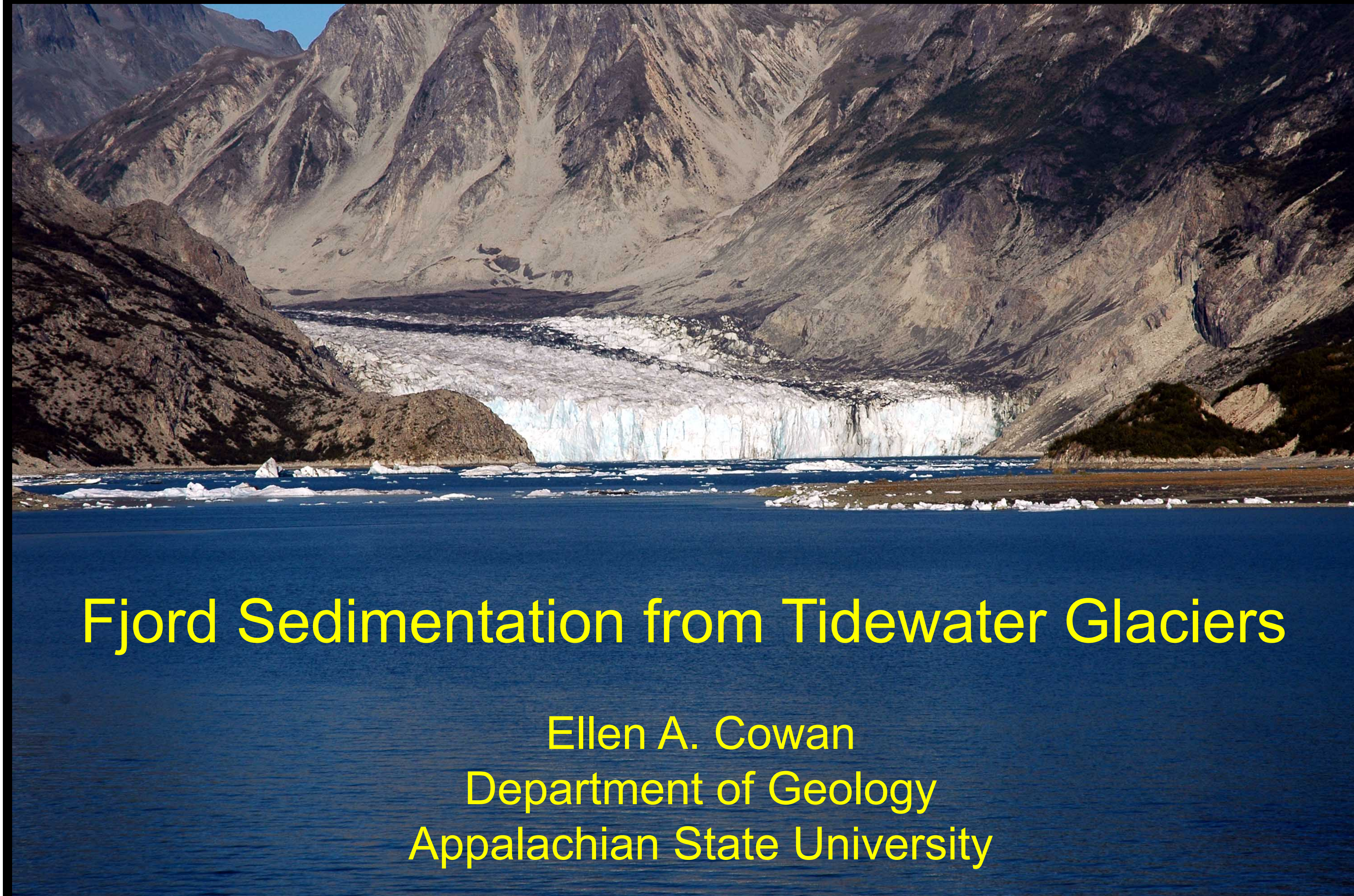
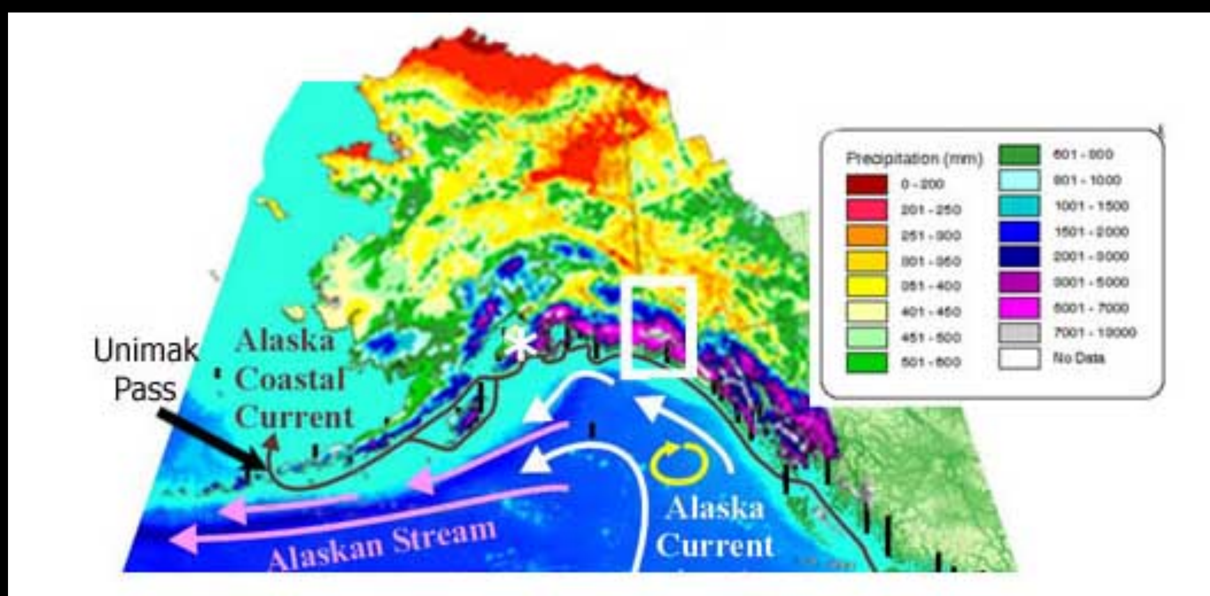
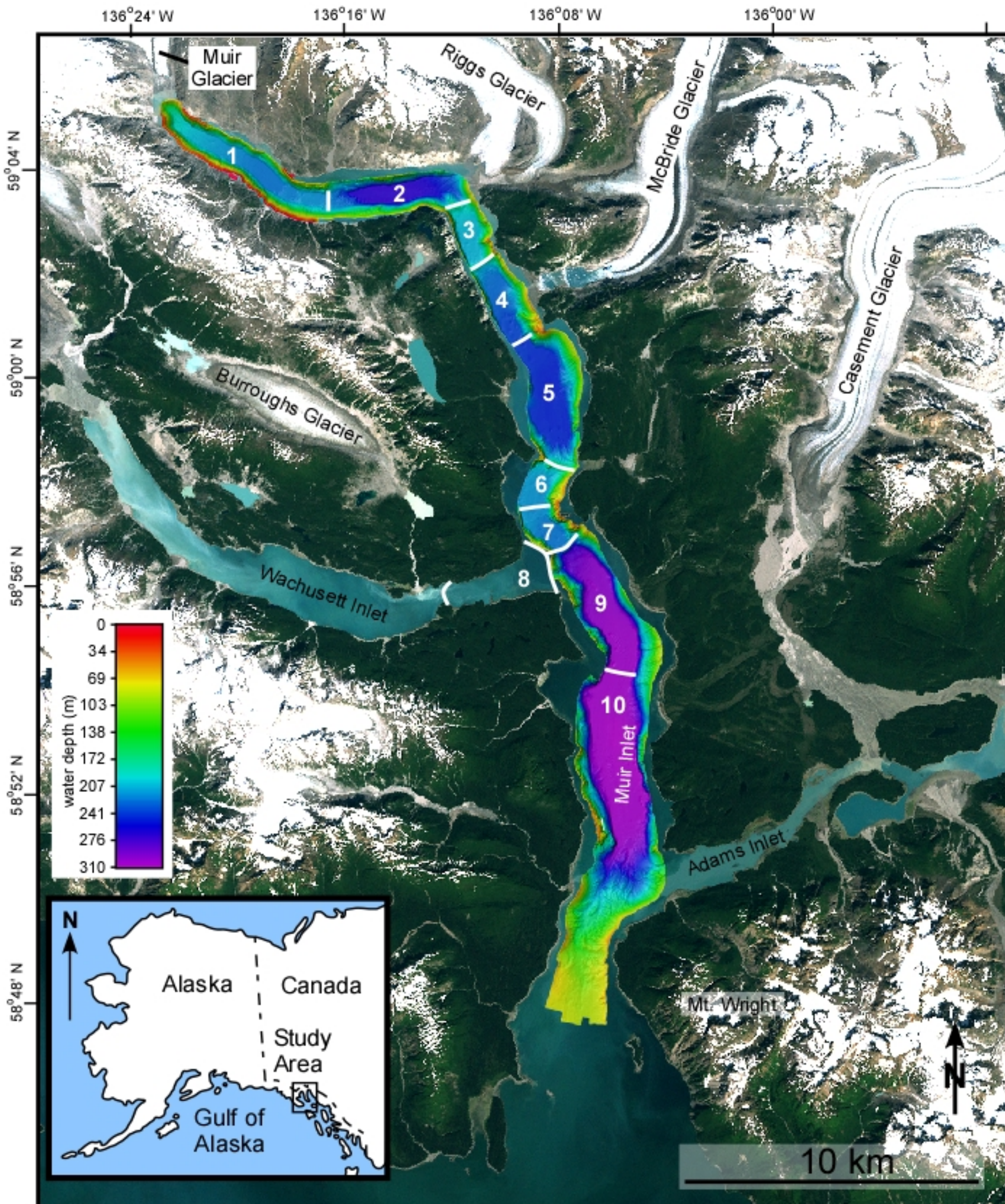


Fjord Sedimentation from Tidewater Glaciers

Ellen A. Cowan
Department of Geology
Appalachian State University

- •Largest temperate glaciers
- •Orographic precipitation from Gulf of Alaska
- •Highest sedimentation rates





Cowan et al., 2010. GSA Bulletin

Sediment transfer from Tidewater Glaciers to Alaskan Fjords

- Meltwater discharge – 4 months from May to Sept.

