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Introduction to the Milankovitch Theory, Ch 3, p. 1

In this chapter we will look at the process taken to define the start of the Pleistocene epoch

A review: Milankovitch measured the sun's radiation, which was measured at the top of the atmosphere. Its radiation is measured with **1-2% differences** because of the earths eccentricity which can have a tremendous affect on the atmosphere, land, and water depending on season, latitude, earth's place in orbit, tilt, and wobble. (eccentricity, obliquity, precession)

Solar radiation impacts glacial melting, vapor, and sublimation (ice → vapor),

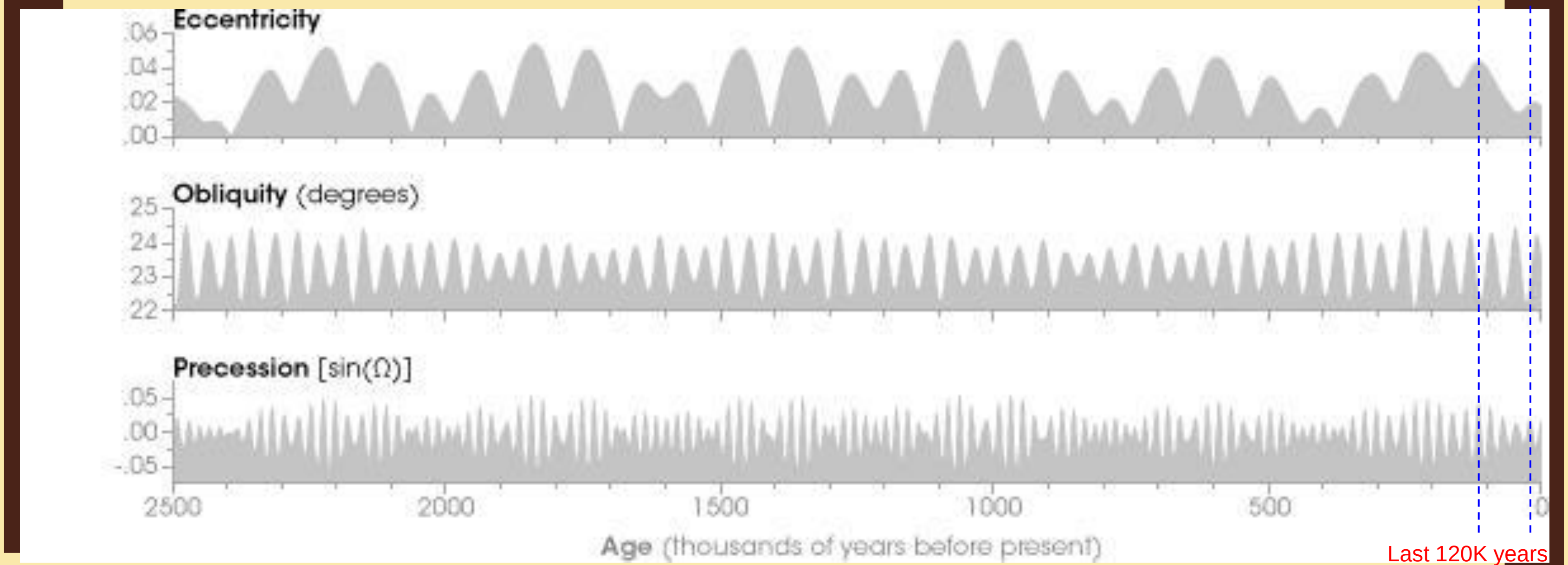
Solar radiation impacts atmospheric gases such as, CO^2, Methane, and Nitrogen,

Solar radiation impacts ground and water temperatures, terrestrial/water biomasses,

And, where the Northern/Southern hemispheres are pointing during aphelion (farthest) and perihelion (nearest point to sun).

