Geochronology and Myth – are Gods Catastrophes ?

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"Man is certainly crazy; he could not make a mite, but he makes gods by the dozen." (Michel de Montaigne)

The power of speech emerged from a spandrel, and made it possible for information to pass from one generation to another. Art and writing reinforce this process, prevent the downgrading of information, and perpetuate it as myth. Some myths may encode catastrophic events in history as deities, and contain internal evidence of their chronology. The evidence of geology may allow us to construct an absolute time scalefor myths.

INTRODUCTION

It is said that a Harley Street psychiatrist can live very well on the fees of a mere twelve patients a year. Consultations with the Oracle of the Dead, organized by the Sibyl of Cumae in Baia near Naples were also expensive. Odysseus and Aeneas were amongst the famous who could afford such luxuries. The supplicant first had to pay for the sacrifice, i.e., in Aeneas' case, the roasting of seven bullocks and seven ewes, as well as the olive oil with which they were basted, and the wine, barley bread, and other accompaniments, these for the Sibyl herself. Further expenses were due to the priests and assistants who conducted the ceremonies. After exposure to a sophisticated blend of psychological preparation which included sensory deprivation and consumption of psychedelic drugs, the victim was conducted to the Underworld. A child's first communion is far less harrowing, but is perhaps a dilute echo of similar principles. Most people reading Virgil's *Aeneid* imagine it as myth or allegory. *But it really happened*! "What is not widely appreciated is that these episodes were based on an actual physical location" wrote Temple (1984), who summarizes the archaeological evidence, and explains in detail how the fraud was stage-managed*. How the architects at Cumae were able to construct this underworld, apparently without any exploratory boreholes, remains unknown, but detailed geological knowledge of the site including its subterranean rivers and groundwater dynamics was clearly an essential prerequisite. Could ancient dowsers have been involved ?

Much else once believed mythical has subsequently revealed a factual basis. Herodotus' mythical Scythians, fearsome horsemen of the steppes, were identified by Gordon Childe with the "corded ware" culture and as proto-Indoeuropeans, with Kurgan culture by Marija Gimbutas (Renfrew 1987). It was the *Iliad* that inspired Schliemann's search for Troy. But we should not

* Another entrance to the Underworld has been described in northwest Greece (Fouache and Quentin, 1996).

fall into the trap of positing a naturalistic explanation for all the details of mythology. “We need not try to make history out of legend, but we ought to assume that beneath much that is artificial or incredible there lurks something of fact.” (Woolley, 1934). Here I examine some places where facts are thought to lurk, i) in the armories of battling deities, and ii) in the waters of flood myths.

Chronology is the vertebral column of the earth sciences, as it is of all disciplines which seek to understand historical and evolutionary processes. Mythology too contains internal evidence of chronology analogous to that which can be obtained from analysis of stratigraphic sequences. The Fall precedes the Deluge. Odin succeeds Ymir. *Et sic deinceps*. Genealogies inform us that Gaia follows Chaos and precedes Tartarus, Uranus, and Pontus ; the Titans and Cyclopes, Erebus and Hemera, Aether and Eros, and the Hecatoncheires were contemporaries of Uranus’ generation. We can represent this succession in the same way as a geological section with Chaos near the bottom. Deeper still, we can see the Goddess identified by Cauvin as the first deity (see below). There is an unconformity between Her and Chaos; Her origin must be sought in an earlier cultural age. She is in fact a different kind of deity from those in overlying layers, since She (accompanied by the Bull) has pierced the latter in the manner of a magmatic dyke, left metamorphic remains in the younger strata, and enriched the mythological landscape. She is also distinguished from later deities in that her origin seems to have been biological and astronomical (in cyclical time) rather than catastrophic.

i) The weapons which allowed Zeus and the Olympians to overcome Kronos and his allies, leading to the succession of one generation of gods by another, may encode volcanic phenomena, and specifically the great eruption of Thera in the 17th century BC (Greene, 1992). In his foreword to *Centuries of Darkness* (James, 1992), Colin Renfrew identifies the dating of the Thera eruption as one of the two key issues in archaeological chronology (the other is the dating of megalithic monuments in northwest Europe). In the present context, we can also see that it is a key issue in any attempt to construct an absolute chronology for geomythology. The identification of this eruption as the source of Hesiod’s *Theogony* is therefore reviewed, as well as the dating problems associated with it.

ii) Presently very topical is the hypothesis that the site of the flood recorded in *Gilgamesh*, *Genesis*, and elswhere is the Black Sea basin. Even if such a flood took place (see Lericollais, this volume), and there is substantial evidence (e.g., Aksu *et al.*, 2002) that it did not do so in the way described by Ryan and Pitman (1998), it is pertinent to examine other floods known to geologists as putative sources of flood myths.

