TONIGHT'S PRESENTATION:

Don West

Don West, L.G, L.E.G., an Engineering Geologist, has over 45 years of consulting experience in the characterization of regional and site geomorphology and geology as they relate understanding to geologic units, structure and processes that may influence geologic conditions and potential geologic hazards that may impact, or affect the built environment. Mr. West's technical specialties include the identification, characterization and evaluation of slope stability, seismic, and volcanic hazards.

Geologic processes and their resulting hazards, both naturally occurring and human-triggered, can adversely affect buried pipelines systems. A significant number of releases from pipelines have resulted from geologic processes (hazards) acting directly, or indirectly on a pipeline; e.g., landslides, and fluvial erosion. In the Pacific Northwest, erosion by the Missoula Floods in the Columbia River Gorge triggered massive landslides, some of which are still active today and adversely affect natural gas pipelines.

Other news about Puget Lobe Chapter happenings:

Because of the current virus pandemic we will not have any in-person meetings. All meeting will be by Zoom® an on-line meeting program. Our President, Dale Lehman has/will send out an e-mail indicating when the meeting will take place and the meeting URL. Please note that Zoom® will be opened at 6:45 to allow for "logins". At that time, we will start running the "Newsreel" which introduces the guest lecturer, chapter happenings, and the newsreel itself. At 7:00, Dale will take possession of the meeting, bring everyone up to date on breaking news, and introduce the lecturer. The presentation will last one hour, with a 15-minute Q&A period afterwards. We will close the meeting at 8:15.

Please check the IAFI website for IAFI and Puget Lobe Chapter for announcements and events occurring during the year

Other news about **Puget Lobe Chapter** happenings:

A. The IAFI 2020 Annual Meeting and Field Trip is cancelled due to the uncertainty of the progress towards combating the COVID-19 virus. There are too many variables that mitigate against having an annual meeting and field trip this year. SO, the next IAFI Annual Meeting and Field Trip will be still hosted by our Chapter and held in September 2021.

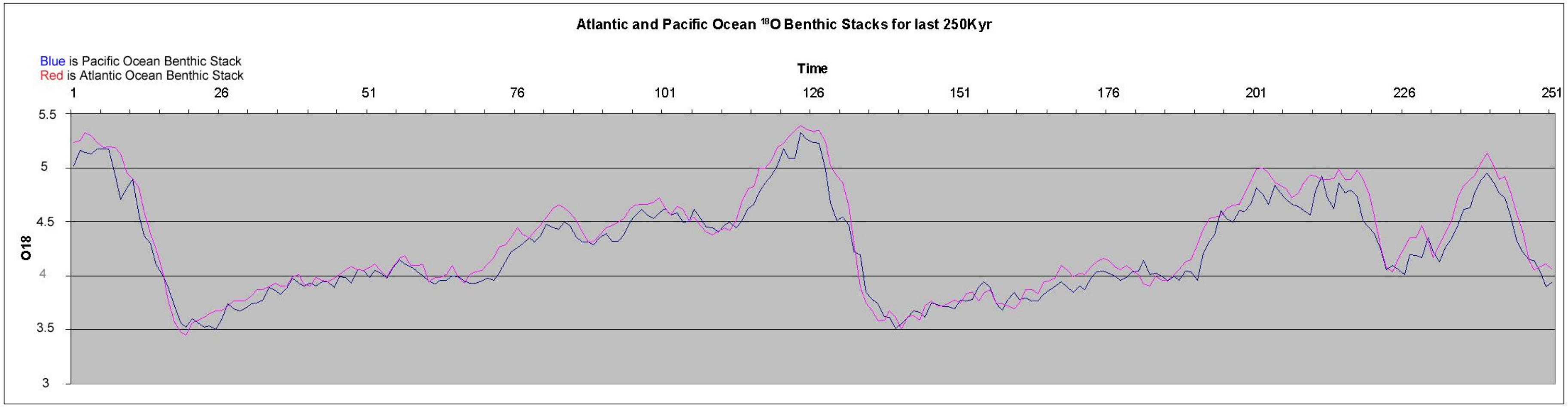
B. There is a rumor that our Chapter wants to host hybrid field trips where we meet on Zoom® and discuss an area of interest, then have folks drive to the site at their leisure and own cars. After about 2-3 weeks we will hold a post-trip discussion in Zoom®. We will start with sites mentioned in our Puget Lobe brochure. And, if successful, people can suggest places of interest. Remember our brochure only mentions five sites. However, there are a multitude of sites all over the Puget Sound – Olympic Peninsula area.

Now to Chapter 4 of the monthly newsreel!

Introduction to the Milankovitch Theory, Ch 4, (p. 1)

Last time we talked about how marine sediment cores helped develop the stratigraphy we now use for the Pleistocene timeline and Continental Ice sheet timelines. This stratigraphy is applied worldwide. See the lists in the lower left-hand corner (below) of the applicable marine sediment cores for the Atlantic and Pacific Oceans:

The below chart reflects 20 combined Atlantic (red) and 14 combined Pacific Records (blue). Note how similar they are.



