

Updating George F. Dodwell

Summary: *In his retirement up to 1959 the Australian astronomer George Frederick Dodwell conducted extensive research to check whether the standard formula for the secular variation of the obliquity of the ecliptic could be proven by ancient observations of the sun at the solstices. He came to a conclusion that the formula could not be proven; and that in fact the data showed the likelihood of a catastrophe around 2345 BC, which he equated with the Flood of Noah. His work was never published, but it continues to be cited in all sorts of contexts despite being based upon science that is now half a century old. This article will examine how well his conclusions stand-up after fifty years of new discoveries.*

George Frederick Dodwell (1879-1963) was the Government astronomer for South Australia for forty-three years until his retirement in 1952; responsible among many notable achievements, for the accurate determination of Australian state boundaries. In his later years he seems to have pursued a strong personal interest in the secular variation of the obliquity of the ecliptic.¹

That Dodwell also held a profound, yet scientific, interest in the Bible cannot be doubted, for in 1959 he completed his manuscript entitled: *The Truth of the Bible: astronomical investigations of the obliquity of the Ecliptic.*² The work in two volumes, comprising some 327 pages, was unpublished - yet it remains a milestone in the history of astronomy.³ His manuscript does offer a unique mix of science and faith, but any religious inspiration for the research must not be overstressed. His approach remains scientific throughout.

The manuscript is structured with an introduction and summary chapter, where he presents his conclusions and charts. Chapter 2 considers the likely errors in the ancient

data, with a discussion of the accuracy of the various types of gnomon instruments that were used to measure the solar shadow. He then offers a detailed discussion of each source, taking care to adjust all his results for refraction, solar parallax and reduction to the centre of the sun's disc:

Chapter 3 – Ancient Chinese

Chapter 4 – Ancient Hindu

Chapter 5 – Greek sources

Chapter 6 – Medieval Arab sources

Chapter 7 – Medieval and modern sources

Chapter 8 – Ancient Egyptian Monuments

Chapters 9 and 10 respectively consider the Stonehenge alignments and those of Tiahuanaco in Peru, although he finds no datable measurements from these monuments and makes no use of them in his calculations.

It is clear from the summary that Dodwell believed a catastrophic flood of the sea, akin to that recorded in the Bible, must be accompanied by a tilt of the Earth's axis. It is less certain however, whether he originally set out to prove the authenticity of the Flood by science, or whether it was his study of the secular variation which subsequently led him to believe that it showed a catastrophic element in recent Earth history.⁴

Dodwell's work owes much of its recognition beyond Australia to a letter that he wrote to the author Rene Norbergen in 1960, which was quoted in Norbergen's highly successful book *Secrets of the Lost Races*. The book details that author's expedition to Mount Ararat; and his claim to have discovered remains of Noah's Ark had evidently caught Dodwell's attention. Norbergen quotes from Dodwell's letter:

... I have been making during the last 26 years an extensive investigation of what we know in astronomy as the secular variation of the obliquity of the ecliptic, and from a study of the available ancient observations of the position of the sun at the solstices during the last three thousand years, I find a curve, which after allowing for all known changes, shows a typical exponential curve of recovery of the earth's axis after a sudden change from a former nearly vertical position to an inclination of $26\frac{1}{2}$ degrees, during the interval of the succeeding 3,194 years to AD 1850...

The date of the change in the earth's axis, 2345 BC...

Dodwell concluded that this event was none other than the Biblical Flood and that the story of Noah must therefore be historically true.⁵

Therefore in 1998, while researching the astronomy for my own later book *Under Ancient Skies*, I attempted to look further into Dodwell's work on the obliquity⁶ Unfortunately, I was forbidden by Dodwell's heirs to quote from the manuscript; neither would they allow me to make a copy for the purpose of checking his source material in more detail.⁷

A trawl of internet references will bring up numerous citations by religious groups and creationists, each seeking to utilise Dodwell's professional credentials as proof of the Bible.⁸ Witness a typical example taken from a creationist website: ⁹

After further calculations which he [*Dodwell*] plotted on a graph it showed it was a log-sins curve showing that the spinning earth returned to a new angle when it had been suddenly deflected from its original position. He said it had happened around 2,345 BC. This would have happened from the start of the flood (2,470) and lasted many years until the birth of Peleg (c2,372) when the continents were formed.