MOTT GREENE’S GEOMYTH

The great eruption of Thera, now Santorini, in the Aegean Arc has been linked to the collapse of Minoan civilization in the late Bronze Age, to the Biblical *Exodus*, and to the destruction of Plato’s *Atlantis*. Hesiod’s *Theogony* provides a genealogy of Greek gods and godesses and of their power struggles. The drama has a varied cast. *Kyklopen*, means circle- or round-eyed, and these creatures were sons of earth (Gaia) and sky (Uranus). In the *Theogony*, Hesiod has them with a single eye in the middles of their brows. They helped Proitos build the “cyclopean walls” of Tiryns and Mycenae, were the earliest inhabitants of Sicily, and worked at the forge of Hephaestos under Mount Etna. The scholiasts identify three kinds: Hesiod’s “Thunder” and “Lightning”, weapons of Zeus; the wall builders, *gastrocheires* or *cheirogastores*, whose hands emerge from their bellies; the giant Polyphemus of the *Odyssey*. Greene (1992) wrote: “When I read that a Mediterranean tradition contains figures... who are like gods... mighty unpredictable giants who live in high peaks in hollow caves from which they issue forth with sporadic violence... that they gave invisibility to Pluto and gave Poseidon the trident that shakes the sea; and that they are associated with fire demons, I think about volcanoes.” He then suggests that the variety of *kyklopen* form a classification “of a diverse but related series of natural phenomena”, and illustrates it with examples such as the “contrast between the peaceful solfataric activity of the *Campi Phlegrei* and the brooding unpredictability and menace of Vesuvius ...”. As mentioned below, the *Campi* are not always as peaceful as Greene implies.

Mediaeval sources offer parallels; the *mons igneus* and *mons fumosus* of St Brendan’s *Navigatio* may refer to Hekla in Iceland, and the ‘bursting forth’ of loughs in *Leabhar Gabbala* to local floods. Similarly, when biologists read in *immrami* of stinging creatures the size of frogs

infesting oar blades, and worms which eat through the outer hides of a curragh, they must think of jelly fish and the shipworm *Teredo*. The absence of classificatory systems into which such observations could have been placed by witnesses from earlier traditions does not prevent us from recognizing them as items in our own systems.

The *Theogony* is very old, and some parts are of Hittite and Hurrian origin, a thousand years older than Hesiod's Greek, and thus a thousand years nearer in time to the eruption of Thera (the fifth tablet of Gilgamesh dreams of a darkened earth, loud roarings, and flames, and the earliest known representation of an eruption, of Hasandag, was found at Çatal Hüyük, dated about 8000 BP). This is now recognized as a common (universal ?) feature of ancient literature, that natural knowledge existed side by side with myths and theogonies, and that both draw on roots deep in the preclassical period (Burckert, 1998; West, 1997). This raises two important points, i) about the routes by which eye witness accounts of an event were transmitted to the present day, and the corollary of how accurate these processes are, and ii) what cocktails of fact and poetic inspiration have reached us.

i) If Greene is correct in his reading, the thousand years of transmission between the Hittite account of Thera's eruption and Hesiod's version in the *Theogony* led to little distortion, since in his opinion the unique signature of the volcano is still recognizable. If the transmission was oral, there must have been something very special about the event – that it acquired sacred meaning (Wyatt, 2001), or became 'fossilized' by persistent anthropomorphic and animistic icons - to ensure that the details were accurately preserved from generation to generation. Greene does not consider the possibility that the *Theogony* may encapsulate an earlier eruption of Thera, i.e., that of Cape Riva, dated to about 21,000 ka by radiocarbon or an eruption of some other volcano in the Aegean arc whose signature may be similar enough to Hesiod's chronology of events. But he does see that some of the weapons can refer to volcanic activity elsewhere in the Mediterranean, especially that of Etna.

The Welsh antiquary Edward Lhuyd interviewed one Cormac O'Neill in 1927, and was retold the legend of Elkmar's expulsion from Bru na Boinne (Wooding, 2000); I don't know the history of the punishment of being cast adrift, but I suppose it went out of fashion quite a while before 1927. Much longer transmissions are possible by means of art/ritual. Archaeoastronomer Luz Antequera Congregado traces the Palaeolithic bull/man with lance/bird on stick theme from Lascaux via the tomb of Senmut (reign of Hatshepsut) and a Roman temple at Dendera (Egypt) to the nineteenth century (Bode, *Les Étoiles et les Curiosités du Ciel*, 1882). The first link in this chain lasted more than 10 000 years. What happens to oral transmission as stories pass from one language to another, and one by one the languages themselves become extinct? Old Irish *immrá* means to row about, and *immrama* are mythological voyages in search of the "Otherworld". They were written down by monks in the 7th and 8th centuries, garbled, bowdlerized, censured, but certainly contain earlier material, some of it prechristian. In an 8th century compilation, the hero Maelduin visits a variety of islands in which we can perhaps recognize seals, walruses, and great auks, as well as phenomena like sea ice. Thorfinn Karlsfin (in the same year that Leif Ericsson was there, 1010 AD?) was told by Esquimos on the Labrador coast of Hvitrmannland, that a settlement of white men and Irish anchorites, *papars*, preceded the Norse in Iceland by 80 years. What we now call the Irminger Sea between Greenland and Iceland is labelled on at least one old map the Irish Sea, and Mercator's famous 1538 map distinguishes the Labrador Sea as *Oceannus Deu calidonius*. Several examples of oral tradition perpetuating genealogies and myths over long periods (centuries, millennia) are collected by Collina-Girard (2002).

ii) It is now widely accepted that myths mix history and legend. We might perhaps analyse specific myths to discover the principles of the blending process, and construct analogies of Shepherd's diagrams to represent the cocktails which we have (Fig.1). For one axis of such a diagram, we might select a line between natural (external) phenomena, such as astronomical cycles and catastrophic and uniformitarian geological processes on the one hand (apex 1), and psychological (internal) imperatives like Jungian archetypes on the other (apex 2). From these two extremes, we could draw two further axes meeting to form the third apex (3) of a triangle, which can be labelled « ideology ». The ideological apex is the focus of the reworking of myths which has taken place with the aim of providing blueprints for social control; the Priestly school's adap-