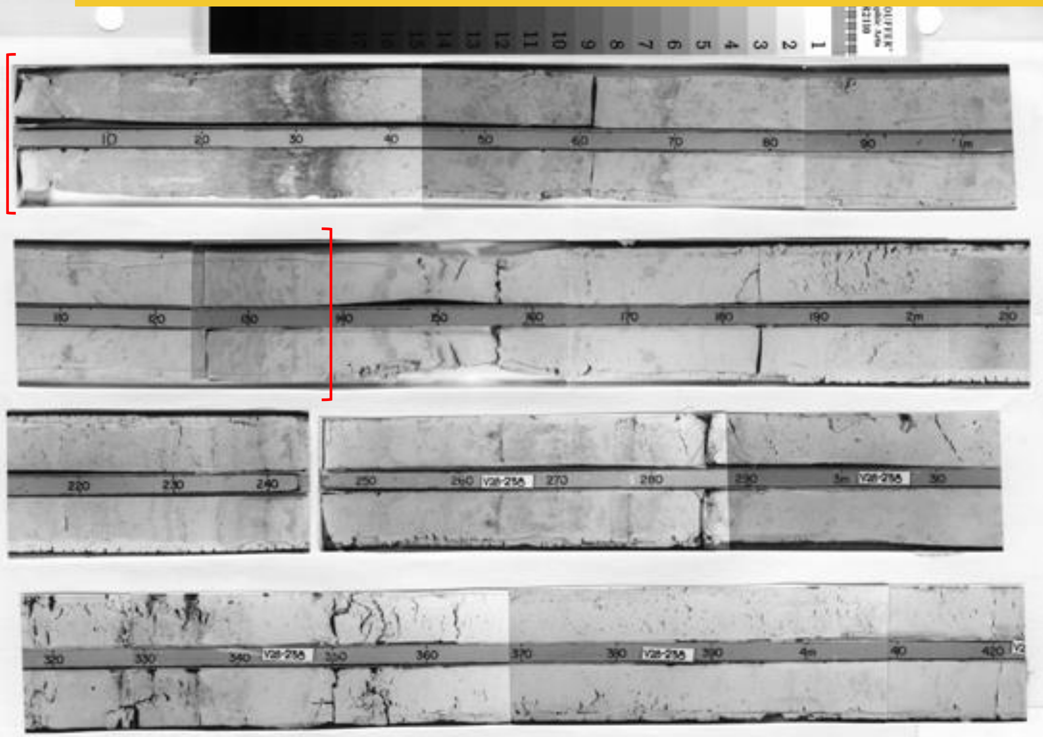
Atlantic records are from ODP sites 980, 982, 983, 984, 552, 607, 664, 502 658, 659, 925, 926, 927, 928, 929, and 1090, and 1089, and sites RC13-229, GeoB1041, and GeoB1214.
Pacific records are from ODP sites 677, 846, 849, 1012, 1020, 806, 1123, 1143, and 1146, and sites V19-28, V21-146, PC72, and PC18

Original reference:
Lisiecki, L.E. and Yaymo, M.E. 2009
Diachronous benthic d180 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 4, (p. 2)

Marine Core V28-238 – A view of the first four meters w/descriptions of the first 140 cm (see brackets). The $\delta^{18}O$ was measured and resulted in the values shown on next chart.



Core V28-238 - First Four Meters

Lamont Geological Observatory
of
Columbia University
Preliminary Description
NOT FOR PUBLICATION

VEMA 28-238

Megascopic Description of a Split Core

Latitude:	01°01'N	Longitude:	160°29'E
Corr. depth:	3120 m	PDR depth:	1670 fm
Date taken:	8 May 1971	Date opened:	7 December 1971
Date described:	8 December 1971	Date photographed:	7 December 1971
Described by:	J. Lovegreen	Flow-in:	323 cm
Core length:	1602 cm		

