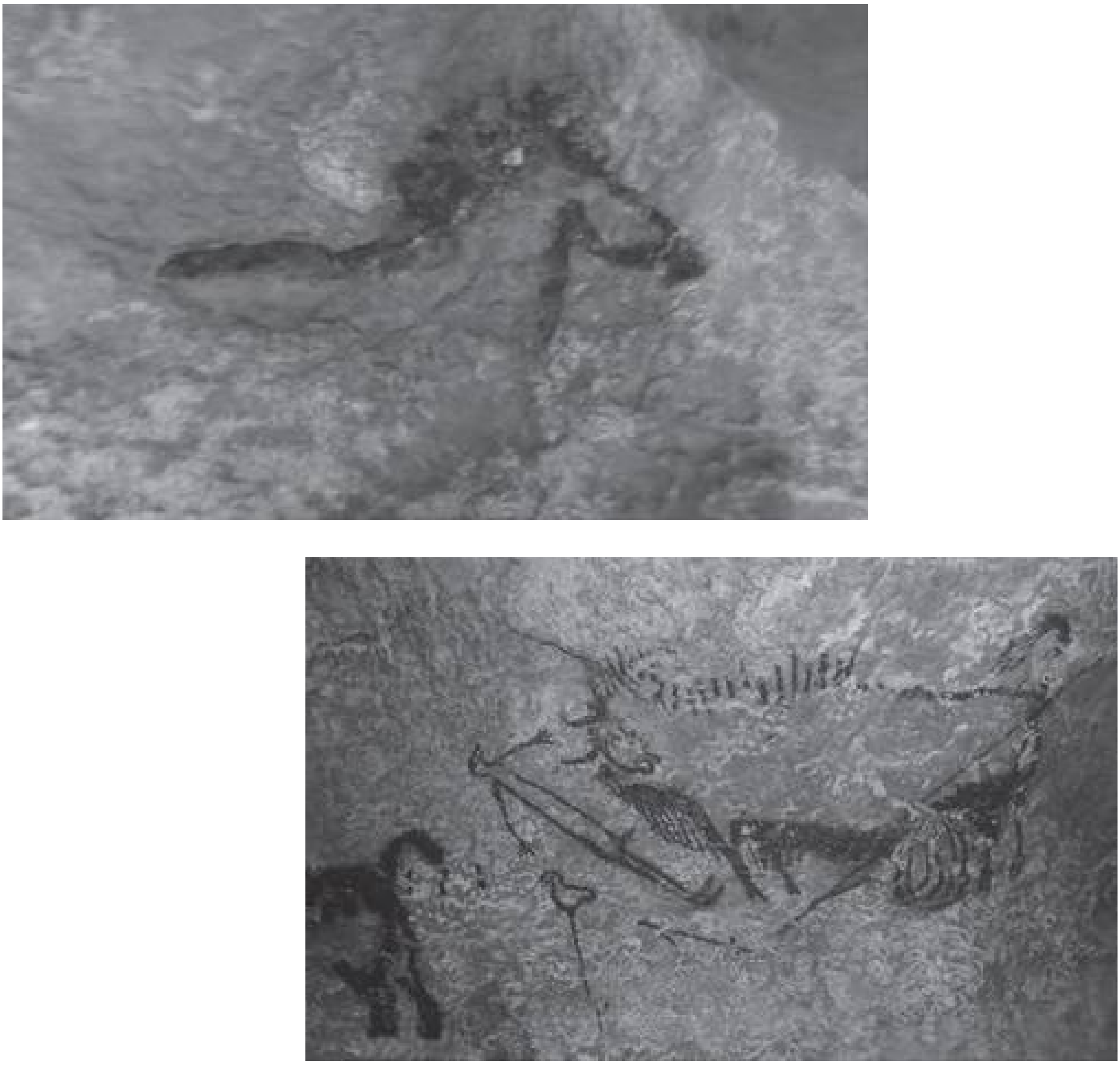


Figure 30. The Lascaux Shaft Scene (reproduction). Left: main panel with rhino, duck/goose and disembowelled aurochs/bison with dying man. Right: horse on rear wall (images courtesy of Alistair Coombs).

Partly, it was the peculiarity and uniqueness of this scene that caused me to ponder and mull it over. Another intriguing reason was that I already knew from analysis of Pillar 2 at Göbekli Tepe that nodal (longitudinal) precession causes the Taurid meteor stream radiant, the position in the sky from which it appears to emanate, to move at the rate of one zodiacal sign every 6,000 years[141]. Today, the Taurid meteor stream radiant is centred, and therefore most intense, over Aries/Taurus. This means at the time of the Younger Dryas event, around 13,000 years ago, it would have been centred over Aquarius, two constellations along the zodiac from today's position, and described at Göbekli Tepe in terms of the fox. But, at the time Lascaux was painted, apparently around 17,000 years ago, its centre would have been one more constellation further along the zodiac. This brings us to Capricornus, which we know from Göbekli Tepe and Çatalhöyük is represented by an aurochs or bull. Therefore, the injured bull in the Shaft Scene is perfectly consistent with its interpretation as a Taurid meteor strike from the direction of Capricornus. And, the injured or dying man might indicate another catastrophic encounter with the Taurids, as for the Vulture Stone of Göbekli Tepe.

The connections were tantalising, but it was not until I learned that there was more to the Shaft Scene than just these three characters, the bull, man and bird, that I had my Eureka moment. Just to the left of the dying man is a painting of what is thought to be a rhinoceros. And, on the rear wall of this shaft is a painting of a horse. It is not often described as being part of this scene, but it is actually central to its interpretation. Only when I discovered that this horse painting even existed did it all begin to make sense.

Of course, the Shaft Scene at Lascaux has the same purpose as the Vulture Stone at Göbekli Tepe. It is probably a memorial of a devastating encounter with the Taurid meteor stream. Both the Vulture Stone and the Shaft Scene involve four animals that represent the constellations corresponding to the solstices and equinoxes and therefore define the date of an event. The dying or dead man in each case is telling us the event was a major disaster. The similarities are striking and perfectly consistent. The event depicted by the Shaft Scene was surely no ordinary one. Let's see if we can work out what the date is.

The four animal symbols in the Lascaux Shaft Scene are the bison/aurochs, duck/goose, rhinoceros and horse. Now, we know the bison/aurochs represents Capricornus, and the duck/goose represents Libra (see Tables 1 and 2), but what do the other two animals represent, and are any of them even consistent with a specific date? To find out, we need to use Stellarium again. Noting the bison/aurochs and duck/goose symbols in the Shaft Scene, and using Tables 1 and 2 and Stellarium, we immediately find the following:

- Bison/aurochs = Capricornus = summer solstice between 15,350 and 13,000 BC
- Duck/goose = Libra = spring equinox between 15,700 and 14,100 BC

Therefore, this scene might represent a date anywhere between 15,350 and 14,100 BC, as this would be consistent with both these animal symbols. To narrow down this range we need to consider the other two animal symbols, the rhino and horse. Unfortunately, neither of these symbols has previously been decoded – neither has appeared, so far, either at Göbekli Tepe or Çatalhöyük. But logically, they are unlikely to correspond to constellations that have already been decoded. When we consider the date range consistent with the aurochs/bull and duck/goose, and locate the corresponding constellations for the autumn and winter events we see the following possibilities:

- Autumn equinox: Taurus 15,350 to 14,950 BC, or Aries 14,950 to 14,100 BC
- Winter solstice: Leo 15,350 to 14,800 BC, or Cancer 14,800 to 14,100 BC

Now, we know from decoding Çatalhöyük (see Table 3) that Aries is represented by the ram and Cancer is represented by a large feline, and that rams and felines are both represented in Palaeolithic cave art. The remaining options, then, are the autumn equinox corresponding to Taurus and the winter solstice corresponding to Leo. It follows that the date is limited to between 15,350 and 14,950 BC. We can write this as 15,150 BC, to within 200 years.

After discovering this, I knew I was on to something. The Shaft Scene required us to decode two animal symbols, the rhino and horse, which likely represent Taurus and Leo, the two symbols that were so far missing from our ancient zodiac. This was amazing, and surely no coincidence. All we have to do now is decide which way around they go – is Taurus represented by the rhino or the horse?

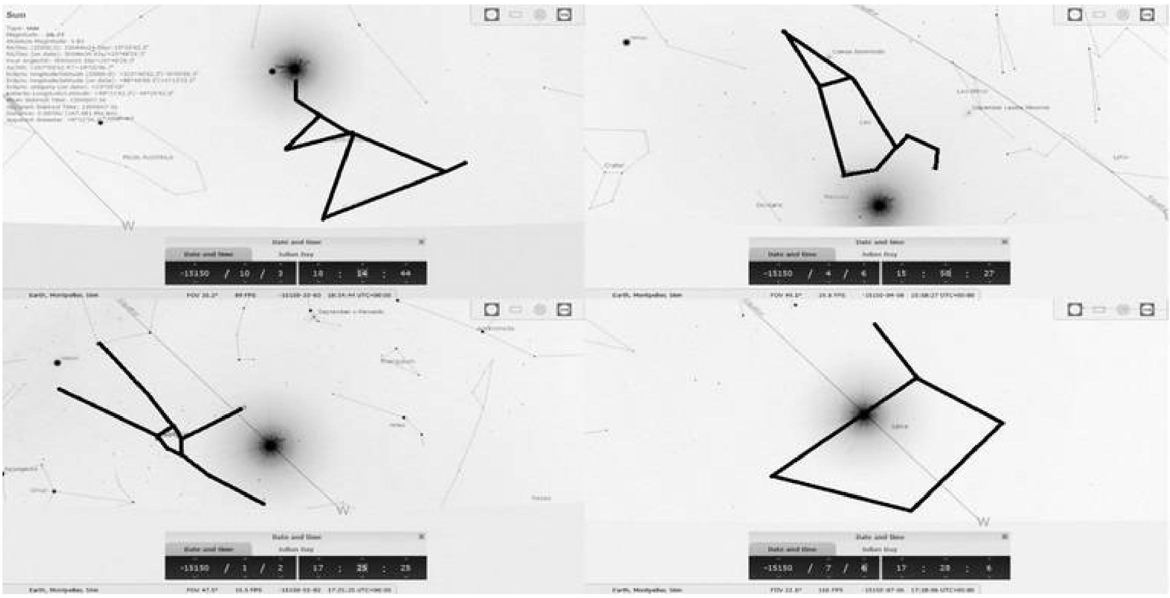


Figure 31. Summer solstice (Capricornus, top left), autumn equinox (Taurus, bottom left), winter solstice (Leo, top right), and spring equinox (Libra, bottom right), at 15,150 BC, as seen from southern France (adapted from Stellarium).

When we consider these constellations at sunset, which is the convention for this system, we find that the rhinoceros fits Taurus quite well while the horse is an excellent fit to Leo, which provides further confidence in this interpretation[14,142]. We have now completed our ancient zodiac. Table 4 lists these final entries to our ancient zodiac while Figure 31 shows the corresponding scenes from Stellarium.

Surely, You're Joking?

What has just happened here? What have we actually achieved by all these logical deductions?

This.

We have defined a zodiac that is consistent with the Lascaux Shaft Scene, Çatalhöyük shrines and Göbekli Tepe using precession of the equinoxes. It is also consistent with some animal patterns on pottery shards from Tell Zeidan.

When we use it to work out the date of the Lascaux Shaft Scene, we find it is 15,150 BC to within 200 years, which agrees with proposed dates for the paintings at Lascaux. In addition, the wounded bull at Lascaux describes the position of maximum intensity of the Taurids when Lascaux was occupied.

When we use it to work out a date range for when Çatalhöyük was occupied, we find it is 7,400 – 6,500 BC, which agrees with the main occupation phase of Çatalhöyük.

And, when we use it to work out the date of the Vulture Stone at Göbekli Tepe, we find it is 10,950 BC to within 250 years, which agrees with the known date of the Younger Dryas event. Moreover, we also find that Pillar 2 at Göbekli Tepe describes the path of the radiant of the Taurid meteor stream when Göbekli Tepe was occupied, and Pillar 18 describes the position of the maximum intensity of the Taurids.

And we get all this from a single zodiac, using precession of the equinoxes.

The evidence to support this view is this:

1. According to my view of the pattern matches, the probability that the Vulture Stone could match the relevant parts of the sky is extremely tiny, around 1 in 140 million by pure chance.
2. According to my view of the pattern matches, the probability that the Vulture Stone describes the date of the Younger Dryas event, at the same time that Pillar 2 describes the path of the radiant of the Taurid meteor stream, at the same time that Pillar 18 describes the position of its maximum intensity, is around 1 in 200,000 by pure chance.

For many people who more or less agree with my view of the pattern matches, this is probably enough evidence. But 'my view of the pattern matches' is not really good enough to justify a scientific discovery. It's too subjective. What we need is more evidence, preferably concrete physical evidence and not just the subjective 'my view of the pattern matches' kinds of evidence.

Obviously, we should seek independent evidence of a catastrophic comet strike at the time indicated by the Lascaux Shaft Scene. The Younger Dryas event is known as a millennial-scale climatic fluctuation, so it makes sense to first investigate if there is a strong climatic fluctuation at the time indicated by the Shaft Scene. Very interestingly, there is. Remember, the Greenland ice cores provide a record of Earth's climate in the northern hemisphere. When we examine the GISP2 ice core, we do indeed find a clear signal at this time, around 15,300 BC according to the Greenland ice core chronology, which is well within the range of dates covered by the Shaft Scene (see Figure 32). Converting this ice-core date to the radiocarbon chronology suggests it occurred around 15,200 BC, which is even closer to our estimate of 15,150 BC.

During this climate event, Greenland's temperature, which is used as a proxy for northern hemisphere climate more generally, suddenly dips by around 3 degrees Celsius for about 400 years, before recovering to its previous ice-age level. Although not nearly as dramatic at the Younger Dryas climate event, this is still very significant and would definitely have been noticed by people of the time. Possibly, it was a more local, international scale event, rather than intercontinental. Perhaps a super-Tunguska.

However, there are lots of climate fluctuations shown in the Greenland ice core – the probability of not finding one within a given 400 year period is quite small. So, this is hardly convincing evidence. What else is there?

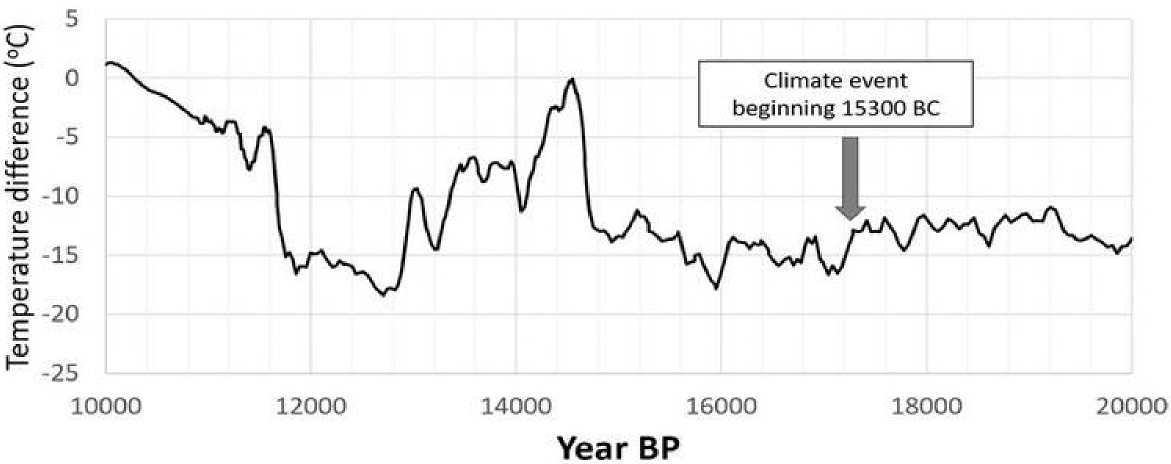


Figure 32. Greenland temperature variation reconstructed from the GISP2 ice core[27]. Year BP is the number of years before 1950 AD.

Proof

We are fortunate that radiocarbon dating methods have progressed so far. These days, using a method that involves atomic mass spectrometry, or AMS, only a tiny sample of once-living organic matter, such as wood-charcoal or bone marrow, is needed to make a radiocarbon measurement. A mass spectrometer is a tremendously sensitive piece of equipment that allows radiocarbon dating of archaeological artefacts whose ages could previously only be guessed at.

At the same time, radiocarbon calibration curves have been continuously updated as more and more data has been uncovered. The latest internationally accepted version of the radiocarbon calibration curve is known as IntCal13, published just a few years ago[143].

This means we now know the true age of many of these splendid ice-age artworks with unprecedented accuracy. For example, we know with good accuracy that the Lion-man of Hohlenstein-Stadel cave is around 39,800 years old, to within 700 years (95% confidence), because the layer of sediment in which this statuette was found is this old. Okay, this is not a direct measurement of the age of the statue – taking samples directly from the Lion-man is unthinkable. But, we can expect the Lion-man was created at a similar time as the age of the sediment in which it was found. The same holds for the horse figurine of Vogelherd cave.

Regarding the cave paintings, many of these have been dated directly. Small samples of charcoal have been scraped from them and analysed using the latest AMS radiocarbon dating methods. And it is now clear, beyond any doubt, that the paintings in Chauvet cave are extremely old. The oldest so far, including images of bison, lion, rhino and horse, are around 36,000 years old. And the quality of these artworks is quite extraordinary – it is absolutely clear these people were no different to us.

These advances in radiocarbon dating techniques are crucial because it means the ages of these artworks can be compared directly against my hypothesis. A proper scientific test can be conducted. No longer are we limited by what appears to be a good pattern match. Instead we can simply compare predictions of dates using our zodiacal hypothesis against actual measured dates using the latest radiocarbon methods.

For example, consider one of the horse paintings from Chauvet cave that has a radiocarbon date of 30,000 BC, accurate to within 920 years with 95% confidence. Using the IntCal13 calibration curve this gives an actual age of 33,870 BC to within 980 years with 95% confidence. This means, provided there have been no mistakes in the measurement process, there is only a 1 in 20 chance that it was actually painted earlier than 34,850 BC or later than 32,890 BC.

Now, as it is a painting of a horse, according to my hypothesis it is expected to represent the constellation Leo on one of the solstices or equinoxes at the time it was painted. Using Stellarium once again, we find the following possibilities:

- Leo at summer solstice = 28,600 BC
- Leo at spring equinox = 34,200 BC
- Leo at winter solstice = 41,000 BC
- Leo at autumn equinox = 48,400 BC

These dates correspond to when the respective solstice or equinox is near the middle of Leo. As the constellation of Leo is quite large, it spans over 2,600 years of precession. But the centre of Leo can be estimated with reasonable accuracy.

In this particular case, it is found that this horse painting is perfectly consistent with the zodiacal hypothesis provided it represents the spring equinox. In fact, the difference between the prediction and the radiocarbon measurement is only 34,200 – 33,870 = 330 years. This is excellent agreement. As Leo is around 2,600 years wide in terms of precession, any predicted date within 1,300 years, earlier or later, of one of these solstices or equinoxes would have been fine. This result, a difference of only 330 years, is well within that.

The maximum separation between a zodiacal prediction and a radiocarbon date is 3,222 years, as this is 1/8th of an entire cycle of precession. If you consider a compass, the maximum angle between any randomly chosen direction and one of the four cardinal directions is 45 degrees, which is 1/8th of the entire 360 degrees. It's the same for precession; 3,222 years is the maximum separation. This means that if our theory is wrong we should find the difference between predictions based on our zodiac and the true ages of the animal symbols are randomly distributed between 0 and 3,222 years. There should be no correlation at all.

The chance of finding agreement with one of the solstices or equinoxes by pure chance, ignoring any uncertainty in the radiocarbon age, is simply 1 in 3, because there are 12 zodiacal signs and 4 solstices and equinoxes to choose from. Now, a chance of 1 in 3 is not so small. But if we find that every time a zodiacal prediction is compared against a calibrated radiocarbon age for an animal painting we get good agreement, then the chance of this happening reduces. For example, if we compare the predicted and measured dates for two animal symbols, and they both agree, the probability for this to happen is 1/3 x 1/3 = 1/9. If we find that our predictions keep on lining up with radiocarbon measurements then the probability of this happening by pure chance gets smaller and smaller – it gets smaller by 1/3 each time.

Clearly, in order to reduce this probability to a value that is scientifically significant, say less than 1 in 2 million, I need to make lots of comparisons using lots of different animal paintings. Fortunately, there is now a lot of very reliable radiocarbon data for a great many animal symbols to compare this hypothesis against.

In the following test, I survey all radiocarbon dates for ancient west European cave art animal symbols available in English language science journals, and repeat the above analysis for each case[4,135,136,138,144-146]. But, before going through the results of this study, there are some complicating issues that need to be dealt with. First, we can obviously only compare dates for the animal symbols used in this derived zodiac. Radiocarbon dates have been obtained for a few other animal symbols that appear in west European caves but are not included in this zodiac, notably the mammoth and megaloceros (a kind of giant reindeer). Clearly, predictions cannot be made for any of these symbols. Very likely, they are local variations to the zodiac – perhaps some tribes used slightly different versions of the zodiac, which is hardly surprising given the timescale under consideration, many tens of thousands of years.

Second, we need a strategy for dealing with the experimental uncertainty in the radiocarbon measurements. Some measurements are not so precise, perhaps because they were performed before sophisticated AMS measurements became available or because they used a very small sample. It doesn't matter what the reason is, a cut-off in the level of experimental uncertainty allowed must be chosen to enable a proper scientific test. For example, suppose in the case above the experimental uncertainty in the horse's calibrated radiocarbon date was 5,000 years, and not 920 years. This would no longer be of any use, as it would not be possible to detect a correct prediction. This is because the 5,000 year uncertainty is much larger than the maximum difference of 3,222 years in the predicted and measured dates.

But what cut-off should be chosen? A sensible level of experimental uncertainty that can be accepted is around 1,000 years, because at this level of uncertainty it should still be possible to discriminate between those radiocarbon dates that agree with the hypothesis, and those that do not. But, rather than choosing 1,000 years arbitrarily, I suggest a cut-off of 1,074 years, which is exactly 1/3 of the maximum separation between prediction and experiment. Therefore, any calibrated radiocarbon measurement with an uncertainty greater than this is not used, as it simply isn't useful. Only the most precise data is useful for this test.

