The IAFI Puget Lobe Chapter monthly newsreel:

Introduction to the Milankovitch Theory, Ch 5, p. 1

Last time we talked about how marine sediment cores helped develop the stratigraphy we now use for the Pleistocene timeline (updated by USGS Fact Sheet 2018-3054) and Continental Ice sheet timelines. This stratigraphy is applied worldwide. We looked at the first 4-meters of marine sediment core V28-238 to give you an idea of what they looked like. A non-normalized chart giving the results of reading of the core established the ocean content of the oxygen isotope $\delta^{18}O$, which then was the oxygen isotope prevalent on foram shells, as the lighter $\delta^{16}O$ (isotope- $H_2{}^{16}O$) had evaporated and deposited as snow and built the Ice Sheets; but, not recycled back to the oceans.

We reviewed some of the feedback mechanisms and particularly the Heinrich Events and Dansgard-Eschner Events (D-O event) and their impact on ice sheet collapse and sea level/iceberg generation.

And CO^2 on the effects of the atmospheric. North Atlantic Deep Water (NADW) was shown to move south to around Portugal during colder periods (due to ice bergs/sea ice).

In Chapter 5 we will look at ETP, a non-normalized and a normalized $\delta^{18}O$ timeline. Where/how our Puget Lobe originated, and how the Fraser Glaciation developed. Then step back to 248mya and work our way forward to understand how our earth responded to internal geological functions that resulted in our present physical geological configuration. And, by no means is our present physical configuration static. We're just a blink of the eye in geological time (1:392,088). 4.5By (earth age) / 11,477y (Holocene).

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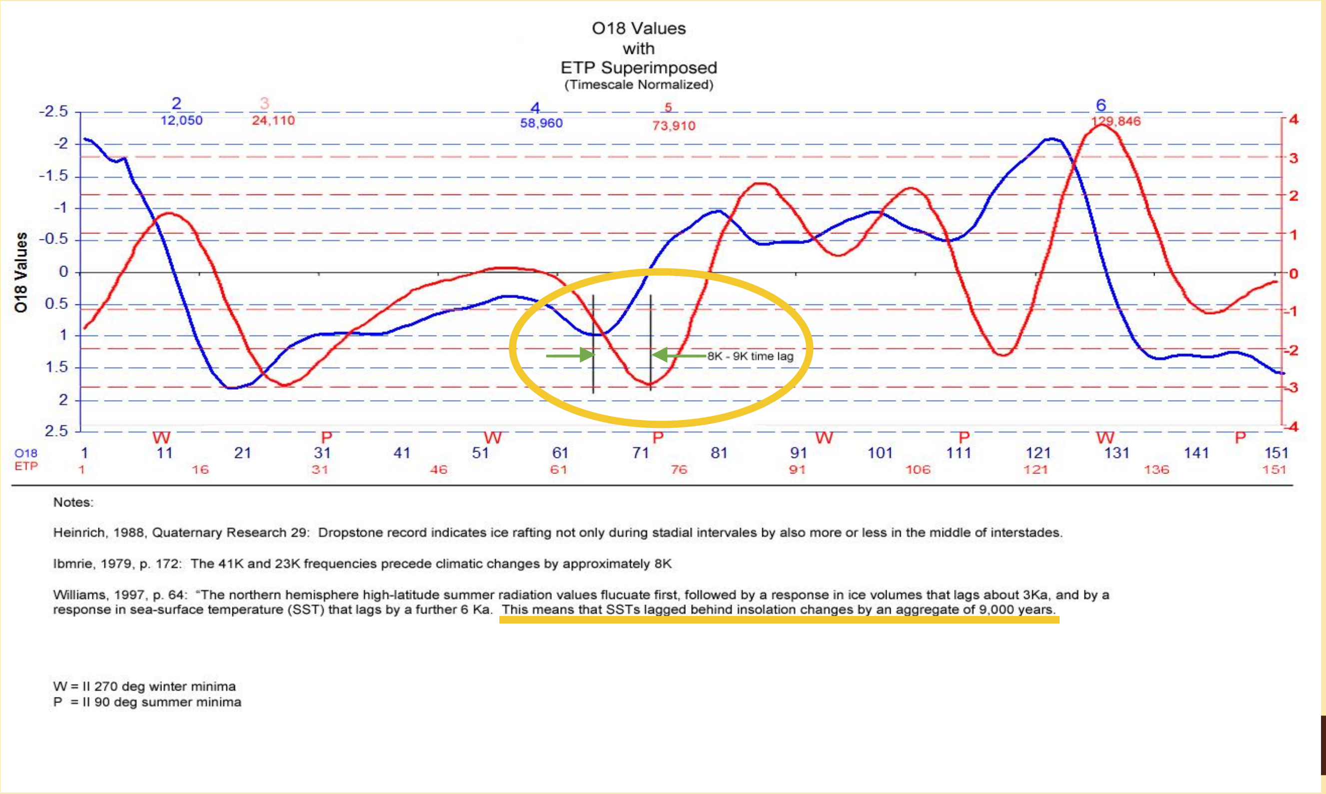
And finally a view of the timeline of the creation of Continental Ice Sheets. Yes, as the chart shows there if a correlation between the earth's movement around the sun (ETP), and sea surface temperature - around 9,000 years.