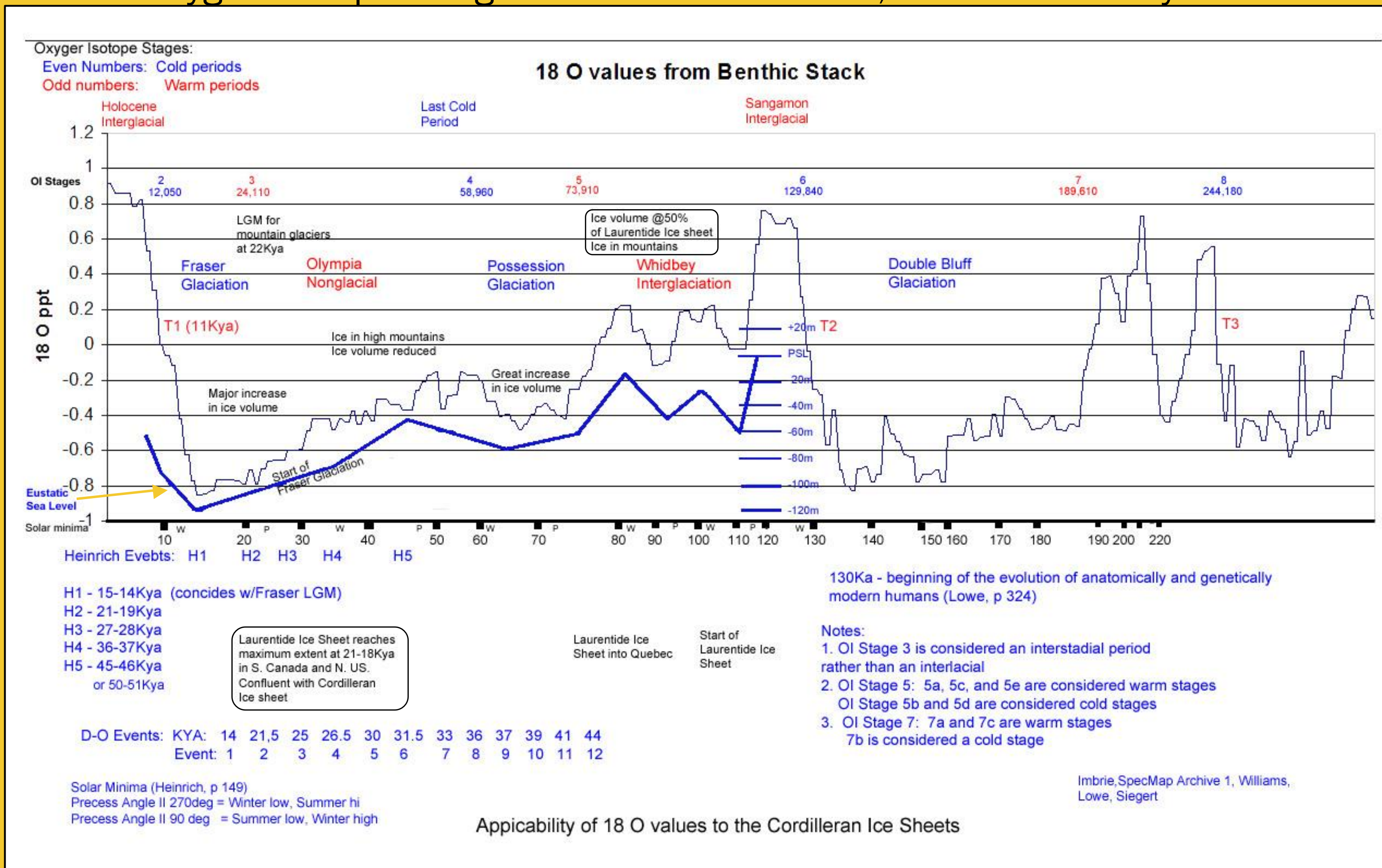
GENERAL:	Foraminiferal chalk (white, very light gray, yellowish gray and light gray) interbedded with foraminiferal chalk ooze (white, very pale orange and pale blue to blue gray), chalk, (white, light gray and yellowish gray) and foraminiferal ooze (white). High carbonate content. Coarse fractions contain primarily planktonic foraminifera with minor sponge spicules and pteropods.
0-2 cm	Foraminiferal chalk ooze, white (N9), moist and firm. Carbonate content high. Coarse fraction 40%, consisting of planktonic foraminifera. Basal contact a sharp color change.
2-25 cm	Foraminiferal chalk ooze, very pale orange (10 YR 8/2), moist and firm. Carbonate content high. Coarse fraction 50%, consisting of planktonic foraminifera. Basal contact a gradational color change.
25-35 cm	Foraminiferal chalk ooze, pale yellowish brown (10 YR 6/2), moist, firm and mottled. Carbonate content high. Coarse fraction 35%, consisting of planktonic foraminifera. Basal contact a sharp change in color and composition.
35-50 cm	Chalk, yellowish gray (5 Y 8/1), moist and firm. Carbonate content high. Coarse fraction 5%, consisting of planktonic foraminifera. Basal contact a burrowed change in color and composition.
50-140 cm	Foraminiferal chalk, yellowish gray (5 Y 8/1), moist, firm and burrowed. Carbonate content high. Coarse fraction 15%, consisting primarily of planktonic foraminifera.

140 cm = 55.11 in

The Macroscopic Description gives a physical description; however, N. J. Shackleton spent ten years developing a spectrometer that would measure the $\delta^{18}O$ in the foraminifera shells samples.

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

Consequently, a non-normalized time chart* could be developed upon which the marine oxygen isotopes stages could be shown. Yes, this chart is busy.



*The time is not normalized – meaning the time tick marks at the bottom of graph are not equally spaced.

Introduction to the Milankovitch Theory, Ch 4, (p. 4)

Location of Ice Domes and ice flow lines over North America

This chart does not appear to show eustatic sea level, which would be 120 m/390 ft lower than the current shoreline that is shown.