Dodwell later read Professor McReady Price's book; "Hyphothesis of a World Catastrophe" and he realised that he had discovered the cause of the Noahian flood!

Dodwell's manuscript was also cited by M. M. Mandelkehr in his various articles in the C & C Review;¹⁰ and in his recent books, to support a case for a disturbance of the earth's axis around 2300 BC,¹¹ This date would loosely coincide with the First Intermediate Period of Egyptian history, as it is conventionally dated. Various authors from the 1970s and early 1980s also made a case for an astronomical catastrophe around this era, of which perhaps the most influential examples would be Clube and Napier's book *The Cosmic Serpent*.¹²

Many academic papers up to the mid-1970's published *uncalibrated* radiocarbon dates for climate and sea-level changes c.2300 BC which, when calibrated, have to be pushed back by around 800 years. Once this is done their apparent correspondence with the Biblical dating of Noah's Flood is lost.¹³ Despite this, creationists and others continue to cite Dodwell and other older sources as scientific support for the Biblical chronology.

In 1981 a discussion of Dodwell's conclusions was included in the SIS Journal, within a *Focus* article entitled *Catastrophism Old and New*. It minutes the presentation of speaker's Peter Warlow and Peter James at the Society's meeting of 6 June 1981.¹⁴ The diagram included here, showing a simplified version of Dodwell's graph, is reproduced from a 1978 article entitled: *The Celestial Dynamics of "Worlds in Collision"*.¹⁵ It captures the essence of, but differs significantly from Dodwell's original curve (which I have no permission to reproduce). *[Include the earlier SIS diagram near here]*

The graph plots an exponential decay curve passing through a scatter of observations of the sun at the solstices, as derived from modern, medieval and classical sources, plus earlier Chinese and Indian observations from the first millennium BC. The curve then continues

precisely through two older alignments derived from the Egyptian temple of Karnak, to an asymptote at 2345 BC, which Dodwell equated with the date of Noah's Flood.

Some significant additional details appear on Dodwell's original graph. He believed that the curve of adjustment of the axis had commenced at 2345 BC (he was most precise in his comparison with Archbishop Ussher's date for the Biblical flood) but had completely decayed by 1850. His summary diagrams are presented in portrait rather than landscape, with many more recent observations crammed into the curve. He actually shows *two* observations from Karnak, one dated to 1570 BC, which he admits is an interpolated value; and the earliest at 2045 BC, which he attributes to the Twelfth Dynasty and states the obliquity as $25^{\circ} 09' 55''$.¹⁶ The dotted line of 'theoretical values' were derived from Newcomb's formula.¹⁷ This gives the uniformitarian view of the 'secular' variation of the obliquity of the ecliptic that most astronomers had long accepted; and which Dodwell set out to check against contemporary observations.

The 1978 article continues with a minute of a discussion session, in which a speaker, Dr Robert Bass, introduced the subject of Dodwell's curve. If I may quote him here:

When he [Dodwell] charted these historical observations (see figure), they led to a curve very different from that given by Newcomb's formula, which most people think would be valid for thousands of years. His interpretation of his data indicated that the earth is recovering from being turned upside down around 2300 BC...

This shows us how unintentional bias may creep-in through second-hand reporting, in this case when it was cited to support Velikovsky's theories. As we may see from the letter quoted above, this certainly was *not* Dodwell's own opinion. He did not state that his data proves the Earth turned upside down around 2300 BC; quite the contrary. Dodwell thought

that the obliquity of the Earth's axis had been closer to vertical before the crisis (perhaps only 5°) – although on what evidence he believed it to have been near-vertical is equally unsubstantiated. The references that he intended to cite are left as empty brackets and ellipses in the manuscript.