- Iceberg and sea ice rafting – poorly sorted and coarse grained

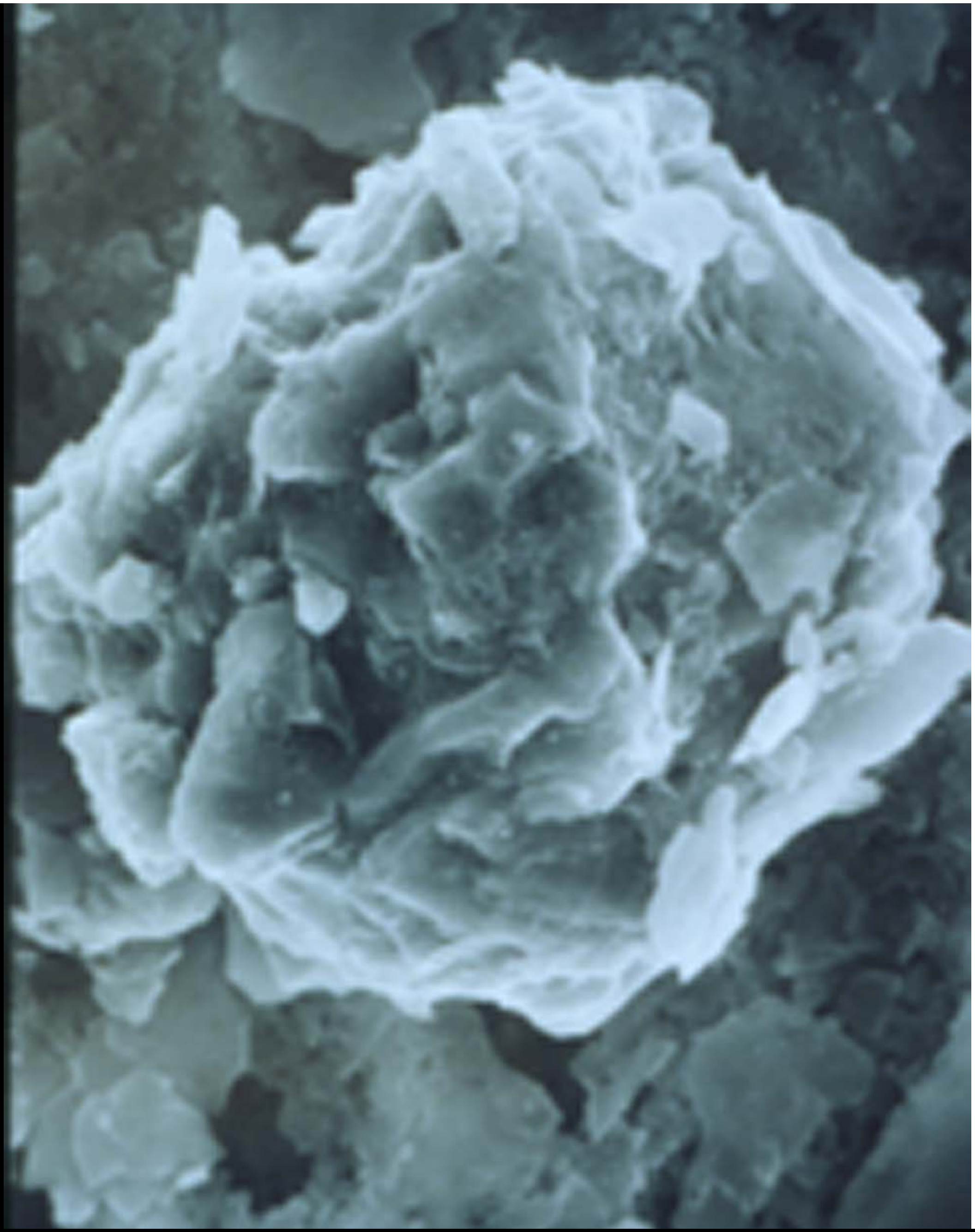
- Sediment gravity flows – debrites and turbidites originating from the groundling line and bathymetic highs (fjord walls and sills)

- Subglacial streams upwell at the terminus
- Suspended sediment is transported in turbid plumes

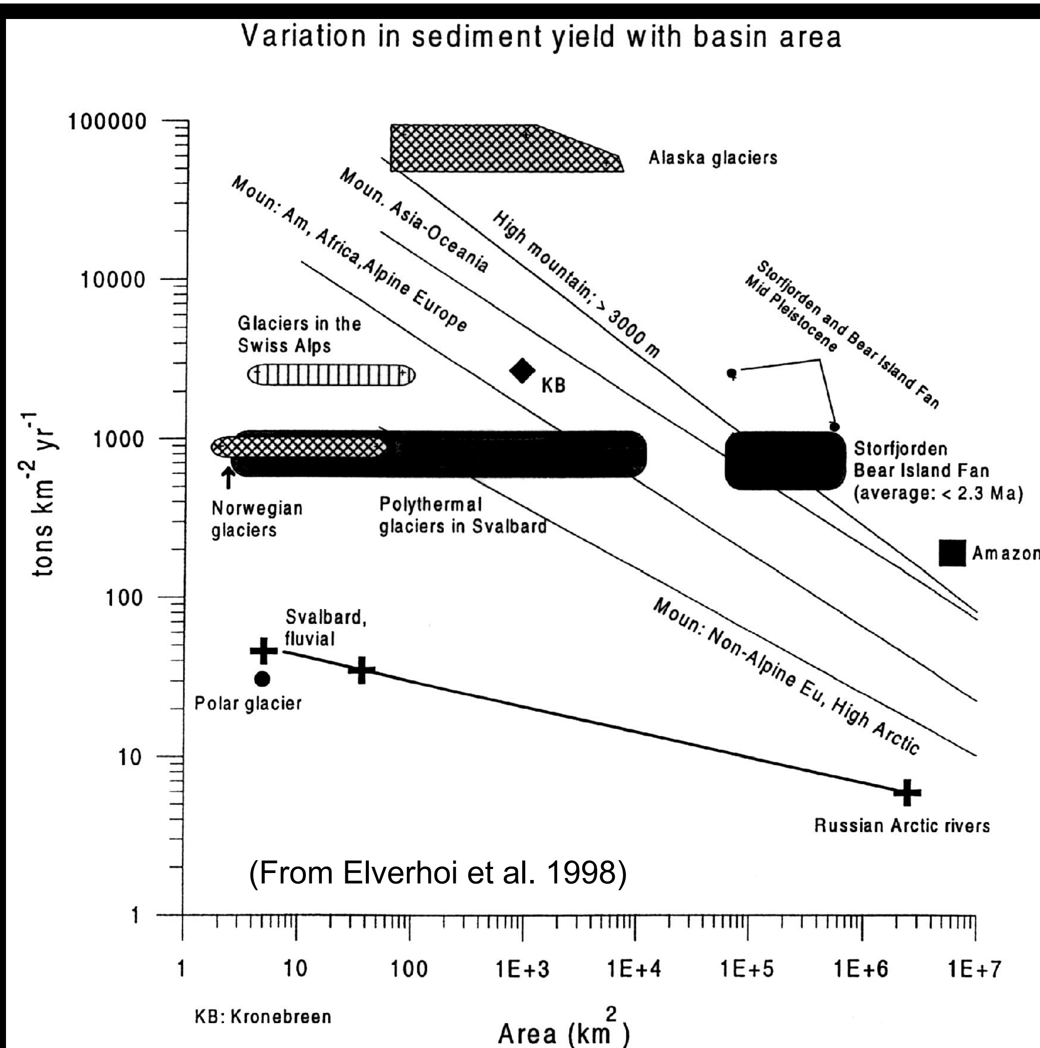
Once released from the plume flocs sink at rates of 80 m/day:

- short residence time of particles in the water column

- high sedimentation rates.

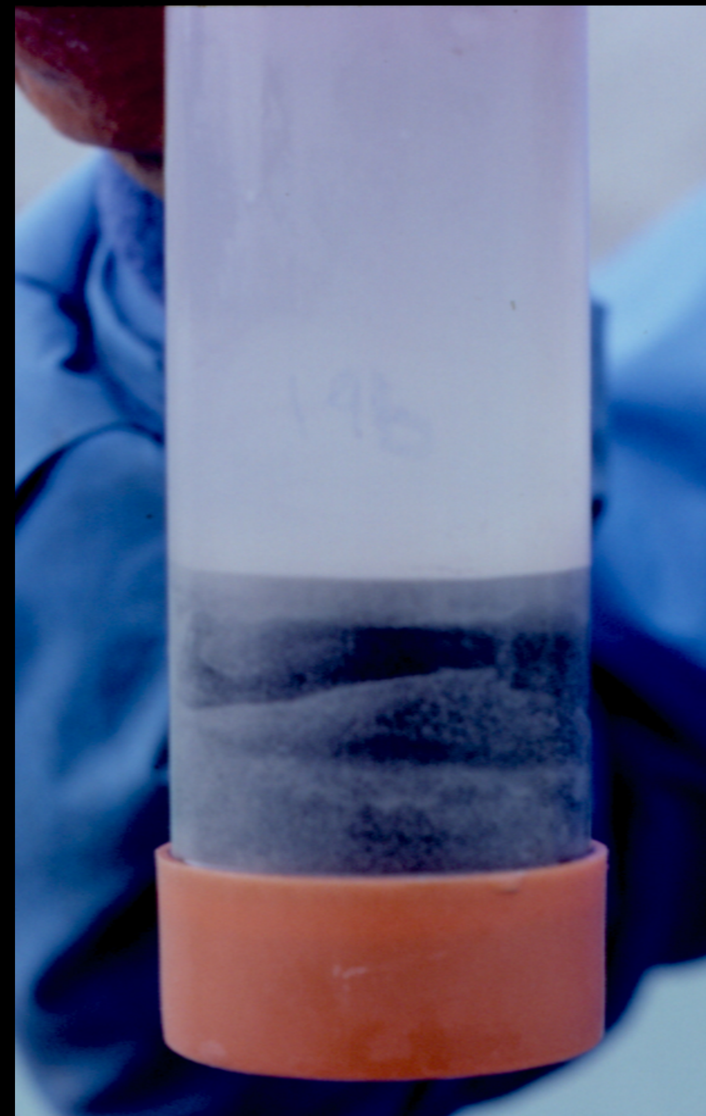


10 microns



Sedimentation Rates

- Up to 13 m/yr in the ice-proximal basin
- exponential decrease downfjord



What Sediment Record is Deposited?
(can a chronology be developed in terrigenous sediment?)

Forcing Variables and Time Scales	
Seasons	Annual
Tides	Fortnightly spring-neap
Meltwater	Diurnal solar radiation
Rainfall events	Episodic – in fall?

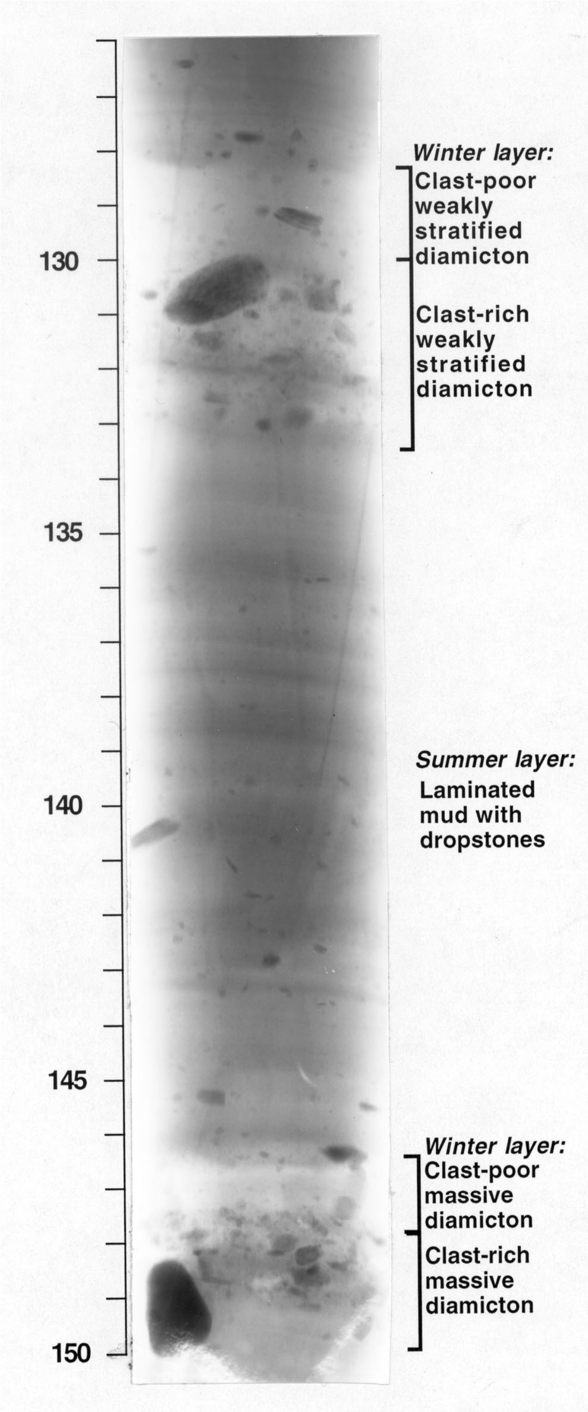
Seasonality

Winter

- No Meltwater
- Icebergs and sea ice distribute sand and gravel

Summer

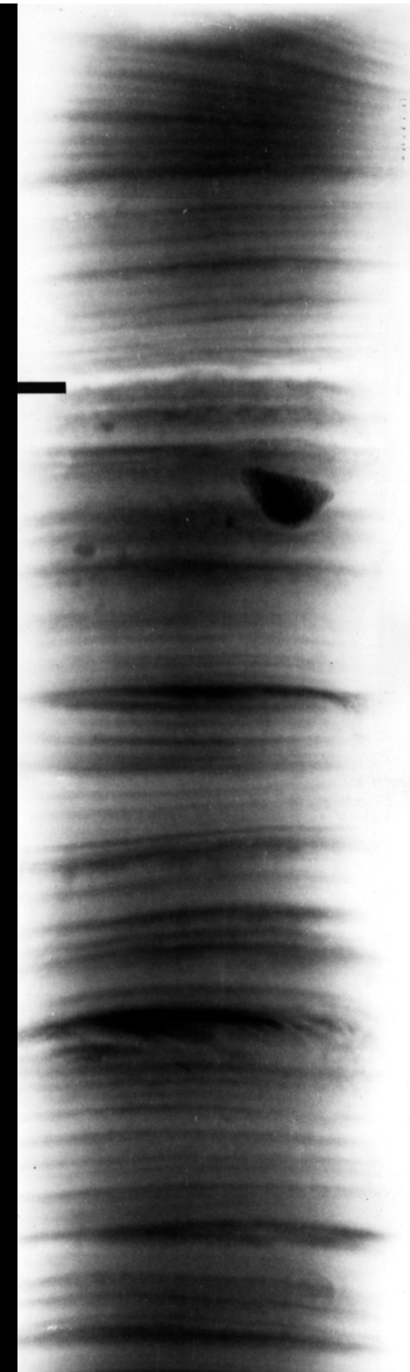
- Abundant meltwater for four months
- Thick laminated mud accumulates