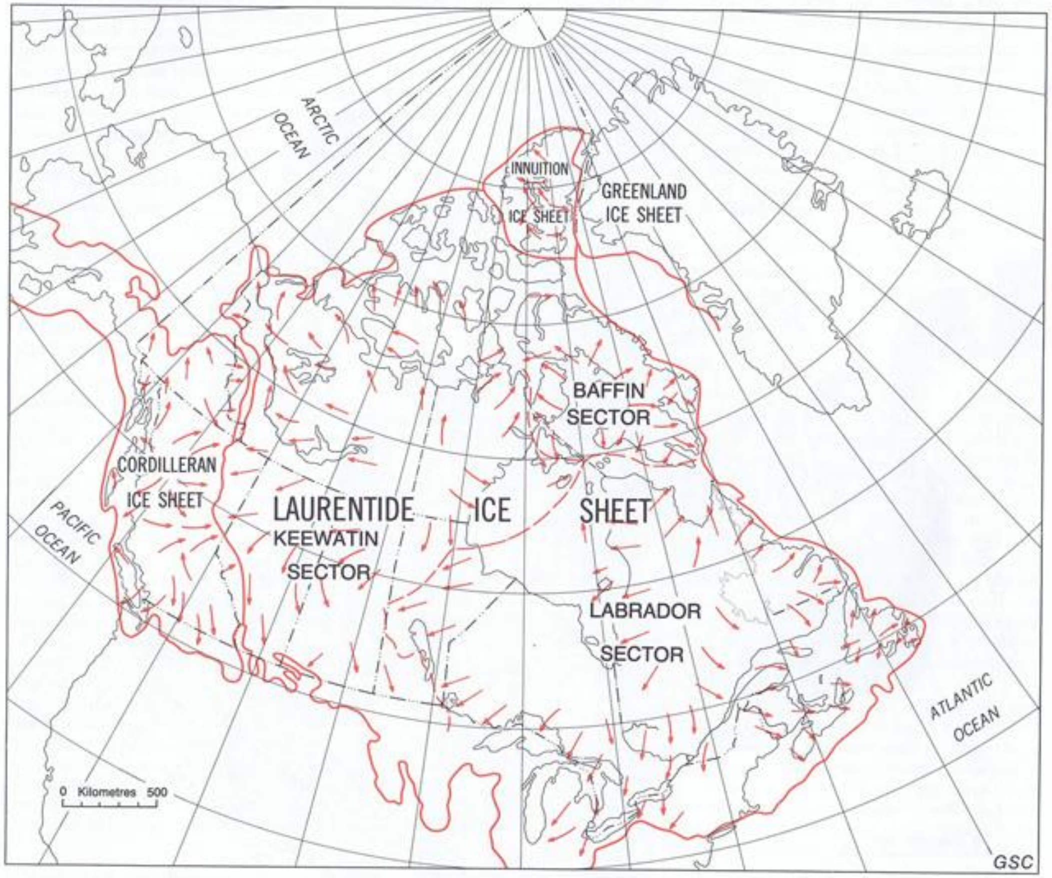


Figure 4. Approximate extent of main ice sheets during the last (Wisconsin) glaciation; arrows indicate probable directions of ice flow at the glacial maximum. Taken largely from Prest et al. (1968) and Prest (1984) but with some modifications.

From: Fulton, 1989, p.8

An IAFI Puget Lobe Chapter monthly newsreel:

Introduction to the Milankovitch Theory, Ch 4, (p. 5)

The driving condition for starting a Continental Ice Sheet

Insolation – The amount of sun received on the earths surface w / m^2 * which varies between 1 - 2% based on eccentricity.

Aphelion: the furthest point from the sun in earths orbit around the sun

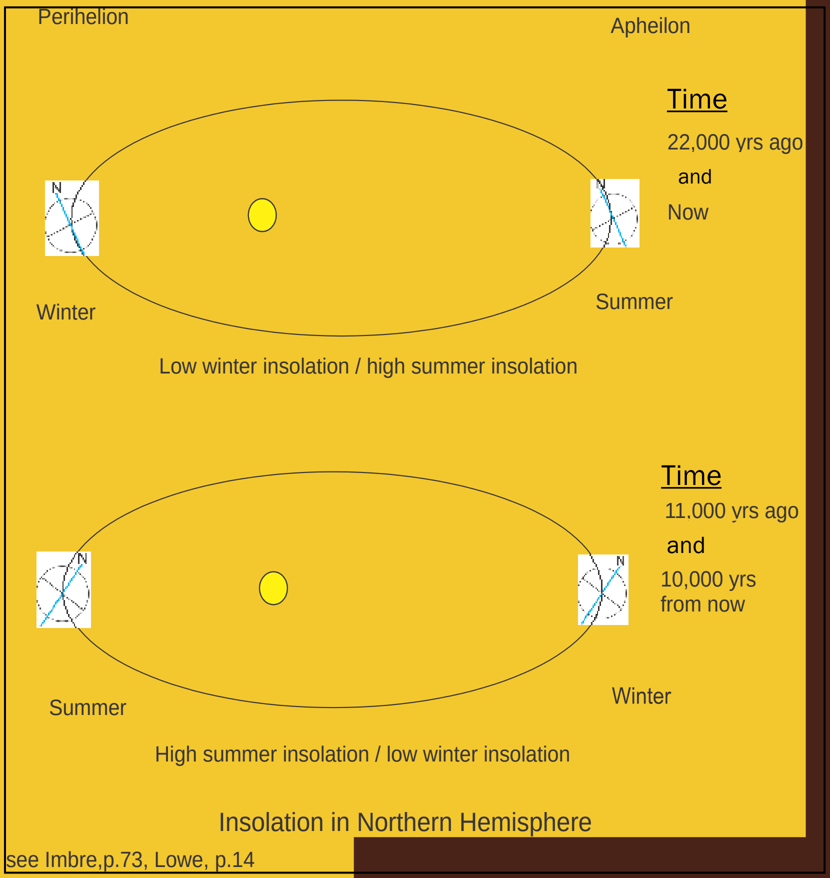
Perihelion: the nearest point to the sun in the earths orbit around the sun