Introduction to the Milankovitch Theory, Ch 3, p. 2

Timeline for Eccentricity, Obliquity, and Precession 120K to Recent
Or from before the last interglacial (Eemian – Europe, or Sangamon – North America)



There is a rough ratio of 1:2:4 between eccentricity, obliquity, and precession. To the right, the dotted lines encompassing 120K years, takes you through one complete eccentricity cycle (the longest cycle) and shows the apparent ratio.

Chart provided by NASA

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Introduction to the Milankovitch Theory, Ch 3, p. 3

How did the *Pleistocene* (epoch) of the Quaternary (system) get its *start time* established. The time divisions are part of the requirement for consistant use of stratigraphic nomenclature time divisions of geologic time. (USGS Fact Sheet 2007-3015, Mar 2007 was used until Aug 2018 – see the Note at bottom of page for current divisions of Geologic Time)

The early definition of the Pleistocene was the presence of organisms living in cold conditions and 90-95% had to be living today
In 1948 a type location was added:

> "was marked by the first appearance of cold-water species in well exposed sedimentary successions in southern Italy" (Imbrie, p 152)
> That wasn't something that could be used worldwide - how do you correlate other formations or other places.

Note: USGS Fact Sheet 2018-3054 dtd Aug 2018 moved the Quaternary/Pleistocene boundary between the Tertiary/Pliocene back to 2.58 mya from its 1.8 mya date.

An IAFI Puget Lobe Chapter monthly newsreel:

Introduction to the Milankovitch Theory, Ch 3, p. 4

Back in 1906 in a French brick yard, B. Brunhnes noticed baked bricks became magnetized

He checked out local lava fields and they showed magnetization from north

Along about 20 years later M. Matuyama noticed that lava fields retained the existing magnetic orientation when they cooled. And he found several reversals.

By the 1950-1960 several geophysicists concluded that magnetic reversal did in fact exist.

And, yes, the author has seen the old Navy P-3's flying low over the Crescent Formation west of Port Ludlow (it's been a couple of years since last sighting).

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Introduction to the Milankovitch Theory, Ch 3, p. 5

Pleistocene could then be identified as the Olduvai normal in the Matuyama reversal:

> “the first appearance of the cold-water marine ostracod *Cytheropteron testudo*.” (Lowe, p.3)

> Later evidence put the date of the Olduvai normal at 1.81 mya. Evidence, such as, Lake records, loess, and deep-sea cores substantiated the date.

> There was a debate as to whether it should be pushed back to around 2.5 mya (Lowe, p.3). (*And USGS Fact Sheet 2018-3054 dtd Aug 2018 did just “that”.*)

> The Hays, Imbrie, and Shackleton article (Science, 1976) confirmed the start of the Pleistocene epoch. See next page.

That date defined the beginning point that Pleistocene stratigraphy could be applied worldwide; however, it has subsequently been moved to 2.58 mya.

Introduction to the Milankovitch Theory, Ch 3, p. 6

Hays, Imbrie, and Shackleton, in the 1976 issue of Science (Vol 194), titled "Variation in the Earth's orbit: pacemaker of the Ice Ages" proved the Milankovitch Theory.

Williams calls this a "famous paper": "which reveals the presence of eccentricity, obliquity, and the two main precession frequencies within this record." (Williams, p 90-91)

100K eccentricity
41K obliquity
23K and 19K precession

Their paper was based on $\delta^{18}O$ collaborating evidence found in two marine cores from the S. Indian Ocean that substantiated marine sediment core V28-238 stratigraphy.

Did they do this alone? Oh, they did not.

Introduction to the Milankovitch Theory, Ch 3, p. 7

Their success was the culmination of work done by many people and institutions: (just a few)

a. C. Emiliani as early as 1955 discovers at least seven glacial and interglacial periods in deep sea cores (14 stages)
   In 1966, using core P6304-9 which extended the isotope stages back to Stage 17

b. N. Shackleton spent 10 years modifying "a mass-spectrograph for isotopic studies of Pleistocene fossils." (Imbrie, p. 164) He recognized that the mass-spectrograph must be able to count fewer specimens in the core. I.e., he "therefore resolved to modify the instrument so that accurate readings could be obtained from a small number of specimens."