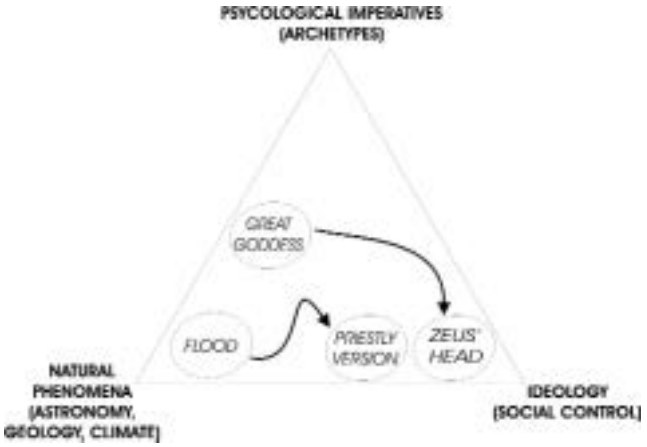

Fig.1. Diagram to illustrate how the composition of myths which may encode natural phenomena can become modified by psychological and ideological forces. Two examples are shown, the Great Goddess who dominated Palaeolithic myths and was later converted to a mere consort of a god, and the "universal flood" of many cultures later edited by the Priestly School to foster Old Testament patriarchy.

tation of the Babylonian and Canaanite myths embedded in *Genesis* is a well-studied example, the downgrading of the Mother Goddess mentioned later is another. In the biblical story, Cain is the bad guy who wins; this myth is sometimes seen to encapsulate the conflict between agriculturalists and pastoralists, and perhaps encodes the new demographic pressure of the emergent Neolithic. But in a Sumerian version of the same story, the roles of the two brothers are reversed, and then we might interpret it as an ideological response to increasing aridity (witness the Assyrian kings who lived in tents, or the contemporaneous collapse of Egyptian Old Kingdom, both about 2200-1900 BC). Ideologies change in response to natural forcings; memes evolve.

Mott Greene's detailed analysis of the battle sequences "leaves no doubt that the phenomena described are volcanic eruptions. Not only that, but eruptions described so carefully and in such detail that the volcanoes in question can be identified and the particular eruptions of the volcanoes dated. The battle of Zeus and the Titans recounts the eruption of Thera, in the Aegean arc..." ? Here is Greene's comparison of Hesiod's lines with the volcanic signature of Thera identified by geologists:

	Hesiod	**Thera**
1	a long war	premonitory seismicity
2	both sides gather strength	increased activity
3	terrible echoes over sea	first phase explosions
4	ground rumbles loudly	tectonic earthquakes
5	sky shakes and groans	air shock waves
6	Mt. Olympus trembles	great earthquakes
7	steady vibrations of ground	earthquakes
8	weapons whistle through air	pyroclastic ejecta
9	loud battle cries	explosive reports
10	Zeus arrives; lightning, thunder, fields and forests burn	volcanic lightning, heat of ignimbrites
11	Earth and sea boil	magma chamber breach
12	immense flame and heat	phreatomagmatic explosion
13	sound of earth/sky collapse	sound of explosion
14	dust, lightning, thunder, wind	final ash eruption
15	Titans buried under missiles	collapsed debris

The tsunami generated by the collapse of the caldera could have been 50 m high. Cita *et al.* (1997) link deposits up to 20 m thick on the Sirte Abyssal Plain to this tsunami. But there is no tsunami in Hesiod's cast.

The story of the fabled island-continent of Atlantis has come down to us from the dialogues of Plato, the *Timaeus* and *Critias*. Serious scholars sometimes interpret the story as a literary

device, or dismiss it as a folk tale. Others, although a literal reading of the details given by Plato does not warrant it, have suggested that Atlantis was in fact Santorini or Crete, and that the destruction of Atlantis "in a single day and night" was due to the great eruption. Akrotiri was buried by the eruption, but unlike the victims of Vesuvius at Pompeii, its inhabitants had sufficient warning to escape – they may have fled by sea – with their movable belongings. A unique feature of the myth of Atlantis is that Plato is our only source, so that it post-dates the time when all other myths considered here were formed (see below); it has a different "body plan", and we can perhaps recognize a non-conformity additional to that between the Great Goddess and Chaos (Fig. 2).

The pre-Greek or proto-Greek Late Bronze Age civilization of Crete was named *Minoan* by the British archaeologist Sir Arthur Evans, since he associated Knossos with the legendary King Minos. This culture reached its peak in the 17th century BC, and its strength was based on sea