Which hemisphere (North/South) is pointed towards the sun during its orbit determines insolation amount received:

The northern hemisphere has the majority of land mass

Glaciation is more severe in the northern hemisphere when it is pointed away from the sun

- During obliquity
- During precession



* (watts per square meter)

Introduction to the Milankovitch Theory, Ch 4, (p. 6)

Associated feedback processes:

As the conditions for continental ice sheet generation increase, feedback mechanisms increase. $\delta^{\underline{16}}O$* is the main oxygen isotope constituent in the evaporation of sea water.

A drop in sea level enriches the ocean with $\delta^{\underline{18}}O$, as $\delta^{\underline{16}}O$ is the main oxygen constituent of sea water(i.e., and a lighter isotope- $H_2{}^{16}O$).

> $\delta^{18}O$ in ice is also a function of snow elevation and distance from moisture source as sea water becomes depleted of $\delta^{\underline{16}}O$*; consequently, the heavier $H_2\delta^{\underline{18}}O$* will start evaporating more due to the lowered incidence of $H_2{}^{16}O$.
>
> Because of the enrichment of $\delta^{18}O$ in the oceans during glacial periods, foram shells will be enriched/contain more $\delta^{18}O$ as evidenced by deep sea cores and is measured.
>
> The "increased concentration" of $\delta^{18}O$ in seawater is an "indicator" of the size of the ice sheets.

In addition, sea level drop was due to ice accumulation of the Fennoscandian, Siberian, Tibetan, and Antarctica ice sheets (a relatively stable ice sheet).

* Underline added to differentiate isotopes of Oxygen

Introduction to the Milankovitch Theory, Ch 4, (p. 7)

Conversely, ice melting/iceberg generation (Heinrich/D-O events) will cause sea level rise (transgression) during glacial periods; which

> floats the grounded ice on the exposed Continental Shelf which caused the glacier to calve and generates icebergs
>
> which will allow ice behind it to become unrestrained and subsequently cause a surge.
> Sea level can vary '**x**' meters due to Heinrich/D-O events

A Dansgard-Eschner Event (D-O event) is a decades /century long warming event that culminates or is followed with a rapid decrease in temperature.

At this point we will digress and explain Heinrich and D-O events. Heinrich Events are mostly associated with iceberg generation in the North Atlantic. While D-O Events are "sudden" warming periods followed by return to cold periods.

The last Heinrich Event (H1) is associated with Fraser LGM and termination of the Fraser Glaciation. A D-O Event also occurred at Termination 1 or Fraser Ice Sheet termination.

Introduction to the Milankovitch Theory, Ch 4, (p. 8)

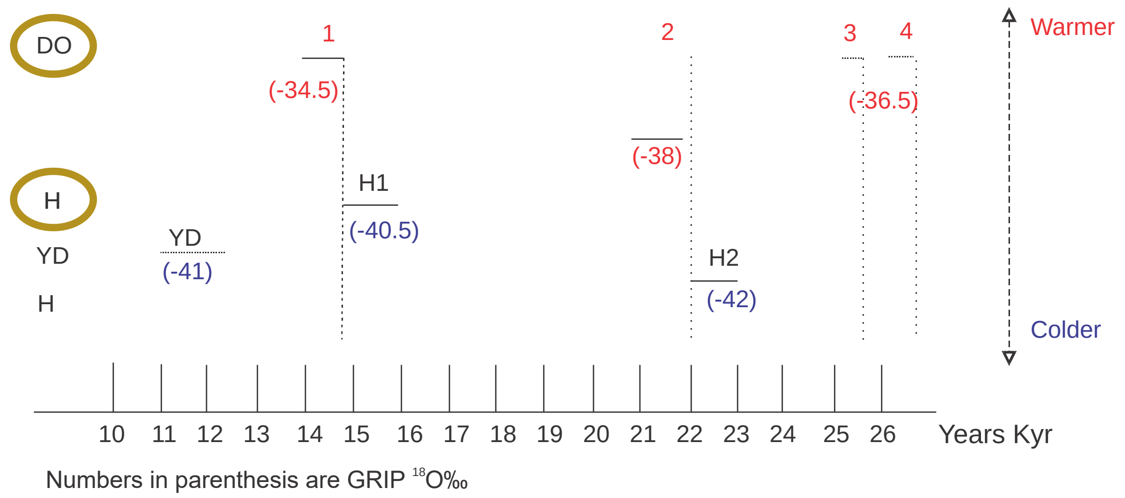


Figure xx: Correlation between Heinrich (H) Events and Dansgaard-Oeschger (DO) Events also showing Younger Dryas (After Siegert, 2001, page 68; and Lowe et al, 1997, page 341)