Another problem we find with the radiocarbon data is that some animal symbols have been sampled more than once. In fact, one animal painting, a bison in El Castillo Cave, northern Spain, has been measured three times. What should we do with these cases? We can't use each individual measurement because that would bias the statistics of our test. For example, suppose the radiocarbon age of a single animal symbol had been measured a hundred times. We wouldn't use all of these individual measurements because it would heavily bias our final result toward this particular animal symbol.

I suggest the following strategy for dealing with this issue. It is reasonable to assume that each animal symbol was painted in one go by a single artist. It's unlikely that any symbol was completed by several artists over a timespan of hundreds or thousands of years. Therefore, if we find that two or more radiocarbon measurements of the same animal symbol are consistent with each other, within the level of 95% confidence, then we should take an average of their values to get a more accurate date for that symbol. On the other hand, if we find that two or more measurements for the same symbol are inconsistent with each other at the level of 95% confidence, then one or more of these measurements is likely to be faulty in some way. Perhaps the scientists made a mistake somewhere in their measurement process, or perhaps the painting has become corrupted by fungal overgrowth. It doesn't matter what the reason is, if two or more radiocarbon measurements of the same animal symbol are inconsistent, then neither of those measurements are reliable and so cannot be used.

Just a final couple of points about the data that can be used. First, as well as the paintings, some of the radiocarbon measurements of figurines found in caves are also sufficiently precise for this test, including the Lion-man of Hohlenstein-Stadel cave in Germany. And the data from Cosquer cave near Marseille, southern France, must be considered carefully as this is a coastal cave partly below sea level. Many of the paintings in this cave, at one time or another, have been immersed in sea water, and therefore are likely contaminated with algae or other marine growths. Unsurprisingly, most of the radiocarbon measurements from this cave below the high-water mark are inconsistent with each other. So, for this cave, only consistent measurements taken from above the high-water mark are used. Other than these exceptions, all other radiocarbon dates available for prehistoric European cave-art animal symbols are used. In other words, I am not cherry-picking the data that fits this hypothesis. Instead, I am selecting the highest *quality* data available, which is essential for this test.

In total, useful radiocarbon data for twenty-three animal paintings from nine caves in France and Spain, and four animal figurines from caves in Germany are used. If the hypothesis is false, there should be no obvious agreement, or correlation, between specific solstices and equinoxes and the radiocarbon dates of these animal symbols. Alternatively, if the hypothesis is correct, the difference between the predicted date of the artwork, according to the hypothesis, and the actual date, according to the radiocarbon measurement, should usually be less than 1,074 years. Actually, we can expect some of these differences to exceed this value, as some of the constellations are ‘longer’ than others, in terms of precession, and because of the uncertainty in the radiocarbon measurements. This means that if the hypothesis is correct, we should expect to see a roughly uniform distribution of results up to differences of around 1,000 years, followed by a steady fall-off in the number of results for larger separations.

This is exactly what is observed (see Figure 33). Indeed, Figure 33 shows there is an extremely strong correlation in this data. The largest difference for any animal symbol is for a bison from Cosquer cave. The prediction of its age differs from its radiocarbon age by 1,720 years, which is fine because Taurus is a large constellation and the uncertainty in its radiocarbon age is around 820 years (95% confidence). For all the other animal symbols, the difference in their predicted and measured ages is less than 1,450 years. Checking the uncertainty in every piece of data shows they are all consistent with the hypothesis at the level of 95% confidence. In other words, all the differences larger than 1,074 years can be explained by the uncertainty in the radiocarbon measurements.

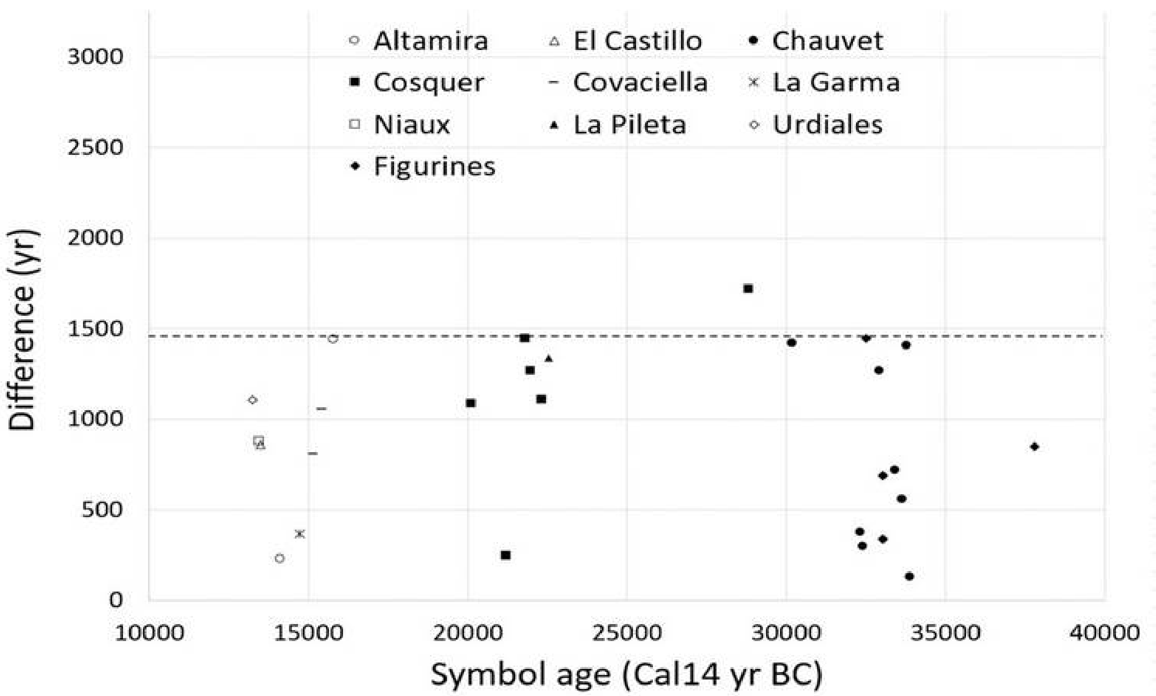


Figure 33. Correlation between the dates of solstice/equinox constellations and the radiocarbon dates of the corresponding animal symbols.

By drawing a horizontal line across this plot corresponding to a maximum difference of 1,450 years in the calibrated radiocarbon age and the predicted age, it becomes clear all the data points fall below the line, except for the bison from Cosquer cave. If the hypothesis were wrong the data would be uniformly scattered across this plot – both above and below this line. If these data points were placed randomly, the probability for twenty-six out of twenty-seven data points to fall below this line, with the twenty-seventh to be just above it, is around 1 in 380 million. You have more chance of rolling eleven sixes in a row on a dice, or of flipping heads on a coin twenty-eight times in a row.

In other words, the radiocarbon dates of these animal symbols agree perfectly with the dates of their associated equinoxes and solstices. In a scientific sense, a chance of 1 in 380 million is completely negligible and the hypothesis is validated. This ancient zodiacal code has definitely been cracked.

Furthermore, combining this evidence with that from Göbekli Tepe, the probability that all these matches could have occurred by pure chance is vanishingly small. It is in the region of 1 in 53 thousand trillion. No amount of splitting hairs about matching animal symbols to constellations is going to alter the fact that this probability is essentially zero. The case is scientifically proven and should now be accepted by everyone.

Satan's Legacy

For so long, historical scholars of all flavours have been telling us, in forthright terms, that astronomy was hardly known before the Babylonians. And that major transitions in climate, the biosphere, human culture and so on, over the course of human development have conventional terrestrial causes. We now know that this is wrong. In fact, quite the opposite. The world is a much more dangerous place than many people realise.

We can be quite certain the Taurid meteor stream has been overlooked as a major player in not just our cultural development, but the evolution of many other species as well. The reason this can be stated with very high confidence is that the Shaft Scene implicates the Taurid meteor stream once again. Remember, by decoding the pillars of Göbekli Tepe, it was shown that the probability that Satan is not implicated in the Younger Dryas event is about 1 in 200,000. Although this is a very small chance, it is not quite small enough to conclude definitively that the Taurids were to blame for the Younger Dryas event.

But now there is further evidence. The Lascaux Shaft Scene is almost identical to the Vulture Stone at Göbekli Tepe. We know this, because I have proven, in a scientific sense, that these animal symbols represent a date using precession of the equinoxes, and the bull/aurochs in this scene therefore represents a cosmic event from the direction of Capricornus. We also know the Taurids were centred over Capricornus at this time. The probability of singling out Capricornus for this event at random is 1 in 12. When this probability is factored into the existing estimate of 1 in 200,000 from Göbekli Tepe, we get a chance of 1 in 2.4 million. This is now so small that it constitutes a scientific discovery.

The Taurid meteor stream was almost certainly responsible for the Younger Dryas event and an earlier, possibly more local, event around 15,200 BC. To confirm this new cosmic impact event, the corresponding geochemical evidence, in terms of nanodiamonds, enriched magnetic grains and platinum dust, or similar evidence, will need to be found. There is now enough evidence here to motivate this search.

The possibility of other cosmic events caused by Satan’s decay was already evident from Chapter 5. The recurring black mats at different time horizons in sediments in the USA and Chile indicate multiple cosmic impact events. The scientists that discovered these multiple black mats insisted they are nothing unusual – apparently, they are just boggy wetlands that occur naturally from time to time, and just happen to collect unusual geochemical signatures. But this speculative argument now looks to be wrong. Much more likely, these other black mats were formed in the same manner as the Younger Dryas black mat, via an encounter with Satan's debris. The latest research by the Comet Research Group also indicates that multiple cosmic impact events are implicated in the Yukon, Alaskan, and presumably Siberian boneyards locked in northern permafrost. It all adds up and points in the same direction.

How many of these events have there been? What is their timing and global distribution? How did they affect our climate and biosphere? These questions cannot be answered yet, as there is simply not enough information. The science of encounters with cometary debris is in its infancy. Certainly, worldwide studies that analyse sediment and ice cores for the geochemical signals of these events are needed. These can then be compared with reconstructions of climate, human populations and migrations, and animal extinctions to gain a better understanding of the role of these events.

What about Satan's legacy, specifically on human development? How much of our history and prehistory should be re-evaluated? Again, these are difficult questions. Only for one of these events, perhaps the most significant one – the Younger Dryas event – do we have very strong evidence. Being associated with the origin of civilisation, this is also one of the most interesting and important events, and we will tackle its impact on human development in later chapters.

But, any thoughts on how other potential impact events might have affected human cultures, either before or after the Younger Dryas event, must remain quite speculative at this point. Considering the artwork at Lascaux to begin with, a good reason for its existence can be suggested – similar to Göbekli Tepe's. Lascaux was presumably another sanctuary or shrine, and the Shaft Scene was a memorial to that particular event. Can the same be said about the other well-known caves as well? Are these extraordinary ancient caves with their fabulous artworks all types of ice-age cathedral, to which people fled to seek protection from the falling sky? After all, these dark and difficult caves are not easy places to spend much time – they are unusual places to find such spectacular artworks.

And what about our knowledge of advanced astronomy? How could that change our understanding of prehistory? Possibly, if people were capable of tracking and recording precession of the equinoxes at these very early times, as much as 40,000 years ago, then they might also have been able to navigate across the oceans using the lunar distance method (see Appendix B). This method uses the position of the moon relative to the stars to keep track of longitude. It was routinely used by mariners until the mid-19th century AD, when the invention of accurate timepieces changed navigation forever. All one needs to use the lunar distance method is an appreciation of the moon's clockwork-like cycle around Earth – basic astronomical knowledge compared to precession of the equinoxes. Latitude is much easier to track than longitude. It can be measured simply by observing the height in the sky reached by the southern stars (see Appendix B). Put them together, and our ancient ancestors could have navigated the oceans as soon as they were capable of building sufficiently robust vessels. And given that they could make musical instruments with a pentatonic scale 40,000 years ago, I expect the construction of a seagoing vessel would have been well within their capabilities.

If they could have navigated the oceans, then, obviously, it would have made it much easier to populate distant, isolated islands. The Pacific Islands, for example, are spread across thousands of miles of treacherous ocean. Typically, it is assumed they were populated by Homo sapiens only relatively recently, within the last few thousand years. The evidence for this comes mainly from the similarity of

Pacific Islanders' DNA and language. But is it possible that there were earlier waves of migration into the Pacific, creating earlier Pacific Island cultures whose existence at a much later time came to a dramatic end?

The reason to think this might be the case is that these Pacific Islands are the most exposed places on Earth. People who live there face the greatest risks of all from cosmic impacts – far more than anywhere else. This is because the Pacific Ocean itself is the largest expanse of open water on Earth. It accounts for around one third of Earth's surface area. This means that cometary debris is much more likely to land on the Pacific than any other single ocean or continent. At the same time, if any of the impacting debris is large enough to reach the surface before exploding, it will create a powerful mega-tsunami – a giant wave – that will travel right across the Pacific area. No Pacific island or continental coastline would be safe, even from an impact into the Pacific Ocean thousands of miles away, because the impact energy would be transformed efficiently into wave energy, which would then be carried smoothly outwards in all directions until encountering solid land. And to compound it all, many Pacific islands are low-lying. They do not have vast mountain ranges or highland plateaus within which to seek refuge. A large impactor anywhere into the Pacific Ocean would create a vast wave hundreds of metres tall that would overwhelm most Pacific islands, leaving nothing but the most robust evidence of the earlier civilisation behind.

Considering that the northern continents have been bombarded by Satan to devastating effect, it is only reasonable to expect Pacific Islands and coastlines to have faced even greater risks from Satan's decay. It is an inescapable conclusion. Quite possibly, the current Pacific Island cultures of Micronesia, Melanesia and Polynesia are just the latest in a series of cultures in that region over the last 40,000 years.

What about events since the Younger Dryas event? We have seen that Lascaux implicates Satan in a catastrophic event around 15,200 BC. But is there any evidence for more recent encounters – ones over the course of civilisation? Clube and Napier explored this idea in their books, *The Cosmic Serpent* and *The Cosmic Winter*. Although they were not the first, or last, to do this, their approach was probably the first properly scientific attempt, being based on their astronomical and astrophysical research published in peer-reviewed research journals. Since then, a few other notable scholars have braved the harsh criticism of orthodoxy – including Mike Baillie, a Professor of dendrochronology at the University of Belfast and one of the world's leading experts in historic and prehistoric dating. For example, his work on tree-ring chronologies contributes to the radiocarbon calibration curves used routinely by scholars of the ancient world. Baillie had observed in the rings of trees, going back many thousands of years, indications of several anomalous climatic upheavals whose timing seemed to coincide with important historical events[147]. Following Clube and Napier, he associated these with a series of encounters with the Taurid meteor stream.

Combined, these works suggest some of the most notable events in history, such as the beginning and end of the Bronze Age, the biblical exodus and the fall of western Rome might have been triggered by Satan's wrath. Let's look at another potential case next.

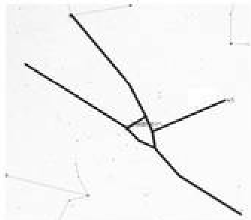
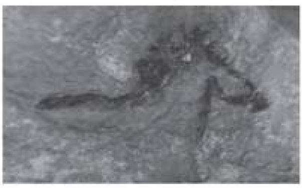
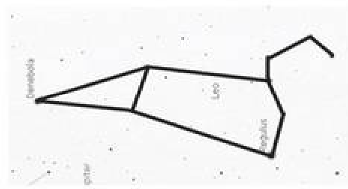
Symbol	Asterism
 Rhinoceros at Chauvet (from 'Inocybe' via French Wikipedia)	 Taurus
 Horse at Lascaux (courtesy of Alistair Coombs)	 Leo

Table 4. Animal symbol – asterism associations identified from the Lascaux Shaft Scene.

10

Zep Tepi and the Great Sphinx

The Great Sphinx and Great Pyramids of Giza, on the outskirts of present-day Cairo, are probably the most famous ancient monuments in the world. Built with superb precision and accurately aligned to the cardinal directions, they are also absolutely immense. The Pyramid of Khufu, the largest of the three Great Pyramids at Giza, is nearly 140 metres tall and estimated to weigh nearly 6 million tonnes.

Apparently built around 2,500 BC, it remained the tallest man-made construction until the Middle Ages. Remarkably, it is still amongst the heaviest – only major public construction works such as the most massive modern dams and bridges can compete with it. Its construction was an incredible feat of engineering that we would struggle to repeat even today. According to Egyptologists, it was likely built within the span of a single lifetime. The seeming impossibility of this feat at such an early time has led to a profusion of bizarre theories and intense speculation about Ancient Egypt and its pharaonic dynasties.

Conventionally, the history of Ancient Egypt begins around 3,000 BC with the 1st Dynasty and ends nearly 2,500 years later, around 500 BC, with the 26th Dynasty. During this immensely long period, despite episodes of strife and occasional breaks in pharaonic succession, Ancient Egypt became the pre-eminent civilisation of the Bronze Age. Nothing else from antiquity can compare with its majesty. Its steady decline during the classical period that followed occurred as Ancient Greece, and then Rome, ascended.

Its emergence and cultural development are dominated by the mighty Nile River. Seasonal flooding of the Nile created a very fertile strip of land bordering its banks upon which life in Egypt depended. Successive dynasties built massive megalithic monuments along 1,000 kilometres of its length, from Thebes in the southern region of Upper Egypt to Memphis, Heliopolis and Giza near the Mediterranean coast in Lower Egypt (see Figure 34).

Ancient Egypt's life as a single nation is thought to have begun when the first pharaohs united Upper and Lower Egypt at the beginning of the Bronze Age as the 4th millennium BC was drawing to a close. Previously, Egypt had been ruled by independent warlords in Upper and Lower Egypt. Although some of the very first hieroglyphic inscriptions date from this period of unification, leaving clues about how it occurred, the truth is this era remains shrouded in mystery.

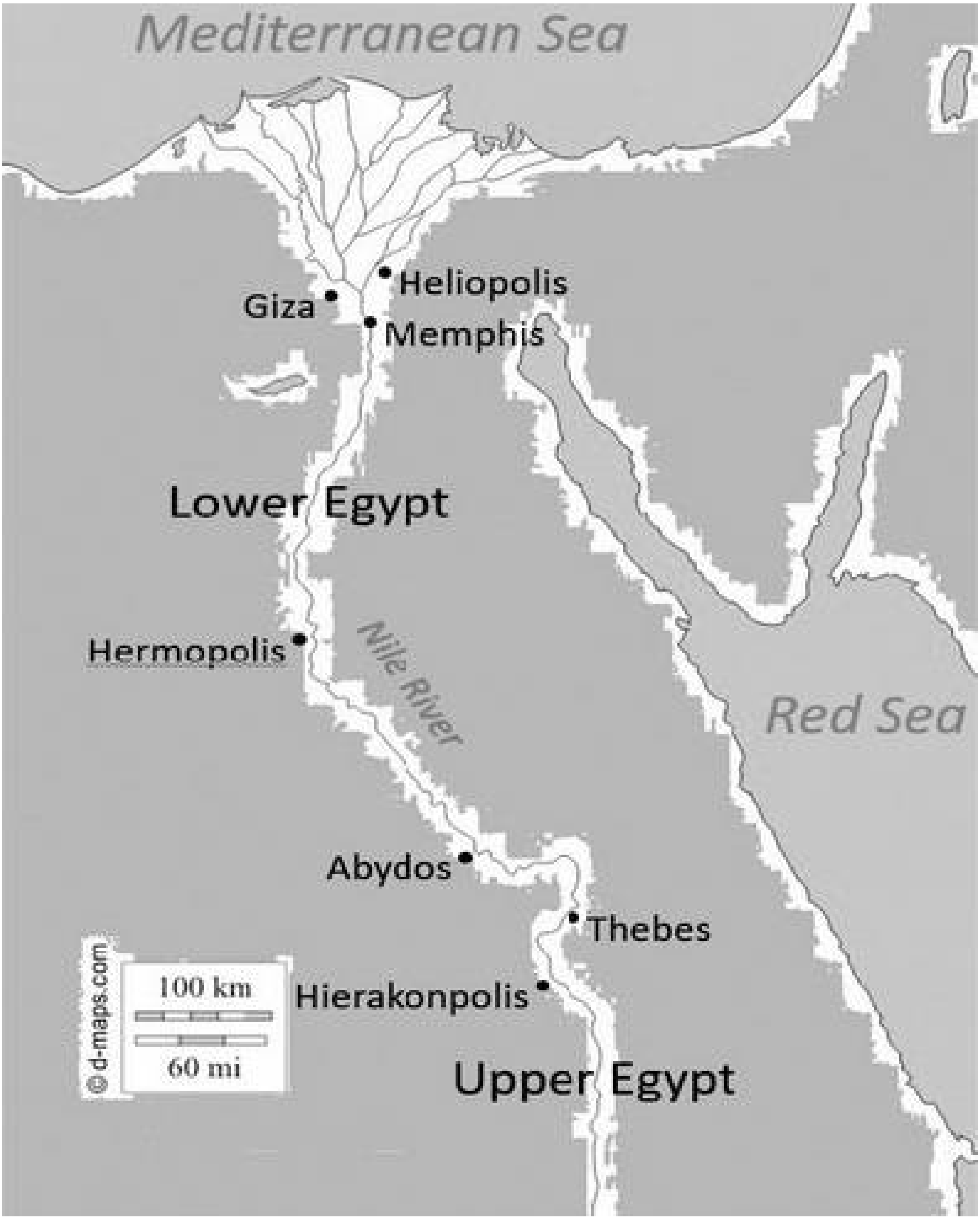


Figure 34. Map of Ancient Egypt showing major population centres along the Nile.

Egypt's prehistory, long before unification, is even more hazy and a hot topic of debate among Egyptologists. Evidence from this time is rare, and its interpretation is fraught with uncertainty. One of the most important finds thought to date to this early predynastic period that provides some insight is a massive ancient limestone mace-head that currently resides in the Ashmolean Museum in Oxford, England (see Figure 35). Discovered at the end of the 19th century in the ruins of ancient Hierakonpolis, beside the Nile in Upper Egypt, it is covered with hieroglyphic-like symbols that appear to show a predynastic pharaoh, known as the Scorpion King. The reason for his name is the appearance of a scorpion symbol to the right of his image on the mace-head. But, although these symbols are familiar and follow some of the conventions of later hieroglyphic writing, the mace-head scene does not seem to translate directly. Naturally, this artefact has caused a great deal of controversy.