Introduction to the Milankovitch Theory, Ch 3, p. 8

Their success was the culmination of work done by many people and institutions: (con't)

c. T. Saito located Core **V28-238** which spanned the Brunches-Matuyama boundary (confirmed) at Lamont. This was a complete record that allowed age dating of the Pleistocene. (see Slide 5 for update). The below cores helped substantiate V28-238.

1. Core **RC11-120** raised in 1967 from the S. Indian Ocean (E79° 52', S43° 31'),

2. In 1971 Core **E49-18** was raised from the Southern Indian Ocean (E90° 09', S46° 03') (Imbrie, p. 198-201, Hays, et. al., Science, Vol 194, p1121-1132)

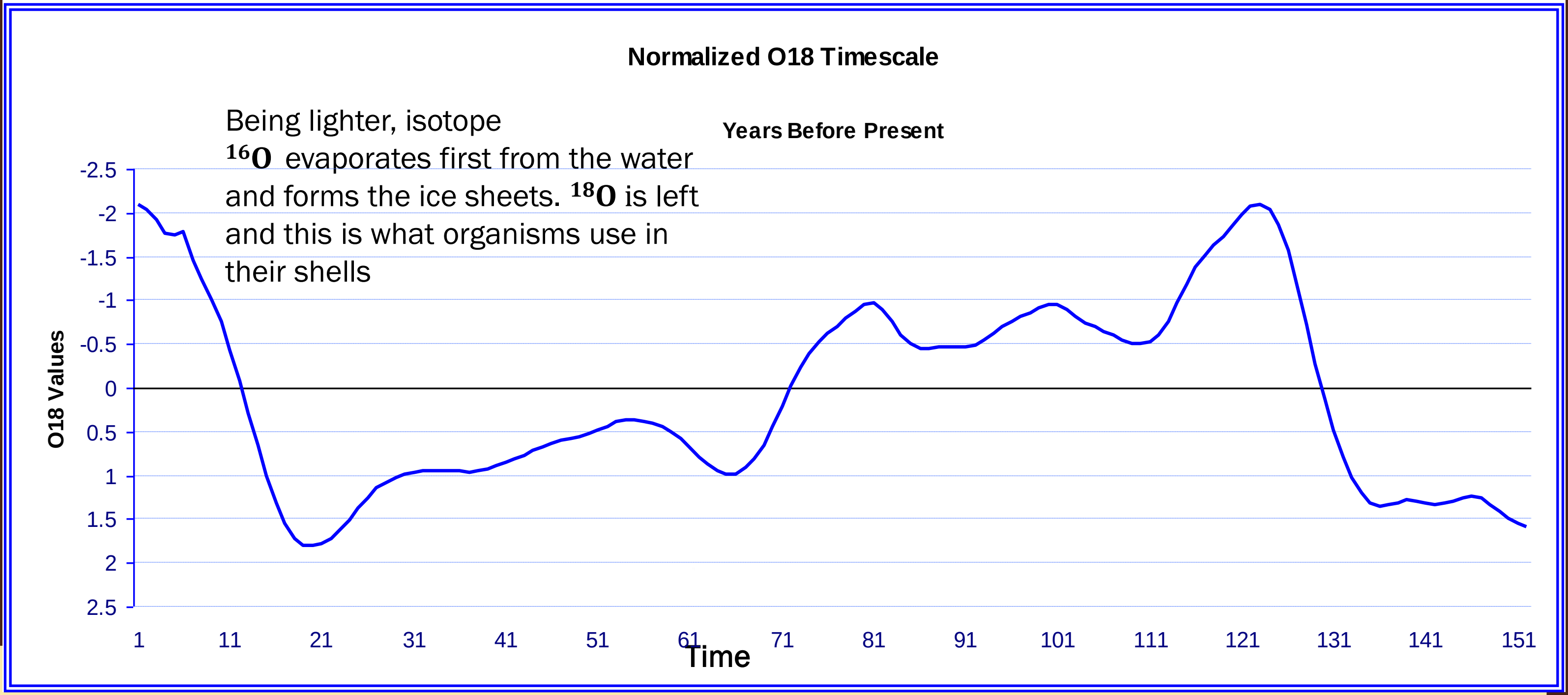
D. Subsequently, Lisiecki and Yaymo developed a globally distributed benthic $\delta^{18}O$ record (algorithm) that took the results of 57 cores back to 5.2Mya (see Slide 10 for reference)