Ratio of $\delta^{16}O$ to $\delta^{18}O$:

500:1

Ice sheets retain the $\delta^{16}O$ that would normally be returned to the oceans as runoff,

Consequently, more $\delta^{18}O$ is found in shells as the ocean is enriched with $\delta^{18}O$ during glacial periods.

Introduction to the Milankovitch Theory, Ch 4, (p. 9)

Associated feedback processes (cont):

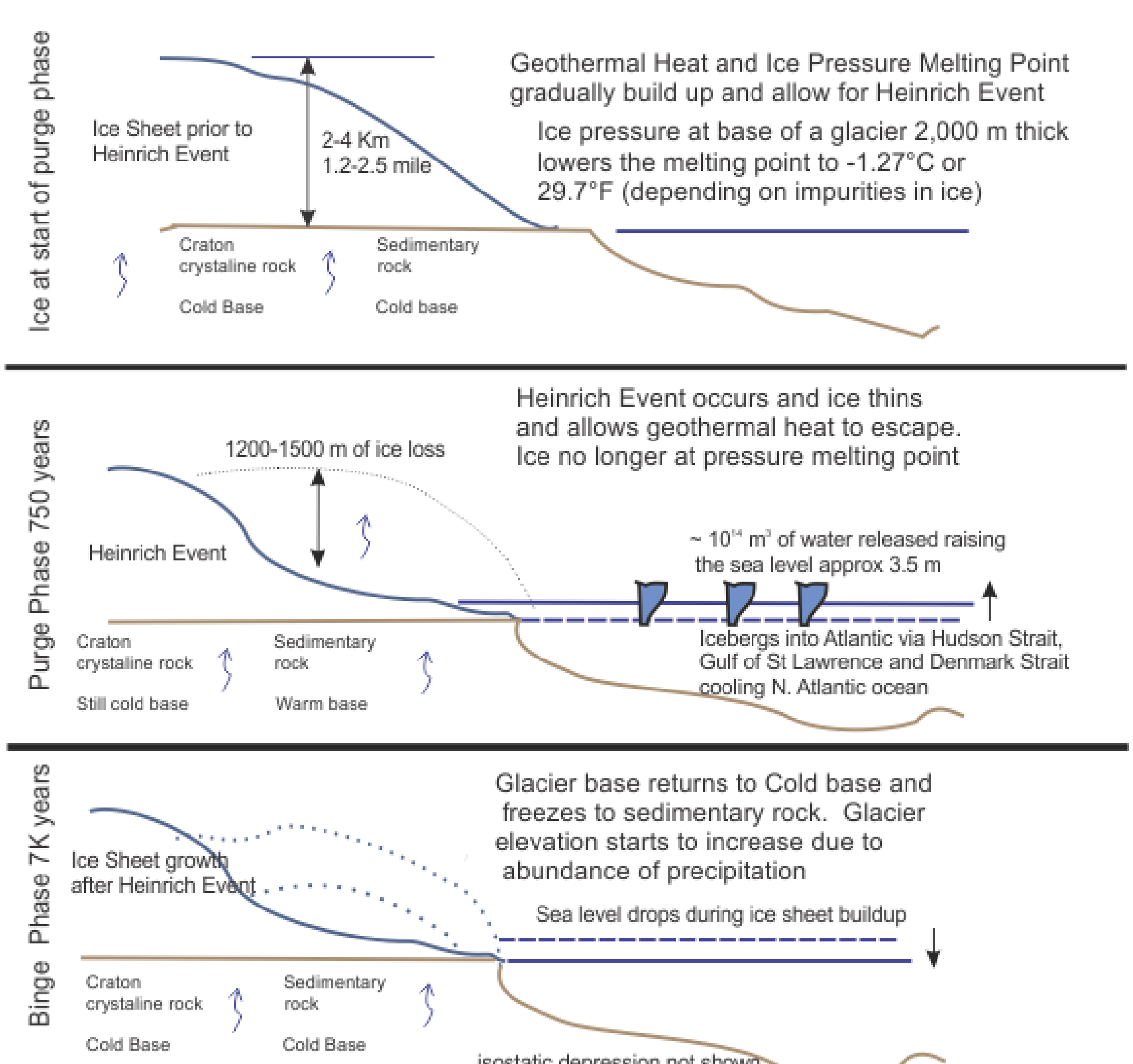
Ice Sheet Elevation – Snow accumulates over greater distance and depth