For let us be sure of one thing: the recovery of a rotating body, following a disturbance, can tell us nothing of the attitude of its axis *before* that event; to establish that, we must consult other data. We can only assert that *after* a disturbance of the axis (and barring any subsequent agitation) it would wobble in the manner established by geophysical theory, before ultimately settling to its modern attitude.

It is evident that Dodwell also knew something of contemporary geophysical theory, for he considers his own curve to be the result of an “Eulerian nutation”; and although he refers to the modified 430-day period of the Chandler Wobble rather than Euler's 305-day period, he never refers to it by that name. He also presents a modified curve, showing the effect of an oscillation of period 600 years, caused he says, by latitude variation “accounted for by the inertia of the rotating body alternately retarding and hurrying the precession”.¹⁸

Another fact about which we must be clear is that, despite his faith in the Biblical account of the Flood, George Frederick Dodwell was in every way a conventional professional astronomer of the early twentieth century. His reaction to Velikovsky's unique form of catastrophist astronomy would surely have been as negative as that of his professional contemporaries. We must however, view his conclusions in the light of the astronomical and physical science of the 1950's, for much of that background is now outmoded.

We may see that for the modern and medieval period back to 400 AD, Dodwell derives some sixty dateable values for the obliquity, but these become progressively fewer as we go

back in time. For the early centuries BC he utilises points derived from Ptolemy, Hipparchus, Pytheas and Thales as the oldest of the classical sources. He plots the curve to pass through Thales observation at 558 BC leaving the other points as a scatter around the curve; Dowell also considered his postulated 'oscillations' to give a more precise fit to the scatter of points, although this is distinct only in the medieval and modern period where most of his data points lie. The curve then continues *precisely* through his two oldest points derived from the Egyptian temple of Karnak at 1570 BC and 2045 BC.¹⁹

The two early Egyptian data points, taken alone, are insufficient evidence to plot such a graph; ideally we need to see a statistical scatter of many more ancient observations clustered around this early part of the curve. If these two vital points should be considered unreliable then we can as well reconstruct the curve to pass through almost any date we wish.

The first problem arises with modern dating for Dynasty XII as lying between 1991 BC and 1786 BC.²⁰ The oldest phase of Karnak: of which only the granite thresholds survive, is believed to have been built by Amenemhat I, the first king of the dynasty. This would place Dodwell's oldest point at c1991 BC not at 2045 BC. However there is some reason to believe that this pharaoh only restored an older Amun temple built by a Dynasty XI king Intef II, who ruled this Nome during the First Intermediate Period.

In the 1950's, conventional Egyptologists held that the Karnak solstice alignment was mere coincidence. The pioneering work of J. Norman Lockyer, had originally suggested that the main axis was aligned towards the midsummer sunset (or rather toward clock stars that heralded this event at various epochs).²¹ However, interest in the earliest alignments was renewed by Gerald Hawkins in the 1970's.²² Based upon some difficult inscriptions

within the temple itself, most Egyptologists now accept that the alignment was actually in the opposite direction towards the winter solstice sunrise. The surviving temple preserves the last attempt by a native king: Nectanebo I (380-362 BC) to restore the old monuments. The sun would have risen behind the Gate of Nectanebo, being framed within a rectangular slot high up in the gate.²³ We may therefore reasonably infer that the earlier phases of the temple were similarly oriented towards midwinter sunrise.²⁴

The observations of Thales (believed to date from 558 BC) are another crucial point on Dodwell's curve, yet precisely how Thales performed his determination of 24° , which Dodwell adjusts to $24^\circ 00' 56''$, must remain uncertain. Diogenes Laertius (I.24) recorded that Thales was the first astronomer to determine the true length of the year and the sun's course from solstice to solstice; and that he acknowledged the lost astronomy of Eudemus as his primary source.