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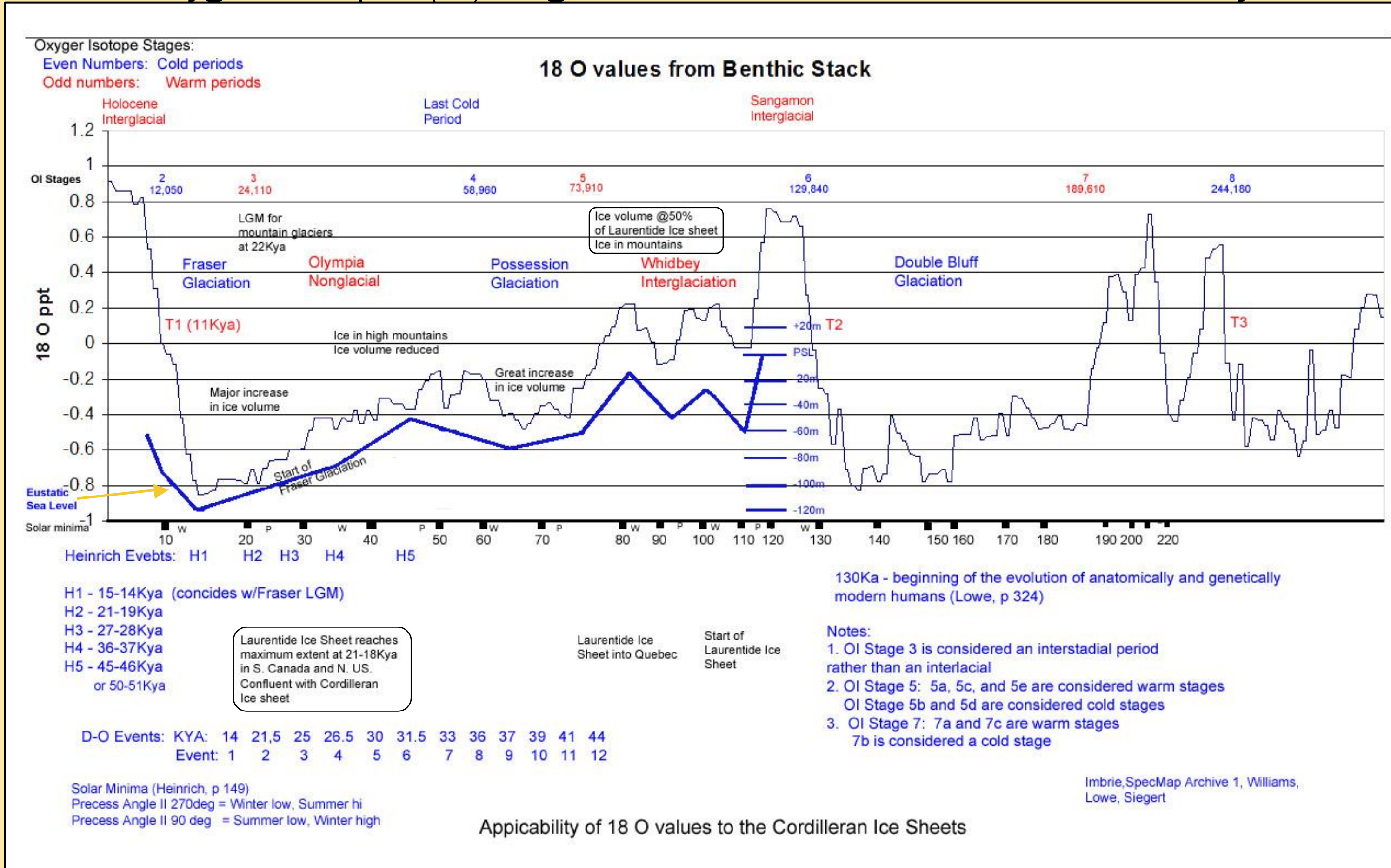
Consequently, a non-normalized time chart* could be developed upon which the marine oxygen isotopes (OI) stages could be shown. Yes, this chart is busy.



*The time is not normalized – meaning the time tick marks at the bottom of graph are not equally spaced. The jagged appearance of the ^{18}O line is due to each data point being repeated once.