A similar figure, often interpreted to be the same predynastic pharaoh, appears on a large shield-shaped palette, now in the Egyptian Museum, Cairo, recovered from the same ruins as the mace-head. It appears to show the unification of Upper and Lower Egypt to form the dynastic Egypt we are familiar with, circa 3,100 BC. But the name on this palette, known as the Narmer Palette, is different – there are no scorpions here. Instead, we find the properly written hieroglyphic name of Narmer, who is often linked with Menes, the first pharaoh of the 1st dynasty according to established king lists compiled from several independent sources.

Figure 35. Mace-head of the Scorpion recovered from Hierakonpolis in 1897. Image © Ashmolean Museum, University of Oxford.

Because of the similarity of the figures on the mace-head and the Narmer Palette, the Scorpion King has been associated with Ancient Egypt's unification, although this idea is much debated. We cannot be sure if the mace-head and Narmer Palette refer to the same person. It may well be that the Scorpion King is Narmer/Menes himself, or an ancestor of Narmer/Menes. It might even be the case that there was no king named Scorpion, or that the image on the mace-head is not of a king at all. Whatever the relationship between Narmer/Menes and the Scorpion King, it is generally thought they were warrior-kings that united Ancient Egypt circa 3,100 BC.

Note, however, that the Scorpius constellation corresponds to the autumn equinox over the period 3,700 BC to 2,400 BC. Does this mean the scorpion symbol on the mace-head refers instead to a date, and not to a king at all? Could this be evidence that the Ancient Egyptians knew about our zodiac and how to write dates using precession of the equinoxes, like the people at Göbekli Tepe and Çatalhöyük in much earlier times? If it is, then it would imply the Egyptian deities, as suspected in Chapter 9, are indeed derived from a zodiacal mythology stretching back at least 35,000 years.

But, this could easily be a coincidence. The probability for Scorpius to correspond to one of the solstices or equinoxes by pure chance is about 1 in 6, because it is a short constellation in terms of precession. This probability is far too high to be convincing. Much more evidence is needed to make a scientific case that our ancient zodiac was known by the Ancient Egyptians.

Enter the so-called Scorpion Tableau, a section of rock graffiti found in the desert 25 miles to the north-west of Thebes by Yale archaeologists John and Deborah Darnell in 1994. Figure 36 shows a section of it[148]. Its discovery caused quite a stir among Egyptologists, many of whom took it as further evidence of the Scorpion King. They interpreted the pair of symbols on the right, the vertical sequence: falcon, scorpion, as meaning King Scorpion, because in later dynastic Egypt the falcon symbol usually refers to the deity Horus and means ‘King’ in combination with the names of pharaohs.

Furthermore, the pair of scribbles on the left of this scene have been interpreted to be a depiction of the Scorpion King leading his vanquished foe by a leash. There are other scribblings on this tableau, mainly animals not shown in Figure 36, but Darnell does not interpret these. They are, apparently, just animals.

Now, to my eye, the figure of a man with a mace, claimed to represent the Scorpion King, is clear, but the figure next to him could be almost anything. In fact, it looks as though one picture has been scratched on top of another. Nevertheless, this tableau, it is claimed, lends strong support to the Scorpion King myth.

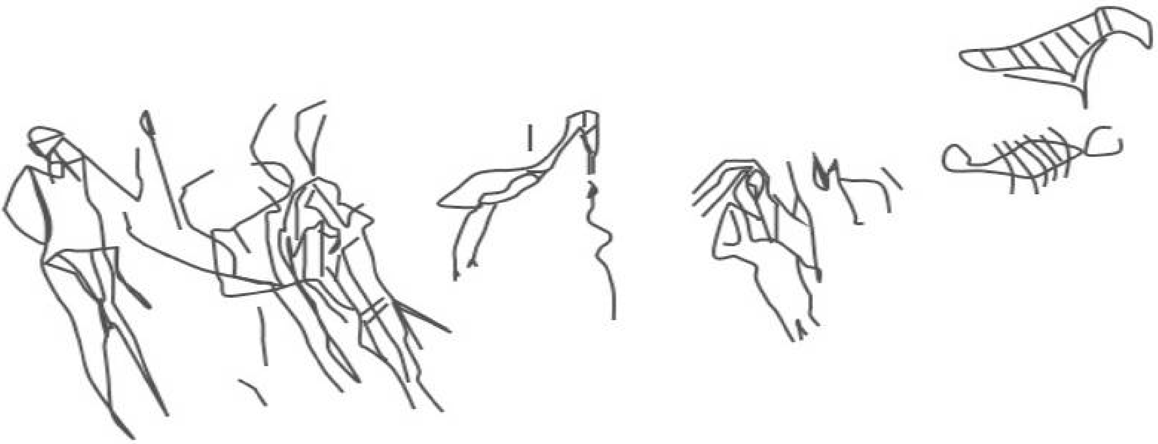


Figure 36. Copy of the lower part of the Scorpion Tableau rock inscription near Thebes[148].

But, having decoded animal symbols used throughout the Stone Age, I can supply an alternative interpretation for this scene. According to this zodiac and precession of the equinoxes, this tableau instead might represent a date. The two symbols occurring together on the right probably indicate the autumn equinox is transitioning between Sagittarius, represented by the falcon, and Scorpius, represented by the scorpion, which is consistent with our zodiac if the eagle/vulture is replaced by a different bird of prey, here the falcon. Although we haven't seen this kind of notation used before, it makes sense. So far, only one symbol, whichever is closest, is used to represent the position of an equinox or solstice relative to a constellation. But here, it appears, both symbols are used if the equinox or solstice is midway between them. Using Stellarium again, this date corresponds to 3,500 BC, to within a few hundred years (see Figure 37).

A similar sequence of symbols has been seen on other items from this period. For example, wine flasks found in the grave of an important person in ancient Abydos, thought to be the Scorpion King himself, have the sequence: falcon, scorpion, duck, the exact same sequence of three zodiacal symbols found on the main part of Göbekli Tepe's Vulture Stone. This is very unlikely to be a coincidence.

Further evidence that this zodiacal interpretation of these animal symbols might be correct is provided by the tall bending bird and snake symbol in the middle of Figure 36. At this time, around 3,500 BC, the Taurid meteor stream would have been centred over Pisces. Remember, longitudinal precession causes the Taurid meteor stream radiant to move along the zodiac at a rate of about one zodiacal symbol per 6,000 years. As the centre of this meteor stream currently resides over Aries/Taurus, in 3,500 BC it would instead have been centred over Pisces, which is represented in the zodiac by the tall bending bird (see Table 1). Therefore, images of tall bending birds accompanied by snakes in combination with the falcon/scorpion pair are compelling evidence of knowledge of the zodiac in predynastic Egypt. The animals in the rest of this tableau (not shown), for which the conventional explanation is they are just random animals, can also be interpreted in a similar way giving a consistent date of around 3,500 BC to within a few hundred years.

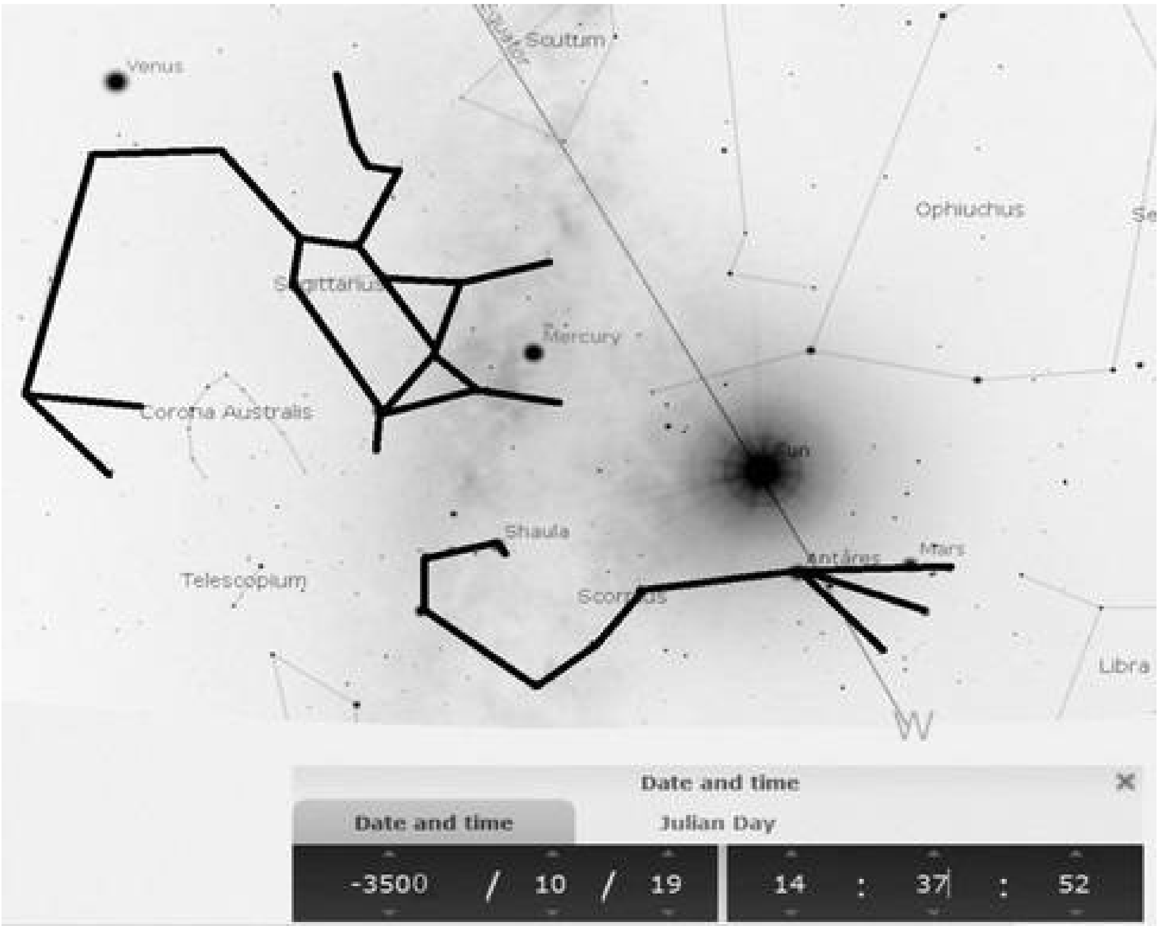


Figure 37. Position of the sun on the spring equinox at 3,500 BC between Sagittarius and Scorpius (adapted from Stellarium).

But does this tableau convey a more interesting message than simply a date? Could it perhaps be, like the Vulture Stone at Göbekli Tepe and the Lascaux Shaft Scene, that this rock carving is depicting another Satanic collision event, this time around 3,500 BC, indicated by the snake next to the tall bending bird? Figure 38 shows the northern hemisphere temperature reconstruction from the GISP2 ice core for the whole of the Holocene period, the last 10,000 years. If another collision with cometary debris occurred at this time, it might show up in this temperature record. Although the climate looks to be very unstable in Figure 38, with large peaks and troughs every few thousand years, it is not actually that bad. These fluctuations are much smaller than those over the preceding ice age; they only appear large because of the expanded vertical scale on the left.

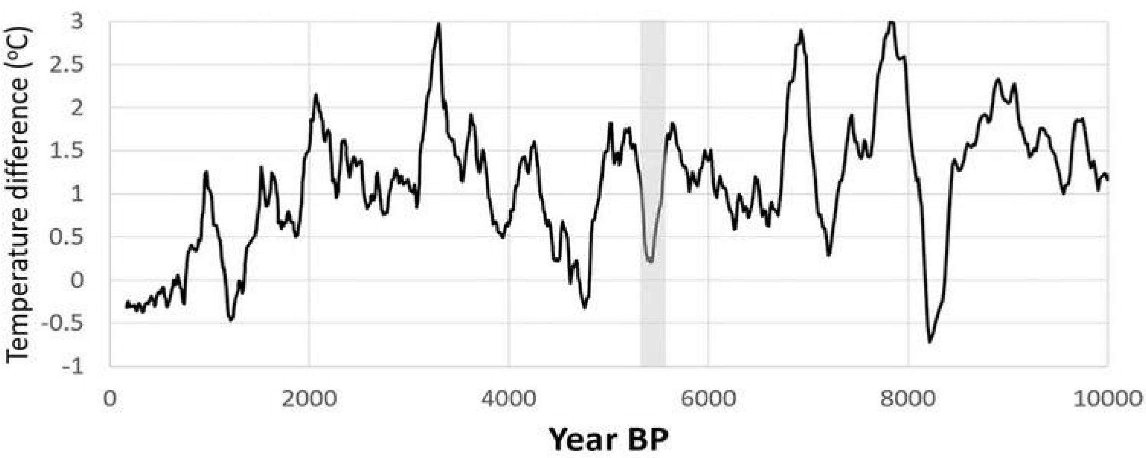


Figure 38. GISP2 temperature reconstruction over the Holocene period[27]. The grey bar marks the climate event that precedes the Bronze Age. Year BP is the number of years before 1950.

As expected, we see that 3,500 BC does indeed coincide with another major climate event; probably the fifth largest climate fluctuation in the northern hemisphere over the whole Holocene. Average temperatures appear to have dropped by around 1.5 degrees Celsius for 400 years, beginning 3,600 BC. It is probably no coincidence that the end of this period, around 3,200 BC, also marks the transition from the end of the New Stone Age (Neolithic), to the beginning of the Bronze Age in this part of the world. It seems, once again, that an important cultural transition is preceded by a strong climate event, which in turn might have been triggered by an encounter with the Taurid meteor stream. We see a consistently repeated pattern. Naturally, climatologists see this climate fluctuation as a natural feature of Earth's climate rather than a consequence of Satan's wrath.

But, there is a difference between this scene and the carvings found at Göbekli Tepe and the paintings at Lascaux. The Shaft Scene and Pillar 43 both show dying men, probably indicating the date refers to a catastrophic event. But here we have only a man leading another figure, which is hard to make out, on a leash. Altogether, it is hard to know for sure what this scene refers to. Nevertheless, the date 3,500 BC, to within a few hundred years, is probably correctly interpreted.

While we can be fairly confident of this date, the broader meaning of this rock-graffiti scene remains obscure. But it is quite clear the Scorpion King appellation has probably been misinterpreted by Egyptologists. The problem we have in interpreting this scene as well as other inscriptions from this period is that Egypt does not yet seem to have developed its hieroglyphic system of writing. Therefore, attempts by Egyptologists to use hieroglyphic conventions to decode these earlier inscriptions are likely to mislead.

Neolithic Egypt

Not a great deal is known about even earlier times deep in the Egyptian Neolithic as megalithic monuments covered in hieroglyphics were not built during this period. Instead, the remains of late Stone Age village farmsteads with reed or mud-brick houses are found buried deep in the sand or sediment together with more basic tools, pottery and decorated personal items, such as combs and little figurines.

The Nile river causes a major problem for archaeologists working in Egypt. It lays down silt during annual floods which typically covers or removes what little evidence from this predynastic period remains near the river where much of the population would have lived. Nevertheless, many items from foreign lands have been recovered from archaeological sites across Egypt dating to this time, making it clear that Egypt traded with its neighbours before unification. It appears, then, that Egypt was a developing nation during this period. Essentially, a more or less continuous phase of settlement within predynastic Upper and Lower Egypt beside the Nile can be traced back to around 6,000 BC. This provides a suitably long backdrop of history and cultural development against which the later incredible dynastic achievements can be rationalised.

But there the trail seems to stop. There is almost nothing in the archaeological record along the Nile from before 6,000 BC. Oddly, there is more evidence of human presence in Egypt before the 9th millennium BC, than for the next three millennia leading up to 6,000 BC. It is as though Egypt became uninhabitable for 3,000 long years.

This archaeological black hole is troubling. It deserves an explanation. Until around 9,000 BC the archaeological record indicates the people that inhabited Egypt were quite similar in many ways to the Natufian people of the Levant. They appear to have been hunter-gatherers that made semi-permanent camps, hunted wild game, fished and collected wild plants and grains. But they seem to have deserted the Egyptian Nile for 3,000 years, not returning until after 6,000 BC. Given the Neolithic revolution was gathering pace in the Fertile Crescent to the north over this multi-millennial period, with the development of large towns like Çatalhöyük in Turkey and Jericho with its massive city walls in Palestine, you would have thought that life by the Nile in Egypt would also be thriving, especially considering the abundance of its environment.

Not so, apparently. Instead, we see farmers and pastoralists occupy the Egyptian Nile only after 6,000 BC. It doesn't make sense. The reasons archaeologists give for this odd hiatus in settlement include the 'Wild Nile' scenario, whereby the Nile itself is responsible for washing away whatever civilisation existed beside the Nile due to massive flooding. Similarly, it has been suggested the Nile Delta was just too wet and boggy for people to make a living during this period.

While there might be some truth in these suggestions, it seems there is another mystery here to be solved. Could there instead have been another catastrophic event slightly before 6,000 BC which erased a very early phase of Neolithic Egyptian civilisation? Could this same disaster also have led to the abandonment of Çatalhöyük by around 6,200 BC? Are these events connected by yet another collision with Satan's debris?

If we look at the climate record again, we find this is a distinct possibility. In fact, the GISP2 ice-core record shows that the largest climate fluctuation in the northern hemisphere of the last 10,000 years, the whole of the Holocene period, occurred just before 6,000 BC (see Figure 38). It is known to climatologists as the 8.2 kiloyear event. It corresponds to a rapid cooling of the northern hemisphere by around 2 degrees Celsius for nearly 300 years beginning around 6,300 BC.

Naturally, climatologists assume this is yet another natural climate fluctuation caused, like the Younger Dryas mini ice age, by another great pulse of meltwater from the Laurentide ice sheet. Apparently, this new meltwater pulse corresponds to the final death throes of this ice sheet, which collapsed suddenly into the Arctic Ocean, causing the North Atlantic Ocean current to stall, leading to colder conditions in the northern hemisphere until the meltwater cleared. Whilst this might be true, it does not address what triggered this final collapse of the Laurentide ice sheet. Did it die of natural causes, or was it murdered?

Zep Tepi

Like everywhere else, Ancient Egypt had a creation myth. In fact, it had several. We have met one of them already – the creation myth centred at Heliopolis, one of Egypt's most ancient cities founded in predynastic times, involving the Ennead, a group of major gods created by the primordial god Atum. Other creation myths originated with other ancient major population centres along the Nile, such as Memphis, Thebes and Hermopolis.

Despite the differences in these creation myths, including which gods were venerated above the others and the name of the primordial creator god, they also share some clear similarities. The common theme running through all of them that indicates a shared origin involves the emergence of the world from the chaotic waters of Nu. The first land to emerge from these waters was a pyramidal mound, from behind which the sun rose to banish the darkness and create the first day.

Fortunately, the Ancient Egyptians wrote their myths down, not just on papyrus, which is perishable, but on stone – all over their temples and inside their tombs. They tell of a time, known as Zep Tepi, or the 'First Time', when the newly created gods lived among the people as their kings. A golden, civilising age of plenty. Of course, this account is a massively compressed summary of a complex mythology that developed over several millennia in different cities across Ancient Egypt. Mythologies from different cities were likely merged and used as political tools to create alliances and coerce populations.

Nevertheless, despite their tapestry of interconnecting tales, the core themes of i) creation from chaotic waters, and ii) emergence of the Sun from a primordial mound to banish darkness are consistently retold. A similar tale, a generalised flood myth, is told the world over. Given that we can expect massive coastal flooding by mega-tsunamis whenever large comet fragments impact into an ocean, perhaps there is more to these tales than simple superstition. After all, we have seen how stories of a great conflagration, the Phaethon myth for example, might recall the Younger Dryas event or similar events. Could the universal flood myth also contain a kernel of truth?

The problem with interpreting mythology as historical events is that we cannot know how to separate fact from fiction in any reliable way. This is why these tales are ignored by science. But, where a great many different myths seem to have similar themes, especially where a common origin is not obvious, it can be useful to compare and contrast them to see which, if any, of the themes are reliably repeated. This kind of study, known as comparative mythology, is rather like the study of the evolution of language, or indeed of DNA. We can now add the zodiac and its constellations to this list. Different branches of myth are presumed to connect to an earlier common source, whose thematic elements can be used as a guide to ancient systems of thought and perhaps even ancient events. Although expressed as supernatural stories, they probably represent the science of their day – encoding knowledge in a form relevant to people at the time.

It is therefore legitimate to ask whether the Ancient Egyptian creation myth, the First Time of Zep Tepi, refers to a golden age of civilisation that followed a cataclysm and has since vanished, or been destroyed by another cataclysm. If so, was this golden age before or after the 8.2 kiloyear event? It seems unlikely that it could have been after, since the archaeological record is relatively intact and clear in showing a process of gradual and sustained development from 6,000 BC towards the glorious dynasties of the Bronze Age. More likely, perhaps, is that if there is any truth to the core Zep Tepi myth at all, it refers to an extremely ancient time during the archaeological black hole that preceded the 8.2 kiloyear event. Perhaps this earliest Egyptian civilisation has since been washed away by the waters of chaos unleashed by the 8.2 kiloyear event, either via the Wild Nile scenario or a mega-tsunami inducing surface impact.

While it is fine to speculate about this possibility, ultimately it is hard scientific evidence that we should seek. Otherwise, all we have is a curious story. Is there any scientific evidence that the 8.2 kiloyear event was caused by a cosmic impact, like the Younger Dryas event?

The Great Sphinx of Giza

Nobody knows how old the Great Sphinx of Giza really is. Yes, Egyptologists will tell you with great force and conviction that the Sphinx was built at the same time as the Great Pyramids of Giza, around 2,500 BC. But, the truth is they are guessing. There is not a shred of evidence that supports their story. Their views of the Sphinx are no more reliable than the ancient myths they dismiss as, well, myth.

We pretty much know how old the Great Pyramids of Giza are, or at least how old the ones we see now on the Giza plateau are. This is because there is fairly consistent evidence for their construction during the Old Kingdom dynasty, around 2,500 BC. Radiocarbon dates have been obtained from mortar used in some sections of the pyramids, from the archaeological remains of bakeries used by workers thought to have built the Pyramids, from pigments found inside the Pyramids, and from a papyrus that describes planning their construction. They agree, mostly to within a few hundred years, with construction around the middle of the 3rd millennium BC.

But none of this evidence applies to the Sphinx. There are no radiocarbon dates that pertain to it at all. Indeed, it is unique among Ancient Egyptian monuments. Most of them are giant megalithic temples or palaces, or huge pyramids or other tombs. There are also immense stone statues, for example the Colossi of Memnon at Luxor perhaps weighing over 700 tonnes each. But there is only one example of direct sculpture from bedrock in the form of an animal on the scale of the Sphinx – the Sphinx itself. Nothing else even comes close to it.