The various fragments of Pytheas, speak of the Arctic Circle lying some six days sailing north of Britain, from which only loose information may be derived about the solstice. Dodwell derives a value of $23^\circ 53' 46''$ for the obliquity at 323 BC, based on the latitude of Marseilles from where Pytheas set out in search of Britain and Thule. However, we also know that Pytheas considered Marseilles and Byzantium (Istanbul) to lie on the same parallel, although these differ in latitude by as much as one-and-a-half full degrees.²⁵ This shows us the degree of approximation that was sufficient for his navigation.

The observations of Eratosthenes (probably dating from 205 BC) lie slightly off Dodwell's curve. Eratosthenes' method for determining the size of the Earth relied upon an observation that on the day of the summer solstice, the sun penetrated precisely to the bottom of a deep well at Syene south of Thebes in Egypt. Yet Syene lies some 50 km north

of today's Tropic of Cancer. According to Ptolemy, Eratosthenes derived the tilt of the axis as $11/83$ of 180° , plotted as $23^\circ 51' 59''$ by Dodwell. The graph of 'theoretical values' show a retro-calculated angle of approximately $23^\circ 43' 12.2''$ at 200 BC. However, consider how tiny this difference is in comparison to the various observational uncertainties. We cannot know the depth of the water in the well or whether its walls were vertical; indeed we cannot be sure whether the observation was a measured angle using a gnomon or just an anecdotal report.²⁶

Older measures of obliquity are available from Indian and Chinese documents. Dodwell's oldest Hindu source dates from around 900 BC (in another place he says 945 BC) where he uses a value of $24^\circ 11' 04''$ based on observations in southern Sri Lanka; but again the date and location can only be known approximately.²⁷ Chinese documents supply observations around 700 BC and 1120 BC. The corrected obliquity for Mo in Shantung province gives $24^\circ 12' 06''$ for 1120 BC.²⁸ Dodwell noted that all these derivations were trending consistently above the prediction of Newcomb's formula.

When Dodwell was gathering his data during the 1950's, radiocarbon dating was in its infancy and the technique of tree-ring calibration was yet to come. We can now examine other dateable solstice alignments that were unavailable to him. The archaeological textbooks of that decade gave the era of Stonehenge and other aligned Neolithic monuments as no older than 1800 BC based on cross-dating techniques. It is now generally accepted that the first phase at Stonehenge – though possibly aligned towards midwinter sunset rather than midsummer sunrise – must date to as early as 2900 - 3000 BC. This shows us that the alignment of the solstices were certainly close to their present state fully six centuries before the date that Dodwell derived for the Biblical Flood. A change in the

tilt would affect the azimuth of the rising or setting sun at the solstices; and better astronomers than I have concluded that the early Neolithic monuments do indeed agree with retro-calculated alignments; Gerald Hawkins, Alexander Thom and others would never have been able to make their case for Neolithic alignments if that were not so!

For example, 1960's excavations at Newgrange in Ireland and contemporary passage graves in Anglesey and Orkney show that these monuments were also aligned towards the solstices. It is well established that at midwinter sunrise, a beam of light penetrates a narrow slot known as a roof box to illuminate the back wall of the Newgrange chamber. A survey by the excavators established that the winter solstice sunrise would still penetrate the chamber regardless of secular changes in the obliquity of the ecliptic.²⁹ The Newgrange mound was radiocarbon dated to a date around 3150 ± 100 BC from charcoal remains found between the stones.³⁰ This sets a limit to the most recent era at which any flood catastrophe could have occurred; and also indicates the range and variation of the obliquity at that era.