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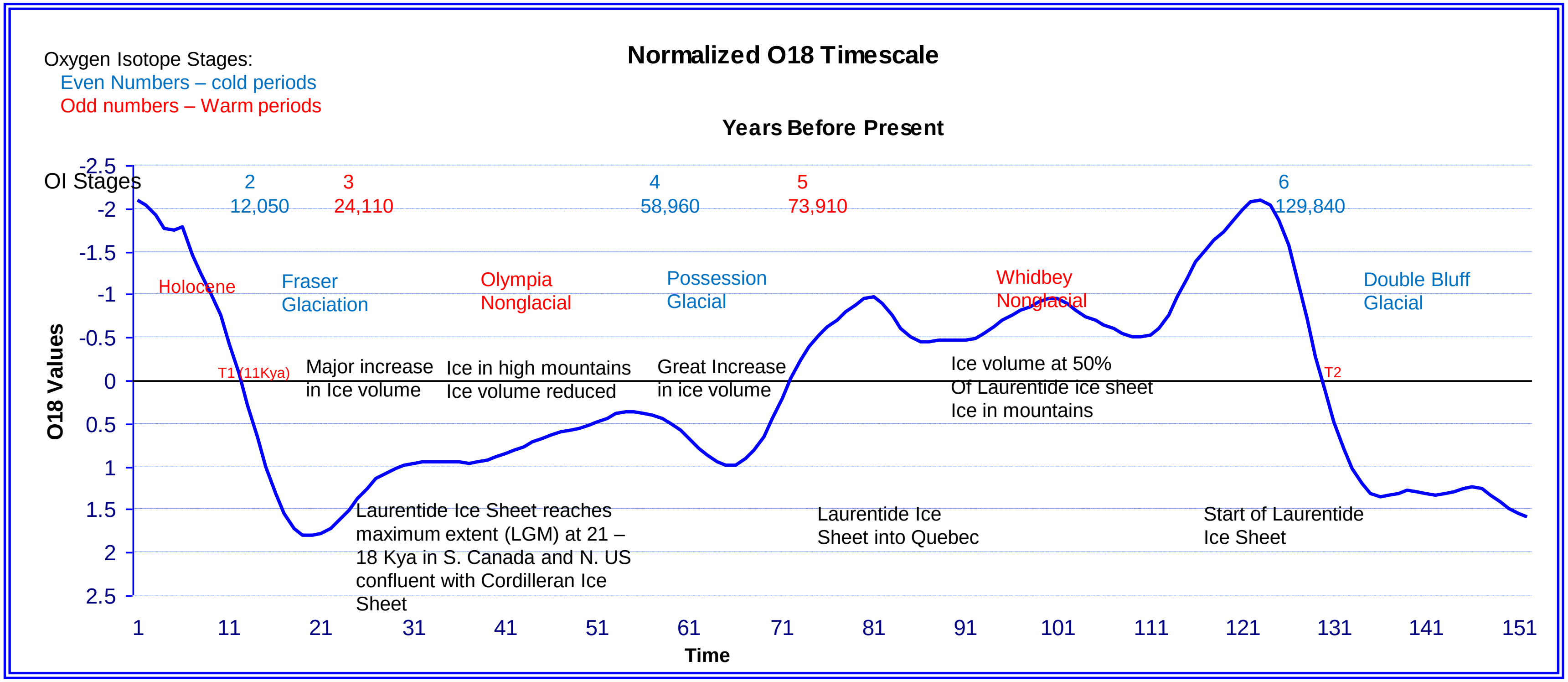
This chart shows a normalized view from Marine Sediment Core V28-238 with the same data which has been smoothed. And without the clutter.



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

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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.

Note the area that supplied ice to the Puget Lobe is the area of ice west of the Cascades.

Note the green line it shows the dividing line between the Puget Lobe and Okanogan Lobe