Glacimarine Varves

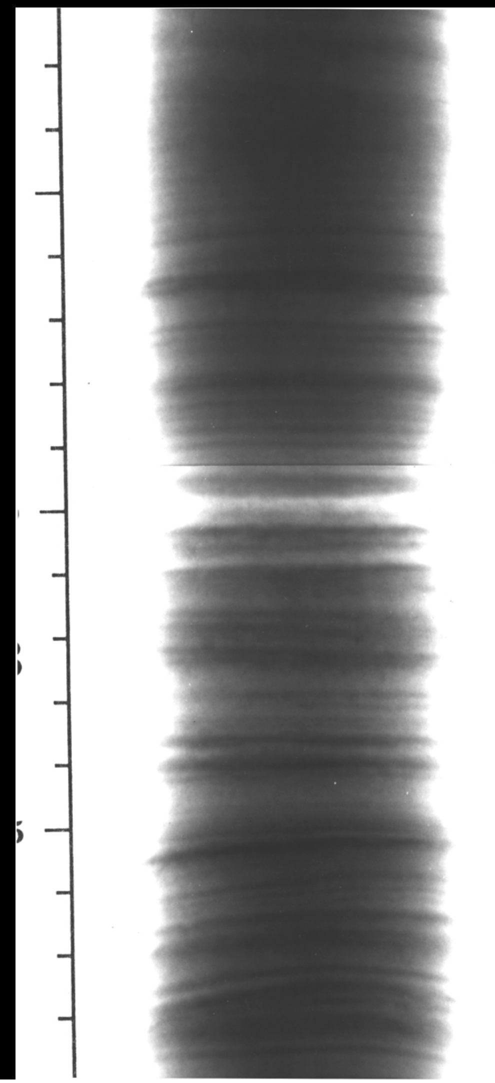
Examples of core x-rays showing the:

- coarse-grained *winter layer* and
- laminated mud *summer layer*.



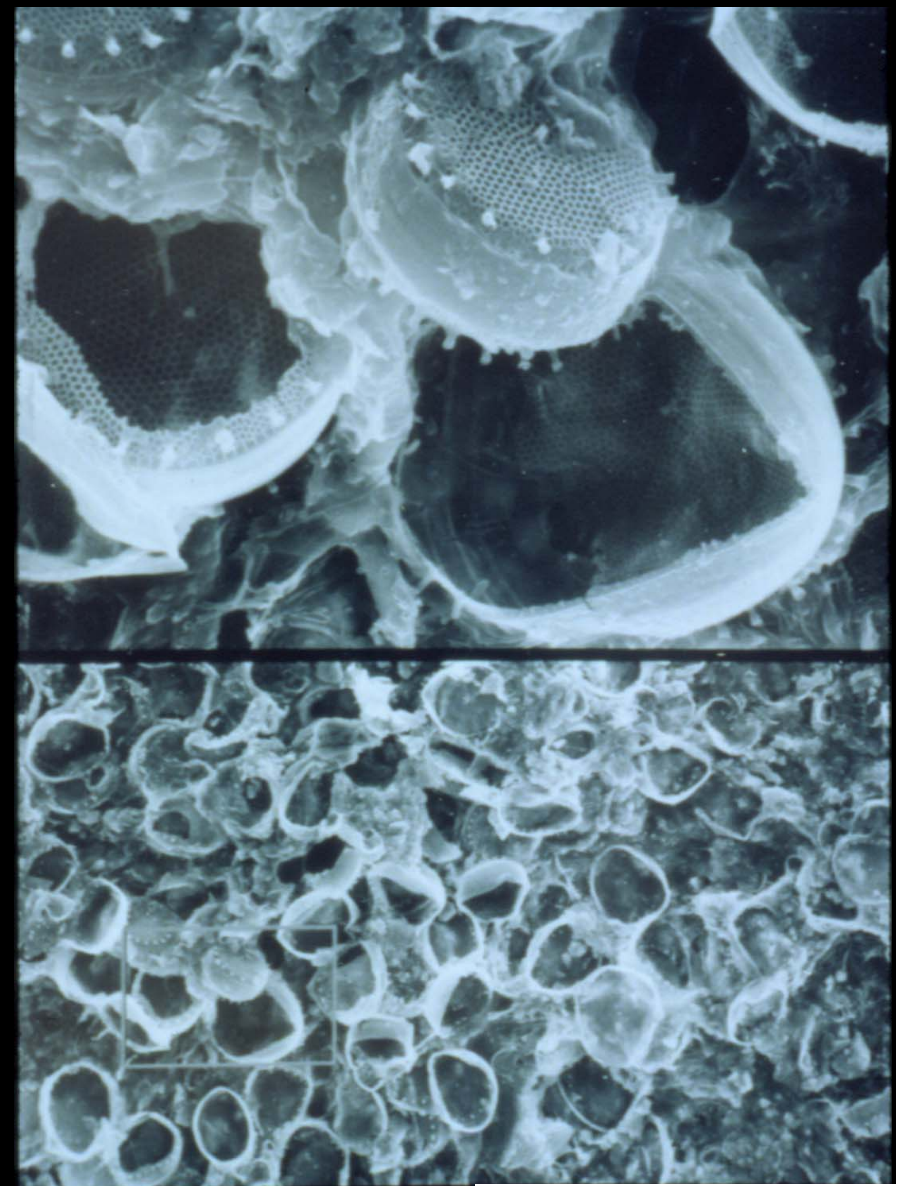
Seasonality

Black layers occur above coarse winter-layers in the springtime



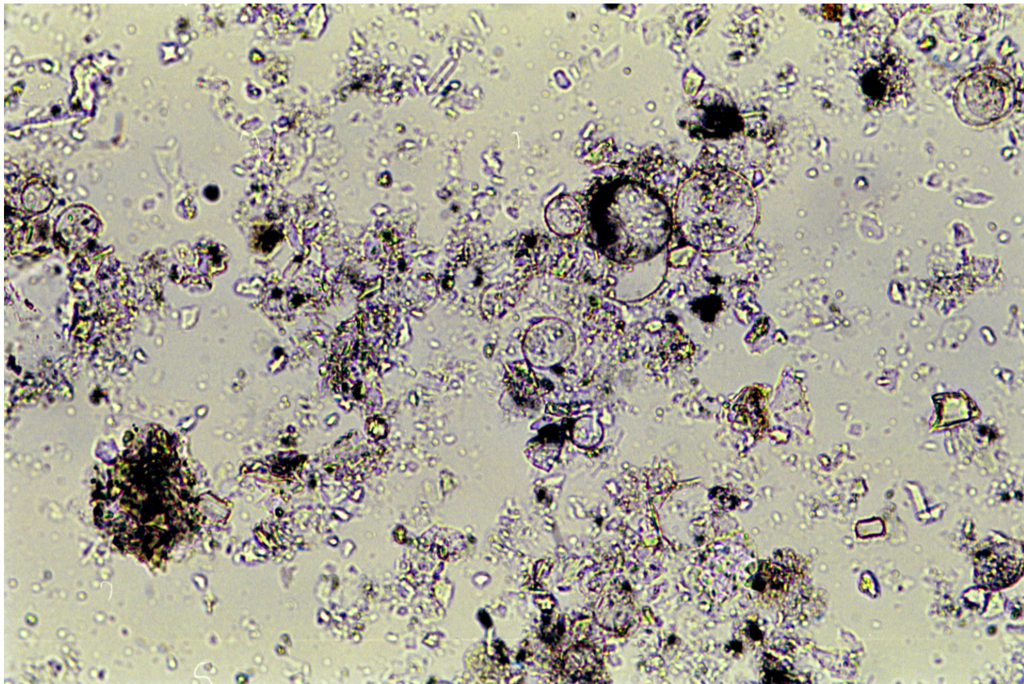
Black Layers

- formed by diatom blooms that
- settle BEFORE the meltwater season begins



Thalassiosira pacifica

100 microns

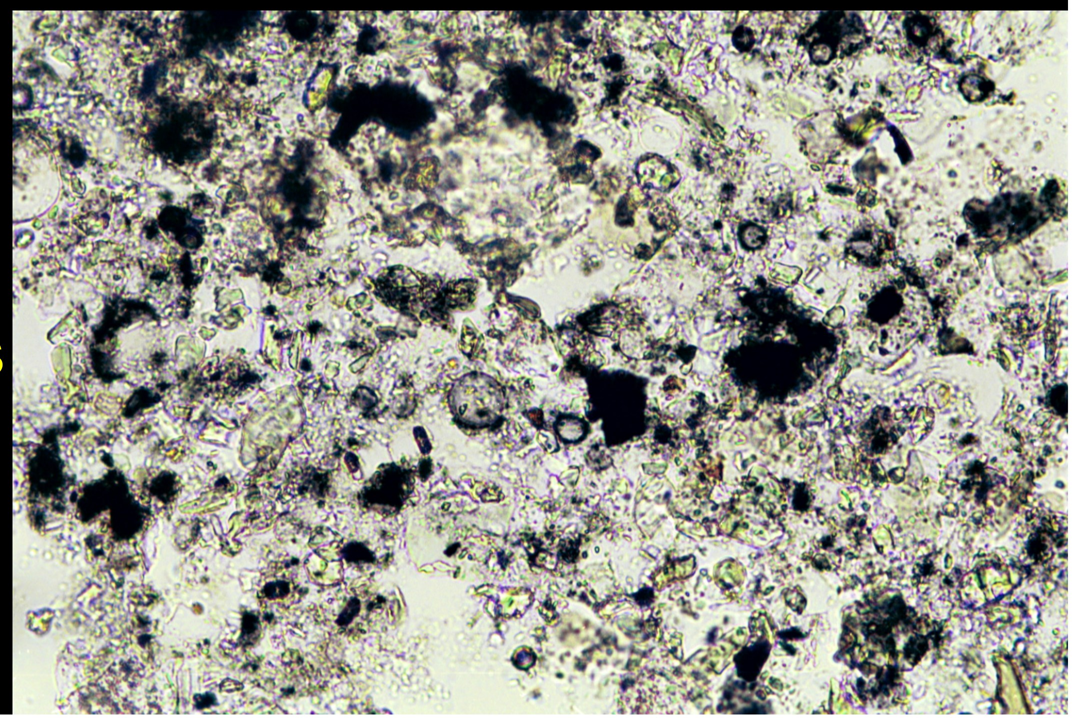


←

Smear slide of sediment from a black layer at 35 cm depth in Muir Inlet core 62JC.