Perhaps the most significant advance since the 1950's has been in the geophysics and the understanding of the earth's wobble. Astronomers of that era certainly believed that they understood this phenomenon, but experience has proven otherwise. It had been understood since as long ago as 1839 that a disturbance of the rotation axis would give rise to two modes of free wobble. One has a short lifetime, decaying exponentially within about 20 years (the *Chandler Wobble*, named after its nineteenth century discoverer). The other mode has a longer lifetime (between 2,000 and 5,000 years has been suggested) and it can only be the exponential decay of *this* wobble to which George Dodwell was alluding in his research. It would occur should the axes of mantle and core become misaligned.

It was not until the 1980's that geophysicists actually proved the existence of this theoretical motion.³¹ Although it is vanishingly small on the modern Earth, the data shows that it causes a wobble of the axis in space of period approximately 430-440 days, together with a body-motion component, known as the *nearly-diurnal wobble* on account of its retrograde period of just under one day.³²

The true characteristics of this core-wobble, as a cause of latitude variations, were unknown to astronomers of the 1950's. Indeed the subject was of interest to only a few of the most eminent geophysicists. Geophysical textbooks such as that of Sir Harold Jeffreys, the foremost authority of the time, were available but apparently not used by Dodwell.³³

The axis cannot simply tilt over gradually as Dodwell's graph implies, for that would require the period of the wobble (i.e. each circuit of the pole) to be precisely one year, in order for the horizon alignments to return close to the same rising and setting each annual solstice. However, since the true period is closer to 440 days it would combine with the annual 365-day period to give a seven-year rhythm.³⁴ The solstice alignment would therefore lie sometimes north, sometimes south of its mean position (albeit following an exponential decay curve). This mean position, to which the motion would ultimately decay, is given by the modern rising and setting points after suitable adjustment for the secular variation at each era.

Dodwell's original calculation of the secular variation was based on Newcomb's 1894 and 1906 formulae. Newcomb had only intended his approximations to be accurate for 250 years either side of an 1850 epoch. His calculation for the pull due to Saturn was slightly incorrect and he did not know of the small effect of Pluto. Other astronomers from the 1950's onwards also began to question Newcomb's equation. So in 1976 (based on

computer-calculated analyses of ancient and medieval data similar to that used by Dodwell) the International Astronomical Union adapted the revised formulae of Lieske.³⁵ These astronomical constants continue to be refined and extended.³⁶

Even if we had many more ancient observations marking the extreme limits of a wobble at any particular era, then we should expect the resulting graph to show plots both *above* and *below* the theoretical line given by the retro-calculated secular variation. To use Dodwell's own statement: if the maximum of the disturbed obliquity were indeed some 26.5° then this lies some 3° above the mean; so we should also expect to find some evidence for points lying between a *minimum* obliquity of 20.5° and the mean of 23.5°.

However it would make no sense for ancient builders to align a solar temple on either of these extremes, for it would become immediately obsolete as the sun would never again reach it. It would be far better to align upon the mid-point of the wobble, through which it would pass each 3 or 4 years and would ultimately converge. The absence of any points on Dodwell's graph showing an axis tilt *less* than that of the present day, in addition to the points of increased obliquity, shows us that the evidence is incomplete. Alignments to the mid-point of a transient motion can neither prove nor disprove its former existence! For example: release a pendulum and wait for it to come to rest; how do you prove that it ever swung at all?

In summary it must be concluded that much as a catastrophist researcher might wish Dodwell's work to support a case that the Earth's axis has changed, unfortunately it cannot reliably be used in that way. Certainly it cannot be used to support the Biblical chronology as he intended. However, it may offer evidence that the axis was indeed disturbed at some

point in antiquity; and that a residual free nutation remained detectable up to Medieval times.

Nothing in my conclusions here should be taken as a criticism of Dodwell, for it remains a remarkable insight for an astronomer of his day to even consider the possibility of a change of axis, let alone to attempt to prove it. It is a tragedy that Dodwell's research did not achieve publication in the 1960's. It might have generated serious interest in catastrophist astronomy among professional astronomers; whereas the fringe debate, dominated by the ideas of Velikovsky – another piece of outmoded 1950's science – has simply caused them to look the other way.