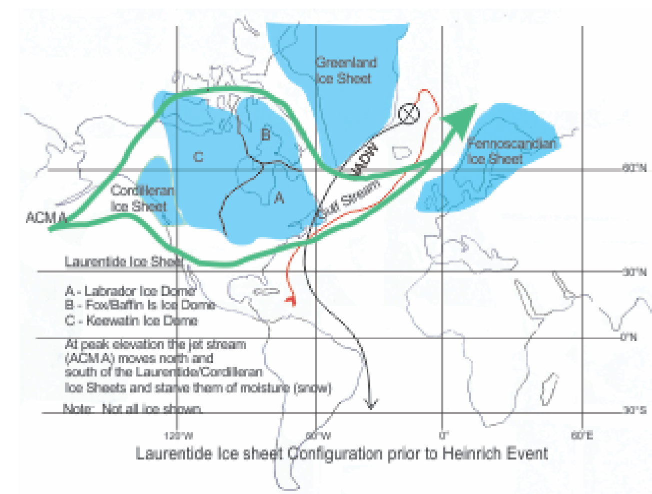
- Too great an elevation can also starve the growth of the ice sheet because moisture is blocked by the high elevation.
  - Greater snow accumulation occurs on the windward side of the ice sheet and at lower elevations
  - Consequently, the Laurentide ice sheet's northeast section was starved for snow
- Snow accumulation over a greater distance and depth caused a separation of the jet stream into two streams in the North American hemisphere (ACM A / ACM B) as a result of ice height.
  - Jet stream bifurcated into a northerly and southerly stream around the Laurentide ice sheet
  - Once the ice sheet lowered, the jet stream returned to its normal stream (only one stream)

See Laurentide Ice Sheet Heinrich Event representation on next chart

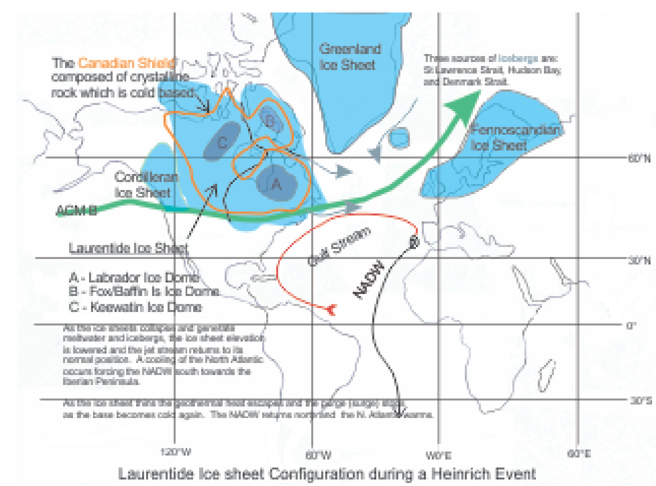
An IAFI Puget Lobe Chapter monthly newsreel:

A graphic representation of an Heinrich Event





Laurentide Ice sheet Configuration prior to Heinrich Event



Laurentide Ice sheet Configuration during a Heinrich Event

Introduction to the Milankovitch Theory, Ch 4, (p. 11)

Associated feedback processes: (cont)

Carbon dioxide –

Oceans contain 60 times as much CO^2 as the atmosphere and it is from this reservoir that CO^2 is taken in or released to the atmosphere.

Increase of atmospheric CO^2 warms the atmosphere causing precipitation. CO^2 taken out of the atmosphere help induce a colder climate.

With the lowering of sea level (120 meters) and the additional area uncovered by ocean recession, the vegetation growth could have caused additional CO^2 to be sequestered.

Colder seawater absorbs CO^2 more readily than warm water; however, during glacial periods the reduction in water volume and increase in salinity may compensate for most of the additional CO^2

CO^2 has an atmospheric lifetime of between 50 – 200 years, the longest of any the gases

Introduction to the Milankovitch Theory, Ch 4, (p. 12)

Associated feedback processes: (cont)

Upwelling provide the larges source of natural CO^2 to the atmosphere

During colder periods more biological activity may draw more CO^2 from the atmosphere

Productivity at Last Glacial Maximum (LGM) was twice that of today (Williams, p67)

An increase in rock weathering during glacial period reduces atmospheric CO^2

An increase in forams which use calcium carbonate in their shells. Upon death some of the calcium carbonate is sequestered in sediment

Skinner, B.J., et.al., Dynamic Earth…,, p. 199

Introduction to the Milankovitch Theory, Ch 4, (p. 13)

Associated feedback processes: (cont)

Ocean circulation – North Atlantic Deep Water (NADW) can be shut off, reduced, or modified

Sea ice enhances the albedo effect especially if the sea ice lingers during the summer

Heinrich events (iceberg formation) in the North Atlantic and cools sea water which reduces evaporation which starve ice sheets by reducing the amount of snow to build ice sheets

Subsequently, the NADW and Fennoscandian DW can be shut off or reduced

The NADW does not completely turn off.