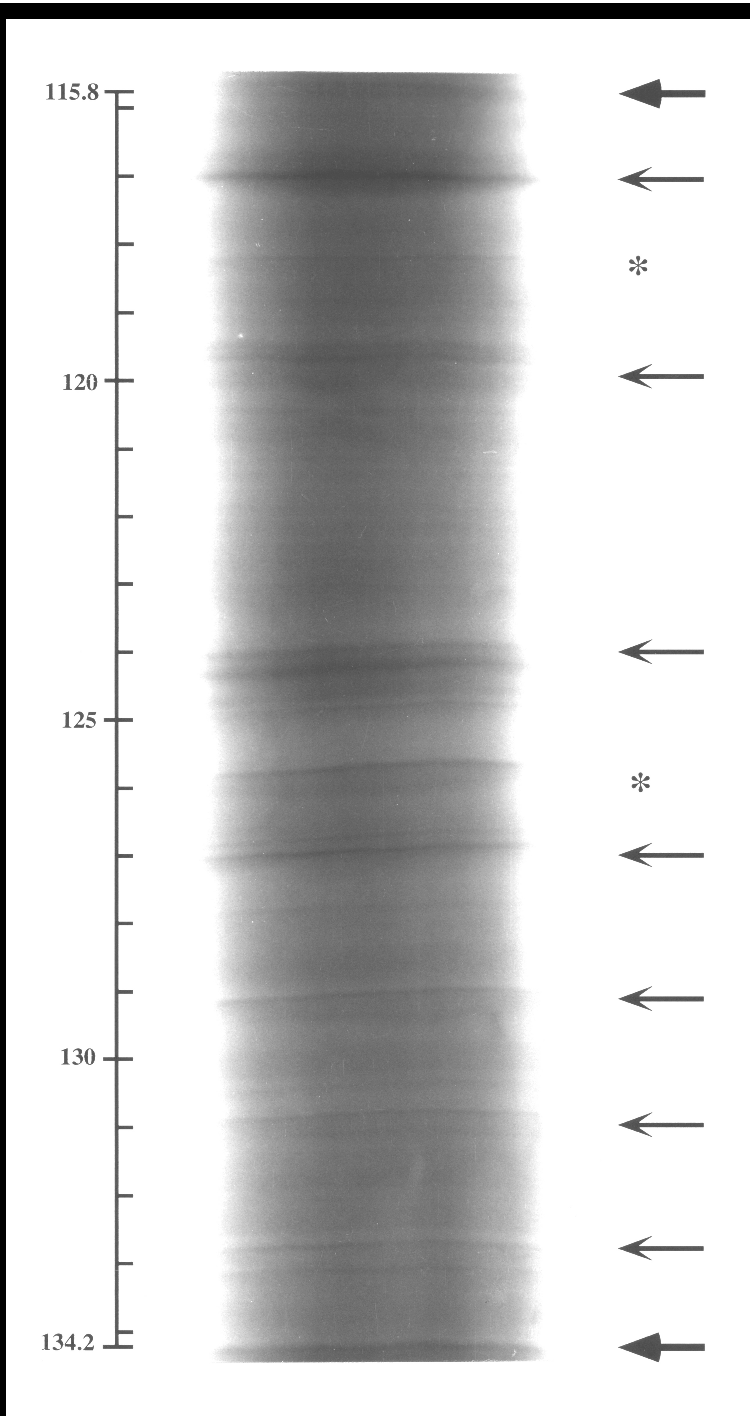
Diatoms occur in abundance only in black layers.

Smear slide from 130 cm depth in core 62JC →



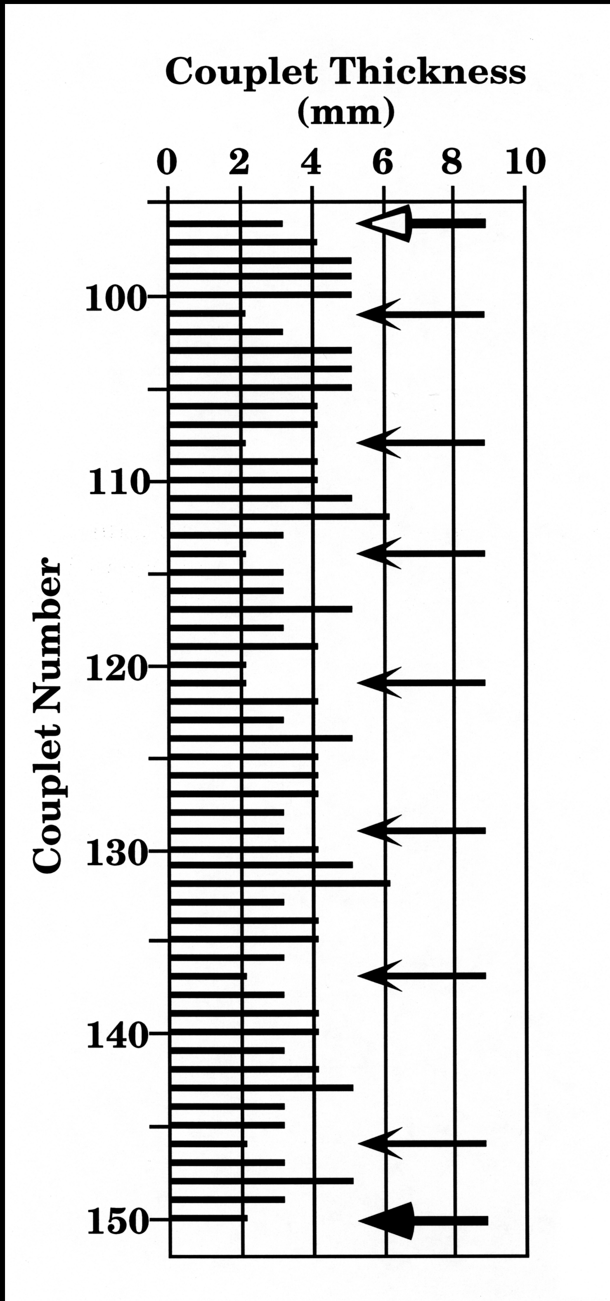
Early diagenesis appears to form monosulphide minerals

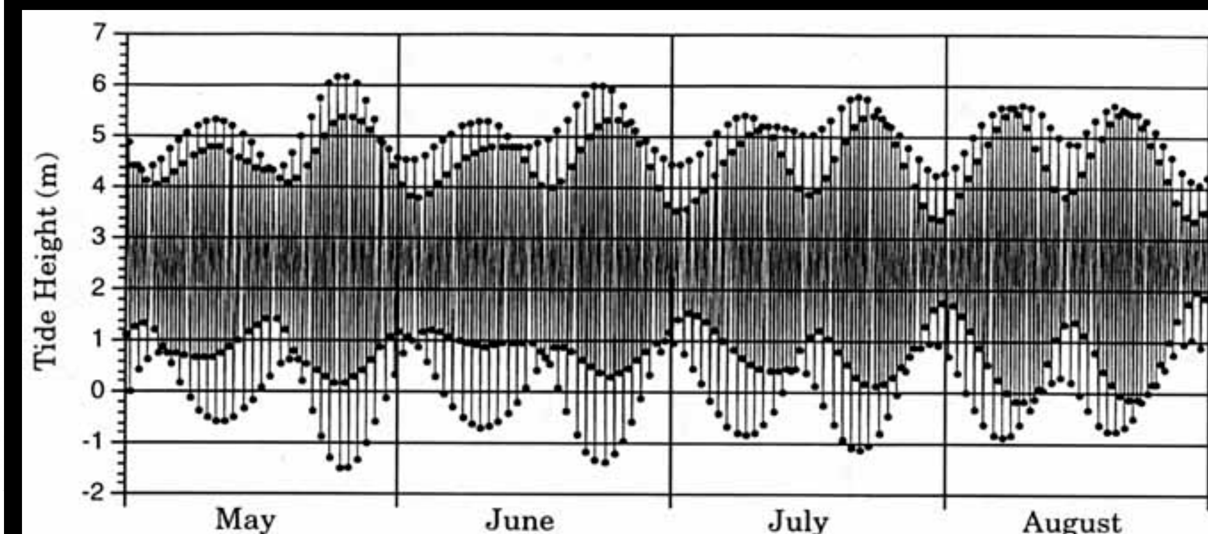
Decay of organic matter produces H_2S that reacts with Fe^{3+}.