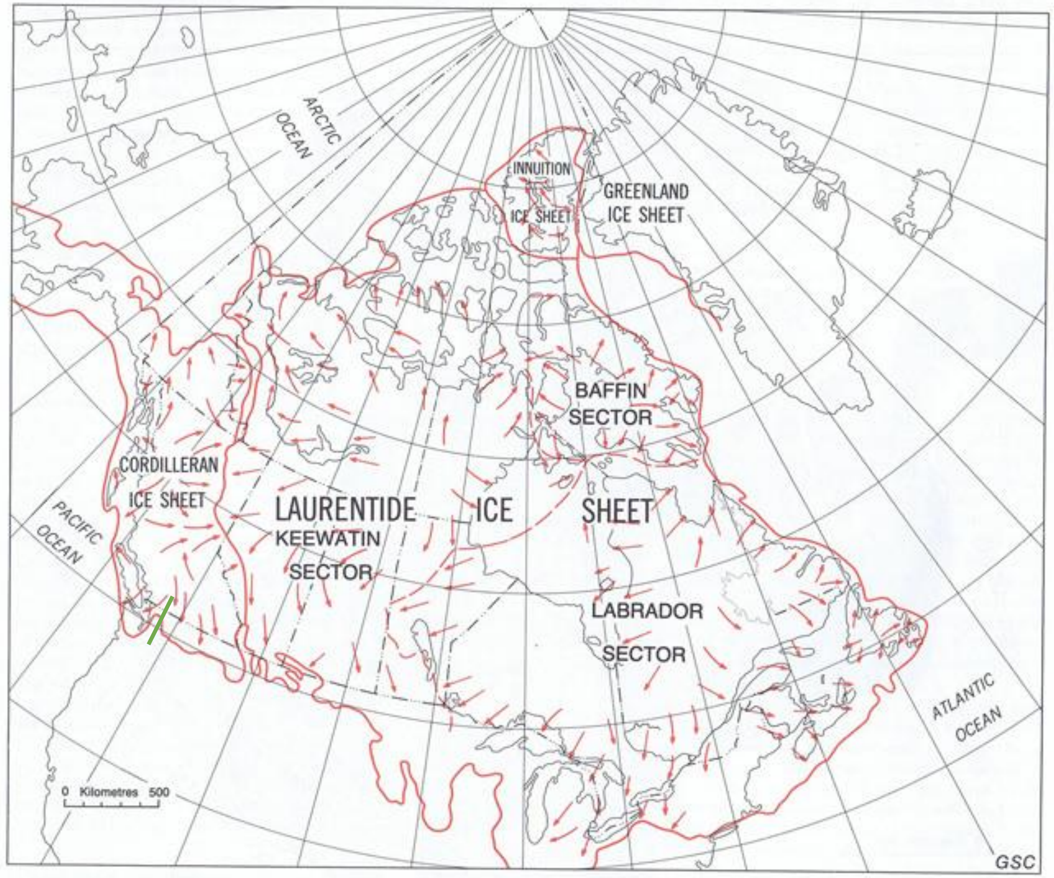

Figure 4. Approximate extent of main ice sheets during the last (Wisconsin) glaciation; arrows indicate probable directions of ice flow at the glacial maximum. Taken largely from Prest et al. (1968) and Prest (1984) but with some modifications.

From: Fulton, 1989, p.8

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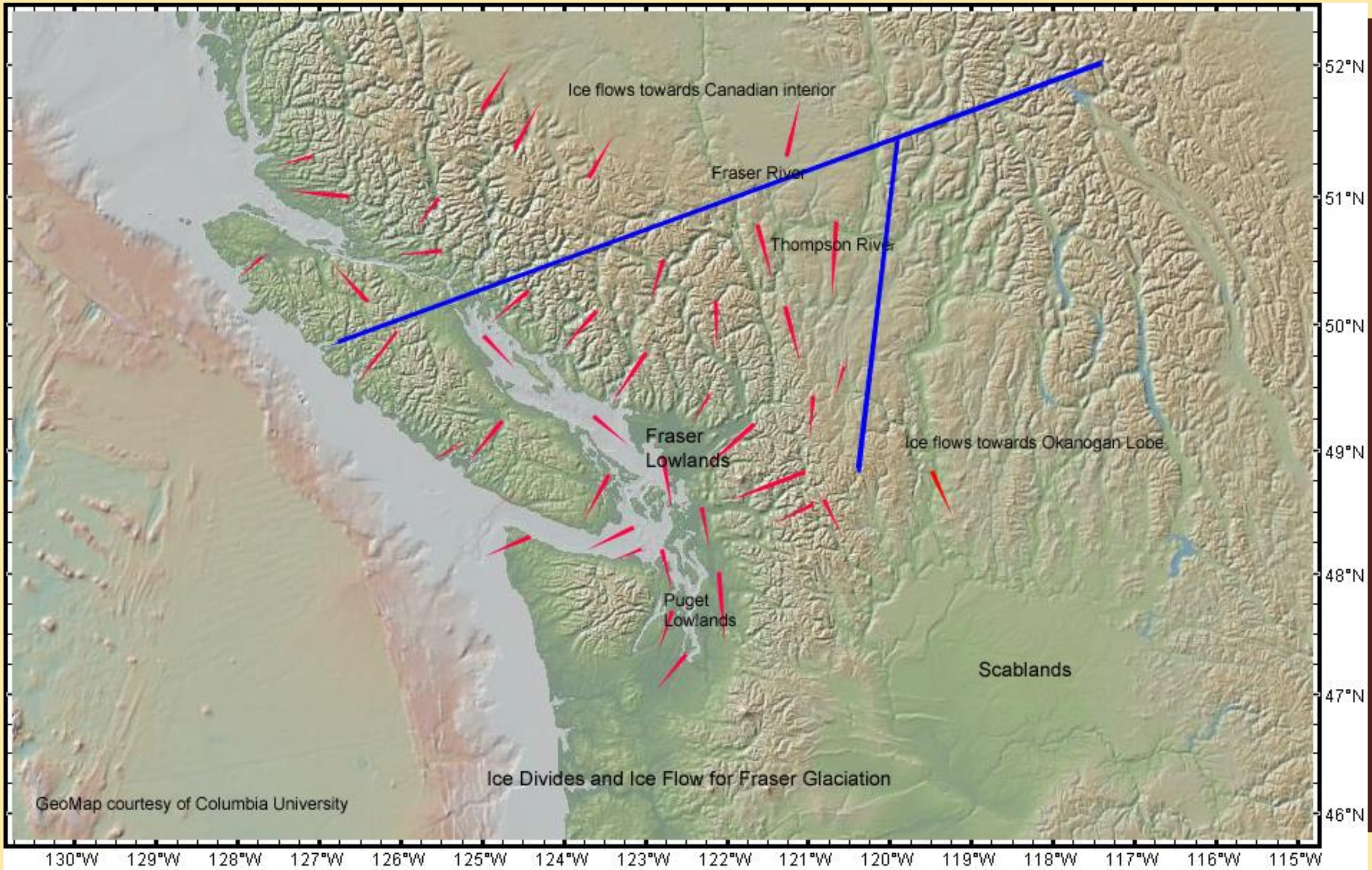
Ice divide and Ice flow patterns based on Prest (1968)