The lack of water overturn in the N Atlantic is supplemented by a "tongue" of water from the Antarctic at a subsurface level.

This tongue will disappear when NADW "turns on" again

Introduction to the Milankovitch Theory, Ch 4, (p. 14)

Associated feedback processes: (cont)

Sea surface temperature (SST) – will be reduced during glaciation

In the northern hemisphere during the last 185 kya the following scenario prevailed for the reduction of SSTs. This is an important concept – as ice builds slowly (Williams, Imbrie, and Heinrich)

Solar isolation values in the high latitudes of the northern hemisphere fluctuated, followed by

A response in ice volume (greater) that lags about 3ka, followed by

A response in sea surface temperature (SST) (cooler) that lags by a further 6 ka

Hence, SST lags atmospheric temperature by 9,000 years (Williams)

Oceanic cooling precedes and is enhanced by Heinrich events (iceberg release)

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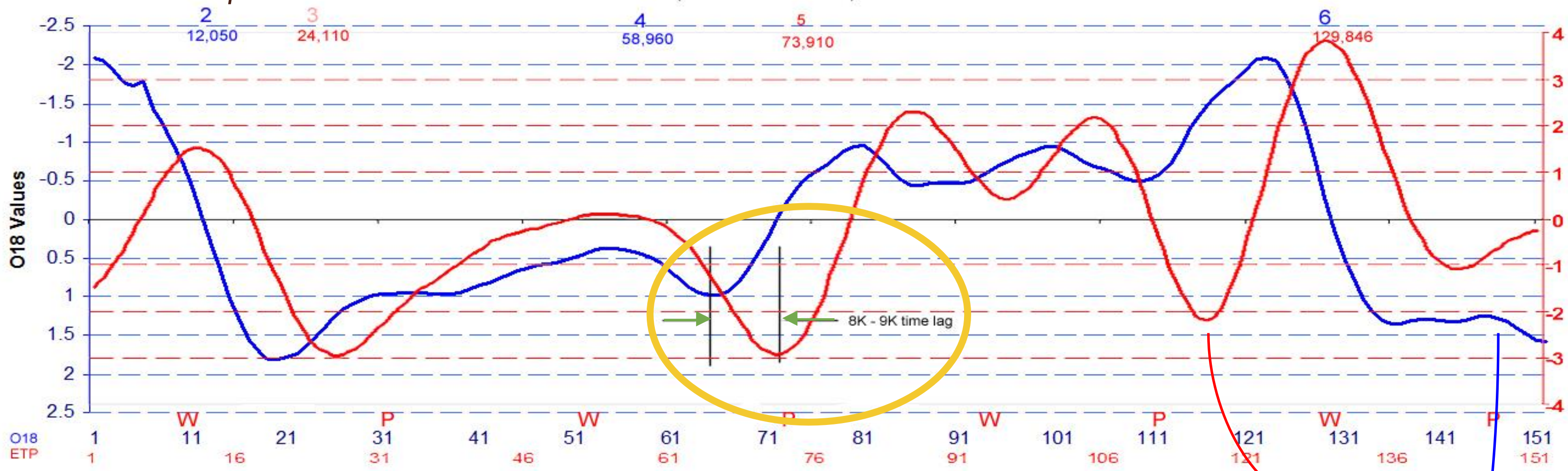
Introduction to the Milankovitch Theory, Ch 4, (p. 15)

ETP (red) superimposed upon ‰^{18}Oxygen (blue) isotope 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.

Imbrie, 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 is red
O^{18} is blue

An IAFI Puget Lobe Chapter monthly newsreel:

Introduction to the Milankovitch Theory, Ch 4, (p. 16)

Volcano activity – adding dust to the atmosphere

- Lowers atmospheric temperature

- Dust can coat ice sheets and initially cause ablation; however, over time the increase in dust will insulate the ice.
  - This, in concert with covering of ice by debris from mountain landsides.

- Increase in SO_4, CO_2, dust, and ash can block insolation and decrease atmospheric temperature
  - Similar to what happened after Tam Bora and Krakatau
    - After each eruption there were a number of years where atmospheric dust blocked the suns' rays and created cooler summers

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The above are some of the associated feedback mechanisms.

And they are considerable in number and impact

In many cases, the total impact is unknown or poorly understood

An IAFI Puget Lobe Chapter monthly newsreel:

Introduction to the Milankovitch Theory, Ch 4, (p. 17)

In September 2020, the newsreel will continue with Chapter 5:

a. Setting the stage for glacial activities during the Pleistocene. And a look at how complex a Continental Ice Sheet is during its life.

b. We will go back and get a perspective in time and look at how climate / geological features set up the Pleistocene.

A short review of: The Mesozoic (248-65mya)/Tertiary era (65 -1.8mya), then a review of timelines for the Cordilleran Ice sheet of the Fraser Glaciation with a nod at what was going on with the alpine glaciers.

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