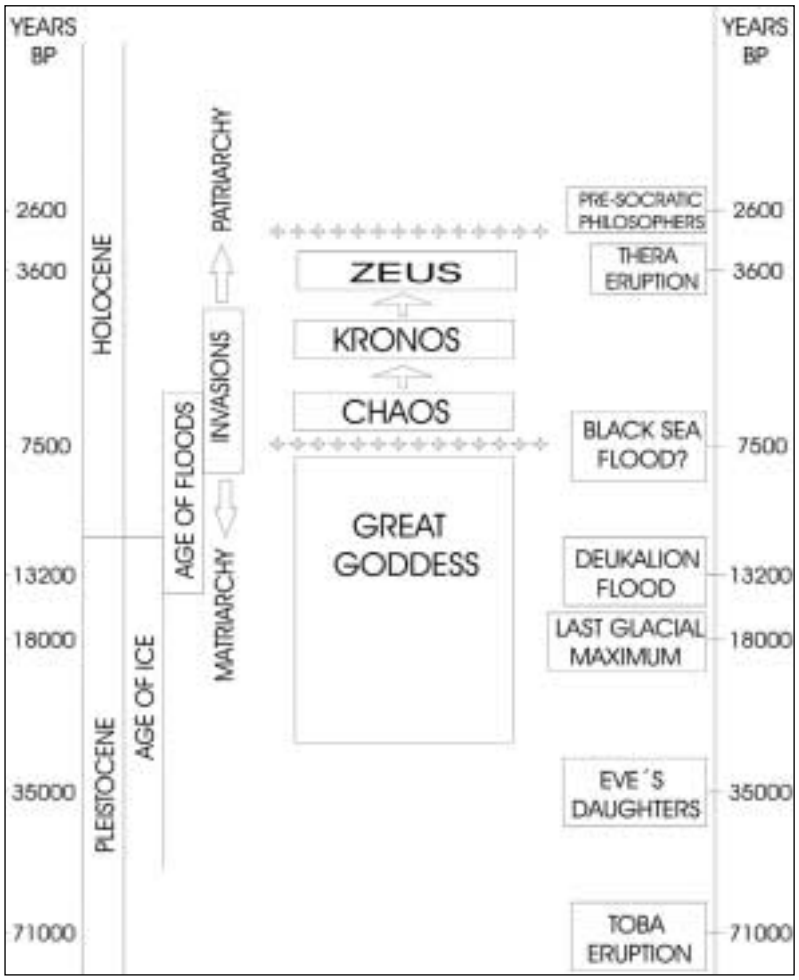

Fig. 2. Tentative sketch of mythological timeline represented (centre column) as geological section; note time scale is logarithmic.
Two nonconformities are indicated, between the Great Goddess and Chaos, and above Zeus; Plato's *Atlantis* is younger than the second nonconformity, and here considered to be a distinct form of myth. The right hand column shows some catastrophic events which may have influenced the evolution of myths. Sakellariou's and Ryan's floods are considered elsewhere in this volume (by Sakellariou and Lericollais respectively); Tchepalyga's flood, a glacial outburst from northern Eurasia, was described at a recent meeting of the Geological Society of America (Seattle, November 2-5, 2003 http://gsa.confex.com/gsa/2003AM/finalprogram/abstract_63243.htm). These floods are named for their authors, since there is so far no general agreement which of several candidates (Ryan's, Tchepalyga's, and others in Mesopotamia, the Persian Gulf, and even as far away as the Sunda Sea) might have inspired the Gilgamesh/Noah myth. Also indicated are the Toba eruption which may have extinguished mid-Pleistocene myths by fragmenting any then existing "small world" of cultural transmission, Eve's daughters whose descendants now people Europe, and the pre-Socratics philosophers to whom we can trace post-mythical models of nature. The invasions which bridge the trend from matriarchy to patriarchy are those of genes and memes, not necessarily marauding hordes.

power. The decline of its power has been attributed to the loss of its navy, caused by the Thera tsunami (?), and the vacuum left by this decline has been used to explain the rise of the Iron Age Dorians and the shift of the centre of power to the Greek mainland.

Several details of the biblical account of the plagues of Egypt and the Israelis' subsequent flight suggest volcanic events; darkness over the land for three days, a pillar of cloud by day and a pillar of fire by night, and the opening of the waters (Pomerance, 1970). The darkness would then be due to the dust veil, the pillar the plinian column - but out of sight over the horizon from Lower Egypt, and leading the Israelis in the wrong direction too! - and the opening of the waters caused by the tsunami (Bernal, 1991). There is evidence that the tsunami from Thera reached Levantine coasts (Stanley and Sheng, 1986), so it must have reached the lower delta too.

DATING THE THERA ERUPTION

The accompanying table summarizes the main efforts to date the Thera eruption, taken mainly from Bernal's (1991) account. Bernal concludes that "the scholarly consensus in favour of the 15th century collapsed in 1987". As the table indicates, this collapse was mainly due to the acceptance of dating techniques additional to those of traditional archaeology.

AD	authors	evidence	BC
1939	Spyridon Marinatos		1450
1960s	Akrotiri excavations	LM IA pottery or earlier, so before 1500	16th century
1970s	Leon Pomerance	Exodus linked to Ramses ; no 'break' in Egyptian records in 15th century	13-12th century
1970s	Philip Betancourt	Radiocarbon (olive stones)	17th century
1970s	Valmore LaMarche	Dendrochronology ; no large Krakatoa effect in 15-14th centuries	1628
1979	Peter Warren	Redate of LM IA following comparison with Levantine pottery	1600
1980	Barry Kemp, Robert Merrillees	Egyptian/Aegean radiocarbon synchronies	1600/1575 'or even earlier'
1980	M. Marthari	Pottery from Thera destruction with Middle Helladic (ended 1600) features	17th century
1980	Hammer *et al.*	Ice cores	1390
1985	Michael Baillie	Krakatoa effect in Irish bog oak	1628
1984-87	Kevin Pang, Hung-hsieng Chou	Bamboo Annals etc ; end of Xia Dynasty	1625
1987	Hammer *et al.*	retraction	1644

Since 1987, further evidence from tree rings in favour of the 1620s has been published, but tephra from Greenland ice cores for this decade seems not to be from Thera (unpublished rumours !), and an earlier date (1645-1647) like that of Hammer may be proposed (I am indebted to Floyd McCoy, pers. comm., for this information). Thus one possible anchor for an absolute time-scale for mythology is 1645-7 BC.