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You get some idea of the complexity if our Ice Sheets, no only in time but as physical "beings". In Chapter 4 the impact to the ice sheets by feedback mechanism, such as, CO^2, Volcanic dust, ice dome height, atmospheric gases and conditions, etc. all conspired to build or reduce ice sheets.

The following charts (page 8) incorporate the Canadian research done prior to the 1990's and US research. Ice sheet building in Canada was not serial, rather it was parallel. Parallel defined by location, landform height, and obstacles to overcome. But mainly how ETP affected insolation and feedback mechanisms. Page 9 incorporates INTCAL09 in the bottom graphic.

The perspective is looking east on the Olympic Peninsula.

Page 8 – The original Chronology prior to INTCAL 09 or establishment of "normalized" C^{14} dates.

Page 9 – With INTCAL 09 applied to selected events on bottom graphic. INTCAL 13 gives accepted dates to 50Kya.

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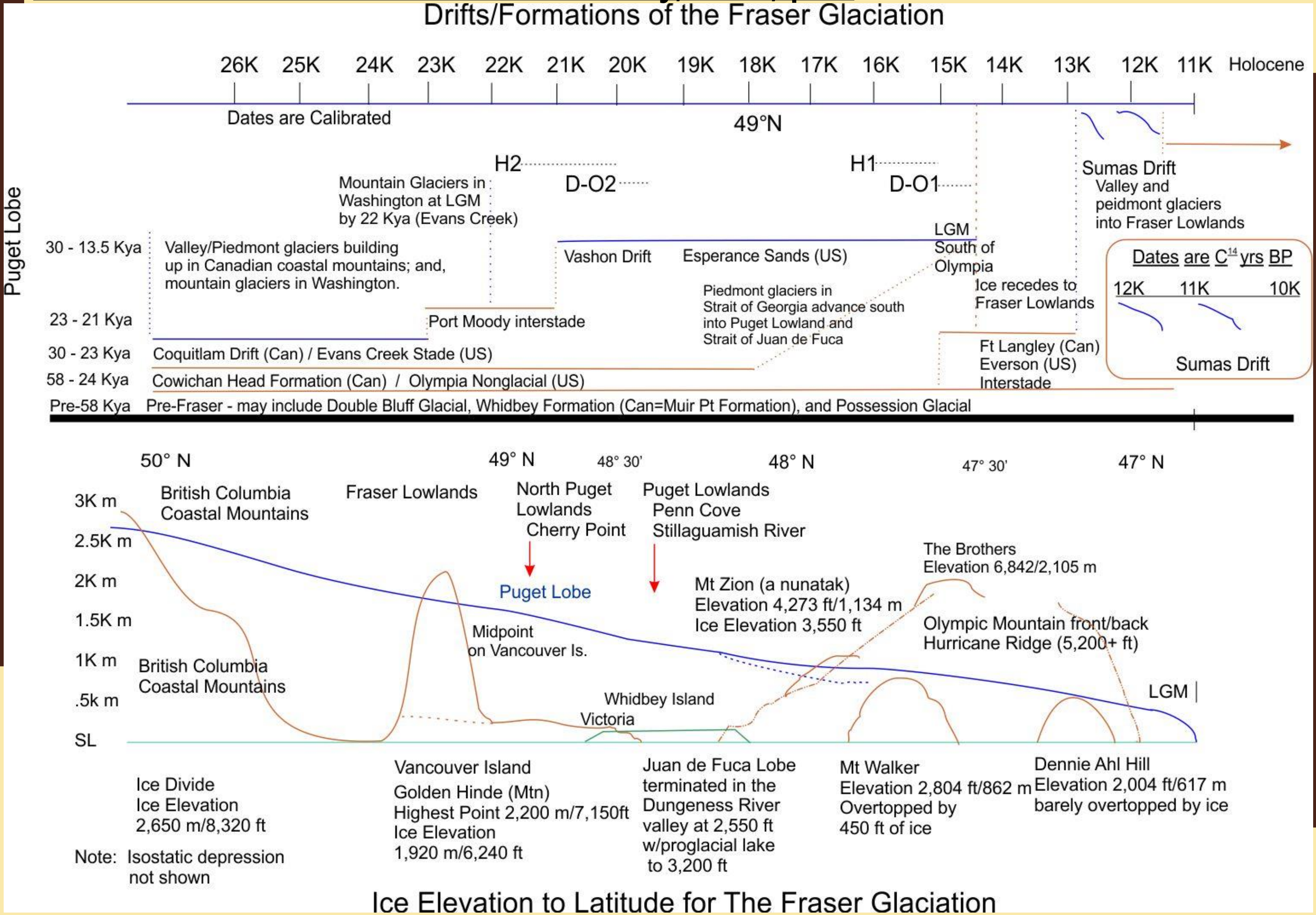