¹ In astronomy, *obliquity* is the inclination angle of a planet's rotational axis in relation to the perpendicular to its orbital plane. It is sometimes also called *axial inclination* or *axial tilt*. The obliquity is expressed as the angle made by the planet's axis and a line drawn through the planet's centre perpendicular to the orbital plane. For the earth this is currently about 23° 27'. Long term changes in this angle are termed secular variations to distinguish them from those that occur on shorter cycles.

² Dodwell's unpublished manuscript "The Truth of the Bible" is in the Mortlock Library at the University of Adelaide.; Barry Setterfield, late of the Astronomical Society of South Australia, attempted to have the manuscript published in the early 1960s, without success – see: www.setterfield.org/bio.html

³ I first heard of Dodwell's work in the mid-1980's via second hand reports – and I did not realise its possible significance for my own theories at that time. I later received a letter from a reader of my own book noting some apparent similarities. [see: *The Atlantis*

Researches: the Earth's Rotation in Mythology and Prehistory Third Millennium Publishing, (1995)]

⁴ For a highly entertaining summary of the Dodwell manuscript, see that given by V. Lloyd in: www.adam.com.au/bstett/SkepticsObliquityEcliptic33.htm

⁵ Norbergen, R, *Secrets of the Lost Races*, New English Library, London (1977), pp 20-21.

⁶ Dunbavin, P, *Under Ancient Skies, Ancient Astronomy and Terrestrial Catastrophism*, Third Millennium Publishing, Nottingham (2005)

⁷ This is unfortunate, but understandable. It seems there was no way that I could win. To have his unique theories criticised by the astronomical establishment was clearly undesirable; but to have them praised by a 'catastrophist' would surely be even more detrimental to his reputation. As I do not use aeroplanes and unable to travel to Australia, I am therefore indebted to Moe Mandelkher for supplying to me a copy of the manuscript from a USA source; and also to Philip Clapham for directing me to the earlier SIS discussion of Dodwell's work.

⁸ Various Internet references illustrate this usage:

www.creationism.org/ackerman/AckermanYoungWorldChap11.htm;

www.grazian-archive.com/quantavolution/QuantaHTML/vol_04/lately_tortured_earth_04.htm;

www.iidb.org/vbb/archive/index.php;

tccsa.tc/archives/debate/rso_vs_lawson_9_2000.html;

gondwanaresearch.com/hp/set.htm.

⁹ www.enlightened.org.uk/science.html; The Science of Creation

¹⁰ M. M. Mandelkehr, *An Integrated Model for an Earthwide Event at 2300 BC, Part I: The Archaeological Evidence*, S.I.S. Review, Vol. V:3, pp. 77-95 (1983). Also *Part II: The*

Climatological Evidence, C & C Review, Vol. IX, pp.34-44 (1987). Also *Part III: The Geological Evidence*, C & C Review, Vol. X, pp.11-22 (1987).

¹¹ MM Mandelkehr, *The 2300 Event : Archaeology and Geophysics. The Meteoroid Stream*, published by Outskirts Press of Denver, Colorado:2006.

¹² Clube, V. And Napier, W., *The Cosmic Serpent*, Faber & Faber, London, (1982).

¹³ My own proposal concerned a wobble commencing around 3100 BC and decaying exponentially by about 500 BC.

¹⁴ SIS Review Vol V No 2 (1980/81)

¹⁵ SIS “Ages in Chaos” conference, 1978, p78

¹⁶ Dodwell’s conclusions were based upon the work of Sir Norman Lockyer and a 1921 survey of Karnak by F.S. Richards: Survey of Egypt Paper No 38.

¹⁷ According to Dodwell the calculation of this line was based on:

$$\epsilon 1900+T = 23^{\circ} 27' 8''.26 - 46''.845T - 0''.0059T^2 - 0''.0181T^3$$

from Newcomb’s formula, where T is in Julian centuries from the epoch 1900. For further information see: Newcomb, S.: 1906, *A Compendium of Spherical Astronomy*, Dover Publications., New York, 1960 (pp 226-238).