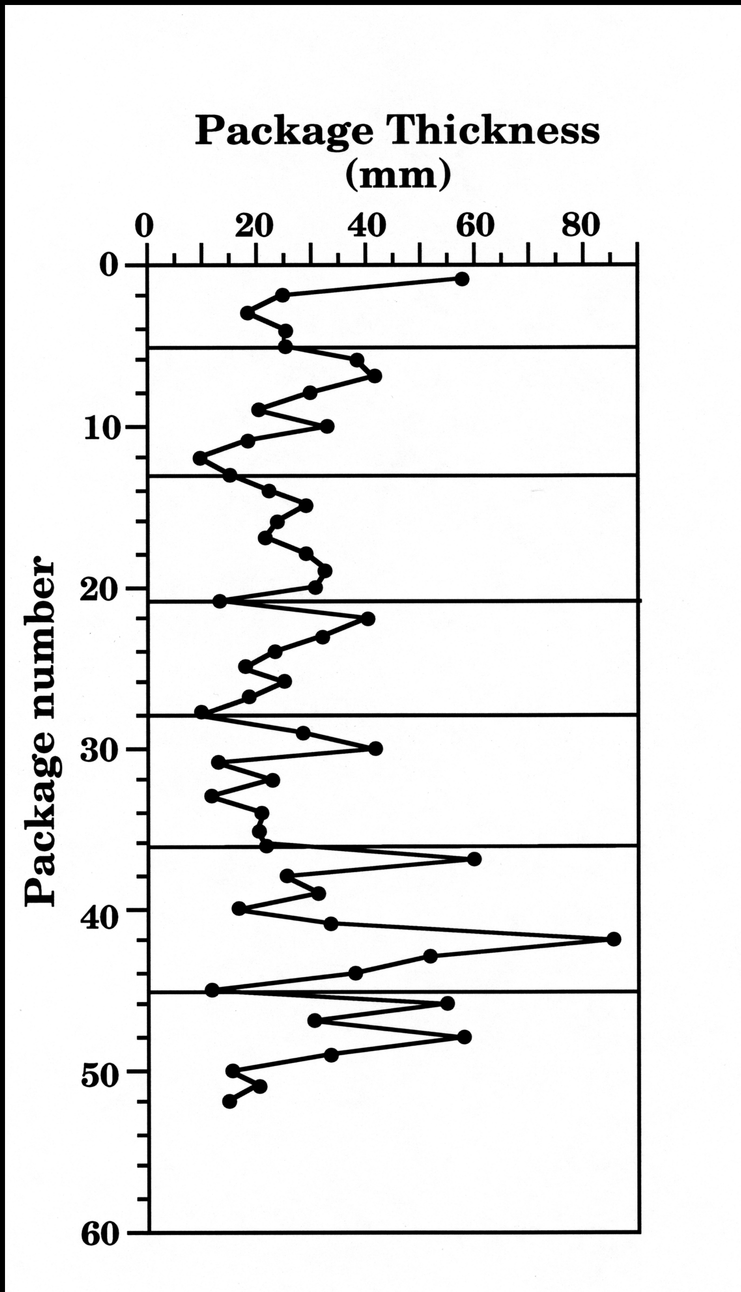
Deep-water tidal rhythmites

Fortnightly spring-neap cycles





Monthly Sediment Flux from Muir Glacier



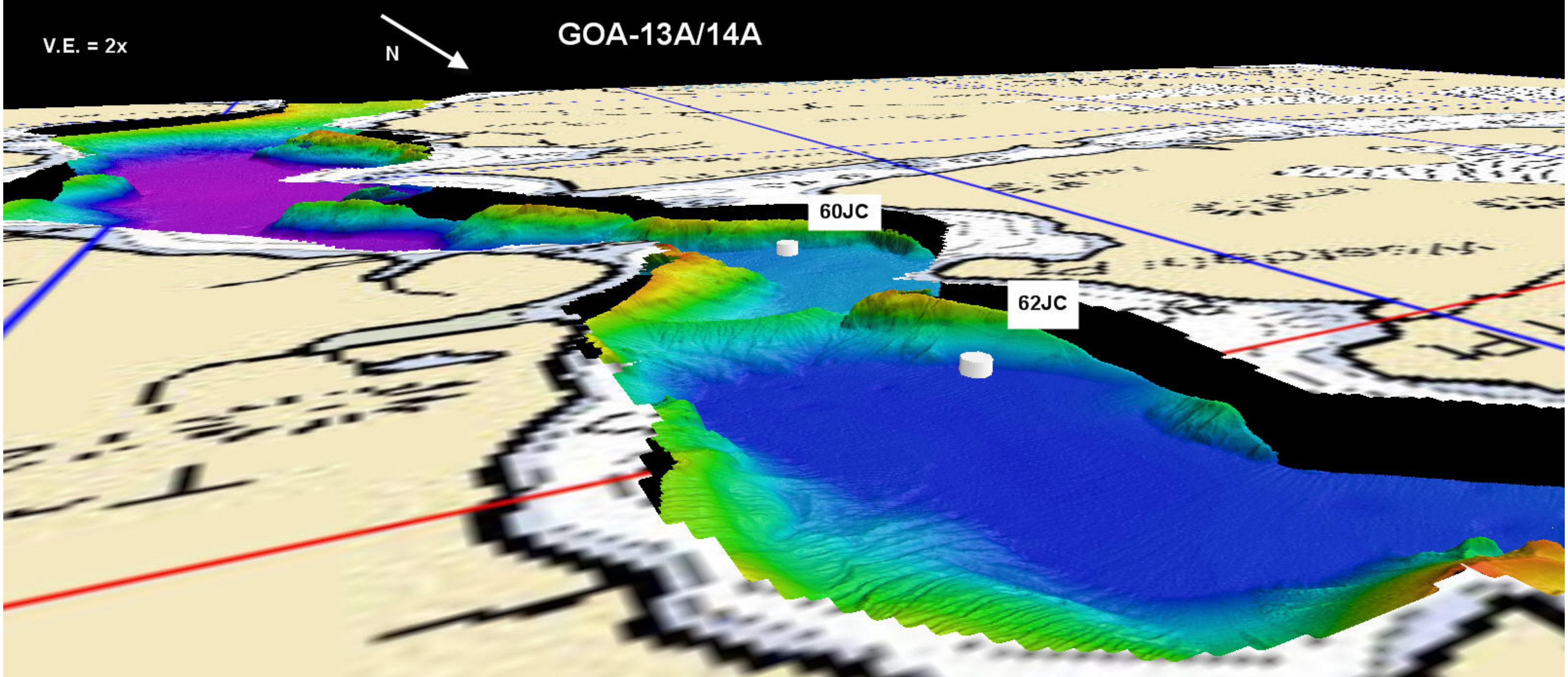
Annual variability determined from sediment rhythmite record

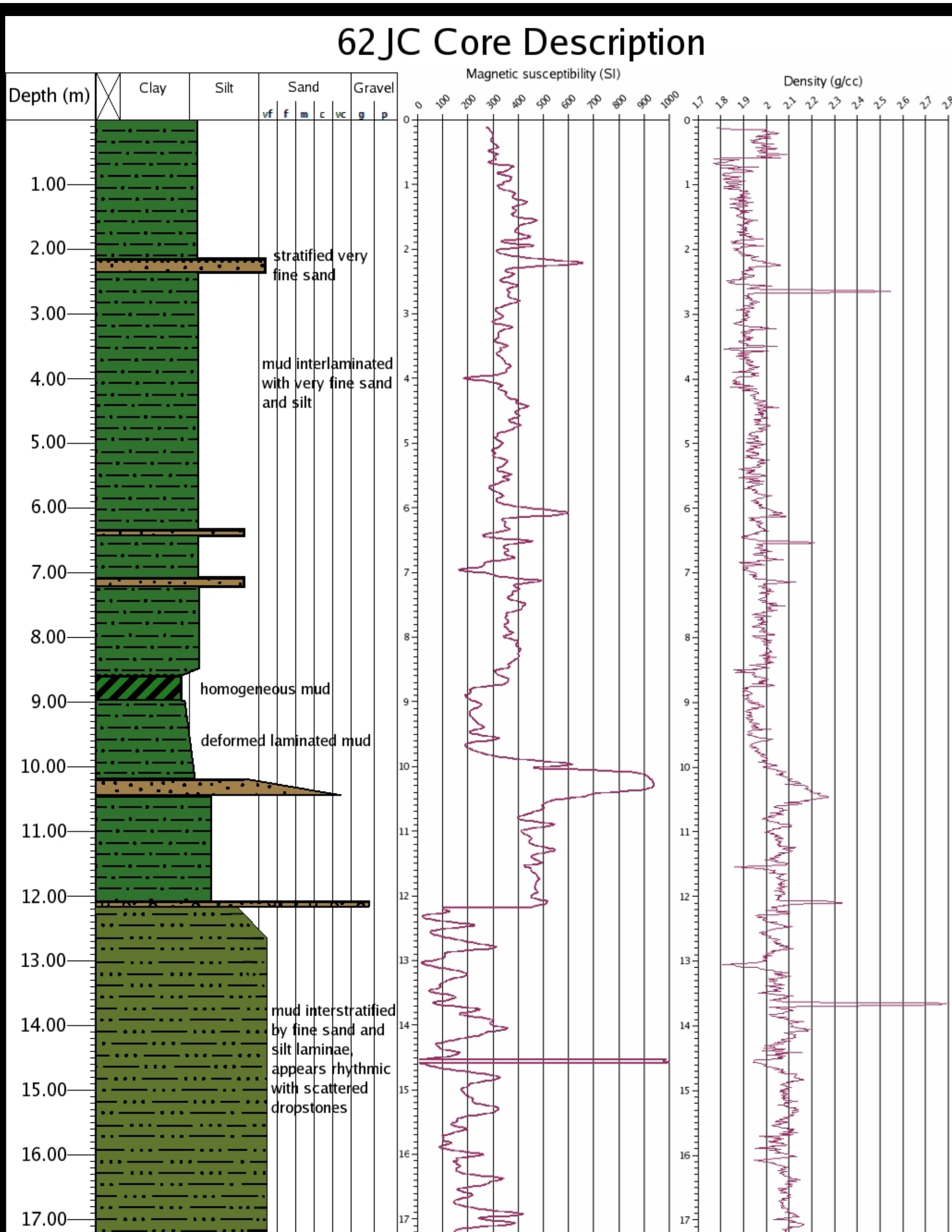
Two peaks each year:

- the initial flushing of sediment stored over winter, and
- peak glacier melt

Two core sites in Muir Inlet

basins opened up as Muir Glacier
retreated from 1907-1929 and 1929-1948





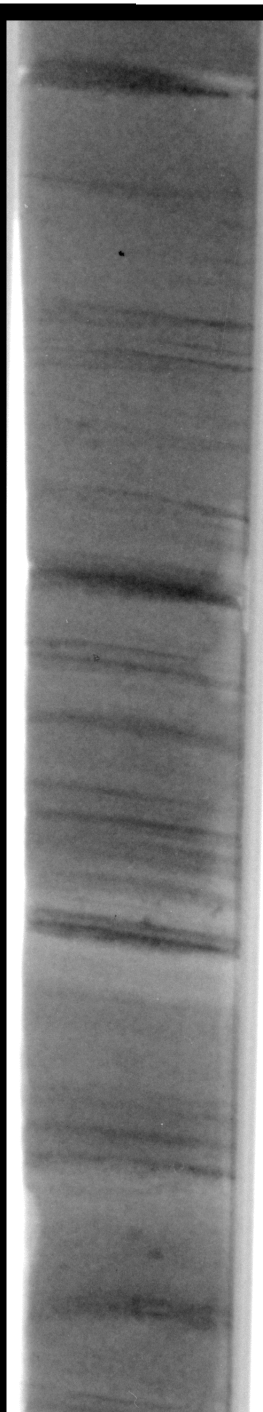
Core stratigraphy:

0-8.5 m cyclopels (fine grained couplets deposited from suspension; ave. rate 20 cm/yr)