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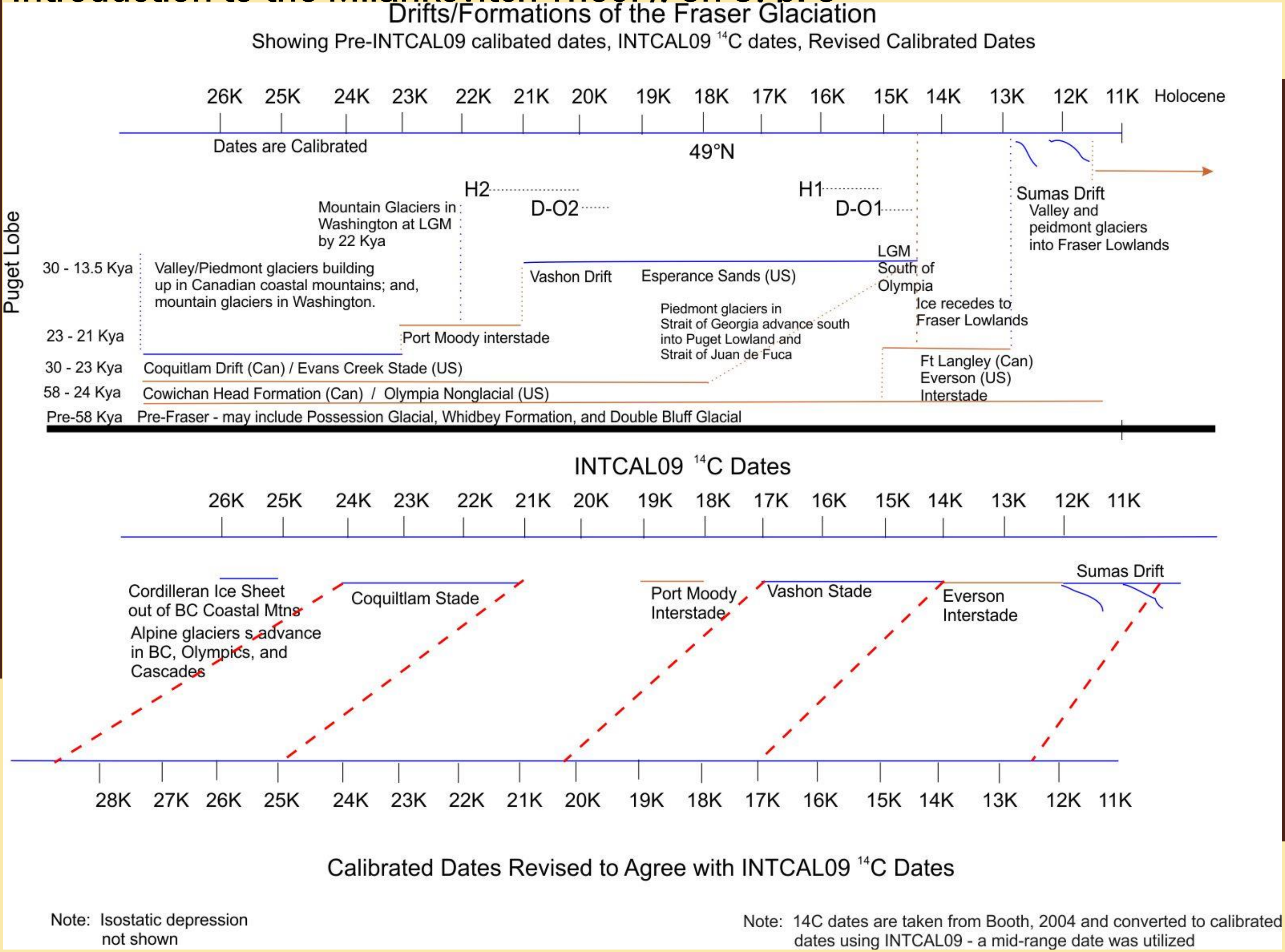