CATASTROPHIC FLOODS

Flood myths are found nearly everywhere, and we are familiar with catastrophic floods episodically in our own time due to exceptional rainfall, storm surges, tsunamis. Some future scenarios due to global warming include severe risks of flooding in many regions. It is probably reasonable to assume that if any or all of these myths contain folk memories of real events, then the floods which inspired them occurred after the last glacial maximum (LGM). Two mythical floods have dominated the imagination of *western* man, that of Plato's Atlantis, and that of Noah from *Genesis*, the former marine, the latter nominally due to forty days of rain. There have been other dramatic floods since the LGM, but for many of them knowledge is largely confined to specialists. Examples are those following the breaching of proglacial lakes in northern Eurasia, which

led to high stands of the Aral and Caspian Seas, the latter perhaps 50 m above its present level (Mangerud *et al.*, 2001). The 4th century Roman historian Ammianus Marcellinus (in *Res Gestae*, citing the 1st century BC scholar Timagenes) described the Gauls as partly autochthonous and partly immigrant from land and islands beyond the Rhine, driven from their homes by wars and the flooding of the tempestuous sea; this may mean from areas now submerged in the North Sea, which we know has episodically expanded in recent millennia at the expense of the surrounding lands (e.g., Gram-Jensen, 1985). The English Channel and Celtic shelf may have been flooded catastrophically by the breaching of the land link between the hills of Artois and the North Downs in England (Smith, 1985).

Flooding due to the evacuation of proglacial lakes is now known to have been a frequent and widespread phenomenon. Catastrophic flooding from the intermontane depressions of the Altai-Sayany mountains and regions farther east in northern Eurasia have been described by Rudoy and his colleagues. Flow rates following ruptures of the ice-dams are estimated to have been 30 or more times greater than during present day thaws, with flow volume exceeding 10^6 m^3/s. The greatest flow power was determined for a Chuya-Kurai floodstream (about 13 thousand years ago) ; its volume was more than 18 million m^3/s (Grosswald and Rudoy, 1996; Rudoy, 2002).

New World floods seem a more likely source of flood myths there, and some of them were so massive that they must have affected the Old World too. Among the largest catastrophic outbursts of fresh water from Lake Agassiz into the North Atlantic Ocean were those at 10,900 ^{14}C yr BP (9500 km^3), 10,100 ^{14}C yr BP, (9300 km^3), and 7700 ^{14}C yr BP (163,000 km^3). These outbursts coincide with the start of the Younger Dryas, Preboreal Oscillation, and 8.2 ka cal yr event, suggesting that outbursts from Lake Agassiz may have repeatedly influenced hemispheric climate by affecting ocean circulation and North Atlantic Deep Water production (Teller *et al.*, 2002). The flow at 8.2 ka is 5-12 Sv, equivalent to a major ocean current. “Although none of these short outbursts of Lake Agassiz waters to the oceans resulted in sea level rises of more than 0.5 m, some caused rapid transgressions of the ocean across shallow continental shelves and marine basins. For example, the 163,000 km^3 outburst from Lake Agassiz at 8400 yrs BP would have caused an abrupt marine transgression of 0.7 km in one year across the floor of a gentle continental shelf with a slope of 1 in 1500, like that of the Mississippi River delta. On the nearly flat floor of the Persian Gulf (1:25,000 slope), which was dry during the last glacial maximum, the final outburst from Lake Agassiz would have resulted in a transgression of 12 km in only a year. Thus, in the Persian Gulf basin, not only did melting ice sheets produce a continuing ocean transgression of 140 m every year for 7000 years, but there was also an abrupt transgressive flood of 12 km about 8400 years ago.” (Teller *et al.*, 2002). A permanent rise in sea level of 0.5 m must of course be catastrophic for low-lying coastal areas, but even temporary rises of that magnitude may be devastating, a realization which has led contemporary man to make enormous investments in barriers against storm surges.

The Tamils have a tradition that their poets’ academy or Sangam existed for ten thousand years, and that its seat (along with the entire Tamil capital) had to be moved thrice because of the rising sea level. They also believe that their country once stretched far to the south, including Sri Lanka and the Maldives, a lost Tamil continent called Kumarikhandam.

The mean rise in sea level since the Last Glacial Maximum is estimated at about 100-120 m. This rise was not monotonic as is sometime assumed, and as the example of Lake Agassiz illustrates, and the evolution of continental shelves is not simply a matter of slow encroachment of the sea, even if processes on longer time scales like isostatic crustal uplift are ignored. The appropriate models are fractal, as the annual Nile floods illustrate, and as Holocene climate changes show. When the Younger Dryas ended and the Neolithic began, there was a 7 degree rise in global mean temperature in a decade.

HOW FAR BACK IN TIME SHOULD WE LOOK?