Anyone who views the Sphinx close up will immediately be awed by its immense size. Its feline body is the size of a ship, resting amid the hot desert sands as its giant pharaonic head stares impassively eastward. At around 75 metres in length, and 20 metres tall and wide, it's an amazing accomplishment for any civilisation, let alone a very ancient one. This is one reason for the intense interest in its origin.

But the next thing you'll probably notice is just how weathered it is. It's quite extraordinary and, like the Great Pyramids half a kilometre behind it, quite baffling (see Figure 39). Deep vertical drainage channels are worn into its surfaces and all along the sides of the stone enclosure in which it rests, suggesting extensive rainwater run-off. Because the Great Pyramids don't show the same extreme weathering as the Sphinx, it is natural to think that either the Sphinx must be much, much older than them, or it must be carved from much softer limestone that yields more quickly to the elements. The problem with the latter view is that both the Sphinx and the Pyramids are hewn from practically the same rock – the Giza Plateau itself. Another oddity is the Sphinx's human head – it also displays almost no weathering at all and appears too small for its body. The contrast between the weathering along its body compared to its head is perplexing, and demands an explanation.

To this end, John Anthony West, a well-known maverick Egyptologist who recently passed away, invited Professor Robert Schoch, a geologist from the University of Boston, to investigate the Sphinx in the early 1990s. After performing some seismic surveys of the rock surface surrounding the Sphinx within its enclosure, and through analysis of the extent of its surface erosion, Schoch concluded that the Sphinx was most likely constructed between 5,000 to 7,000 BC, during a period of much wetter climate in Lower Egypt[149].

Figure 39: The Great Sphinx of Giza, with Khufu's Pyramid behind (by Hamish2k, CC BY-SA 3.0).

This caused uproar among archaeologists. According to them, this was simply impossible as no civilisation existed at that early time capable of building it. But, this is an odd criticism to make, as they would have known of Jericho in Palestine, which is not so far from Egypt, where a massive stone tower and wall were uncovered in the 1930s dating to around 8,000 BC. By itself, this indicates the capability to construct the Sphinx might have existed even before Schoch's estimated range of dates.

Schoch received some (limited) support for his interpretation from other geologists. Colin Reader, a chartered geologist from the UK, later pointed out that quarries excavated to provide the giant stone blocks for the pyramids, situated between the Great Pyramids and the Sphinx, would have collected rainwater running off the Giza Plateau, diverting it away from the Sphinx. This means the exceptional extent of weathering on the western wall of the Sphinx enclosure, between the Sphinx and the Great Pyramids, indicates the Sphinx must predate these quarries by a considerable amount of time. According to Reader, there is no way this extreme erosion of the Sphinx's enclosure could have occurred if it was built at the same time as the Pyramids. His preferred date of construction for the Sphinx was around 3,200 BC, the earliest possible date consistent with any known Egyptian dynasty. A few other geologists have agreed with the general sentiment of an older Sphinx, but most geologists have stayed well clear of this debate.

More recently, other maverick investigators have suggested a far older origin for the Sphinx, including Graham Hancock who wrote *Magicians of the Gods*, the book that prompted my decoding of Göbekli Tepe. Noting its alignment, which faces almost perfectly due east towards the sun as it rises on the spring and autumn equinoxes, he suggested the Sphinx likely gazes directly at its own image in the sky as the sun rises on one of these auspicious days.

On any other day of the year, apart from the spring and autumn equinoxes, the sun rises either to the north or south of due east.

Using Stellarium again, and assuming the Sphinx looks directly at the constellation Leo as the Sun rises on the spring equinox, a date of construction somewhere between 10,500 to 7,900 BC is obtained. Schoch was persuaded by Hancock's argument, and extended his suggested weathering timeline back to 10,500 BC to fit with this idea. Probably, he should have stuck with his original estimate.

This proposal was considered even more outrageous by Egyptologists, as it implied knowledge of precession of the equinoxes at this very early time, contrary to accepted norms of scholarship. Moreover, the Sphinx has the head of a pharaoh, not a lion. So why should it have anything to do with the constellation Leo? But, as we have already seen, the Sphinx's head looks to be far younger than its body. Therefore, so the story goes, the head could have been re-carved from the shape of a lion to that of a pharaoh when the Pyramids were built.

The counterarguments of archaeologists are that the Sphinx's head looks much younger than its body because it is formed from a harder layer of rock, and that the heavy weathering seen on its body and enclosure walls is due to wind and salt erosion, not rainwater run-off. Nevertheless, even taking this into account, Schoch and Reader argue this is insufficient to explain the observed pattern of weathering.

The question is, who is right? Who has the strongest evidence? Egyptologists argue that because the Sphinx is near the Pyramids, they must have been built at the same time. But there is no logic to this. As scientific evidence trumps all other kinds, the most reliable evidence so far produced must be Schoch's weathering analysis. Everything else is just speculation. This means, until Schoch's methods are shown to be flawed, the most likely date for the Sphinx's construction is between 5,000 and 7,000 BC. This places it either side of the 8.2 kiloyear event, and potentially into the archaeological black hole of the early Neolithic period.

If this is true, then it solves a major problem. The archaeological black hole before the 8.2 kiloyear event is perhaps not a black hole after all. There might have been a relatively sophisticated Egyptian civilisation occupying the Nile at this time, remembered as Zep Tepi by the Dynastic Egyptians, who built the Sphinx and a few other surviving structures. Their civilisation was then largely destroyed or washed away, leaving only a few of the most robust structures behind. These, like the Sphinx, have been completely misdated and misunderstood by Egyptologists. This scenario would appear to be more likely than the alternative where the Sphinx is built shortly after the 8.2 kiloyear event, as that would be inconsistent with the established archaeological record.

As things stand, with the evidence we have, the existence of an early and relatively advanced Egyptian civilisation prior to the 8.2 kiloyear event is good, but not yet conclusive. It is clear from Schoch and Reader's analysis the Sphinx is unlikely to have been built at the same time as the Great Pyramids, but we only have Schoch's evidence for a construction date before the 8.2 kiloyear event. If his analysis turns out to be flawed the whole proposal collapses. Is there any other strong evidence that supports it?

We now know our ancient zodiac had been observed for 35,000 years before the Egyptian dynasties of the Bronze Age. Across Western Europe the solstices and equinoxes were tracked and recorded using animal symbols to represent the corresponding constellations. We see this custom is continued at Göbekli Tepe, 11,000 to 8,000 BC, and then at Çatalhöyük from 7,200 BC until the 8.2 kiloyear event, only a few hundred miles from the Sphinx. We see the most important and ancient Egyptian deities are represented by many of the same animal symbols, and we find that predynastic rock inscriptions have probably been misinterpreted, and instead likely show the continued use of this system for representing dates until at least 3,500 BC in Egypt.

So what chance is there that an ancient giant feline sculpture in Egypt that looks directly towards the sunrise on the spring equinox has nothing whatsoever to do with this tradition? Especially considering the dynastic Egyptian name for the Sphinx was Hor-em-akhet, which means ‘Sun on the horizon’ if we equate the Horus prefix with a popular composite Horus-sun deity in Ancient Egypt. It seems almost inconceivable that, given the Sphinx gazes directly at the rising sun on the spring and autumn equinoxes, it is unconnected with this astronomical custom that stretches back tens of thousands of years.

If we apply our ancient zodiac to the Sphinx, where Cancer, *not* Leo, is represented by a lion/leopard symbol (see Table 3), we find the range of dates for the spring equinox corresponds to 7,700 to 6,400 BC, which overlaps perfectly with Schoch’s original weathering analysis (see Figure 40). This is astonishing. We now have two independent pieces of good scientific evidence that agree with each other. It seems there really could have been a more ancient and advanced Egyptian civilisation by the Nile prior to the 8.2 kiloyear event, remembered by the Egyptians as Zep Tepi, solving the mystery of the archaeological black hole.

How secure is this evidence? How much confidence can we have in it? Schoch’s weathering analysis has not been contested by other expert geologists. But, as scientists, we prefer to see important studies repeated by others to ensure there have been no errors in the methodology or interpretation of results. Unfortunately, this has not yet been done. Regarding our zodiacal evidence, this relies on the Neolithic Egyptians using the same zodiac that others have used across Western Europe for the previous 30,000 years. Although there is some good evidence they did know of this zodiac and of precession of the equinoxes, we can’t be sure of this, nor can we be sure they used the lion/leopard symbol to represent Cancer rather than Leo. Clearly, at some point in antiquity, this symbol was switched to represent Leo, and we don’t know how, why or when this happened. But, presumably, it occurred after the 8.2 kiloyear event because the same zodiac, with the leopard representing Cancer, is used at Çatalhöyük. So, again, this evidence is not strong by itself. But when we put these two pieces of evidence together they are more convincing.

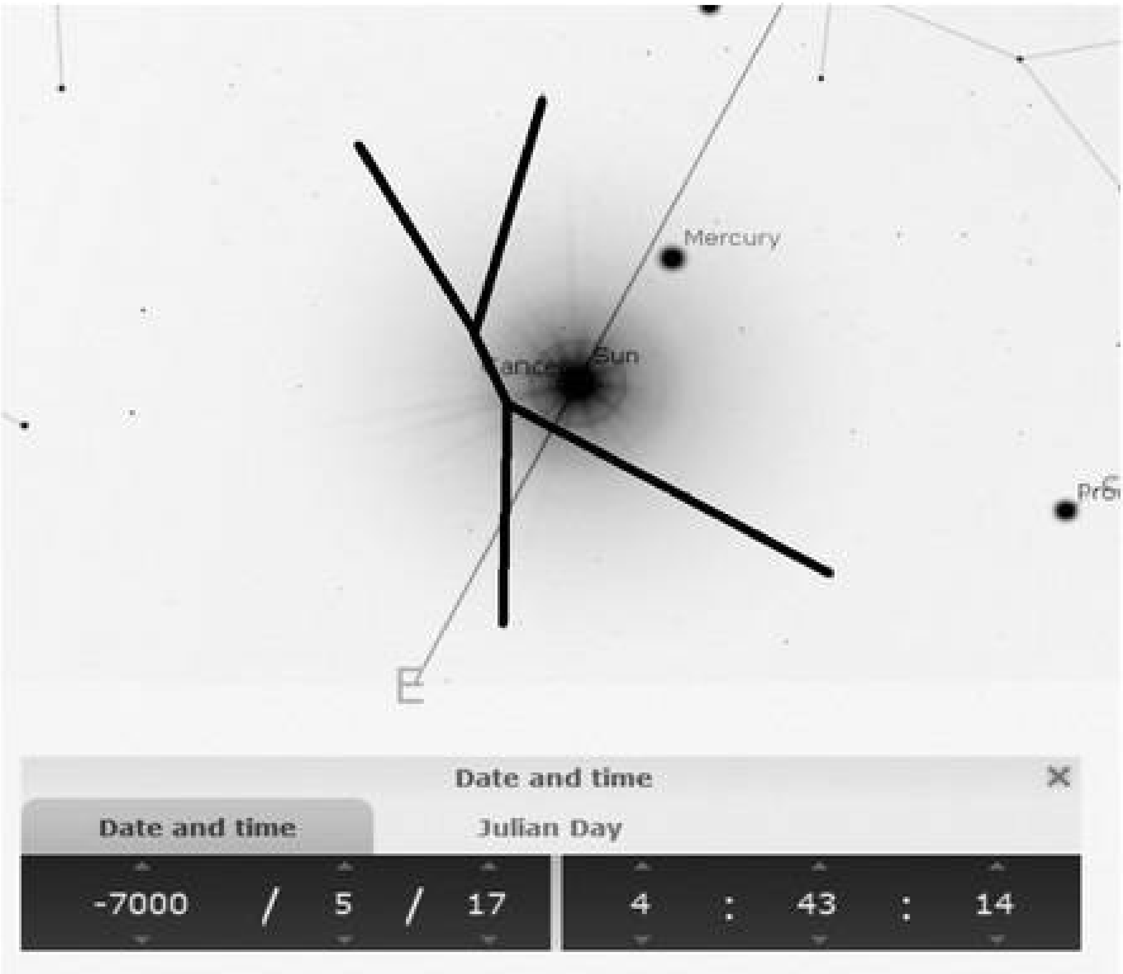


Figure 40. Sunrise on the spring equinox at 7,000 BC in the constellation Cancer (adapted from Stellarium).

There is one more piece of scientific evidence to consider in our deliberations which, in my view, sways the argument firmly towards a very ancient Sphinx. Standing right next to the Sphinx are two ancient buildings, the Sphinx and Valley temples. They are made mainly from huge limestone blocks, although in places these limestone blocks have been covered by protective granite facing blocks. It is generally thought that the oldest limestone blocks forming these temples were cut directly from the Sphinx enclosure when it was first carved. This is because the limestone patterns on these blocks match very well to those in the Sphinx enclosure. This means the oldest limestone blocks in these temples must have the same age as the oldest phase of construction of the Sphinx. Clearly, if these oldest blocks can be dated, then the Sphinx is also dated.

Now, in recent years a method for dating stone constructions has been developed, known as stimulated luminescence. It measures the amount of electric charge stored within specific minerals, like quartz, which is proportional to the time that has elapsed since those minerals were last exposed to sunlight. When suitably calibrated, it can therefore measure when specific types of stone block were constructed, or at least when they were last worked or reworked.

A recent study has found, using this method of dating, that the granite facing blocks to some of the core limestone blocks in these temples were emplaced around 3,000 BC, although there is considerable uncertainty in these dates[150]. Specifically, three stimulated luminescence measurements for different granite blocks have ages of 3,060 BC, 2,740 BC and 3,100 BC, although the uncertainty in each of these dates is around 1,000 years at the level of 95% confidence.

Naturally, it is tempting to conclude that these dates are in line with the conventional view that the Sphinx has a similar age to the Great Pyramids. But this ignores a crucial fact pointed out by Schoch[151], which is that these granite facing blocks have been deliberately shaped and moulded to fit the surfaces of the limestone blocks they cover, which are extremely weathered. Just like the Sphinx and its enclosure, these limestone blocks show signs of extreme age on behalf of their weathered surfaces, which the granite facing blocks were presumably designed to disguise. Clearly, if these limestone blocks were faced, or corrected, with deliberately carved granite blocks, whose age is consistent with the Pyramids, then the very weathered limestone blocks they cover, corresponding to the true age of the Sphinx, must be thousands of years older.

If this proposal is true, then according to Schoch's weathering evidence and my zodiacal interpretation, this early Neolithic Egyptian civilisation would be contemporaneous with Çatalhöyük in Anatolia. It would mean the Sphinx is the Egyptian analogue of the leopard shrines at Çatalhöyük. While the people at Çatalhöyük prayed at their leopard shrines on the spring equinox, Egyptian people 500 miles to the south beside the Nile were perhaps performing rituals under the nose of the Sphinx, which was then either a lion or leopard. But then disaster struck, both cultures were 'reset' by the 8.2 kiloyear event, and the myth of Zep Tepi was born. It would also mean the Lion-man of Hohlenstein-Stadel cave, the lion paintings in Chauvet cave, the leopard shrines of Çatalhöyük and the Great Sphinx of Egypt are all connected by an ancient tradition stretching back 30,000 years.

The 8.2 Kiloyear Event

For the above scenario to be credible, there should be scientific evidence that the 8.2 kiloyear event was catastrophic, and not just a relatively benign fluctuation in northern hemisphere climate. Ultimately, to prove there was a cosmic encounter with Satan at this time the relevant geochemical signals will need to be found. Unfortunately, unlike the Younger Dryas event, there have not yet been any studies of this kind for the 8.2 kiloyear event. Therefore, other indicators of catastrophe at this time must be sought.

Very interestingly, a recent summary of research concerning the cause of the 8.2 kiloyear event concludes that it exhibits similar climate signals to the Younger Dryas event, although of a smaller magnitude, and therefore is likely caused by a similar mechanism[152,153]. This supports the view that the 8.2 kiloyear event was caused by yet another huge pulse of meltwater rushing into northern oceans off the Laurentide ice sheet. Typically, it is thought this ice sheet was in the final stages of its life, and collapsed into the Hudson Bay north of Canada. So, the question we need to address is, what caused this final collapse of this ice sheet?

If this ice sheet collapse, and therefore the 8.2 kiloyear event as well, were both caused by an episode of cosmic bombardment, we should find signals of widespread disasters at this time. And indeed, this appears to be the case. Most obviously, there is the massive Storegga Slide, one of the largest known sub-sea landslides. It occurred on the edge of the continental shelf off the coast of Norway at some point between 6,170 and 6,225 BC, according to radiocarbon dating studies[154]. It involved the catastrophic slump of nearly 1,000 cubic miles of subsea continental shelf onto the abyssal plain, i.e. the ocean floor, a truly enormous collapse. In turn, it is thought to have caused a mega-tsunami that overwhelmed Doggerland, a large but flat island that existed in the North Sea between Britain and continental Europe before sea-level rise drowned it. Boulders were also dumped by this mega-tsunami up to 50 miles inland in Scotland. Clearly, it was a massive wave.

Now, the 8.2 kiloyear event, like the Younger Dryas event before it, began suddenly. The precise date of the onset of the event, which corresponds to the coldest period from Greenland ice cores, is known to have occurred between 6,260 and 6,280 BC according to the Greenland ice-core chronology. But, the Greenland ice-core and radiocarbon chronologies are known to be misaligned by around 70 years at the end of the Younger Dryas period, which becomes about 50 years at the time of the 8.2 kiloyear event. This means the date of the onset of the 8.2 kiloyear event, according to ice cores, is around 6,220 BC in terms of the radiocarbon chronology. Therefore, the dates of the Storegga Slide and the onset of the 8.2 kiloyear event can be viewed as being simultaneous within dating accuracy. Could an encounter with comet debris have also caused this landslide?

Of course, conventionally it is thought these two events, the Storegga Slide and the 8.2 kiloyear event, cannot be simultaneous, or even related in any way, as there is no obvious uniformitarian mechanism that can cause them both. Therefore, an episode of cosmic bombardment, which does have the potential to trigger both events, appears to be a distinct possibility.

Another catastrophic event is also thought to have occurred around this time: the Black Sea Deluge. Before the 8.2 kiloyear event the Black Sea, between Turkey and Ukraine, was much lower than it is now and isolated from the Mediterranean Sea, which although also much lower than today was still much higher than the Black Sea. It was essentially a landlocked inland sea protected from the world's oceans by a low rocky sill near present-day Istanbul. However, seabed mapping and radiocarbon measurements of its sediments suggest the Black Sea filled quickly around the time of the 8.2 kiloyear event. Initial research indicated a catastrophic surge smashed through the low sill to open the Bosporus strait, triggering the Black Sea deluge from the Mediterranean into the Black Sea that followed. Nevertheless, it might have taken hundreds of years for the level of the Black Sea to equalise with the world's oceans.

The original estimate for the date of this sudden inundation corresponds, using a modern radiocarbon calibration curve, to around 6,030 BC, to within 200 years (95% confidence)[155], which is consistent with the onset of the 8.2 kiloyear event. But since this early finding, further research has moved the date of the deluge forwards, and then backwards, by at least a millennium, while others find evidence for a gradual, rather than catastrophic, filling[156].

At around the same time, 6,000 BC, the east flank of Mount Etna, Sicily, collapsed, triggering a tsunami in the Mediterranean. Radiocarbon measurements from the strata of sub-sea debris remaining show this collapse was instantaneous, but its precise date is uncertain[157]. But radiocarbon dating of a thick layer of sediment along the cost of Israel indicates a powerful tsunami occurred in the east Mediterranean around 6,340 BC to within 160 years (95% confidence)[158]. We cannot be sure if this had anything to do with the collapse of Mount Etna's flank, but the timing is certainly consistent with the 8.2 kiloyear event.

Altogether, there are some notable coincidences here that 'raise eyebrows' and deserve an explanation. Could the 8.2 kiloyear event have produced all these different signals? Could it have had an impact on our story? After all, the Nile Delta and Lower Nile Valley are low-lying, and would be prone to the devastating effects of a mega-tsunami.

The truth is, this story remains speculative. These disasters might just as well have been spread over several hundred years around 6,200 BC, rather than occurring on the same day. We just don't know. But, perhaps there is now enough evidence to motivate the search for definitive geochemical evidence for a catastrophic origin to the 8.2 kiloyear event. Being the most significant climate event of the entire Holocene, it should have left conspicuous geochemical traces if it was actually caused by cosmic bombardment.

11

The Godfather

I have shown that an ancient zodiac, which we continue to use today with some minor changes, was probably established at least 40,000 years ago in Western Europe. This zodiac was used at Göbekli Tepe and then at Çatalhöyük until the 8.2 kiloyear event, around 6,200 BC, seemingly unaltered. But between this event and the beginning of the Bronze Age it appears to have undergone a few changes, such as the bull symbol moving from Capricornus to Taurus and the feline symbol moving from Cancer to Leo.

How is it possible for this zodiac to have survived for so long, relatively intact? How did it even begin? Are we seeing the path of a single culture beginning in Western Europe, then moving to the Near East after the Younger Dryas event, writing its zodiacal symbolism in stone wherever it went? This was Mary Settegast's suggestion in her book *Plato Prehistorian*, which she links with the myth of Atlantis. Alternatively, was this zodiacal system already widespread across Eurasia in very ancient times, and we are now only beginning to recognise it? If so, how did this zodiac become so widely distributed?

Answers to these questions, given the very long timescales involved, must always be presented cautiously. The evidence in favour of any theory is scant, but there are a few strands of scholarship that can be drawn on. By weaving these strands together so that they are mutually consistent, we arrive at a new tapestry of understanding for human development.

Archaeology and Ancient DNA

Foremost among these strands is the evidence that comes from ancient DNA. This is the ‘base layer’. It forms the template to which all other strands of evidence must be fitted.

This research field has come of age in the last ten years, yielding new insights into human migration and cultural diffusion. Because of huge advances in the science of DNA reconstruction, it is now possible to recover human DNA, the biological design code that resides within each cell of our bodies, from very ancient remains, sometimes no more than pieces of skull. A favourite place from which to take DNA samples is the very hard and dense bone that surrounds the inner ear. It seems to protect its precious genetic payload particularly well, even for many thousands of years. However, the main reason why ancient DNA research has gained prominence just recently are the massive developments in DNA sequencing.