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During the Mesozoic (248-66mya)/Tertiary era (66-2.58mya) the Mean Global Temperature is described as warm (Benn, p. 43, Fig 1.53)

- The curve moderates towards cooling mid-Tertiary and between the Pliocene/Quaternary timeline
- Supercontinents lower sea levels:
  - Supercontinents capture heat from mantle raising the continental cratons
    - Sea level lowers in relationship to the rising cratons
    - Sea level is "the level continuous with that of the surface of the ocean at mean tide, between high and low water used in reckoning altitudes"
  - Ocean floors become old and cold thus sinking (fewer tectonic plates?)
    - Our oldest oceanic plate(s) are from the Jurassic period (206-144 mya) and are located in the NW Pacific
    - Earth is 4.5 B years old
  - Eustatic sea level lowers as a result of these two actions, and from:
    - Continental Ice Sheets which remove water from the oceans lowering the sea level
- Plate tectonics (Waggoner's continental drift) may raise/lower sea level
  - Super continent separation allows mantle heat to escape allowing continents to sink into the mantle
  - Mid-ocean ridge spreading results in ocean ridges being warm and raise the sea bottom
  - Eustatic sea level rises as a result of these two actions
    - Continental Ice Sheet deglaciation puts water back into the oceans raising the sea level

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During the Mesozoic (248-65mya)/Tertiary era (66-2.58mya) the Mean Global Temperature is described as warm (cont)

Plate tectonics is currently in the spreading mode:

"Pangaea Ultima" will be the new supercontinent in about 250 my (www.scotese.com)

By mid-Quaternary, the temperature line shows peaks and valleys suggesting numerous glacial/interglacial periods (see Shackleton, N., 1996. Core ODP 677 –Timescale Calibration for last 2.6mya)

This is supported by other marine sedimentary and ice core records

Put in temperature scale for Cenozoic and associate with CFBs

As the stage is set for measuring the chrono-stratigraphy of the Quaternary we will look back at the time period before the Quaternary period began

Note: USGS Fact Sheet 2018 -3054 dated August 2018 revised the Pleistocene start to 2.58 mya. That and other changes are applied in this presentation.

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During the Mesozoic (248-65mya)/Tertiary era (66-2.58mya) the Mean Global Temperature is described as warm (cont)

The breakup of Pangaea (100 mya) resulted in continental land masses migrating towards the northern latitudes.

Temperature curve shows overall cooling of the earth atmosphere

Sea level during the breakup is rising (transgressing) (rising due to warm mid-ocean ridges; also, spreading and sinking "cooling" continental cratons)

From 125-30mya the main ocean current was equatorial (circum-equatorial)

Water still flowed east / west through the opening between North and South America (Isthmus of Panama) until 4-3mya. (Drawing in work)

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During the Cenozoic era (66mya – today) ice sheets start around 3mya

The Mid/Late Mesozoic era (248-66mya) / Tertiary period (66 – 2.58mya) was one of climatic warmth (Winter, p. 260-292)

During the Mid/Late Mesozoic Period the following major Continental Flood Basalts (CFB) occurred:

Early Jurassic (199-175mya), Karroo, South Africa (associated with Tristan hot spot)

Early Cretaceous (145-96mya), Parana, Brazil (associated with Tristan hot spot)

Cretaceous-Eocene (145-33.9mya), Deccan, India (associated with Reunion hot spot)

Miocene (17.5 – 6mya), Columbia River Flood Basalts, NW US (associated with the Yellowstone hot spot)

Also see Macdouall, J.D., ed., Continental Flood Basalts, Kluwer Academic Publishers, 1988 for an expanded list of CFBs.

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What geological/climatic features made the Quaternary unique:

- The Indian Subcontinent collided with the Asian continent creating the Himalayan Mountains about 35mya creating a high massif (contributing to Rosby waves)

- By 3mya the opening between North and South America had finished closing which created the Isthmus of Panama

  - Prior to closure, northward flow of warm water into the North Atlantic was insufficient to create conditions for ice sheet development
    - Insufficient warm water reached into the polar regions to provide sufficient moisture for snow fall/accumulation. Warm water could flow out the opening of the pre-isthmus gap in Panama
    - North Atlantic Deep Water was non-existent up to that point

  - Closure of the isthmus caused greater amounts of warm water to flow northward
    - Closure shut off the equatorial flow of water that had been in existence since opening of the Atlantic Ocean between landmass of N. America and Europe between 40-20mya
    - Allowed development of the North Atlantic Deep Water (NADW) which is the driving force for the current surface/deep water currents world-wide (thermohaline circulation)
    - Provided sufficient moisture to the northern latitudes for snow accumulation.