A Must Read: John and Katheryn Imbrie's book "Ice Ages Solving the Mystery", Harvard Univ Press, 1979

Introduction to the Milankovitch Theory, Ch 3, p. 9

Core V28-238 (Below is a normalized curve from deep sea core V28-238)

This curve allowed geologic stratigraphy to be applied world-wide.



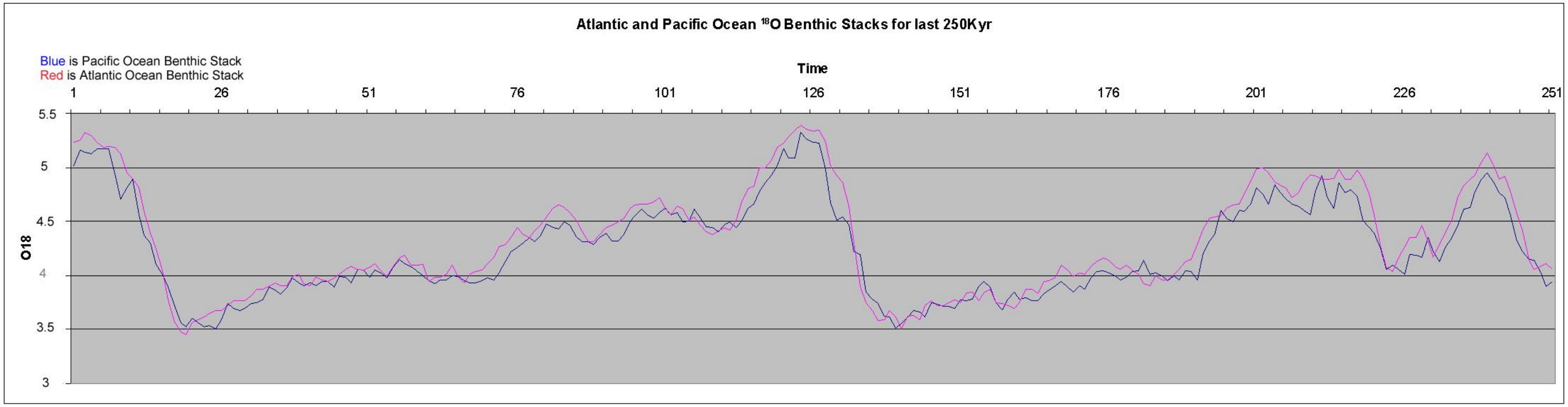
Imbrie, J. et al, 1990, SPECMAP Archive #1. IGBP PAGES/World Data Center-A for Paleoclimatology Data Contribution Series # 90-001. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA (file 17

An IAFI Puget Lobe Chapter monthly newsreel:

Introduction to the Milankovitch Theory, Ch 3, p. 10

With this stratigraphy developed, it would be applied worldwide. See the lists in the lower left-hand corner (below) of the applicable marine sediment cores from the Atlantic and Pacific Oceans.

*The below chart reflects 20 combined Atlantic (**red**) and 14 combined Pacific records (**blue**). They are similar.*



Atlantic records are from ODP sites 980, 982, 983, 984, 552, 607, 664, 502 658, 659, 925, 926, 927, 928, 929, and 1090, and 1089, and sites RC13-229, GeoB1041, and GeoB1214.
Pacific records are from ODP sites 677, 846, 849, 1012, 1020, 806, 1123, 1143, and 1146, and sites V19-28, V21-146, PC72, and PC18