The first human genome, or DNA sequence, was completed as recently as 2003. This global mega-project took over a decade to complete and cost nearly 3 billion dollars, roughly one dollar per biological instruction (DNA base-pair) decoded. Now that methods have improved and the process has been automated, a human DNA sequence can be completed in an afternoon, costing only a few hundred dollars. Today, nearly 100,000 individual human genomes have been sequenced. This means the bottleneck to making further discoveries in the story of human evolution is no longer to be found in chemistry labs. Instead, it is the archaeological discovery of ancient bodies from which DNA samples can be taken that determines the rate of progress.

The insights gained from this transformation in DNA sequencing have been tremendously helpful in uncovering the human story. Until recently, we were reliant on the expert interpretation of fossils to piece together the story of evolution. But the study of ancient DNA and the rate at which it can evolve has changed that, bringing much-needed confidence to anthropological theory.

It is now thought that the evolutionary line that would eventually lead to humans diverged from apes in the region of 5 to 6 million years ago in Africa. But it would take another 3 to 4 million years of evolution before the first species of human, or *homo*, emerged. Another 1.5 million years would pass before *Homo sapiens*, or modern humans, evolved, in the region of 200,000 to 300,000 years ago[3].

It appears these ancient people were confined to Africa until at least 200,000 years ago. The earliest accepted evidence of *Homo sapiens* outside of Africa dates to around 185,000 years ago, for some bones found in a cave in Israel. Of course, the archaeological record from this time is very sparse, so the date of our first adventure outside of Africa is liable to change as new discoveries are made. Other archaic forms of human that evolved prior to *Homo sapiens*, such as *Homo erectus* and *Homo heidelbegensis*, had long since made their way out of Africa and spread across the world before us, perhaps even to the Americas, although their numbers were low.

When we first ventured beyond Africa, nearly 200,000 years ago, the dominant species outside of Africa were the closely related *Homo neanderthalensis* and *Homo denisova*. They were not so different to us, although their populations were very low. They could probably talk and create artworks. They hunted for food and lived in temporary shelters, or sometimes in caves, just as we did. On leaving Africa, we soon encountered and mated with Neanderthals, likely living in the Levant. We know this because the Neanderthal genome has recently been sequenced, and short sequences of our distinctive DNA are found lurking within theirs[159]. This means we must have interbred with them at a very early time. But this first foray beyond the borders of North Africa was not successful. *Homo sapiens* soon died out and was once more confined to Africa.

There might have been other attempts to migrate out of Africa over the next 100,000 years, but it is thought none were particularly successful until about 65,000 to 75,000 years ago. This time we ventured to the south-east along the south coast of Asia, and kept going until we reached Australia.

As before, we bumped into Neanderthals again somewhere along the way, as well as their closely related cousins who lived primarily in east Asia, the Denisovans. Small amounts of the DNA of both these species remain in all of us today. In fact, around 1 to 4% of the DNA of everyone alive today, of non-African descent, is Neanderthal. For people of African descent, the figure is negligible. Likewise, all of us also have some Denisovan DNA within us, although the amount is tiny for most[160]. But for people native to Australia the figure is relatively high – perhaps as much as 7%.

After gaining a foothold along the south coast of Asia, our species slowly migrated northwards into the vast interior of the Eurasian continent, displacing other species of human. Around 45,000 years ago we entered Europe for the first time, reaching its western coast, including Britain, which was joined to the continental mainland at the time, a few thousand years later[161,162].

It appears that almost as soon as we reached Western Europe we began to create extraordinary artworks in stone and bone, leaving a fantastical trail from Germany to Spain. These artworks, like the Lion-man of Hohlenstein-Stadel cave and the Chauvet paintings, are so advanced and so old that they clearly indicate these people were little different to us today, except in terms of their technology. In fact, the level of astronomical sophistication required to track the solstices and equinoxes proves they were essentially as smart as we are.

It is quite likely this astronomical and artistic expertise already existed among the various tribes that migrated westward from central Asia around 45,000 years ago. The probability that we only discovered how to create these artworks on reaching Western Europe is slim. Indeed, given its astronomical provenance, this knowledge was likely known for millennia already and aided our long-distance migration, including the difficult passage across the ocean from Indonesia to Australia, sometime around 55,000 to 65,000 years ago[163]. Probably, our knowledge of astronomy was wrapped together with a mythology, handed down the generations.

In which case, it is possible that we brought this knowledge with us out of Africa, 65,000 to 75,000 years ago, and it has since dispersed across the whole world. Quite possibly, we will find similar artworks across the Eurasian continent in years to come. And, if we are very lucky, we will find even older astro-mythological artworks within Africa. Of course, until this trail of artistry leading back to Africa is found, this is speculation. But we should not be surprised to find it.

Our ancestors expanded north, east and westwards across Eurasia as far as the great northern ice sheets allowed, pushing back other human species into ever more marginal ecological niches. By around 30,000 years ago we had confined the last remaining Neanderthals to the south of Spain. When they became extinct, at around 28,000 years ago on Gibraltar, we were probably the only species of human left on Earth[164]. We no longer had any competition.

Following this expansion into all corners of Eurasia, according to archaeological evidence, several waves of migration, between 10,000 and 20,000 years ago, populated the Americas from the north-west via the Beringian land bridge that existed between north-east Asia and north-west America when sea levels were over 100 metres lower than today[165,166]. We finally brought our astro-mythology to the New World.

Ancient DNA studies have been just as helpful in unravelling the complex pattern of migrations in Europe over the Holocene period, the last 11,000 years or so. The picture regarding European migrations is, by far, the most studied and therefore the most certain. This is simply because of the availability of human remains from this region and period due to extensive archaeological research. Again, a consistent picture has emerged that incorporates ancient DNA and archaeological studies[162].

It seems that until the 8.2 kiloyear event, the people of Western Europe, including the British Isles, were hunter-gatherers descended from the people that had arrived 30,000 years earlier. But then, after the 8.2 kiloyear event, Anatolian farmers, perhaps very much like the people of Çatalhöyük and genetically similar to present-day native Sardinians, who had previously been constrained to Turkey, migrated and occupied Western Europe, bringing their agricultural lifestyle with them. Before long, most of Europe was agricultural, and all European men, except for those in a few tiny enclaves, such as the Basque region of Northern Spain, had roughly equal parts of European hunter-gatherer and Anatolian farmer DNA[167-170].

How and why this Anatolian migration happened is not clear, but once again the unusual signature of the 8.2 kiloyear event is present. Clearly, this was a massively important episode with major population and migration consequences. Even more astonishingly, it seems the female hunter-gatherer population of Western Europe was almost entirely wiped out at this time, except within a few protected enclaves. We know this because of changes in the mitochondrial part of human DNA, which is passed only down the female line. All females in Western Europe a few millennia after the 8.2 kiloyear event, apart from those in these protected enclaves, have almost entirely female Anatolian farmer mitochondrial DNA. Only in recent millennia, presumably due to admixture with the few surviving females in these protected enclaves, has ancient European hunter-gatherer female mitochondrial DNA become prevalent in Europe again.

What can this mean? Why should the female lineage of early European hunter-gatherers be almost entirely wiped out, while the DNA of their male counterparts survived, albeit thoroughly mixed with male Anatolian farmer DNA? The incredible story of the 8.2 kiloyear event remains to be told, but it seems almost certainly catastrophic. The most recent evidence points to prevalent disease, such as plague, within the European population following the 8.2 kiloyear event. Such widespread disease is to be expected following a major environmental disaster, especially one as massive as a cosmic collision. We see similar consequences today after major tsunami and storms in less developed countries.

Another event of this type appears to have occurred around the beginning of the Bronze Age, a little before 3,000 BC. This time it is pastoralist horse-riding people from north-east Europe, who in turn were genetically similar to people from north-east Asia, who invaded Western Europe[170]. These people, the Yamnaya, from the Pontic Steppe in the region of present-day Ukraine, brought their knowledge of horse-riding and the wheel, as well as their specific pottery style, with them. Over the next 1,000 years they migrated both east and west from their homeland north of the Black Sea right across northern Europe and south-east into the Indian subcontinent, leaving their DNA imprint on modern European and Indian populations. Today, native Europeans all have a roughly equal mixture of three types of DNA: early European hunter-gatherer, Anatolian farmer and Yamnayan pastoralist.

Once again, we see this mass migration follows a tumultuous period marking the beginning of history. While the Ancient Egyptian dynasties and Sumerian city-states of the Near East recovered from whatever disaster had befallen them in an earlier age, a great migration east and west across northern Europe and through central Asia to India was underway. Is it a coincidence that another major cultural transition, from the Stone Age to the Bronze Age, follows on directly from another climate event, beginning around 3,500 BC? Is it also a coincidence that two back-to-back epoch-defining episodes of rapid climate change and mass migration are separated by about 3,000 years, the expected precessional period of comet Encke?

Comparative Linguistics and Mythology

Long before this picture was clarified by ancient DNA studies, the prevailing view among linguists and historians of mythology was that the various languages and myths of most of Europe and north India are so similar that they must have spawned from an earlier culture at the heart of this region in central Asia. They called this earlier culture proto-Indo-European, or PIE[171]. This culture was so successful that Indo-European language and mythology accounts for several hundred languages and cultures that, today, cover a vast area from Iceland to Germany and Bangladesh, i.e. much of west and central Eurasia. It includes Irish, Germanic, Celtic, Sanskrit, Nepali, Latin, Norwegian, Greek, Russian and Bulgarian. It also includes ancient extinct languages, such as Phrygian, Thracian, Illyrian and Ligurian.

That these seemingly disparate languages and mythologies can have a common origin might seem surprising, and yet this is generally accepted by scholars working in this area. Key evidence in favour of this view is the similarity in the sound of some common high-usage words, and particularly some old words, such as names of animals, numbers, family members, parts of the body and farming terminology, as well as grammatical rules. Also, their apparently disparate mythologies have some very common core themes. We have already seen this concept of comparative mythology applied to Ancient Egypt and the notion of Zep Tepi. It seems, following the same kind of reasoning, that a PIE mythology can also be defined.

The alternative possibility, which is that any similarity in these languages and mythologies is a result of more recent contact between previously independent cultures, is unlikely – as this mechanism is not thought to be able to affect core aspects of language and belief across such a wide geographical area.

Until the advent of ancient DNA studies, there was a great deal of debate surrounding the origin and timing of this PIE culture. There were two main competing theories. The first, known as the Kurgan hypothesis and developed by Marija Gimbutas, a prominent Lithuanian archaeologist, held that these people originated from the Yamnaya homeland north of the Black Sea and spread west across northern Europe and south-east as far as India[172]. The second, the Anatolian hypothesis, proposed by eminent University of Cambridge archaeologist Colin Renfrew, suggested these people instead originated from Anatolia and the Fertile Crescent around 7,000 BC, spreading their new agricultural lifestyle as they went[173]. These two theories do not seem so different when you consider the two suggested homelands. The Pontic Steppe and Anatolia are separated only by about 700 kilometres as the crow flies. But between them lie the Black Sea and Caucuses mountains, as well as at least 3,000 years of prehistory.

For both theories there was considerable uncertainty as to whether these episodes represent mass migration, or just cultural diffusion without massive movements of people. Cultural diffusion might occur if the successful culture conveys some significant advantages over previous ways of life. We see the same kind of Darwinian evolution of culture today, rapidly accelerated by fast transport and the internet.

We now know, because of ancient DNA studies, there is some truth to both the Kurgan and Anatolian theories, although the Kurgan hypothesis is probably more correct. Moreover, it has also been confirmed, to the surprise of many, that these are indeed both episodes of mass migration, and not just cultural diffusion.

As we have seen, Anatolian farmers colonised most of Europe shortly after the 8.2 kiloyear event, bringing agriculture to Europe and leaving their specific DNA imprint. But the most recent mass migration is due to the Yamnaya of the Pontic Steppe, and it is these people who left the most recent imprint of both their PIE culture and DNA. Following this clarification from ancient DNA, the debate among supporters of the Anatolian hypothesis moved on to consider the extent to which the earlier Anatolian farmer migration might have influenced the later Yamnayan PIE culture. It is thought by some that Anatolian farmers might have brought a kind of agricultural proto-PIE culture to Europe, the Near East and central Asia in advance of the later PIE culture of the Yamnaya.

Regardless of the role of the earlier migration of Anatolian farmers in later PIE culture, scholars have even been able to deduce what this PIE language and religion would have been like[171]. For example, the name of the leading figure in the mythological pantheon is thought to be 'Dyeus Phater', which means 'Sky Father'. From this early root we can obtain, for example, the Roman 'Ju-piter', Greek 'Zeus', Vedic 'Dyaus Pita', Illyrian 'Dei-Patrous', Latvian 'Dievs', Iranian 'Daeva', Gaulish 'Deuos' and Welsh 'Duw'.

In addition to a sky father, there are also proto-deities for 'divine brothers' or 'sky twins', and although there is no 'sky mother', there is sometimes an 'Earth mother'. The sky-twin myth describes how one of them murders or sacrifices the other, and then proceeds to found a new civilisation. Examples include Romulus and Remus at the founding of Rome, Manu and Yama at the founding of humanity (a Vedic myth), and Cain and Abel and the founding of the city Enoch.

Perhaps the most common theme in PIE religion is the sky-battle between a giant serpent, representing chaos and destruction, possibly with multiple heads, and a storm god or great hero. The storm god/hero invariably wins, and the serpent falls to Earth, possibly into the ocean. Examples of this myth include Thor vs Jormungandr (Norse), Zeus vs Typhon (Greek), Tarhunna/Tarhunt vs Illuyanka (Hittite), Indra vs Vritra (Vedic), Sigurd vs Fafnir (Germanic), and Vahagn vs Vishap (Armenian). It is a myth repeated in the epic poem *Beowulf* and much copied in modern fantasy literature.

Another common PIE myth describes a divine being associated with fire who inhabits water. It is often interpreted literally and attributed to the natural occurrence of an oil fire on water. There are other common proto-deities as well, each with specific attributes, such as strength, beauty or welfare, but these are not so important for our story.

Clearly, this PIE mythology appears to align very well with the theory of an ancient giant comet fragmenting within the inner solar system. Let's consider the evidence in some detail.

The PIE-myth of a sky father, or sky deity, is clearly very compatible with our theory of a giant comet, Satan, trapped within the inner solar system. This sky god is unlikely to be the sun or moon, since these celestial objects have their own separate proto-deities in the PIE pantheon: 'Sehul' and 'Mehnot' respectively. Therefore, conventionally, this 'sky father' is thought by scholars of PIE to be the daylit sky itself. But I suggest this interpretation is not quite precise, or perhaps is corrupted from an earlier proto-PIE 'comet-father' deity. Indeed, an alternative etymology yields 'Shining Father', or 'Shining God'.

The 'sky brothers' PIE-myth can also be understood in terms of the comet theory by the fragmentation of Satan, where perhaps two fragments, the twin brothers, evolved in very similar orbits. The death of one of them followed by the rebirth of civilisation can obviously be interpreted as a cosmic collision event with one of these comet-brothers, the one that 'died'.

And the PIE-myth of a hero or storm god who battles and kills a great chaos serpent that falls to Earth is also very clearly consistent with the notion of a collision with a comet fragment, especially given the snake symbolism we see at Göbekli Tepe where snakes likely represent meteors. Even the PIE-myth of 'fire on water' is consistent with this theory, as it can be interpreted as a cometary airburst over the ocean. Everything fits perfectly.

Of course, as we have observed before, the problem with interpreting mythology like this is that it is not a scientific process.

Although we can identify consistent themes across the PIE landscape, indicating a common origin, these themes can be interpreted in almost any way you like to fit whatever preconceived notions you have. Nevertheless, given the proper scientific evidence we now have, from the astronomy to the geochemistry and archaeology, my particular interpretation is likely the correct one.

But there is a problem here – one of timing. We have so far compared PIE mythology with our comet theory, and found it is perfectly consistent. But, according to the Kurgan hypothesis, the original PIE mythology is thought to have belonged to the Yamnaya who inhabited the Pontic Steppe, north of the Black Sea, around 3,000 to 4,000 BC, while Satan is certainly much older than this, and the Younger Dryas event occurred 7,000 to 8,000 years earlier. Although there might have been other catastrophic encounters with Satan's debris since then, the 8.2 kiloyear event for example, these other catastrophes remain speculative. So, how can we square this PIE mythology with Satan's extremely old age? Does it indicate that PIE culture is itself derived from an earlier culture, perhaps related somehow to the Anatolian farmer culture as some scholars suggest?

Linguists have posed similar questions for their own reasons. We have seen how the PIE culture and language family is generally accepted by them. Likewise, there are several other major language families across the world that are generally accepted, and which point towards other early cultures that migrated and spread their language and mythology across contiguous areas of the continents. One such language family, for example, is Afro-Asiatic, which spans northern Africa, the Horn of Africa and southern India. The languages of these regions are so similar that many linguists consider it very likely they all derive from an earlier culture that existed many millennia earlier, spreading its language and mythology across a wide area over several millennia.

Some scholars have proposed that in order to take linguistic scholarship further back in time, it is necessary to understand whether and how any of these major language families are related. Presumably they would have diverged from each other thousands of years earlier than their respective proto-cultures existed. One such attempt of this kind tries to piece together the Indo-European and Afro-Asiatic language families, to create a super-language family, known as Nostratic, that also includes within it ancient Sumerian, an ancient Mesopotamian language that has yet to be related to any existing major language family[173-175]. The Nostratic hypothesis is not widely accepted among linguists, but nevertheless it does have some significant support among notable scholars. Very interestingly, the Nostratic super-family of languages is thought to have originated, as proto-Nostratic, just before the Younger Dryas period in the region of the Fertile Crescent, indicating Natufian as its initiating culture. This now takes us back directly to the Younger Dryas event and to Göbekli Tepe.

Just as for linguistic relationships, there are significant mythological parallels between Indo-European and some Afro-Asiatic cultures. For example, ancient Babylonian mythology, which is likely derived from the earlier Sumerian culture of the same region, has many parallels with PIE mythology. Notably, Babylonian Utnapishtim can be equated with the Vedic Manu and Abrahamic Noah. Likewise, the PIE serpent myth equates cleanly to the Babylonian myth of Marduk, a storm god, who defeats Tiamat, a sea-serpent, or dragon, as well as the ancient Egyptian myth of Set, a storm god, who defeats Apep, the chaos serpent. Also, one of the most significant Ancient Egyptian myths involves the murder of Osiris, the god of the dead, by his brother Set. Osiris is pieced together again by Isis, his wife, and thus life begins anew. This myth shadows the ancient 'sky brother' PIE myth.

Given the serious possibility, according to some scholars, that many Indo-European, north African and south Indian (Dravidian) languages and mythologies have a common origin in a proto-Nostratic culture from the Fertile Crescent around the time of the

Younger Dryas period, it is no less credible to suggest the Western constellations could have survived reasonably intact over this time, as our analysis of Göbekli Tepe shows. Indeed, it could be argued that astronomical symbolism and mythology are complementary and would tend to support each other. They would tend to survive together.

In which case, we have a consistent view whereby the original proto-Nostratic culture of the Fertile Crescent, which we can associate with the Natufian, eventually gave rise to many north African and west and central Asian cultures, including proto-Indo-European and proto-Afro-Asiatic. The Anatolian farmer culture that conquered Western Europe after the 8.2 kiloyear event likely represents an intermediate step between Nostratic and PIE cultures.

If this is true, then we should expect to find aspects of this proto-Nostratic mythology at Göbekli Tepe, considering that it likely represents a high point in Natufian culture and is thought by Klaus Schmidt, who discovered it, to be a kind of ancient temple with mythological symbolism. Proto-Nostratic mythology need not have begun or originated at Göbekli Tepe, but if this line of reasoning is to hold then it should at least be prominent there.

If we now return to Göbekli Tepe, recall from Chapter 7 that each rounded enclosure contains a pair of tall pillars at its centre that very likely represent comet gods. But can we be more specific? Do they represent specific comet gods of a proto-Nostratic mythology? First, notice that these pillars are not identical. The tall pillars of Enclosure D, pillars 18 and 31, have different necklaces. Pillar 18 wears the 'eclipse' necklace (see Figure 19) while Pillar 31 wears a bucranium necklace. Therefore, perhaps they represent slightly different deities. Indeed, do these twin pillars anticipate the sky twins of PIE mythology? If they do, then one should appear to be dead – either sacrificed or murdered. And indeed, Pillar 31, which sports the bucranium necklace, has much less in the way of decoration than Pillar 18. Does, then, this bucranium necklace indicate the sacrifice or death of this sky twin?

If this interpretation is correct, then there should be further associations of bucrania, or dead aurochs/bulls, with death and sacrifice in ancient mythology. In fact, a monstrous bull is a very common symbol for death and sacrifice in both PIE mythology and the mythologies of north Africa. For example, it appears in the form of the 'Bull of Heaven' in the epic Mesopotamian poem Gilgamesh, from around the late 3rd millennium BC, where it represents a form of supernatural mass destruction inflicted on mankind. In Ancient Greece we, of course, have the famous minotaur, while in various PIE mythologies a bull is the steed of choice for the respective storm deity. For example, the Hittite storm god, Teshub, rides two bulls who feast on the ruins of cities. And the Mithraic mystery religion of ancient Rome depicts a Tauroctony, or bull-slaying, as its central scene. Recall, also, the disembowelled bison in the caves of Lascaux, likely representing a cosmic collision with the Taurids from the direction of Capricornus around 15,150 BC. Possibly, this very ancient bull-slaying scene at Lascaux is among the first of its kind.

Of course, this all remains speculation. But there are also other indications of a connection with a proto-Nostratic mythology. The fox symbol is one of the most prevalent at Göbekli Tepe. According to our interpretation it symbolises the northern part of the constellation Aquarius which, at the time Göbekli Tepe was occupied, corresponds to the position of maximum intensity of the Taurid radiant. Therefore, the fox can also be associated with chaos and destruction. However, the fox symbol does not seem to play the same role as snake or bucrania symbols, which specifically represent the death and destruction of a cosmic collision. Given that Pillar 18 sports the eclipse brooch, which I have previously associated with the darkness and atmospheric dusting following a cosmic collision event, is the fox symbol associated more with storm-like atmospheric disturbances, rather than death and destruction per se?