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What geological/climatic features made the Quaternary unique: (cont)

The Cordilleran mountain ranges rose on the western North American continent:

- Canadian Cascades/batholiths, Washington/Oregon Cascades, and California's Sierra Nevada
  - Clague (1989) indicates that the coastal belt has uplifted and eroded between 5 to 25 km during the last 65my and consists primarily of metamorphic and plutonic rocks.

  - In the area of the ice dome (50°N) uplift in the last 10ma was roughly 2 km (>0.2 m/ka)
  - The Washington Cascades have uplifted tbd during the last tbd ma
  - The High Cascades of tbd years ago (shield volcanoes)
  - The modern Cascades of today (composite volcanoes)

  - Also, the creation of the mountain chains across central Asia (other than the Himalayan), thus, Rosby waves are created which pull down colder arctic air into the lower latitudes
    - In the Antarctic the circulation is circumpolar (circulation is unimpeded by land masses)
    - This same effect has been noted during glacial periods when the ice sheets gain sufficient altitude to split the jet stream towards the south which effectively starves the ice sheets of moisture. (see Heinrich Events)

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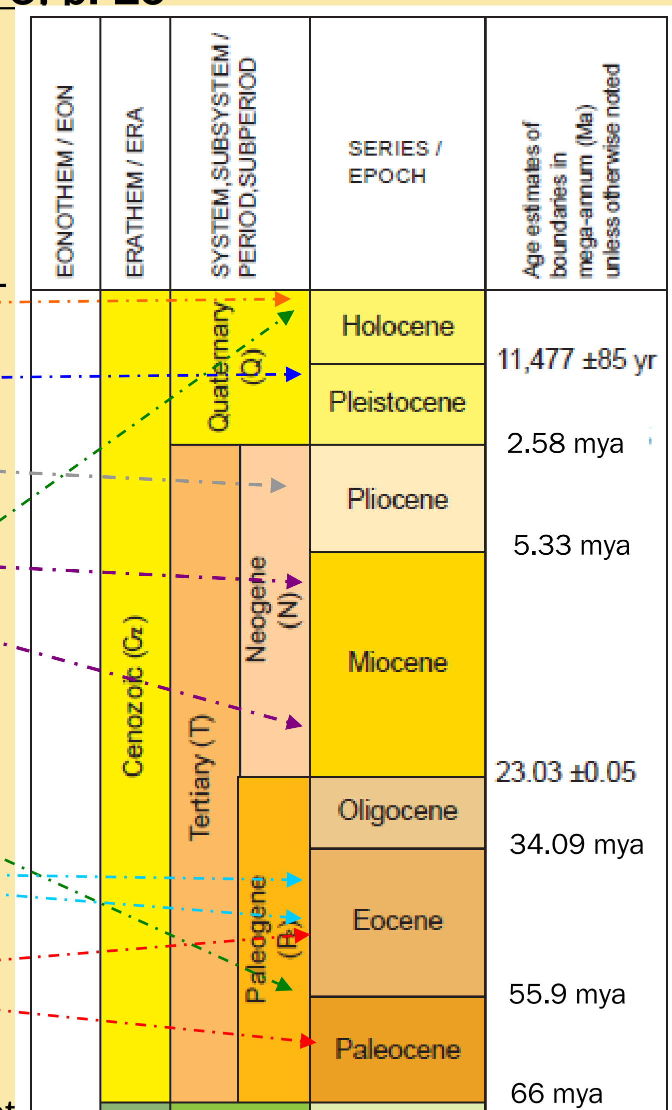
The geologic time scale is important.

The USGS pamphlet FS2018-3054 dtd Aug2018 provides a timescale that covers the Events that took place and the Olympic core trench deposits, and accretion are still taking place:

- The here and now (Recent)
- The Fraser Glaciation (29-12kya)
- Closure of Isthmus of Panama (3mya)
- Columbia River Flood Basalts (17.5 to 6mya)
- Olympic core trench deposits and accretion uplift (55mya thru Recent)
- Indian Subcontinent collides with Asia creating the Himalayas (35 mya)
- Crescent Formation extrusion (58 – 46mya (en 17, p. 146)



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In Chapter 6, the newsreel will continue with:

a. A review of ice ages and where we find on the geology maps the last exposed sediments.

Future Newsreels:

a. Look at the basement rock and bottom sediments of Hood Canal and differences in bottom topography. And the optimum location to have your Port Ludlow home during the next LGM.

b. A catchall of pertinent facts about Continental Ice Sheets including was the last Puget Lobe (Fraser) a true Continental Ice Sheet or a piedmont glacier.

c. And a look at surging glaciers and …?

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