¹⁸ Dodwell cites H. Crabtree, *Spinning Tops and Gyroscopic Motion*, 1909, pages 14 and 124.

¹⁹ Dodwell took a mean value for these historical dates from contemporary versions of the Cambridge Ancient History, Breasted and Budge.

²⁰ Chronology of Ancient Egypt - Dr_ Zahi Hawass.htm

²¹ Lockyer, J.N., *The Dawn of Astronomy*, Macmillan, London (1894), pp 99-120.

²² Gerald Hawkins in 1974 resurveyed the Karnak alignment and concluded that the Amon-Re temple aligned precisely with the rising of the midwinter sun when it was rebuilt by Tuthmosis III. See. Hawkins, G.S. Phil. Trans. R. Soc. London. Series A, Mathematical and Physical Sciences, Vol. 276, No. 1257, *The Place of Astronomy in the Ancient World* (May 2, 1974), pp. 157-167.

²³ Reese, R.L., Sky and telescope (March 1992), *Midwinter Sunrise at El Karnak*, pp 276-278

²⁴ Another recent study suggests that Egyptian temples were typically oriented perpendicular to the Nile and that Karnak may have been chosen because it is the only site where the winter solstice sunrise is perpendicular to the river. See Shaltout, M & Belmonte, J., JHA 2005, *On the orientation of Egyptian Temples I: upper Egypt and Lower Nubia*; www.iac.es/folleto/research/preprints/files/PP05003.pdf.

²⁵ Strabo, Geography, 1. 4. 4

²⁶ On this see V. Lloyd in: www.adam.com.au/bstett/SkepticsObliquityEcliptic33.htm; he tells us: "Mr Dodwell also sent a copy of his manuscript to the Royal Society but this august body decided against publication on the grounds that 'errors of ancient observations needed further discussion'."

²⁷ Dodwell used the translation by C.P.S. Menon, *Early Astronomy and Cosmology*, *Astronomical data from the Jaina Astronomical Treatise called Suryaprajnapti* (undated).

²⁸ Dodwell cites the French translation of the Chou-pei by Eduard Biot in the *Journal Asiatique*, Paris (1841)

²⁹ Ray, T.P., *The winter solstice phenomenon at Newgrange, Ireland: accident or design*, Nature, 337, 343-5. (1989) p344. The range of azimuths for which the beam would shine down the Newgrange passage are given as between $-22^{\circ} 58'$ and $-25^{\circ} 53'$.

³⁰ *ibid*, p 345

³¹ Toomre, A., *On the 'Nearly Diurnal Wobble' of the Earth*, Geophys, J. R. Astr. Soc., 38, 335-348 (1974)