Recall that Set, the ancient Egyptian god of storms, is often represented with the head of a fox. He killed his brother, Osiris, god of the dead who, very interestingly, is often associated with Apis, a sacred bull deity who was sacrificed and then reborn. Set also battled and killed the chaos serpent Apep, who is said to have a head of stone, like a meteorite. Can we, therefore, link Pillar 18 with Set and Pillar 31 with Apis-Osiris? Perhaps these two pillars directly anticipate the Ancient Egyptian version of the sky-twin myth in which Set kills both Osiris, his brother, and Apep, the chaos serpent.

Remember also, from Chapter 2, the belt buckle on Pillar 18 thought to represent a comet. This symbol consists of a series of upturned concentric semicircles bisected by a straight line (see Figure 5). Now consider a small stone plaquette recovered from the debris used to cover Göbekli Tepe shown in Figure 41. The site's archaeologists interpret this plaquette simply as a series of three sketches; from left to right they see a bird, tree or person (the other way up), and snake. But considering the similarity of the apparent 'bird' symbol to the belt buckle on Pillar 18, and given that Pillar 18 is interpreted as a comet god, should we instead interpret this left-hand symbol as a kind of shorthand notation for a comet god? In which case, this plaquette is likely telling the story of how the mighty comet god (left symbol) fought and killed (middle symbol), the chaos serpent who fell to Earth (right symbol). Perhaps this plaquette is the earliest known artistic description of the ancient myth describing the slaying of the chaos serpent by a comet/storm god.

Indeed, this symbol of a line crossed by a curve, which forms the shape of a trident, is a common symbol in the later Indo-European religions. For example, consider the Ancient Greek deity Poseidon, god of storms and oceans, famous for his trident, and also Teshub (see Figure 42), the Hittite bull-riding storm god. Normally, Teshub's tri-pointed symbol is considered to represent a kind of triple-thunderbolt, in keeping with the storm-god interpretation. But given a similar symbol appears at Göbekli Tepe on the plaquette shown in Figure 41, we can now interpret it instead as a comet or meteor symbol.

Figure 41. A stone plaquette found at Göbekli Tepe: possibly the earliest known telling of the proto-Nostratic form of the serpent myth (image courtesy of Alistair Coombs).

As another example, consider Shiva, known as a destroyer of demons (or dragons) in the Vedic pantheon, whose iconographical elements include a serpent around his neck, and a 'trishula', or trident, as his weapon. An older version of Shiva, known as Rudra, also shares this symbolism, as do many other Indo-European deities, sometimes shown as seated figures with horns surrounded by animals, and possibly killing a snake.

An early proto-form of Shiva/Rudra is thought to have been found at the ancient Indus Valley site of Mohenjo-daro, north India, on the Pashupati Seal, shown in Figure 42. It has been dated loosely to around 2,600–1,900 BC, corresponding to the Early to Intermediate Bronze Age. Here we see a seated figure with a multi-pronged headdress, or horns, surrounded by four animals, which we can now interpret as constellations. In fact, we can now read a date for this seal in terms of precession of the equinoxes. Using Stellarium again, we find the rhino, buffalo and tiger indicate a date of around 1,900 BC, to within 150 years (where the tiger now represents Leo, but the buffalo still represents Capricorns). This is consistent with the conventional date range. The elephant then corresponds to the constellation Libra in their zodiacal system. In fact, as this date is almost exactly 13,000 years, and therefore half of an entire precessional cycle, later than that of the Lascaux Shaft Scene, the four animals in the Pashupati Seal scene are the Vedic analogues of the four animals in the Lascaux Shaft Scene, except that the winter/summer solstices and spring/autumn equinoxes are switched.

This ancient scene of a deity with horns or a trident, with serpent associations, likely plays an important role in later Abrahimic religions, especially Christianity, where these earlier pagan gods are cast as the Devil. Indeed, many PIE mythical themes appear to be consistent with Christian symbolism. An obvious example is God as the comet father, with Jesus and the Holy Ghost playing the role of the comet twins, one of whom is sacrificed to save humanity. The trident symbol becomes Jesus draped on the cross. We also have the twelve disciples representing the twelve signs of the zodiac, and throngs of angels with their halos representing other comet fragments. The Biblical flood and armageddon are clearly remembered and anticipated catastrophes respectively, and on and on we could go.

So, we see how this ancient mythology and symbolism has survived from before the Younger Dryas period until today, in combination with a zodiac and constellations represented as animal symbols, although some of the zodiacal symbols seem to have been replaced or switched after the early Neolithic period.

But could this symbolism and mythology go back even further than proto-Nostratic to a time when the remarkable cave paintings in Western Europe were painted? Is it possible this knowledge dates back over 40,000 years to the time of the migrations into Europe from east Eurasia?

Figure 42. Left: Teshub, the Hittite version of the Indo-European storm god (from Aleppo Museum, image courtesy of Verity Cridland). Right: The Pashupati Seal, with Shiva/Rudra, the Vedic storm god, surrounded by four zodiacal animal symbols (image © National Museum of India, Delhi).

Proto-Laurasian Mythology

Scholarly attempts at comparative linguistics and mythology that go this far back in time are rare as it is assumed by most scholars there can be no cultural legacy, such as mythology or language, over such very long timescales. But we have seen how the western set of zodiacal constellations has survived at least 40,000 years, although some of its symbols have swapped positions or changed. And if astronomical symbolism is tightly bound to mythology, then perhaps ancient mythological themes might also have survived this long.

Michael Witzel, a scholar at Harvard University, takes the view that ancient mythology might even have survived from the time we migrated out of Africa, 65,000 to 75,000 years ago[176]. Although he is Professor of Ancient Sanskrit, his interests are much broader than this. He recognised that because languages change relatively quickly, it is very difficult to use comparative linguistics to go very far back in time to reconstruct extremely ancient languages, such as the ones we used while migrating across Eurasia 40,000 years ago. However, he noticed that ancient mythologies all over the world have remarkably similar themes. As these themes seem to change much more slowly than their associated languages, he supposed that comparative mythology could reach deep epochs in time where comparative linguistics could not.

He compared ancient mythologies from across the world, including Eurasia and the Americas, and found several universal themes that are commonly repeated on each continent. His summary of these themes is as follows:

1. Father heaven engenders: two generations ('Titans/Olympians')

2. Four (five) generations/ages: Heaven pushed up, sun released
3. Current gods defeat/kill predecessors: killing the dragon, use of sacred drink
4. Humans: somatic descendants of (sun) god; they (or a god) show hubris [and] are punished by a flood
5. Trickster deities bring culture; humans spread (emergence of 'nobles')
6. Local history begins
7. Final destruction of the world
8. New heaven and earth emerge

Despite the separation between various cultures across continents, both temporally and geographically, he reasoned these common themes were likely present around 40,000 years ago among the tribes that migrated across the Eurasian continent from the south coast of Asia, including those that populated Europe and the Americas. However, he noticed some distinct differences between these themes and those of presumably even older cultures found in south and central Africa and among the indigenous people of Australasia. He therefore supposed the African and Australasian mythologies are the oldest, calling them *Gondwanan* mythologies, likely to have been carried outside of Africa by the migration 65,000 to 75,000 years ago that populated the south Asian coast and Australasia. The more recent mythologies of Eurasia and the Americas, typified by the above list of themes, he proposes are a major reworking of the original Gondwanan mythology that he calls *Laurasian* mythology.

Although his proposals are controversial because of the extreme time-depth and concomitant unreliability of sources, his thesis is nevertheless consistent with all the evidence we have, in terms of archaeology, ancient DNA, linguistics, and of course mythology. Naturally, Witzel makes a gradualistic interpretation of these core mythical themes. For example, he interprets the release of the sun to represent the progression of the seasons, from winter to summer.

But this should not be surprising. Without knowledge of the entry of Satan into the inner solar system on this timescale and the resulting cycle of cosmic catastrophes, by fire and flood, that undoubtedly followed, these mythical themes can only be interpreted in gradualistic terms, even if they do not fit very well. But, now that we know about Satan, we can make better sense of them, as follows:

1. Obviously, father heaven is Satan, our giant comet. According to the timeline Witzel sets out, it appears Satan entered the inner solar system over 40,000 years ago. Possibly, his appearance caused the revolution in mythology to the Laurasian form he identifies. In which case, we should place an upper limit for Satan's age of around 65,000 years. This is in good accord with the astronomical evidence, which suggests Satan appeared around 20,000 to 30,000 years ago, or perhaps earlier if the resulting comet fragments he split into were not so active. It also agrees with geochemical evidence of catastrophic causes for the Yukon and Alaskan boneyards, the oldest of which is radiocarbon dated to about 48,000 years ago. So, an updated estimate for Satan's age of around 50,000 years appears sensible, indicating he was a truly enormous beast. The two or more generations of deities he produced were likely the result of successive cometary splitting events.
2. The four or five generations or ages, consisting of heaven being pushed up and the sun revealed, possibly refer to the succession of cosmic catastrophes generated by Satan's fragmentation. After each catastrophe, described in terms of the sky, or heaven, falling down, the sun is obscured by atmospheric ash and dust and the world becomes very dark, like a continuous eclipse. This dust eventually clears revealing the sun and starlit sky once more.
3. The different generations of deities likely refer to a succession

of fragmentation events. One crop of comet fragments eventually exhaust their surface ices, thereby losing their bright tails and becoming dark and dormant. Meanwhile, new fragmentations occur, producing a new set of comet deities. ‘Killing the dragon’ likely refers to a catastrophic cosmic event yet again. The serpent symbolism likely describes the track of a meteor and the apparent sudden and deadly strike of a comet fragment, as seen explicitly at Göbekli Tepe. The use of a sacred drink, as Witzel notes, perhaps refers to the mundane act of drinking an intoxicating liquor, as part of a ritual, or the taking of drugs to induce a hallucinogenic trance-like shamanistic state.

4. The descent of man from a (sun) god is once again likely a human notion designed to justify power hierarchies. But the flood probably refers to a cosmic catastrophe-induced mega-tsunami.
5. The trickster deities likely represent the various comet fragments, whose motion in the sky is difficult to predict compared to the more predictable planets, and who are liable to dispense divine punishment and vengeance on a whim. After a cosmic catastrophe, culture is reset and mankind begins again, as though children. Humans migrate after a great catastrophe because of population growth and because their homeland has been destroyed. The emergence of ‘nobles’ is another aspect of human power hierarchies. It might also refer to the emergence of competent leaders, warriors and orators from the power vacuum left by the preceding catastrophe.
6. Once a tribe has moved to a new area to seek habitable land, local history begins again. For many of the survivors it is as though the earlier civilisation is just a legend.
7. The final destruction likely refers to the next anticipated cosmic catastrophe …
8. … and the cycle begins again.

Once again, these associations cannot be considered scientific because the degree of uncertainty in them cannot be quantified. Nevertheless, it is clear that Clube and Napier's theory of coherent catastrophism is consistent with this strand of scholarship, comparative linguistics and mythology, as well. A completely consistent view of human history and pre-history is obtained.

But from this analysis we also see that Ancient Egyptian mythology, including the notion of Zep Tepi, the first time, as well as the four generations of gods in the Egyptian Ennead, including an initial creator, the rising of a great mound out of the chaos-water, the emergence of the sun, the chaos serpent Apep whose head is made of stone and is slain by Set, a trickster-storm deity with a fox head, and the descent of the Pharaohs from the sun god are completely consistent with this extremely ancient mythology. In which case, if the core of their mythology stretches back over 35,000 years, to which ancient epoch does Zep Tepi actually refer? As has been mentioned already, this is the problem with interpretation of myth – it can be made to fit any preconceived notion you like. In this case, it causes a problem, because in Chapter 10 we used Zep Tepi to refer to an epoch just before the 8.2 kiloyear event. But, logically, it might instead refer to any epoch over the previous 35,000 years.

Fortunately, in this particular case we have the science to back up our case. According to Schoch's weathering analysis and our zodiacal dating methodology, the Sphinx dates to just before the 8.2 kiloyear event. Until Schoch's analysis is shown to be flawed, this should remain our best estimate for the age of the Sphinx. But Zep Tepi itself might refer to a much earlier epoch.

12

The Origin of Civilisation

Homo sapiens, our species, has probably existed for at least 200,000 years, and possibly more than 300,000 years. We know this because, although dating methods are less precise for such old materials, the remains of what appear to be archaic forms of *Homo sapiens*, between 200,000 and 300,000 years old, have been discovered at several sites within Africa. It's difficult to know precisely how old our genetic lineage is because such finds are extremely rare. But studies of DNA, and the rate at which it can evolve, suggest these early dates are entirely reasonable.

In which case, why did civilisation begin only relatively recently, at the start of the Holocene period, or shortly before, around 11,000 years ago? This issue, the origin of civilisation, is considered one of the most important and difficult in anthropology and archaeology.

It is generally thought that agriculture heralded the origin of civilisation. This is why there is so much interest in the emergence of domesticated strains of crops and animals within the Fertile Crescent after the end of the Younger Dryas period. There appears to have been a revolution in lifestyles that quickly took hold across this region, a process sometimes called the 'Neolithic revolution' that led to larger and more sophisticated communities, and ultimately to our modern world.

But Göbekli Tepe has muddied the water here by indicating that a large community of specialists might have existed thousands of years before farming became established, or at least before domesticated strains of plant and animal are recorded. This means agriculture might have developed in response to the emergence of larger-scale communal living, rather than the other way around.

Perhaps agriculture was simply a means to an end, a way to feed more mouths. As the saying goes, where there is a will, there is a way, and perhaps the will to live together came first. This is one reason why Göbekli Tepe is so important to anthropologists and archaeologists, because it helps to deduce the motivations, the key drivers, for events. Even so, one still has to explain why it took so long for larger communities with specialists to develop, considering that we had existed as a species for at least 200,000 years already.

Environmental conditions are often cited to answer this question. During the last ice, which began over 100,000 years ago, it is thought that resources, like food and shelter, were harder to find, resulting in low populations that limited the potential for civilisation to begin. But while this might be true at higher latitudes, this argument does not hold so readily for regions near the equator, like Africa, India and south-east Asia. Even though, globally, the world was colder during the last ice age, and therefore more arid because more water was locked within polar and continental ice sheets, towards the equator there would have been regions with temperate climates and relatively comfortable conditions sufficient for civilisation to take hold. So, the occurrence of several ice ages over the last 300,000 years doesn't really explain why civilisation began only relatively recently.

Sometimes, it is claimed that extreme climate fluctuations, such as the Daansgard-Oeschger oscillations that occurred over the last 40,000 years of the last ice age (see Figure 11), tend to disrupt and prevent the formation of larger communities. While this is entirely likely, it does not explain why civilisation did not begin during the last glacial maximum, around 27,000 to 17,000 years ago, in the southern hemisphere, or during the last interglacial period, over 100,000 years ago within Africa. Global climate during either of these epochs was relatively stable for at least 10,000 years. So, why didn't civilisation begin during either of these stable climate periods?

This has led some to suggest that the Younger Dryas period, which directly preceded the Neolithic revolution, is in some way special, and led to a change in ‘cognition’, or a change in people’s thinking and motivations. If this is correct, what was the change in cognition that occurred, and was the Younger Dryas event responsible for it? If it was, then why did earlier catastrophes, like the one recorded by the Lascaux Shaft Scene, not have a similar effect? Again, it seems this idea, that the Younger Dryas event led to a change in cognition, by itself, does not solve this problem. There are probably other factors in play.

Göbekli Tepe is the earliest structure in the world yet known that hints at the existence of a sophisticated culture, or civilisation. It is reasonable to think that civilisation existed there before anywhere else in the world, especially considering it lies at the heart of the Fertile Crescent where agriculture appeared for the first time while Göbekli Tepe was inhabited. But, although we have very likely solved core aspects of the symbolism of Göbekli Tepe, we do not yet have an answer to these important questions about the origin of civilisation. To try and find them, it will help to look further afield at the context of Göbekli Tepe in the Fertile Crescent. To get a handle on this issue, it is useful to ask a more direct question – who built Göbekli Tepe?

Natufian Culture

The original construction of Göbekli Tepe has been credited to a New Stone Age (Neolithic) culture, after the end of the Younger Dryas period, by the site’s archaeologists because of the earliest radiocarbon date of some mortar from one of its enclosures, circa 9,530 BC. However, the date inscribed onto Pillar 43, the Vulture Stone, is at least one millennium earlier than this, and corresponds closely to a cultural transition, from Early to Late Natufian in the Fertile Crescent, near the onset of the Younger Dryas period. Therefore, the original builders of Göbekli Tepe are likely Natufian, or contemporaneous with the Natufian, who lived in the Levant near the east coast of the Mediterranean at this time. Is this credible? How much do we know about these people? Were they sufficiently sophisticated to have built a magnificent structure like Göbekli Tepe?

Much research distinguishes between 'Early' and 'Late' Natufian periods[177,178]. The Early period, apparently occurring prior to the Younger Dryas mini ice age (before 10,900 BC), is thought by many to be more settled than the Late period, occurring within the Younger Dryas period (around 10,900 to 9,600 BC), for which evidence of a return to a semi-nomadic lifestyle is often suggested, although this trend is not ubiquitous[178] and is not reflected at Göbekli Tepe. Research that uses the most accurate and modern radiocarbon dating methods supports this separation of cultures, and suggests it was caused by the dramatic change in climate at the onset of the Younger Dryas period[42]. Obviously, we can now point towards the Younger Dryas event itself as the cause of this change in climate *and* transition in culture.

The Natufian are the most advanced pre-Neolithic culture yet discovered in the Levant, so if anyone in the region could have built Göbekli Tepe, they are the most likely. But we cannot be sure of this – we cannot simply make this assumption. We should search for evidence that clearly shows who built Göbekli Tepe. Frustratingly, the actual settlement where the people who built Göbekli Tepe presumably lived has not yet been found. According to the site's archaeologists, Göbekli Tepe is not a residence itself, as they have not found the usual evidence of habitation, such as the everyday implements used for cooking. This makes identification of Göbekli Tepe's builders difficult.

Stone tools found in the fill that covered the site correspond most closely to the Neolithic period after the Natufian phase, suggesting its builders were Neolithic, and not Natufian. But this is only to be expected and is probably a red herring. The fill used to cover the site will naturally consist mainly of materials and waste from later phases of occupation just before the site was abandoned. So, this evidence doesn't help us determine who built the site originally, several thousand years earlier.

To help us unravel this mystery we should search for similarities between Göbekli Tepe and Natufian archaeological sites, or other sites. If the Natufian built Göbekli Tepe originally, there should be evidence of their capability at Natufian archaeological sites prior to the construction of Göbekli Tepe. As the precise date of its construction is unknown, both Early and Late Natufian settlements should be considered. Indicators in the form of i) permanent settlements, ii) agriculture required to feed a large workforce, iii) social organisation required to coordinate the whole endeavour, iv) advanced masonry required to cut, erect and carve the pillars, and v) symbolism and artistry found at Göbekli Tepe should be evident. There are only a handful of Natufian archaeological sites currently known. Let's see what they reveal.

The issue of sedentism is relatively easy to answer, as one of the defining characteristics of Natufian culture, especially Early Natufian, is permanent settlements consisting of boulder-lined huts dug into the ground, forming small villages of a few hundred people[177]. The permanence of these villages is indicated by the energy expended to create the dwellings, for example the movement of large boulders and the levelling of ground, as well as the existence of storage pits, wall plaster, and the remains of small scavenging animals, such as mice and other rodents[179].

There is general agreement among Paleo-botanists that the earliest evidence anywhere in the world for domesticated varieties of any plant or animal occur after the Natufian period[180,181] within early phases of the Neolithic in the Fertile Crescent. However, the story concerning cultivation of plants, as a precursor to proper domestication, is much more contentious, and there is little agreement among researchers as to whether the 'roots' of plant cultivation and wild animal management can be traced to a core area near Göbekli Tepe, or whether these developments are much more dispersed across the Fertile Crescent and perhaps beyond. Neither is there much agreement on the timing of these earliest experiments in farming. Nevertheless, Natufian people are normally viewed as hunter-gatherers, or more correctly, hunter-collectors, as they appear to have stored grain at their settlements[182]. Part of the problem, of course, with establishing timelines is the interpretation of radiocarbon dating methods. And the Younger Dryas event will no doubt have been very destructive, making any archaeological evidence harder to interpret. But, it is probably true that permanent settlements and initial experiments with cultivation and animal-keeping to supplement a largely hunting and gathering lifestyle went hand in hand for Early Natufians[181].

The largest known Natufian settlements likely consisted of up to a few hundred villagers, indicating a limited form of social organisation or hierarchy. Was this sufficient to construct a grand project like Göbekli Tepe? No other older archaeological site yet found compares even remotely with the scale and vision of Göbekli Tepe, and it is only several millennia later that Jericho in Palestine, hundreds of kilometres to the south, comes close to it. This is one of its most astonishing aspects; it is completely anomalous in this respect. Perhaps several hundred Natufian villagers might have been able to construct it given sufficient motivation – the kind of motivation that might be provided by the extreme circumstances of the Younger Dryas event.

Early Natufian dwellings consisting of megalithic circles dug into the ground, with a topping of wood and brush, hardly equate to the level of sophisticated stone-working demonstrated at Göbekli Tepe, but their architecture is not so different. Probably the most advanced masonry skills uncovered at any Natufian site are found at Tell Qaramel, over 150 kilometres south-east of Göbekli Tepe, with the construction of a stone tower supported by megalithic foundations[183]. The tower was rebuilt on the same spot several times over the course of many hundreds of years, with some foundation stones nearly one metre thick. Although these towers are confidently dated to the Late Natufian period and afterwards, there appears to have been an even earlier stone tower built on the same spot in the Early Natufian period, although it is difficult to be sure because little remains from this period.

Regarding the large-scale artistry evident at Göbekli Tepe, there are no clear indications of these skills anywhere within Natufian settlements. Instead, typical artistic finds in Early Natufian settlements appear to be limited to small stone, clay and bone sculptures, with shell and stone jewellery. But, as we have seen, grand artistic displays are found at many ancient cave sites in Western Europe, such as Chauvet, which are tens of thousands of years older than Göbekli Tepe. Considering this expertise existed at such an early time within Europe, soon after people had migrated over long distances westward from Asia, it makes sense to presume this expertise existed across the whole of Eurasia. It was likely ubiquitous, although perhaps it was rarely expressed in such a durable form as stone.