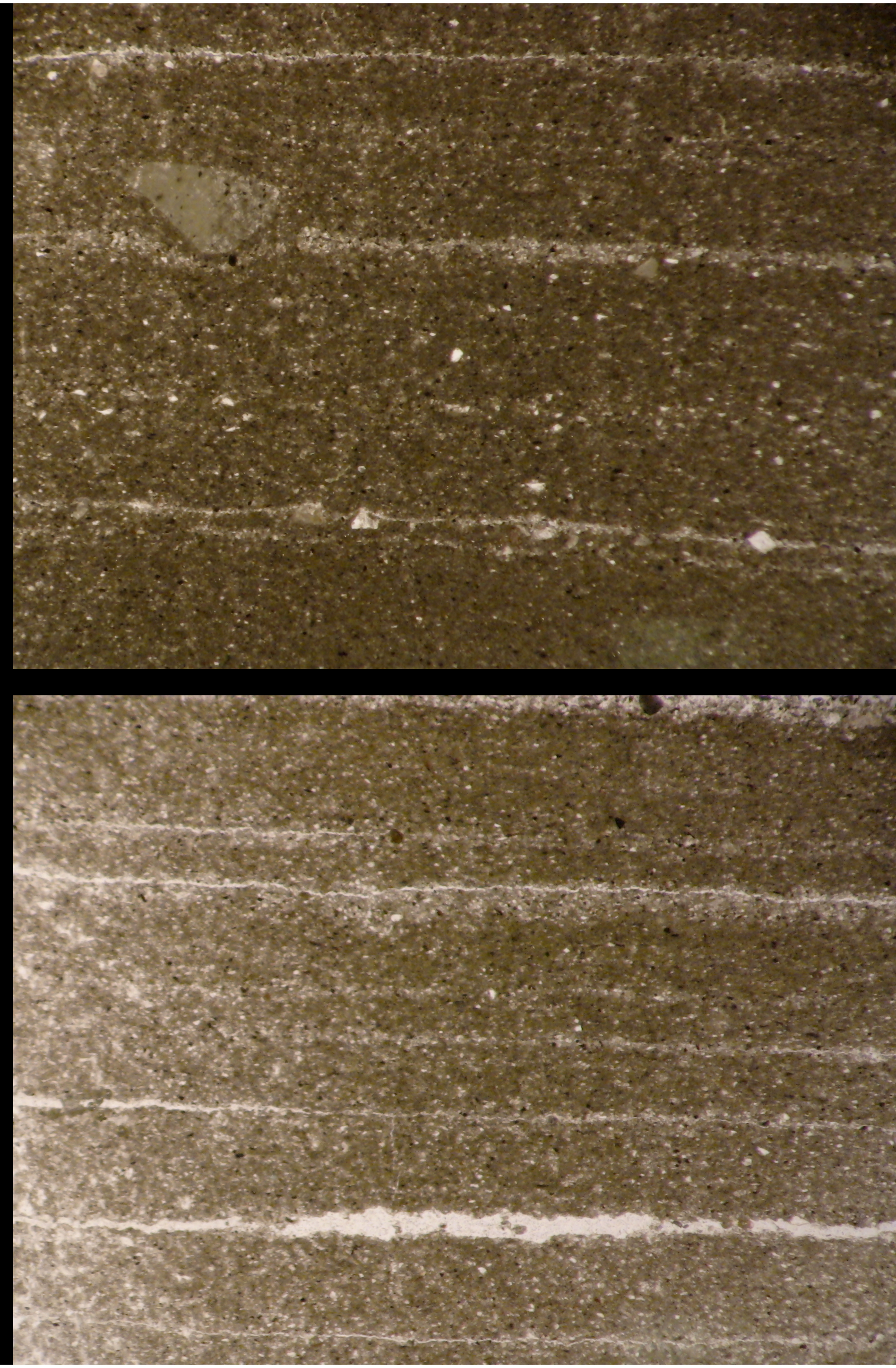
8.5-10.5 m sediment gravity flow unit

10.5-12 m cyclopels

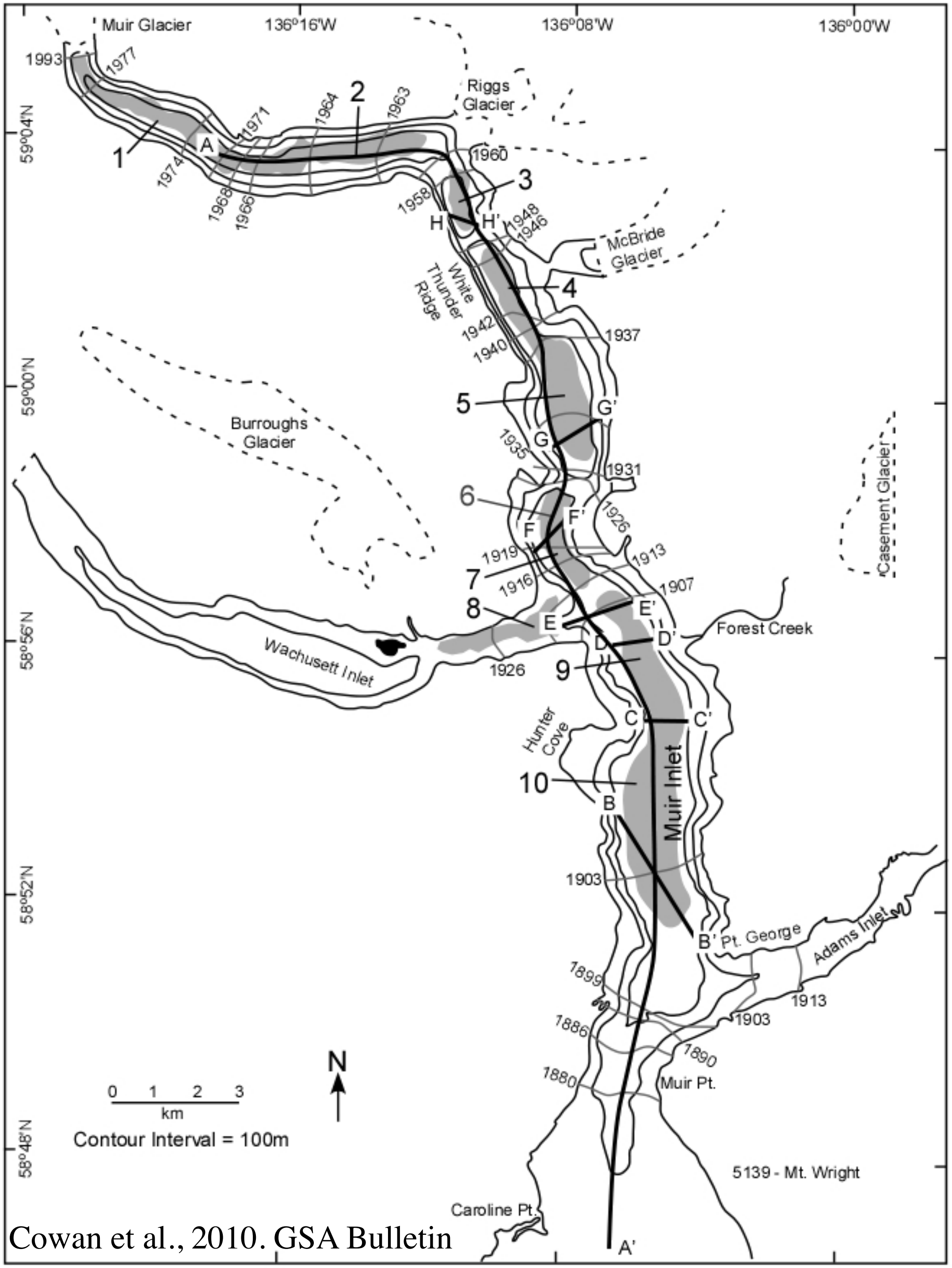
12-17. M cyclopsams (coarser grained couplets deposited from suspension).



62JC
x-ray
and
thin sections



Piston coring glacimarine sediment.

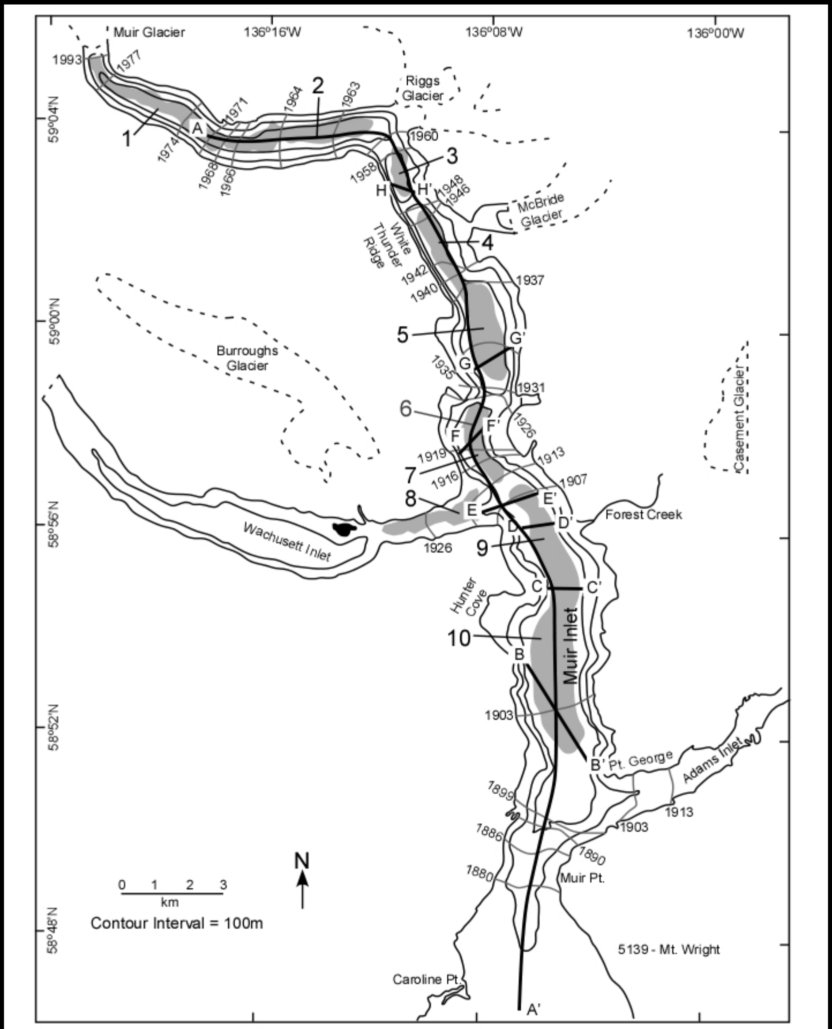


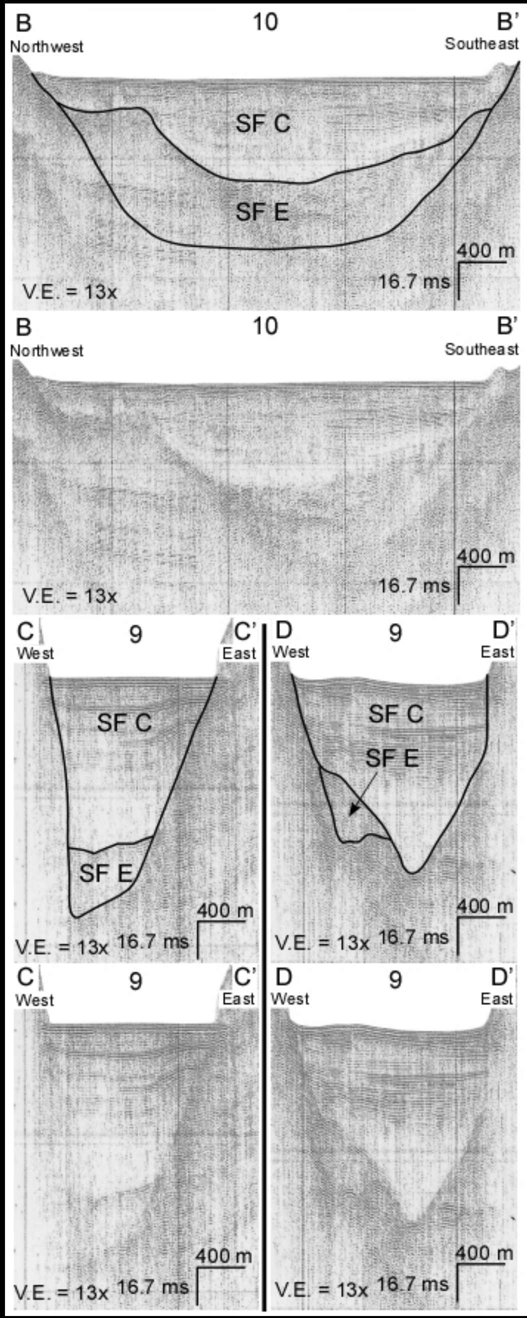
Cowan et al., 2010. GSA Bulletin

McBride Glacier in Muir Inlet in 1961.

McBride Glacier had retreated ~4 km into its inlet by 2004.

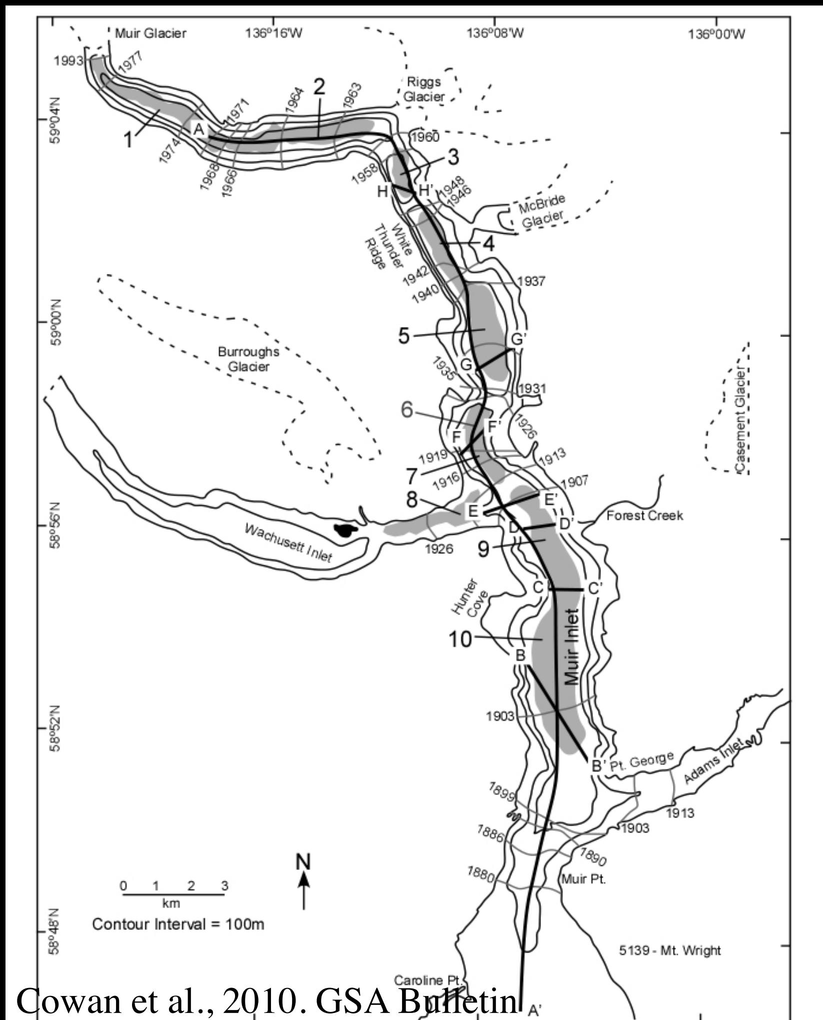
Basin sedimentary fill imaged on 0.5 kJ minisparker profiles collected by USGS(1978-1980).