Studies of single nucleotide polymorphisms (SNPs) suggest that “Mitochondrial Eve” lived 150,000 to 200,000 years ago during the Riss glaciation, and her descendants moved out of Africa 100,000 years ago when the ‘Weak Garden of Eden’ model starts to run (Harpending *et al.*, 1998). Choice of the names Eve and Eden provides ammunition for deconstructivists ! There

may have been a population bottleneck - some estimates (Jones and Rouhani, 1986) suggest there were less than 10,000 breeding adults about 70,000 years ago following the eruption of Toba in Sumatra (Ambrose, 1998). This eruption may have accelerated the cooling which preceded the Last Glacial Maximum. Some American geologists think that another cataclysm of this magnitude is overdue, centred this time on the Yellowstone National Park in North America. We can perhaps assume that most ancient knowledge accumulated prior to the Toba bottleneck was lost as the "small world" (Watts and Strogatz, 1998) of mankind would have fragmented into isolated groups. The slate was wiped clean. This period was followed by the "Great Leap Forward" (Diamond, 1991) which we know as the Upper Palaeolithic ; the human population expanded exponentially (Harpending et al 1998), possibly by virtue of its new tools, art, and mutations of the *FOXP2* gene which may have allowed advanced language skills to be acquired. "The Seven Daughters of Eve" (Sykes, 2001) lived about 40,000 years ago (?) in Europe ; this was about the time of the ultra-Plinian eruption of the *Campi Flegrei* caldera (Fedele *et al.*, 2003). Was there another more localized bottleneck ? Another cleaning of the slate ? The Biblical flood drowned the whole seed of Adam except Noah and his three sons, who were subsequently to repopulate Asia (Shem), Africa (Ham), and Europe (Japhet). Does this myth contain a lingering memory of a population bottleneck ? Or is it just the surviving skeleton of one of the doubtless innumerable mythologies once current among a welter of Neolithic and Bronze Age tribes, most of which have passed irrevocably into oblivion ? Geology enters questions about human expansion in another way too, since mountain ranges, deserts, and water constrain migration routes; these constraints must also modulate the architecture of the smal worlds in which myths evolve.

Jacques Cauvin (2000) argues that there was a mental revolution in the Upper Palaeolithic which created a chasm between man and the divine, and built a bridge from animism to religion; he claims two deities emerged from this revolution, a universal goddess (Great Mother, the White Goddess of Robert Graves) and a bull god, perhaps her totem. Other gods might have been inspired by destructive earthquakes and volcanic eruptions, and their sequelae such as tsunamis, and younger ones by the events, some of them also catastrophic, floods prominent amongst them, which ushered in the Holocene. Cave paintings and other artefacts were already highly developed by 30,000 years ago. This period then is the earliest from which we could expect to find cultural records of geological events. Expert opinion so far however seems to be very varied about the significance of the paintings of Lascaux and other Palaeolithic sites. They may reveal more interest in zoology and astronomy than in geology. Mithen (2003) calls Palaeolithic art "the equivalent of our CD-ROMs today", and writes "The art, the mythology and the religious ritual served to maintain the constant acquisition and flow of information".

But astronomy is the origin of the cardinal points, and must underpin topographical knowledge, an essential tool of the earth sciences. The bull or aurochs is a central character of this art, whose horns may have been seen as lunar crescents, and whose bucrania are said to recall the human uterus and fallopian tubes, and thus to have symbolized regeneration (Gimbutas, 1989). It cannot have escaped the attention of Palaeolithic observers that the human menstrual cycle has a period of one synodic month, that gestation lasts nine synodic months, and that the reproductive and migratory patterns of their food resources were synchronized with lunar phase. The shaman who knew his stuff could guide his tribe to the salmon run at the proper time. Astronomical cycles were a practical concern. Will Durant wrote somewhere that "Civilizations exist by geological consent, subject to change without notice". We could say that they also exist by celestial consent, and that the astronomical future is easier to predict than the geological. Some of the relevent astronomy might be catastrophic too, like the geology. The Underworld (a geological realm) begins in the constellation of Cancer.

According to some scholars**, when Indo-European speakers came, they changed all this. Goddesses which had formerly been created by parthenogenesis were now born of gods, like Athena from the head of Zeus, Aphrodite from the blood spilt when Kronos castrated his father Uranus, Eve from Adam's rib; farcical, really, dirty minded even. The bull became a bully, and raped Europa. It was patriarchal societies (Semitic and Indo-European) which created the Old

** Mother goddesses are not universally accepted as the dominant deities of Palaeolithic times.

Testament and the Iliad: “The death throes of the Great Mother can be read between the lines of these sexist credos” (Schlain, 1998). But She lives on, mutilated perhaps; a modern descendent, the Virgin Mary, is still the most popular member of the Roman Catholic pantheon. We need to bear in mind that ideological impositions may distort astronomical and geological signals hiding in deities’ personalities. But all this is much later. On balance, it looks probable that the mythological big bang occurred in the late Pleistocene and early Holocene when so many events of a catastrophic nature took place.

Alberto Porlan (1998) argues that toponomy preserves a pre-Indo-European systematization of topography, and while we cannot yet read it, might in the long run allow us to recognize a route from Palaeolithic geognosy to that of the literate cultures of Preclassical and Classical times. Porlan relates topography to the names of gods; this intertwining of natural knowledge with mythology still persists, and one challenge here is to unravel the natural from the mythic. Mythologists have identified several potential origins of their subject matter. Bulfinch (1855) for example listed scriptural, historical, allegorical and physical sources, with fire, water and other natural forces becoming personified as deities. Astronomy then provides the empirical basis of chronology and calendars, the key reference points for topography, and the names of deities. So while attention is directed here to fire and water, more specifically to volcanic eruptions and floods, we should not forget the background of celestial mechanics.