Indeed, some of the symbolism found at Göbekli Tepe is also found at Late Natufian sites. A prominent example is Hilazon Tachtit cave, near Galilee, where an elderly woman is found buried together with the remains of a boar leg, eagle wing tip, over fifty tortoise shells, stone martens and an aurochs tail[184]. This is interpreted by the site's archaeologists as the burial site of an important person, probably a shaman. And stone plaquettes, like the one shown in Figure 41, are not uncommon among Natufian sites – they are found at Tell Qaramel, for example. But the age of these plaquettes is unclear – they might be Neolithic and not Natufian. Nevertheless, a potential connection with Göbekli Tepe, in terms of cultic practices involving similar animal varieties and symbolism, is easy to make.

Figure 43. Cupules on the tops of pillars at Göbekli Tepe (courtesy of Travel The Unknown).

Very interestingly, cupules, which are small hemispherical holes carved into a rock surface about the size of a tennis ball, are found in abundance in stone floors near Natufian burial sites[185,186]. The same kinds of cupules are found at Göbekli Tepe, both in the nearby bedrock and on the tops of many pillars (see Figure 43). They are also found at many other ancient sites across Europe and the Near East, indicating use of these marks spans an extraordinarily wide timespan and geography. In fact, they are found across the whole world at megalithic sites, including Easter Island. It is thought by some that these cupules, and megalithic circles and constructions in general, are associated with astronomical observations. Probably, they can be linked to the ancient Laurasian system of astro-mythology defined by Witzel (see Chapter 11).

What should we conclude from this brief survey of Natufian archaeological sites? Is it clear that Göbekli Tepe was built by a Natufian community? Not really. There appears to be quite a large cultural gap between known Natufian sites and Göbekli Tepe. So much depends on whether a phase of Natufian cultural development is discovered that forms a bridge between currently known sites and Göbekli Tepe. This phase of development might, of course, be found eventually at Göbekli Tepe itself. The main problem is that the level of communal organisation required to build Göbekli Tepe does not seem to be present at any known Natufian site.

This is not to say that a Natufian community could not have built Göbekli Tepe alone. The extreme circumstances of the Younger Dryas event might be sufficient to explain the apparent cultural discontinuity between known Natufian sites and Göbekli Tepe. But as things stand, it is not obvious they do.

Therefore, until more archaeological evidence is found, either at Göbekli Tepe or elsewhere, that fills in the details of this gap, this remains an open problem. But logically, we have the following three scenarios.

1. Göbekli Tepe was constructed initially by non-Natufian refugees settling in a new land, perhaps from Western Europe where this level of artistry and knowledge is evident, in line with Mary Settegast's Atlantean hypothesis. The problem with this idea is that evidence of a more advanced civilisation than the Natufian just before the Younger Dryas event is lacking, so one would have to also argue that their homeland was destroyed by the cataclysm or, due to sea level rise over the last 13,000 years, possibly resides under 100 metres of water. This is Graham Hancock's view.
2. Göbekli Tepe was constructed by a Natufian community relocating from elsewhere in the Levant more advanced than any currently known. Again, the problem with this view is that there is no evidence of a more advanced Natufian settlement in the Levant, so again, one would have to argue that it was destroyed by the cataclysm or, perhaps due to sea level rise, has not yet been found.
3. Göbekli Tepe was constructed by a Natufian community, or similar community in Anatolia. The earlier phase of cultural development, which spans the cultural gap between the grandest phases of Göbekli Tepe's construction and known Natufian sites, will be found through further excavations at Göbekli Tepe or nearby sites, like Tell Qaramel.

If either case 1 or 2 is correct, then it implies that civilisation had already begun elsewhere and therefore the Younger Dryas event played only a minor role in its development. In which case, neither a change to a warmer climate nor a change in human cognition are obvious drivers for the origin of civilisation. Normally, the possibility that the green shoots of civilisation could have appeared before our current Holocene period, the last 11,000 years or so, is ruled out by scholars on the basis that agriculture is a necessary prerequisite. But Göbekli Tepe shows this view is not quite correct, and that initial attempts to form larger communities of specialists can occur without recognisable agriculture. In other words, we are no longer constrained in our search for the origin of civilisation by the appearance of domesticated plant and animal varieties. This is the important lesson Göbekli Tepe demonstrates. In which case, how can we know if civilisation began at other sites in earlier times? What evidence should we seek instead? We'll come to an answer for this question in the next section.

But, on the other hand, if case 3 is correct, which I consider most likely as there is no clear evidence to support case 1 or 2, then we should consider whether the Younger Dryas event was pivotal in the development of civilisation. Perhaps, in this case, the extreme nature of this disaster led to a kind of existential crisis that resulted in a more collaborative and cohesive form of religion. And, in turn, this catalysed the formation of larger communities that could develop the specialisms displayed at Göbekli Tepe.

Göbekli Tepe might even represent a kind of nexus, or cultural 'melting pot', where people with diverse backgrounds, including refugees from distant lands, combined their efforts and expertise with Local Natufian survivors to achieve a grand vision. And whether or not it represents the true origin of any particular specialisation is perhaps not the key issue. More important than that is the strong sense of community that it demonstrates. Perhaps it is this sense of community that fuelled the Neolithic revolution that followed. Therefore, it can be argued that through its destructive capacity, the Younger Dryas event might have forced, or persuaded, mankind to cooperate in larger numbers, to civilise, in order to survive and recover via the medium of religion.

The key factor, then, in Göbekli Tepe's importance is possibly its expression of an organised religion, as this likely drove people to cooperate through a shared belief system, and shared vision. The origin of this belief system, which appears to be a kind of comet cult with astronomical mythology, predates Göbekli Tepe according to Witzels's Laurasian hypothesis. However, the construction of Göbekli Tepe, triggered by the Younger Dryas event, appears to represent a step-change in the importance and organisation of this astronomical cult.

It appears, then, that the destructive capacity of comets led to a strengthening of existential inquiry, which today we would call religion. This organised religion, mutated by time and distance into various guises, continued through to the Bronze Age, and shaped later proto-Indo-European and proto-Afro-Asiatic cultures. It appears the Younger Dryas event and Göbekli Tepe represent a step-change in religious or mystical belief and organisation that defined later civilisations and continues to resonate today.

But, this remains quite speculative, and we still do not have a proper understanding of the development of civilisation. While Göbekli Tepe suggests the Younger Dryas event might have been important, I have already argued that it cannot have been solely responsible – there must be other important factors in play.

Giant Clusters of People

Even if the Younger Dryas event was significant, pivotal even, we still need to find evidence that supports the view that a change in cognition, or religion, can lead to larger communities. It is an easy thing to say, and it might appear obvious, but is there any evidence that actually supports this case? How can a change in cognition lead to larger communities of specialists?

Furthermore, taking this view does not explain, given that there are likely to have been earlier cosmic catastrophes, why it was the Younger Dryas event only, and not an earlier catastrophic event, that led to a change in cognition sufficient to cause the origin of civilisation. If there were other events of this kind, what was so special about the Younger Dryas event?

In fact, to address this question properly, it will be useful to think again about what is meant by the 'origin of civilisation'. It is often assumed that there was some specific trigger that caused civilisation to begin. But what if this view is wrong? What if the process is much more gradual than this? And in any case, what is really meant by 'civilisation'? We have taken it to mean something along the lines of 'the emergence of specialisms within larger communities'. But this is quite a vague definition, open to interpretation. Can a more precise definition be found? Probably, to make sense of it all, we should go back to basics. What is meant by a large community of specialists?

In the animal kingdom, especially within ape communities, some of the elements of civilisation are already observed. For example, chimps and gorillas form hierarchal communities of several dozen. They typically have a male leader – the chief chimp or the silverback gorilla. But this falls far short of what we instinctively think of as 'civilisation'.

Nevertheless, it is a useful starting point for thinking about civilisation in a human context. We can think of this kind of grouping, a small tribe of several dozen individuals with a dominant leader, as the most basic kind of organisational group within a human culture. Probably, when our species first evolved, we were organised into many relatively small tribes each led by one or more dominant elders. We hunted and gathered our food, made temporary dwellings, and migrated as nomads. In order to prevent in-breeding, these tribes would not have been entirely isolated. They would have encountered each other frequently along their travels, and interbred to keep the gene pool healthy. And, of course, in addition to this largest organisational unit, the tribe, there would have been smaller groupings all the way down to individuals. We see this amply demonstrated today. Although most of us now live in cities, there remains a major fraction of the population who continue to live more isolated lives in the rural environment whilst still taking full part in society as a whole.

Indeed, we see this most basic level of organisation, the small tribe, even today, among some cultures in South America, Africa and New Guinea. Some of these so-called ‘lost’ tribes continue to live in the remotest regions without any contact with the broader world. They do not take part in our modern global society, and can truly be considered separate cultures.

Clearly, they are not what we mean by ‘civilisation’. Despite the fact these lost tribes have a specific culture, which encompasses their language, traditions, mythology, artistic expression and understanding of the world, and even though their tribes will probably include individuals with specialist skills of some form, such as chief, shaman, weaver and so on, we do not consider these remote tribes to be civilised.

So, what actually is civilisation? It seems the vague notion of ‘larger communities with specialists’ is not particularly useful, because it doesn’t spell out how large a community needs to be, or which specialisms are needed, to be considered civilised. And in any case, it is practically impossible to identify all possible types of specialisation or hierarchal organisation, with all their various nuances, to produce a definition of civilisation on this basis.

So, let’s forget about a definition of civilisation that requires specific hierarchies or specialisms. This road leads nowhere except to prejudice. Instead, let’s use the definite and countable attribute of size as a definition of civilisation. This is much easier, and therefore more useful. In fact, the etymology of the word ‘civilisation’ comes from those who reside in ‘cities’. So, population size is an instinctive indicator of civilisation.

And, rather than becoming bogged down in setting a specific population, or population density, as a target above which civilisation is defined to exist, and below which it doesn’t, let’s instead take a relative definition. Therefore, let’s say that, relative to a specific environment, a culture organised into small tribes is less civilised than one formed of much larger tribes. The nature of the environment is important because it can have an influence on the group size it can support. This means the size, or degree of civilisation, of communities within different environments should not be compared. It's all relative.

However, if we consider two cultures within similar environments, whose communities have very different sizes (or more properly, size distributions), we can say the one with larger groups (on average) is more civilised. This seems like a good definition. Cultures formed of larger groups must be more organised, and therefore civilised, to be able to exist within the same environment. The typical size of the least civilised tribe, judging from archaeological evidence of hunter-gatherers and existing lost tribes, is in the region of 50 to 100 people[187].

Ultimately, then, it comes down to population size. What we need to do is try to understand why communities with specific sizes form. If we can understand this, then we can understand the origin, or more properly, the development of civilisation. Essentially, we need to understand how giant clusters of people form.

Now, it turns out that in the realm of physics, the phenomenon of clustering is fairly well understood. Because stable clusters are seen to occur for all sorts of different physical systems, from atomic nuclei, which are essentially just clusters of more fundamental particles known as protons and neutrons, to stable protein clusters within cells, known as 'organelles' which have important roles in biology, physicists have looked at the question of how stable clusters can form in a very general sense and have come up with some important insights.

In fact, this is an area of research in which I specialise[188]. In my particular case, I was interested to know how giant stable clusters can form in aqueous solutions of small soluble molecules, like amino acids, the building blocks of proteins and therefore an essential component of life. The problem here is that small soluble molecules like amino acids have traditionally been assumed to form uniform dispersions within water. But this view might be contradicted by recent experiments. Instead, it appears giant clusters form in these solutions, which are stable, and my recent research has sought to try and understand this. It might even be important to the origin of life.

I find it quite satisfying that the same kind of insights into these problems can also help to understand the development of civilisation. There is a deep kind of 'universality' here. We see stable clusters form again and again in science in a wide range of completely different systems. Why is this?

The answer, or one answer, to this question is that when the particles of an evolving system are attracted to each other when they are close together, but repel each other, if only very slightly, when they are further apart, then we can expect stable clusters of particles to form. It doesn't matter what kind of particles they are. In our case, when thinking about civilisation, we can equate a particle with a person. So long as there is a kind of interaction between particles, or people, that is slightly repulsive at long range and fairly attractive at short range, if the particles are mobile so that the system can evolve, and the repulsive and attractive interactions are not too strong, then for these systems we expect large stable clusters of particles, or people, can form under the right circumstances.

Therefore, populations of animals, including humans, have this same kind of clustering behaviour because the underlying interactions between individuals, in a very average sense, have a long-range repulsive component balanced by a short-range attractive part. Of course, this assertion needs some justification.

Consider our species, although these observations are quite general across species. We can say that between a pair of individuals, in a very average sense, a weak long-ranged repulsion exists because of the competition for resources. We all need to eat and drink. In an average sense, the closer two people approach each other, the more effort they need to expend to find food and water. This effect is ‘always on’. It doesn’t matter what culture we live in, regardless of its sophistication, we compete for food and water. The more food and water one person consumes, the less is available to other people nearby. In an average sense, this is equivalent to a long-range repulsion. It is long-ranged because the area of land we each scour to search for food and water is large.

This concept of competition for resources has been generalised, for humans in modern societies, to include all the resources we consume, and is known as our ‘ecological footprint’. It is estimated that our personal ecological footprint today ranges from about 0.5 hectares for people in the poorest countries, to as much as 10 hectares for people living in the richest (and most wasteful) countries. This is the amount of land needed to sustain each person for one year. Dividing this area by 365.25 gives the daily ecological footprint.

Let’s take 1 hectare, which equates to a circle with diameter about 113 metres, as the annual ecological footprint of an early hunter-gatherer. This is the amount of land needed to support each hunter-gatherer for one year. For the time being this estimate is good enough – we are thinking conceptually here, we don’t need to know precise values. Although this area seems like a lot, it doesn’t mean that hunter-gatherers could not approach each other closer than 113 metres. That’s obviously nonsense. What it means is that as more hunter-gatherers crowd together within a community, the further they each need to travel, on average, to find food and water. And as travelling to find food and water takes effort, all other things being equal, it will be avoided. Therefore, the competition for resources drives people to form smaller clusters, or communities.

This repulsion between individuals due to competition for resources is weak and long-range, with a distance equal to the maximum distance travelled each day to find food and water, and an ‘intensity’ equal to the daily ecological footprint divided by the average area of land searched for food and water each day. To see this, consider the following example. Compare the effort expended by hunter-gatherers who hunt on foot to those who hunt on horseback. Those on horseback have a much larger range, and therefore they experience the competition for resources over a much larger area each day. At the same time, because their ecological footprint is nearly the same (apart from feeding a horse), it means the intensity of their mutual repulsion is less for those on horseback. In other words, finding food and water via horse-riding is easier, and therefore the competition for resources is less intense. This means horse-riding offers an advantage that enables larger communities to develop. Of course, this assumes a very average view. We are thinking in terms of averages over people in a population as well as an average over each day in the year.

Now, if we only ever experienced this long-ranged repulsion we would forever roam the wilderness as individuals. We would be trying to avoid each other as much as we could to prevent overlapping the areas within which we can search for food and water each day. The closer we approach each other, the stronger this repulsive urge becomes.

Of course, this is not what happens – we do not all roam the wilderness as individuals. Even the least civilised hunter-gatherer tribes, both ancient and modern, have populations of around 50 to 100 people. Why? Obviously, it is because, on average, we like to be together. We enjoy each other’s company, we benefit from helping each other and, of course, we need to procreate. In terms of interactions between individuals, in a very average sense, we can express this desire to be together as a short-range attraction. It is short-ranged because the behaviour that leads to this attraction generally takes place at short-range, whether it is having a conversation, helping someone skin a goat, or having sex.

It is quite clear, then, that in a very average sense we can view people as having strong short-range attractive interactions and weak long-range repulsions. And, as has been said, these kinds of system are known to exhibit giant clusters provided neither the attractive nor the repulsive interactions are too dominant. This idea, of a competition between a long-range repulsion and short-range attraction, has already been applied with some success to model clustering in plant ecologies[189], but here we are using it to understand the formation and stability of human communities.

In fact, the clusters that form will have a preferred size. This is because, on the one hand, if the cluster gets too large then there is more to be gained by splitting into two separate clusters than by growing further. That is, for large clusters the long-range repulsions dominate and force the cluster to separate. On the other hand, if a pair of clusters is too small, they have a lot to gain by merging. That is, for small clusters the short-range attractions dominate and cause small clusters to merge.

Between these cases there is a 'sweet spot', or optimal cluster size, that is preferred where the short-range attractions and long-range repulsions are balanced. The stronger the attraction, the larger the cluster, while the stronger the repulsion, the smaller the cluster. These forces balance against each other to determine a specific optimal cluster size.

A survey of the size of hunter-gatherer archaeological sites illustrates this concept nicely. Analysis of many hundreds of such sites indicates that, because resources vary in their availability significantly throughout the year, hunter-gatherer tribes tended to split into smaller groups during the winter. These would then merge again in the spring or summer. Typically, hunter-gatherer group size appears to have been in the region of a few dozen in winter, while it could be a few hundred in summer[187]. Of course, there is a lot of variation in these sizes; these are just estimated averages.

It appears, then, that the same basic principle applies to us as it does to protein molecules inside cells or to nuclear particles within an atomic nucleus. The same basic physics produces the same basic behaviour.

The Development of Civilisation

Now that it is understood why humans form clusters, or communities, we can begin to understand why the size of these communities can change, depending on their circumstances. We can begin to understand how civilisation, defined as the trend towards the formation of larger and larger communities, can develop. Essentially, we need to think about the factors that influence, in a very average sense, the strength of the short-range attractions and long-range repulsions that exist between us. Pulling together all the strands of evidence from earlier chapters leads to the following synthesis, a proposal for a new understanding of the development of civilisation.

Beginning with hunter-gatherers with only very basic Stone Age technology, it seems the balance between the competition for food and water and the desire to be together, for all sorts of reasons, tends to lead to community sizes from a few dozen to around a few hundred people, depending on the season and environment. Any increase in community spirit inevitably leads to larger communities. Likewise, any new technology, such as horse-riding, that reduces our ecological footprint or increases the range over which we can search for resources, will also increase community size.

With this better understanding that civilisation does not have a single point of origin, but is instead a continuous process of development, we can see how it might appear that the Younger Dryas event was particularly important. For hundreds of thousands of years before this event, mankind simply did not have sufficiently advanced technology to support large communities. The competition for resources within and among tribes was so great that tribes were limited to little more than a few hundred people or so. And the effort expended in searching for resources, for survival, limited the opportunity to develop new technologies. And moreover, perhaps our community spirit, defined by our Gondwanian mythology at that time, did not generate a strong motivation for larger communities. We were caught in a culture trap.

Then, perhaps around 50,000 years ago, Satan entered the inner solar system. This possibly led to a change in existential enquiry, a development in astro-mythology to the Laurasian form, that dispersed with us as we migrated across the Eurasian and American continents. Anthropologists currently call this change of human behaviour at this time, which resulted in the great Palaeolithic artworks discussed in Chapter 9, the ‘cognitive revolution’. Although its cause is currently unknown, some suggest it might have been triggered by a genetic change. That is, by evolution. However, there is no evidence for this within archaic human DNA. The so-called ‘cognitive revolution’ 40,000 to 50,000 years ago does not appear to have a biological trigger. It is therefore another open problem for which I suggest a potential solution.

This supposed cognitive revolution, perhaps triggered by Satan’s appearance, might have led to a significant advance in civilisation 40,000 to 50,000 years ago were it not for the regular bombardments and abrupt changes in climate, known as Daansgard-Oeschger events, caused by debris falling off Satan. Our ancestors memorialised these catastrophes wherever they could with great works of art, but the disruption to climate and local environments impeded the invention of technologies for advancing civilisation, especially agriculture. Whenever the green shoots of civilisation emerged, they were buried by the debris of another catastrophe. People continued to migrate in search of fresh land. Large animal populations across the globe also suffered, although it appears Africa got lucky. Through dint of its huge size, equatorial location and pure good fortune, the African continent avoided the worst effects of these bombardments.

Eventually, the bombings became less regular and severe as Satan’s mass dwindled, and the ice age began to thaw. In a few places around the world semi-sedentary, and then fully sedentary, communities formed that began to develop megalithic architecture, store food and experiment with cultivation and animal husbandry to supplement their hunting and gathering. Community sizes increased to many hundreds throughout the year in some places.

But then the massive Younger Dryas event happened, returning the world to a mini ice age. Community sizes initially shrank, and many people that had begun to civilise, the Natufian for example, dispersed into smaller nomadic bands as the competition for resources intensified briefly. But, this massive event also led to another change in mythology in some places. It became more organised and fearful – more religious. The bonds that tied some groups strengthened, and they gained a new identity. In places, this led to an increase in community size that appears almost like a step-change in civilisation. The earlier experiments with food storage, cultivation and animal husbandry were developed further to support rapidly increasing community sizes, and Göbekli Tepe was created.

After the end of the Younger Dryas period, when climates around the world warmed, the polar ice sheets, glaciers and Arctic tundra receded, releasing vast new ranges of productive landscape. Agriculture developed and spread rapidly outward from the Fertile Crescent propelled by the proto-Nostratic culture of the Natufian tribes. Villages became towns, and towns became cities. Before long, our astronomical notation had developed into a fully fledged writing system.

Satan continued to make his presence known through occasional outbursts that would destroy a city or civilisation here and there. Disease and starvation were rife, and people migrated en masse to find new land. War leaders took advantage of the chaos to secure their legacies. But there were no more global disasters, the land healed quickly, and civilisation survived wherever it was able.

Ultimately, Satan dwindled away, leaving little but a few relatively small inactive comet fragments embedded within narrow bands of debris, themselves orbiting within a broader disk of zodiacal dust within the inner solar system. History became legend, and legend became myth.

So, we see, according to this proposal, that the rapid development of civilisation, commonly known as the Neolithic revolution, after the Younger Dryas period is possibly a consequence of several factors that occurred together. It’s a triple whammy. There was possibly a development towards a more organised and fearful religion at Göbekli Tepe, triggered by the Younger Dryas event, that strengthened community bonds. Added to this, agriculture and food storage were already undergoing an experimental phase within Natufian communities before the Younger Dryas event, and could be developed further to reduce the ecological footprint of new and larger communities afterwards. And finally, a thaw in the ice age released vast new areas of land with temperate climates to accommodate a growing population. Although Satan continued to wreak havoc, his fits of anger were less intense than before and these new communities were able to weather his infrequent outbursts.

Judgement Day

The main issue that springs to mind when considering this proposal, founded on Clube and Napier’s version of catastrophism, is ‘Where are we in this process’? How much of Satan is left – can he cause us any more trouble?