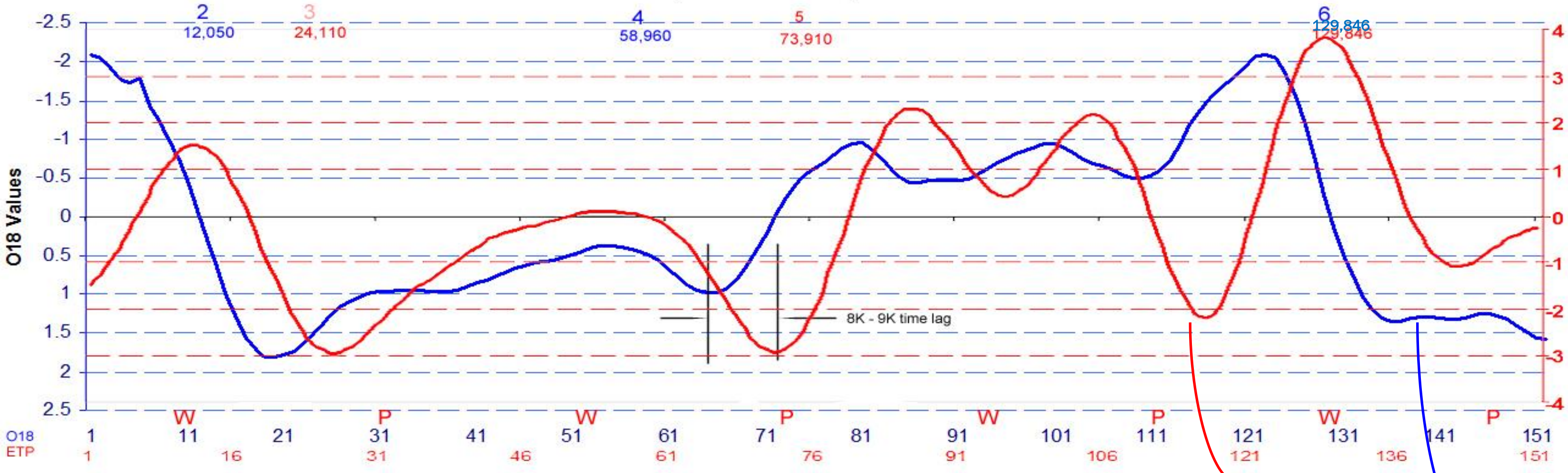
Original reference:
Lisiecki, L.E. and Yaymo, M.E. 2009
Diachronous benthic $\delta^{18}O$ responses during late Pleistocene terminations
Paleoceanography, 24, PA 3110, doi:10.1029/2009PA001732

An IAFI Puget Lobe Chapter monthly newsreel:

Introduction to the Milankovitch Theory, Ch 3, p. 11

- ETP (red) with ‰^{18}Oxygen (blue) isotope superimposed upon graph.
  - *Time is normalized*
  - *Graph lines are smoothed*

O18 Values
with
ETP Superimposed
(Timescale Normalized)



Notes:

Heinrich, 1988, Quaternary Research 29: Dropstone record indicates ice rafting not only during stadial intervales by also more or less in the middle of interstades.

Ibmrie, 1979, p. 172: The 41K and 23K frequencies precede climatic changes by approximately 8K

Williams, 1997, p. 64: "The northern hemisphere high-latitude summer radiation values flucuate first, followed by a response in ice volumes that lags about 3Ka, and by a response in sea-surface temperature (SST) that lags by a further 6 Ka. This means that SSTs lagged behind insolation changes by an aggregate of 9,000 years.

W = II 270 deg winter minima
P = II 90 deg summer minima

ETP set up conditions for Ice sheets, it takes 6K years for those conditions to be expressed on earth as <u>ice sheets</u>

ETP is red
O^{18} is Blue

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Introduction to the Milankovitch Theory, Ch 3, p. 12

In Chapter 4, the newsreel will continue to explore:

a. Exclusions or ground rules for our presentation. (keeping it focused)

b. Feedback and associated mechanisms

c. Setting the stage for glacial activities during the Pleistocene