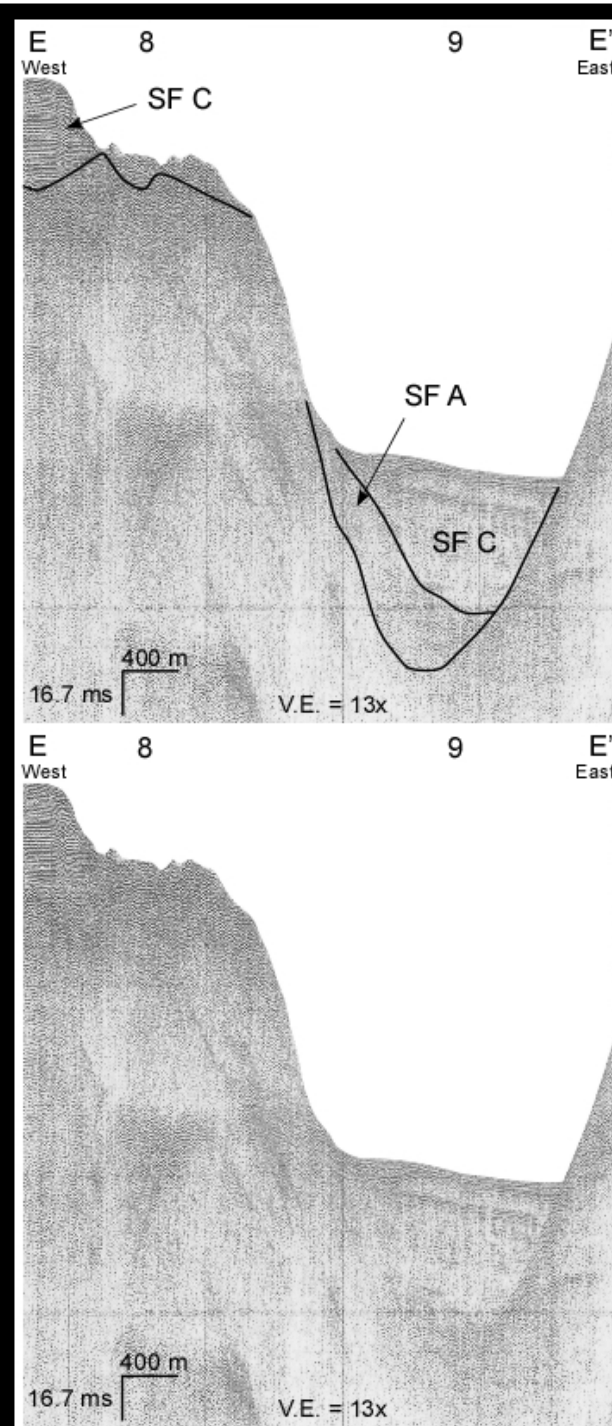


Cowan et al., 2010. GSA Bulletin

Sources of gravity flows: glacier termini, bedrock highs or fjord side walls



Cowan et al., 2010. GSA Bulletin



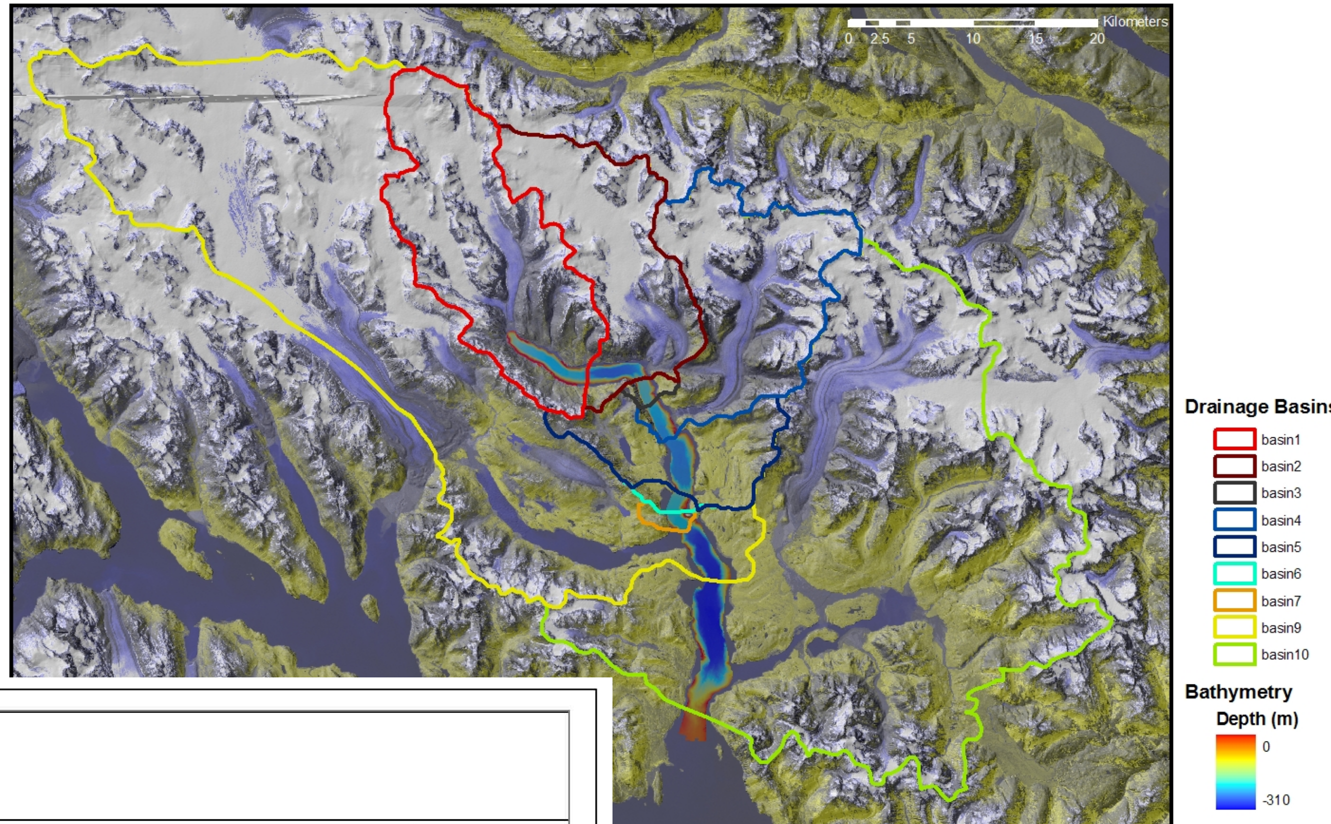
Basin Number	Water Depth (m)	LIA Contributing Drainage area (km^2)	LIA retreat Rate (km/a)	Fjord Floor Surface Area (km^2)	%Depositional surface composed of sidewalls	Volume of Sediment in LIA Basin (m^3)	Max. Sediment Thickness (m) LIA/LGM
1	268	283.56	0.90	4.8	73.8	1.50×10^7	35/ -
2	278	476.09	0.76	4.1	82.3	1.14×10^8	60/50
3	215	483.39	0.17	1.6	79.0	3.62×10^7	40/30
4	246	641.08	0.28	2.6	79.4	1.12×10^8	75/75
5	256	732.97	0.40	5.5	79.9	1.88×10^8	80/80
6	221	741.97	0.23	1.6	91.2	8.99×10^7	
7	228	14.80.47	0.23	1.6	91.2	6.68×10^7	75/20
8	80						
9	301	1510.62	1.30	5.4	84.6	3.79×10^8	70/ -
10	303	2487.93	1.14	12.3	60.1	6.47×10^8	75/300

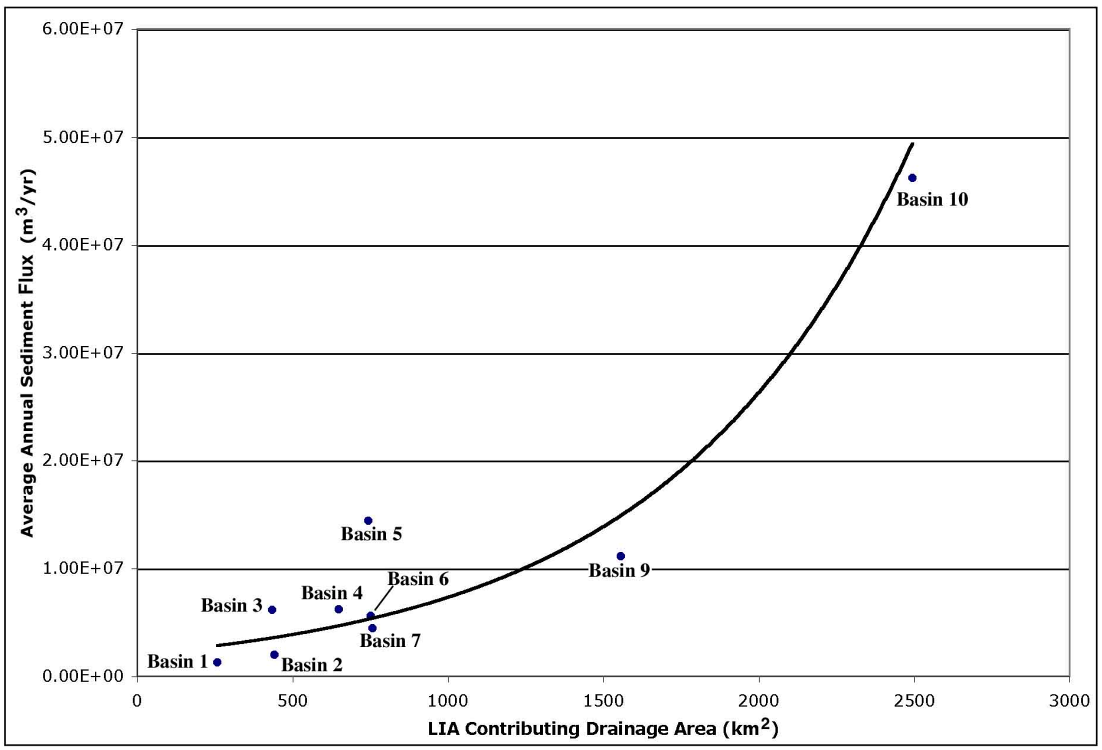
Cowan et al., 2010. GSA Bulletin

Basin Number	Volume of Sediment in LIA Basin (m^3)	Muir Glacier Proximal (years)	Other Sediment Sources Proximal (years)	Total Time of Proximal Sedimentation (years)	Average Annual Sediment Yield (m^3/yr)
1	1.50×10^7	4.5	7	11.5	1.30×10^6
2	1.14×10^8	8.5	10	18.5	6.16×10^6
3	3.62×10^7	8	10	18	2.01×10^6
4	1.12×10^8	8	10	18	6.22×10^6
5	1.88×10^8	8	5	13	1.45×10^7
6	8.99×10^7	11	5	16	5.62×10^6
7	6.68×10^7	4	11	15	4.45×10^6
9	3.79×10^8	8	26	34	1.11×10^7
10	6.47×10^8	4.5	9.5	14	4.62×10^7

Cowan et al., 2010. GSA Bulletin

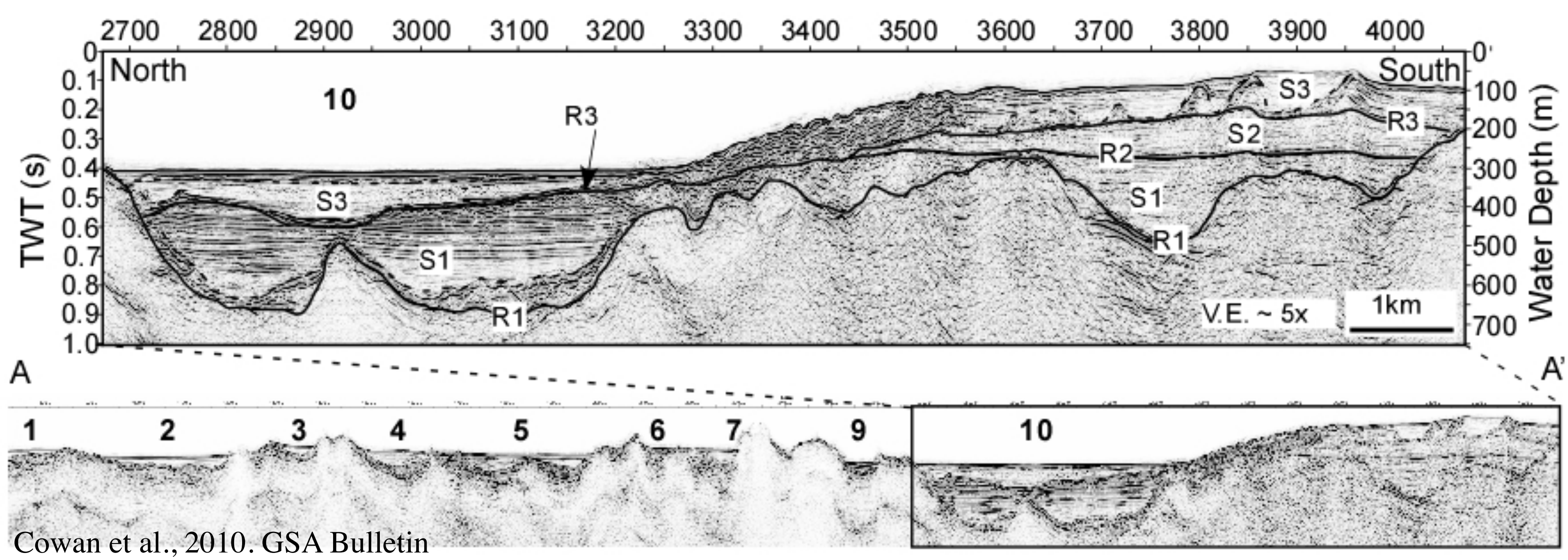
[redacted]





[redacted]

42.5 km longitudinal GI-gun line (firing dual 45 in^3 guns) collected by *UTIG*.