You are no doubt familiar with all the ‘crank’ predictions that the end of the world is nigh. But, as a physicist, I know that predictions of this kind must be wrong. The best place to look for answers to this question is in the scientific literature. In particular, we should seek answers from the astronomers that have made it their life’s work to study the Taurid meteor stream. What do they say?

The Taurid meteor stream to which Satan has decayed is expected to contain one or more dense ‘filaments’ in which most of the remaining large pieces of debris reside. But each dense filament is surrounded by a much larger and diffuse debris field consisting mainly of smaller pebbles and dust. These filaments precess just like comet Encke. This means that, most of the time, we encounter only diffuse regions of these debris streams, observed as meteor showers. Occasionally, we encounter a larger object which appears as a bright fireball. Rarely, we collide with a Tunguska-sized object.

However, due to precession we will eventually encounter the dense core at the heart of each filament. This will manifest as episodes of increased risk, lasting for hundreds of years each, when the orbits of these dense filaments intersect Earth's orbit. If we are lucky, we will pass through them relatively unscathed. But we cannot rely on luck. Obviously, we would like to know when the next filament will intersect Earth's orbit, and how much debris remains within it? What are our chances and how long do we have to prepare?

Unfortunately, none of these questions can be answered with much confidence. But, it appears that Satan has decayed largely to dust already, leaving behind an assortment of mainly dormant or extinct comets with a wide range of sizes. As discussed in Chapter 6, spending on asteroid detection has focused on spotting the largest objects in near-Earth orbits, and we have found most objects over one kilometre in diameter with the potential for globally catastrophic consequences[95]. There are about 1,000 of them. Using Opik's formula (see Chapter 6), which provides an estimate of the probability of a collision with any one of them, we should not expect to collide with any of these within the next few hundred thousand years. Any comet fragment, such as Encke, among this tally should decay to dust well within this timescale. So, it appears, Satan has done his worst.

But, there are an unknown number of smaller Tunguska-sized chunks of 100 metres or so in diameter remaining in these filaments. Because their number is unknown, the risk they present cannot be estimated. However, as the years tick by, the cometary fragments among them, and their concomitant risk, will also continue to decay.

As the risk is concentrated within those eras when a dense filament is close to Earth's orbit, we should focus on their timing. Again, this is not known with much confidence. The cometary scientists who lead this research area, Clube and Napier and their colleagues, suggest comet Encke is associated with the main filament at the heart of the Taurid meteor stream. This means we can use Encke's precession to track the likely evolution of this main filament.

Currently, comet Encke's orbit precesses such that it intersects Earth's orbit roughly every 3,000 years[118]. Although we do not expect to collide with Encke itself, its debris field will present a period of increased risk lasting around 500 years. We also know that our next passage through this dense filament will occur around 3000 AD, or slightly before. We therefore have plenty of time to prepare for this episode, nearly 1,000 years into our future.

However, the filament surrounding Encke is not the only one out there to think about. Chapter 6 showed that it is likely there are at least eighteen large comet fragments associated with Encke, and they all have slightly different orbits with different rates of precession. So, even if Encke is surrounded by the main filament of debris, there are many others that pose a risk, and we know very little about any of them.

If this assessment of Encke's precession and its role in the development of civilisation is correct, then we should see a repeating pattern of climate events and cosmic catastrophes roughly every 3,000 years. Working backwards from the next expected episode just before 3,000 AD, we should expect to see episodes of catastrophism late in the first millennium BC, then again late in the 4th millennium BC, the 7th millennium BC, the 10th millennium BC, and so on. Is this pattern actually observed?

The expected episode around 0 AD is not seen in the Greenland ice core record – there is no corresponding dip in northern hemisphere temperature, although this period does correspond to the rise of Christianity and some severe outbreaks of plague across Eurasia. This is probably good news for us, as it implies Satan might have almost dwindled away to nothing and his fury is nearly spent.[2]

However, the expected late 4th millennium BC episode, which marks the transition from the Stone Age to the Bronze Age and the origin of the Kurgan migrations that spread proto-Indo-European culture across northern Europe and central Asia, is clearly recorded by ice cores (see Figure 44). Chapter 10 showed how this event might also have been recorded on the Scorpion Tableau by the etching of a snake (meteors) issuing from a tall bird (Pisces) – see Figure 36.

Again, the expected late 7th millennium BC epoch of catastrophism likely corresponds to the 8.2 kiloyear event. This episode directly precedes the Anatolian farmer conquest of Western Europe that almost wiped out female west European hunter-gatherers, and might have occurred simultaneously with several major geological events, such as the Storegga Slide, the Black Sea inundation and the final collapse of the Laurentide ice sheet. It might also have brought the first great Egyptian civilisation beside the Nile to an end, leaving the enigmatic Sphinx of Giza as an enigmatic token.

The expected late 10th millennium BC epoch of catastrophism might correspond to the end of the Younger Dryas period and/or to a severe climate event shortly after (see Figure 44). Likewise, the expected late 13th millennium BC episode might correspond to dramatic climate oscillations before the Younger Dryas event. Finally, the expected late 16th millennium BC episode of catastrophism might correspond to the event recorded by the Lascaux Shaft Scene at around 15,200 BC.

So, our expectation of disasters every 3,000 years, beginning around 0 AD going backwards, does appear to be borne out. However, the Younger Dryas event itself does not fit this pattern. Possibly, it was caused by collision with a Taurid debris filament that does not precess at the same rate as Encke.

Therefore, apart from the largely missing period of catastrophism expected around 0 AD, it can be argued that a significant stream of debris might reside close to comet Encke and have caused several episodes of catastrophism over the last 20,000 years. However, this is hardly a scientific case, as there are many other large bodies in Encke-like orbits and many other periods of rapid climate change through the Holocene period. Teasing apart the connections between any of these is a complex research project that has yet to be undertaken.

Once again, past episodes of cosmic bombardment can only be confirmed by locating the relevant geochemical evidence within sediments and ice sheets around the world, and until these studies are performed we must keep an open mind. Prediction of any future episodes is an equally complex problem requiring much greater knowledge of the dense filaments of the Taurid meteor stream. Nevertheless, adopting the precautionary principle, we should keep a close eye on debris around comet Encke, as well as all the other large objects in the Taurid meteor stream.

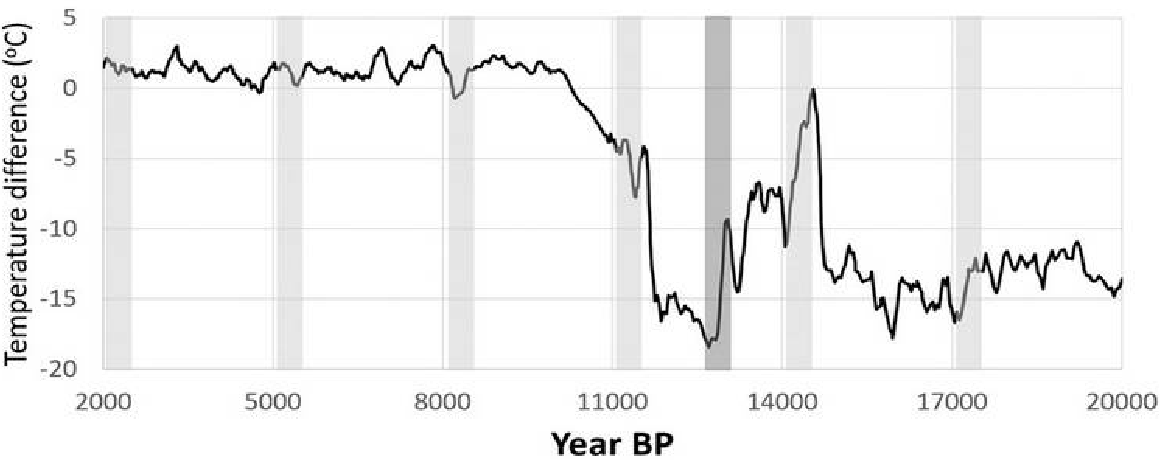


Figure 44. Temperature reconstruction from the GISP2 ice core in Greenland[27]. Light grey bars represent expected epochs of catastrophism according to comet Encke's 3,000-year cycle of precession. The dark grey bar signals the Younger Dryas event. Year BP means years before 1950 AD.

Normally, any evidence of cosmic catastrophes over the course of human civilisation is interpreted as being the result of other causes. Clearly, it is now important that existing scientific data indicating prehistoric and historical catastrophes, including major and correlated episodes of cultural transition, civilisation collapse, population migration, climate change, earthquake, war, famine, pestilence, conflagration and flooding, is reassessed to properly consider cosmic bombardment as a possible causal mechanism.

APPENDIX A:

Placement of Patterns on the Vulture Stone

Consider the probability of the spatial match, i.e. the positional correlation, between the animal symbols on the Vulture Stone and the respective constellations. To do this we can divide Pillar 43 into several regions within which only one animal pattern can appear. Here, we are mainly interested in that part of the pillar where there is some freedom to choose the position of the animal symbols: the main part which constitutes four animal symbols surrounding the scorpion. Given the size of the animal patterns on Pillar 43, we can divide this part of the pillar into eight regions surrounding the scorpion (see Figure A1). Therefore, each region defines an arc of 45 degrees around the scorpion. We suppose that the four animal symbols around the scorpion could have appeared in any of these eight regions, providing their clockwise order is fixed. We need to keep their clockwise order fixed because this kind of permutation (or degree of freedom) is already taken into account.

As it is, the animal symbols appear to be in almost exactly the correct spatial position to match the positions of the constellations relative to the ecliptic and the setting sun, except that the bending bird with down-wriggling fish (which we match to Ophiuchus) is about 45 degrees (i.e. one region) out of place. It should be in region 3, not 2, in Figure A1. Now, what is the probability of this good relative positioning occurring by pure chance, keeping the clockwise order of the animal symbols fixed?

The first animal symbol we place (the eagle/vulture, say) defines where all the following animal symbols can be placed. If we define this first region chosen as region 1, with the remaining regions labelled 2 to 8 clockwise, then the remaining three animal symbols can be placed, in clockwise order, in regions 2, 5, 6, or in 3, 5, 6 or in 2, 4, 6, or in 2, 5, 7. Any of these four situations could be deemed to be as good, or better, than the one that actually occurs on Pillar 43, since each of these combinations is wrong by at most only one region. The total number of configurations available without changing the clockwise order of the animal symbols is 5 + (4 x 2) + (3 x 3) + (2 x 4) + 5 = 35. Therefore, the good orientational positioning of these four animal symbols on the main part of Pillar 43 around the scorpion has a chance of around 4 in 35 of occurring by pure chance.

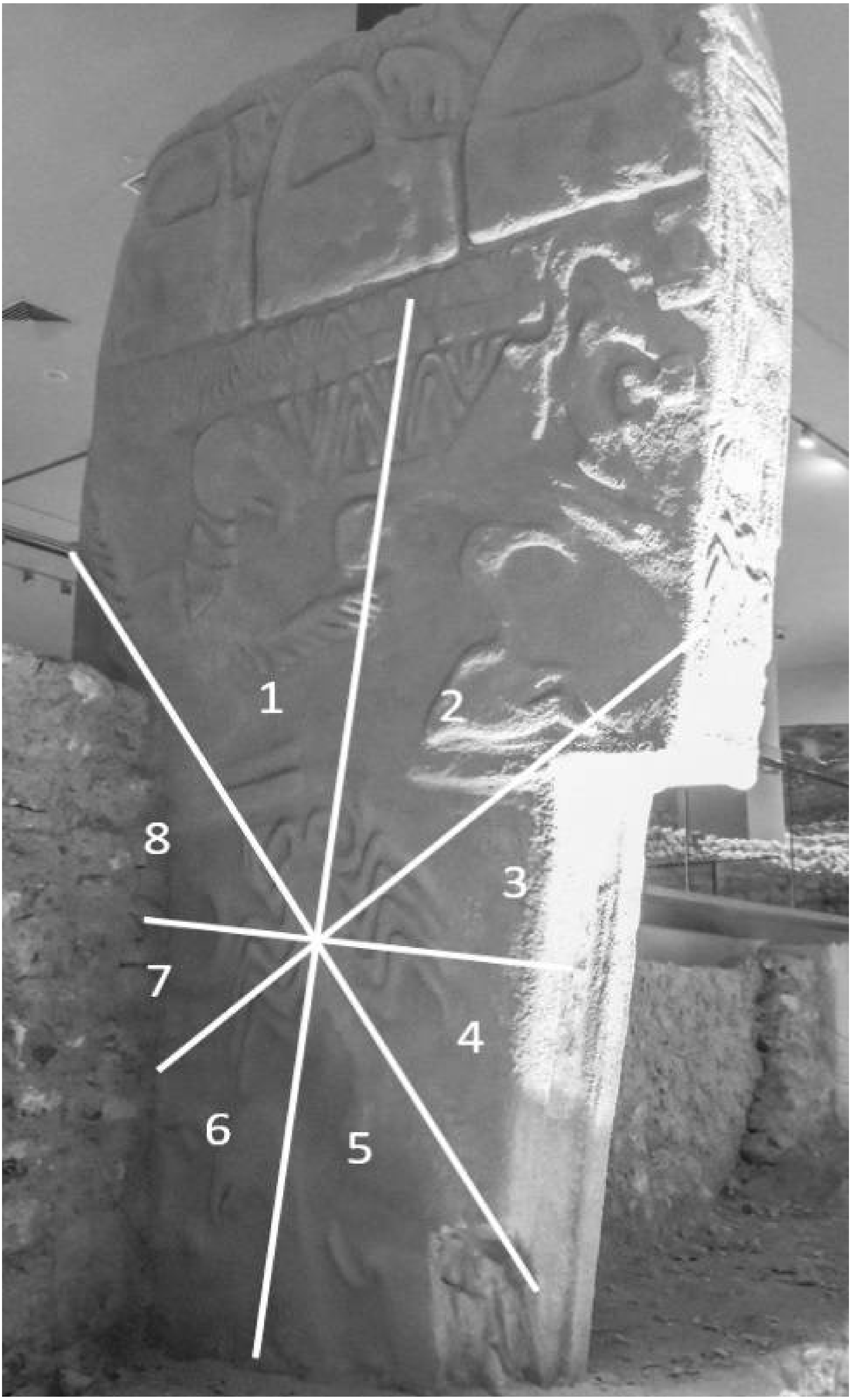


Figure A1. Dividing Pillar 43 into 8 equal regions around the scorpion (image courtesy of Alistair Coombs).

APPENDIX B:
Latitude and Longitude

Ocean sailing is perilous at the best of times, because the ocean looks the same in all directions. If you don't know where you are, or which direction you are heading in, you will most likely keep sailing until you die. This is why astronomy is so useful for ocean navigation – the stars are fixed in the sky and can therefore be used as a reference (at least at night).

The direction in which you are sailing is easy to figure out from the position of the sun. But your position on Earth's surface, which is crucial to also know, is much harder to estimate. But with knowledge of astronomy, this can be estimated with reasonable accuracy, sufficient for ocean navigation.

Every position on Earth's surface can be described in terms of two coordinates: latitude and longitude. Latitude describes how far north or south a given point is. Again, this is easy to estimate by looking at the stars on the horizon, or the height of the midday Sun in the sky if you also know the date. The lowest stars on the horizon can be used to easily determine latitude. But longitude is much harder to estimate. This is why the British Government established the Longitude Prize via the 1714 Longitude Act, to be awarded to anyone who could crack the problem of accurately measuring longitude. John Harrison, an English carpenter and clockmaker, eventually won the prize of £20,000 with his method that used accurate timekeeping, which was more precise than the previous method that relied on astronomy, the 'lunar distance' method.

The lunar distance method uses measurements of the moon's position relative to other astronomical objects (at night) to determine longitude. Anyone with basic knowledge of the moon's passage across the sky along with the expected position of another fixed object in the sky, such as a specific star or group of stars, can use this method. Quite clearly, with their relatively sophisticated knowledge of observational astronomy, even including precession of the equinoxes, ancient people might have estimated longitude using this method. Therefore, if they could also build sufficiently robust boats, they might have crossed the oceans relatively easily and mapped the ancient world. They would not need to know the geometry of Earth or the heavens; this estimate of longitude is an observational phenomenon that does not require a detailed understanding of Earth's shape and place in the solar system. Nevertheless, if they were smart enough, they might have been able to deduce Earth's sphericity, and even its diameter, from their observations.

As Earth rotates on its axis once per day the stars appear to move across the sky from any fixed point on its surface. Of course, depending on your latitude (how far north or south you are) you will see a different set of stars as you rotate around on Earth's surface. The problem is knowing longitude from this motion; it is impossible to know longitude simply by looking at the stars. Imagine your position in space relative to Earth's centre is instead fixed as the Earth rotates beneath you. The stars will appear fixed, but over the course of a whole day you will take on all values of longitude. Therefore, the stars by themselves are not enough to know a specific longitude, and another astronomical object, independent of the stars, is needed. As the sun obscures the stars, it is of no use. Instead, the moon can be used. It is better than other astronomical objects because it moves faster (relatively) across the sky, and therefore allows the most accurate measurement of longitude. Of course, the moon is not always visible, which is partly why other methods for measuring longitude are desirable.

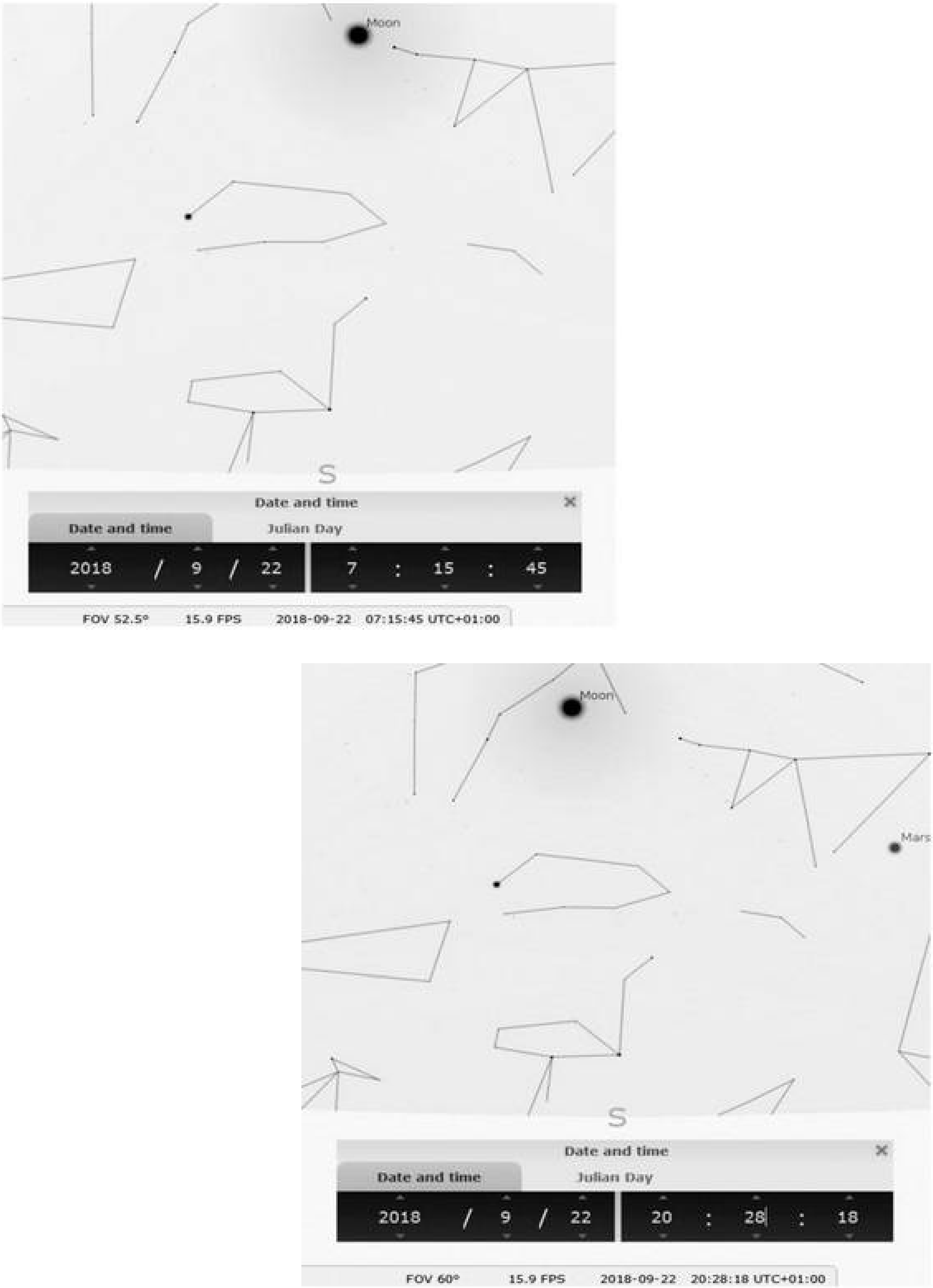


Figure B1. Longitude can be estimated by measuring the position of the moon relative to a star at its highest point during the night. These two images adapted from Stellartium show the relative position of the moon on the same day observed from San Francisco (left) and Sanliurfa (right).

The moon's orbit around Earth is nearly in the plane of the solar system, and it is visible from most latitudes depending on the time of year. It is like a clock. It orbits Earth once every 27.3 days. This means that its position in the sky relative to the position of a specific star near the horizon will vary over the course of 27.3 days. When the specific star reaches its highest point above the horizon during the night you know you are facing in precisely the same direction in space. But the moon's position relative to that star will complete an entire cycle over the course of 27.3 days. That is, it will if your longitude doesn't change. Suppose, instead, over the course of a day your longitude changes by 90 degrees in the same direction the Earth rotates, i.e. one quarter rotation around Earth's axis (of course, we can't sail this fast – but just for example). This means the specific star will appear at its highest point one quarter of a day earlier the next night. This also means the moon will have only moved an additional ¾ of the amount it normally would in one day. Therefore, by measuring the lunar distance at the star's highest point in the sky, and comparing with the previous night, you can estimate your longitude (See Figure B1). While useful, this method suffers from large errors in measurements, so better methods are desirable.

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As this book was heading to the printers, news broke on the 14th November 2018 of the discovery of a massive crater on the north west coast of Greenland. At over 30 kilometres in diameter and apparently between 12 thousand and 3 million years old, it might be the Younger Dryas crater. Certainly, this is the view of some members of the discovery team and the Comet Research Group. We will have to wait and see. Whatever the case, this discovery shows how difficult it is to find even relatively young impact craters – as this one is easily visible on Google Earth once you know where to look.