SPATIO-TEMPORAL SCALES

The volcanic winter which may have followed the Toba eruption could have lasted for decades or centuries, which must make us pause to consider the distinction between long term, progressive trends and “instantaneous” catastrophic events. Marine shells at high altitudes, which so provoked classical philosophers, might have reached there either by uniformitarian or catastrophic processes. Mountain building and major slumps like the tsunami generated by the Storegga slide have very different time scales, but both can place marine shells well above sealevel. The distinction of course is arbitrary, and depends partly on the time filter used, but also on the magnitude of catastrophic events, and how long ago they took place. The greater the magnitude of a catastrophe, the more likely it is that there will be long lasting progressive trend of some kind following it; given events of similar magnitude, those farther back in time are more likely to be classified as ‘instantaneous’ since the records available from which they can be identified are increasingly compressed or eroded. These expectations can often be encapsulated in power laws such as those used to describe the statistics of earthquakes or volcanic eruptions. But on the time scales of interest here, much progress is being made in the analysis of such records as deep sea cores and ice cores, and some records such as tree rings and varves now allow us to probe deep into the early Holocene and beyond with annual (or better) resolution.

Time scale considerations enter our equations from the historical perspective too. Rackham and Moody (1996) write that “The famous eruption of Santorini, once thought to have caused the collapse of Minoan civilization, is now known to have been a least a century too early; it probably had only minor effects on Crete”. This statement is presumably based on the now somewhat out-dated view that the Minoan collapse was an overnight affair. It is natural to assume that major volcanic explosions, earthquakes, etc., cause instant destruction, as they may do to the hardware, the cities and canals; the software, society, may decay more slowly, or the opportunities which disaster offers to rivals may not be exploited at once. Social changes exhibit viscosity. When drought struck the Old Kingdom in Egypt towards the end of the third millenium (see above), there was a progressive reversion from agriculture to nomadism, and persistent migrations to the delta region, which led to perhaps three centuries of social unrest. This was coincident with the fall of Akkadian culture in Mesopotamia, where there is an occupation hiatus lasting from about 2200 to 1900 BC. There are earlier parallels to the end of the Old Kingdom, such as that from Early to Late Natufian coincident with the shift from the last Interstadial of the Pleistocene to the Younger Dryas, triggered by the collapse of the North American ice sheet around 12, 800 BP (Petit-Maire, this volume, provides more details).

Spatial scales are part of the historical perspective too, and our new appreciation of “small worlds” and “six degrees of separation” come to mind again when we consider cultural trans-

mission, whether oral or written. The tragedies of Aeschylus or Sophocles may enact themselves within the back-scratching and back-biting elites of small city states, but *Oresteia* is about homecomings, and *King Oedipus* ends in exile. It is the weak links which these movements imply which make the world small. West (1997) discusses the problem, and believes the flow from the Middle and Near East to Greece was especially strong in the periods 1450-1200 BC and in the 8th and 7th centuries, and concludes that the transmission of poetry was mainly oral but constrained by textual versions. For some texts such as Gilgamesh, the geographical spread of copies, fragmentary now, is remarkably widespread (West's figure on p. 591). He also stresses the role of bilingual poets, the divergences which could stem from different rescensions, and the parts of the process we cannot see due to the poor survival of material in some languages (eg Aramaic, Phoenician). As an example, West sees direct links between 7th century Assyrian court literature on the one hand, and Hittite necromantic rituals on the other, with the *Iliad*, only one degree of separation away in each case. This is an indication of how large the spatial scales of these links are; the corresponding time scales are of the order of millennia. West's oral/textual conclusion may be adequate for the period since writing existed, but if oral transmission alone is effective over *really* long periods, then we would still like to know how long, since the power of speech is plausibly older than *Homo sapiens*, at least if anatomy is our guide. (It has been claimed that the form of the hyoid arch and the size of the anterior condylar foramen through which the hypoglossal nerve exits the skull are consistent with Neanderthal speech (Kay *et al.*, 1998), though this is denied by DeGusta *et al.* (1999) ; perhaps the *FOXP2* gene is needed to complement the appropriate anatomy, and the combination is a Gouldian spandrel***). The end point of these concerns lies in the 6th century BC, when pre-Socratic philosophers of the Milesian School laid the foundations of Lyell's and Darwin's uniformitarian views.

There is of course considerable evidence of sophisticated geological knowledge in classical times, as we can appreciate from reading Book XV of *Metamorphoses*, where processes still recognized by modern geologists emerge from Ovid's Pythagorus (see Lyell, *Principles of Geology*). Aristotle (*Meteorics*) attributed earthquakes to the generation of wind within the earth, and associated them with volcanic phenomena. Strabo (*Geography*) noted both widespread and local sinkings of land, and rises of the seabed; he also suggested that some islands were born of volcanism, and that others were torn from the mainland by earthquakes. He was aware of the growth of deltas, and their control by tidal currents. Seneca (*Quaestiones Naturales*), based on eyewitness accounts of an earthquake in Naples distinguished the up and down motion (*succussio*), the oscillatory motion (*inclinatio*), and perhaps also the vibration. Aristotle saw that first marsh and then dry land was created by alluvial deposits and gave examples from the Black Sea, where ships had had to reduce their draughts in the sixty years preceding his account. Xenophanes of Colophon (614 BC), Xanthus of Lydia (464 BC), and others inferred from marine shells among mountains that the land had risen from the sea. Herodotus, Eratosthenes, Strato and Strabo noted the vast quantities of fossil shells in different parts of Egypt, together with beds of salt, as evidence that the sea had once spread over the land. This knowledge and these models belong to modern times, while the mythical events which may contain memories of geological catastrophes do not. Some of these processes are examined elsewhere in this volume: Andreas Vött and Helmut Brückner describe coastal changes due to progradation and other processes in the Acheloos delta (Greece) and in Aegean Turkey respectively, and Pablo Silva traces the impact of earthquakes and tectonics on coastal morphology in southwest Spain. The time period of interest here is then the millennia preceding Hesiod, and corresponds to the last phase of human expansion, from the Palaeolithic through the Bronze Age and early Iron Age.