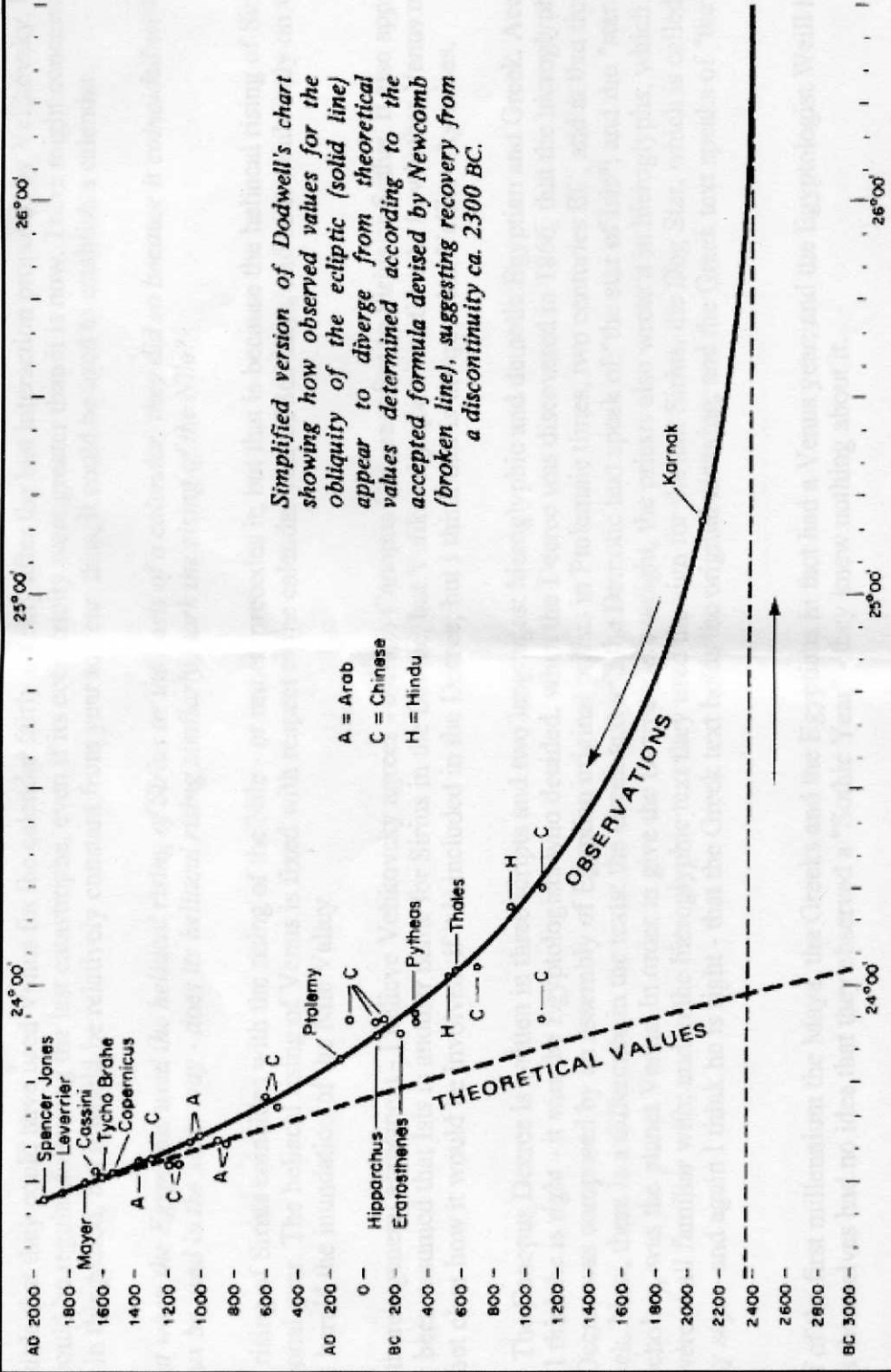
³² Capitain, N. & Xiao, N., *Some terms of nutation derived from the BIH data*, Geophys, J.R. astr. Soc 68, 805-814 (1982)

³³ Jeffreys Sir H, *The Earth*, Cambridge University Press (editions 1924, 1929, 1952, 1959 through to 1976).

³⁴ I have examined the consequences of this motion more thoroughly in chapter 10 of *The Atlantis Researches*, which was republished, with additional notes as: *Atlantis of The West*, Constable & Robinson, London (2002).

³⁵ Lieske, J.H. et al: 1977, "Expressions for the Precession Quantities Based Upon the IAU (1976) System of Astronomical constants.", Astronomy & Astrophysics 58,1

³⁶ The International Astronomical Union has now adopted an obliquity of $23^{\circ} 26' 21.44''$ based on an epoch of 2000 as a base for such calculations.



Simplified version of Dodwell's chart showing how observed values for the obliquity of the ecliptic (solid line) appear to diverge from theoretical values determined according to the accepted formula devised by Newcomb (broken line), suggesting recovery from a discontinuity ca. 2300 BC.

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