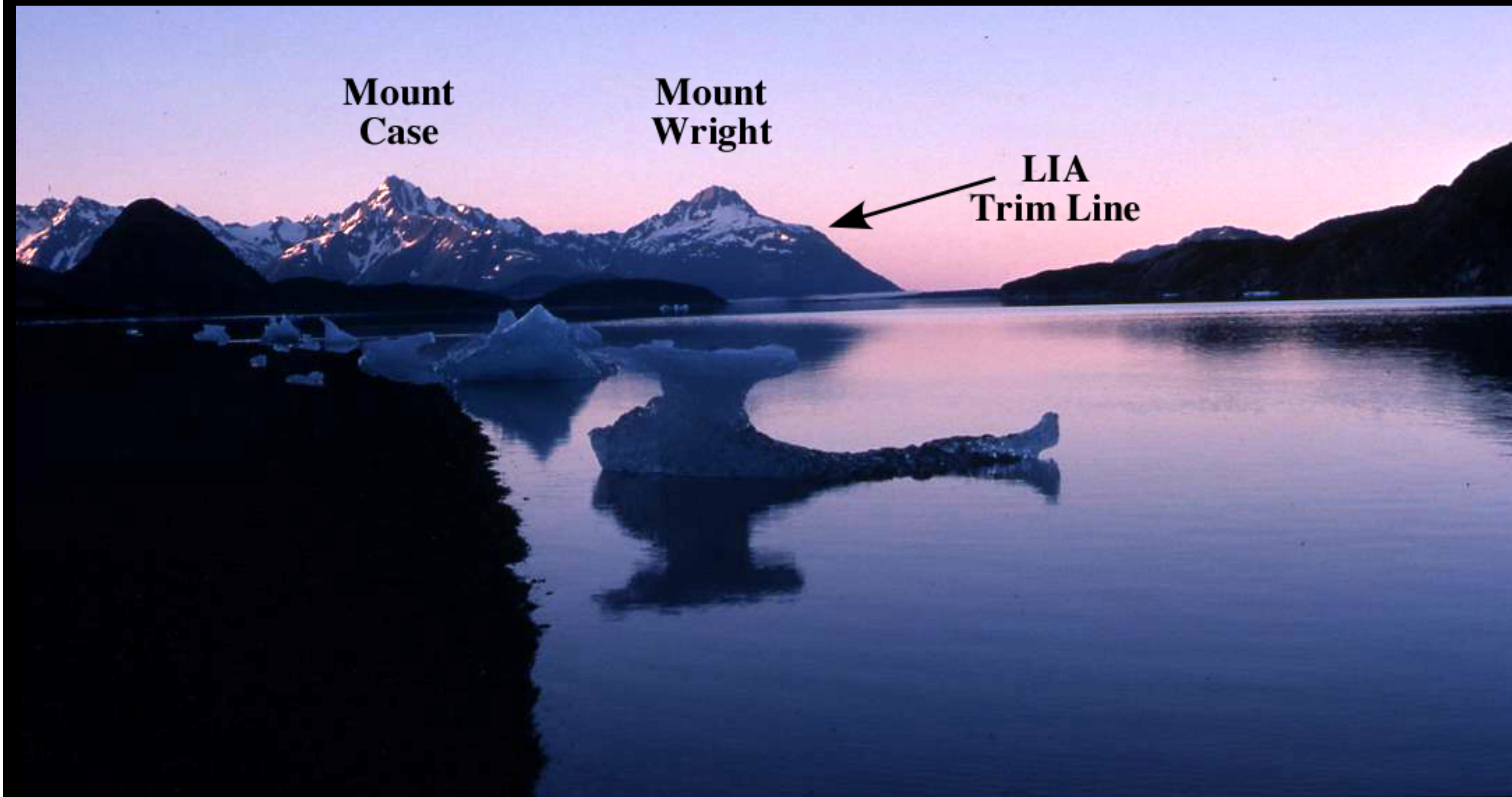


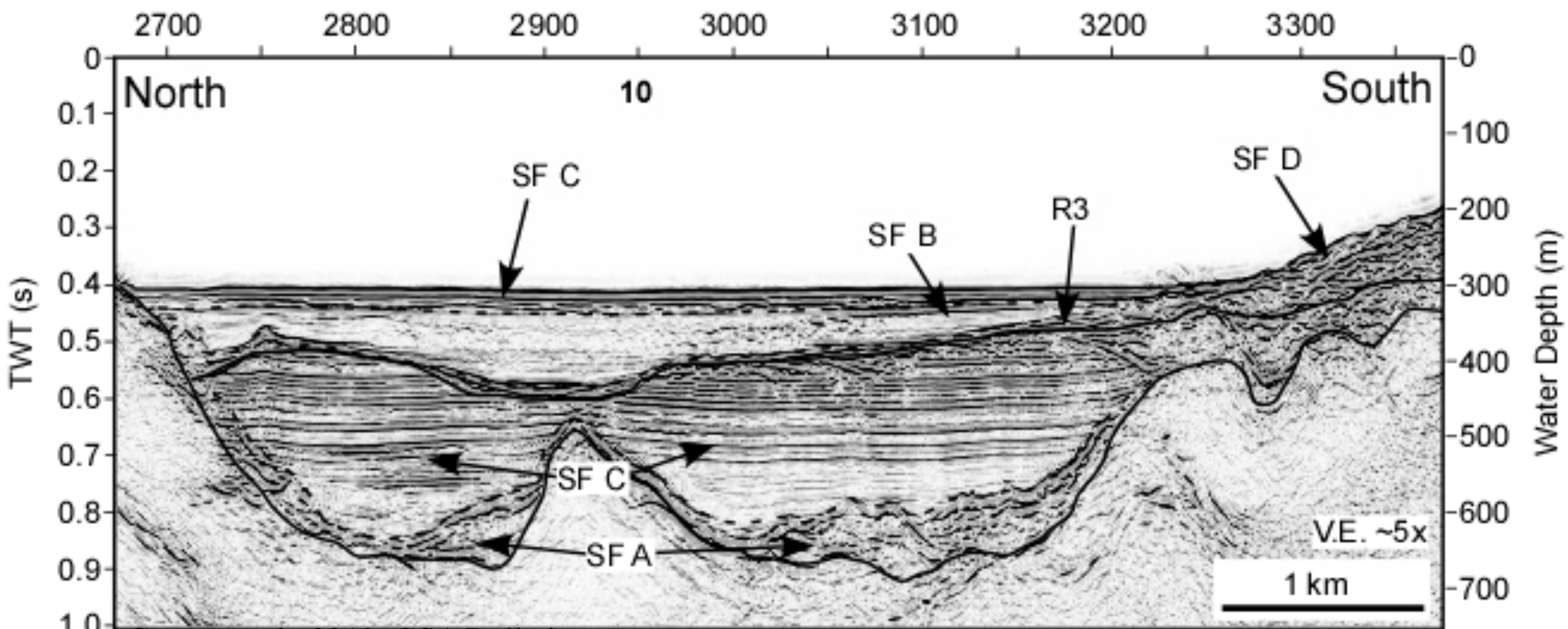
Cowan et al., 2010. GSA Bulletin

Three unconformities (R1-3) separate 3 glacial retreat depositional sequences (S1-3).

Little Ice Age (LIA) - ice thickness 1000 m; ice sheet advanced to the mouth of Glacier Bay

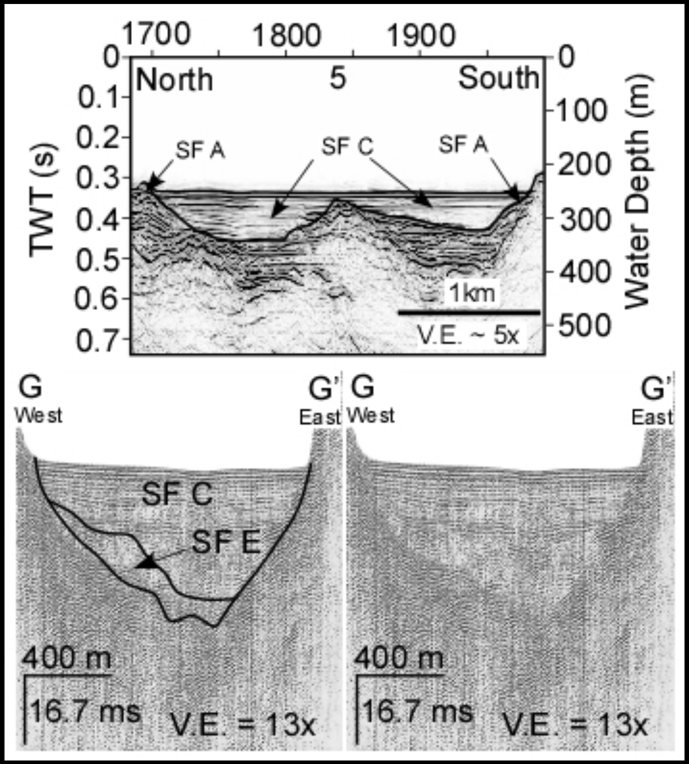
Late Pleistocene (LGM) - ice thickness 1700 m; ice sheet advanced to the continental shelf edge

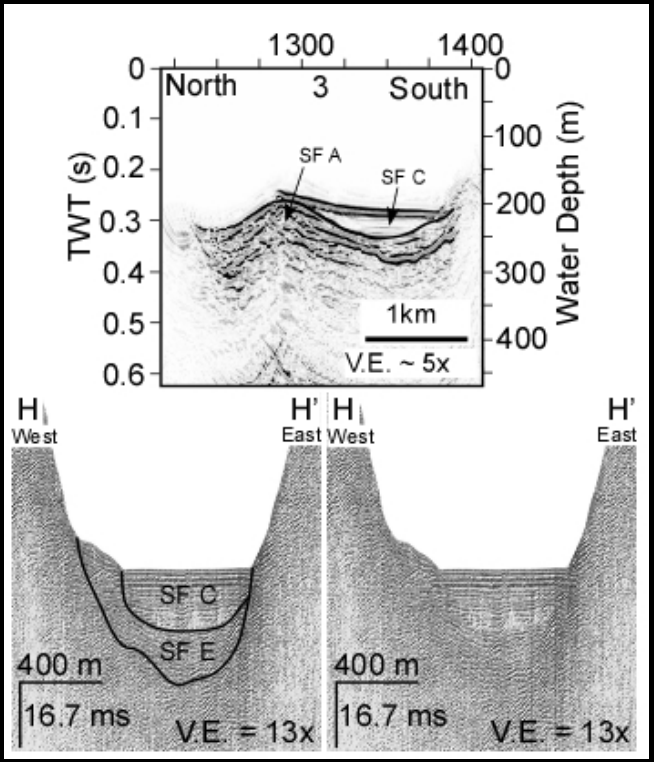

Mount
Case
Mount
Wright
LIA
Trim Line



Cowan et al., 2010. GSA Bulletin

Facies interpretation: SF A - ice contact or debris flows, SF B - distal fan deposits interfingering with basin fill, SF C - ponded basin fill deposited by suspension settling and sediment gravity flows, SF D - push ridges





The depth to contact between SF E and SF C matches the depth to R3. The minisparker imaged LIA fill but not penetrate LGM retreat deposits.

Cowan et al., 2010. GSA Bulletin

Tidewater terminus of Hubbard Glacier in Disenchantment Bay, Southern Alaska in August 2004.