Ancient (Ugaritic, Assyrian, Egyptian, Semitic,...), classical (Greek, Roman), and Mediaeval (Sagas,...) sources contain various categories of pre-scientific information. On the one hand, we recognize that descriptions of nature and theories about how it should be classified are precursors of present day science. Data recorded millennia ago can still play constraining roles in some research fields (Babylonian eclipses, Nile floods, volcanic eruptions, etc.). On the theoretical side, we can, if we wish, trace the roots of Mendeleev's periodic table back to Aristotle's earth,

*** Parts of the cerebral cortex would also have needed to be reorganized somehow !

air, fire, and water, the origins of atomic theory to Democritus, notions on the causes of earthquakes to Seneca, and the landbuilding power of sedimentary processes to Herodotus and Strabo. "Egypt is the gift of the river" wrote Herodotus (and mighty changes are underway today since the Nile was "tamed" at Aswan – anthropogenic impacts on geological processes are discussed by Brückner, this volume). But on the other hand, these sources also contain much more elusive records of events which are traditionally claimed by mythologists and others, and which are not generally considered to be of much interest to natural scientists.

WHAT PROCEDURES SHOULD WE ADOPT IN GEOMYTHOLOGY?

So, should we inspect the ancient gods for signs of their putative geological components, or should we look in the geological record for catastrophes which have been tranformed into gods? As we have seen, Mott Greene (1992) chooses the former course in his analysis of Hesiod's *Theogony* where he identifies the signature of Thera's eruption, but it is more usual to search geological records for evidence that myths are founded on real events, as Ryan and Pitman (1998) do for the biblical deluge. One problem with the latter approach is that *any* evidence of a major flood is likely to be ascribed by students steeped in western traditions to that in *Genesis*. Ruggles' (1999) critique of Alexander Thom's megalithic calendars identifies a parallel problem; if, for example, it is maintained that Le Grand Menhir Brisé (near Carnac) is a foresight for observing standstills of the moon, then backsights can almost certainly be identified (and were !), but their functional role within the archaeoastronomical model is far from being demonstrated. Pleistocene and Holocene geological records show that there have been major floods in many parts of the world, and it is highly likely that some have seeded flood myths.

I think the interesting question in the context of this workshop is, can we link geologically identified floods to particular myths or deities? Do flood myths from different cultures have "signatures", analogous to those of volcanic eruptions, which might enable us to identify the kind of flood which inspired the myth? Can we distinguish mythical analogies and homologies as palaeontologists must when they compare vertebrate and arthropod limbs ? Can we separate opaque allusions to Jungian archetypes from external elements, the waters of the womb from the forty days of rain? Georges Dumézil identified what he thought were homologies in Indo-European mythologies, but Claude Lévi-Strauss argued that some of these same features were analogies, parallel but not necessarily generically related. The conflict cannot be easily resolved without a chronology of the structural patterns alluded to.

Many disciplines can help provide answers to such questions. Genetics synthesizes the historical components of its subject matter by constructing trees which summarize lines of descent and trace separate patterns of content to common ancestors; population genetics, as distinct from the kinds of study already mentioned which identify Adam and Eve, gives us anastomosing structures more like fungal hyphae than trees. Historical linguistics follows similar procedures, and also constructs tree-like and reticulate models of phylogeny. In both cases, the phylogenetic signals can be degraded; the genetic signals in modern populations contain elements of the founders, the products of drift and selection and later migrations from the source population, and mixing with other populations from different trees. Some of these signals may vary between analyses based on mtDNA and Y loci if there are sex specific differences in demography. Linguistic analyses face analogous difficulties due to language replacement and hybridization, and the genetic and linguistic maps can be decoupled.

It may be an exaggeration, but it is said there is as much human genetic variation in a single African village as in all the other continents combined. Nevertheless, recent advances in genetics have made possible the separation of closely related ethnic groups, and these to some extent can be mapped onto language groups. Myths too can be mapped onto languages, though again the mapping is very loose. This looseness might be ascribed to several factors, such as the potential existence of universal (Jungian) archetypes, few degrees of separation, and power law distributions of cultural dominance and their changes in time. We can therefore expect there to be a mapping of myths onto geographical genetic patterns. But it may be in many cases that the factors which blur this kind of mapping have already erased any recognizable signals.

SUMMARY

It is suggested that mythogenesis became possible once we became genetically empowered with speech, and that it more or less ended with the pre-Socratic philosophers. All early myths were probably irrevocably lost following a population bottleneck due to the eruption of Toba. Two non-conformities are provisionally identified, between the Great Mother of the late Palaeolithic and the mythogenic big bang of the Neolithic and Bronze Ages, and between the latter and pre-Socratic models. Many myths may have been inspired by geological catastrophes, but have been transformed by psychological and ideological imperatives, notably by patriarchy.