Lecture 1: Tectonic and Climatic Setting of the Skeena Watershed

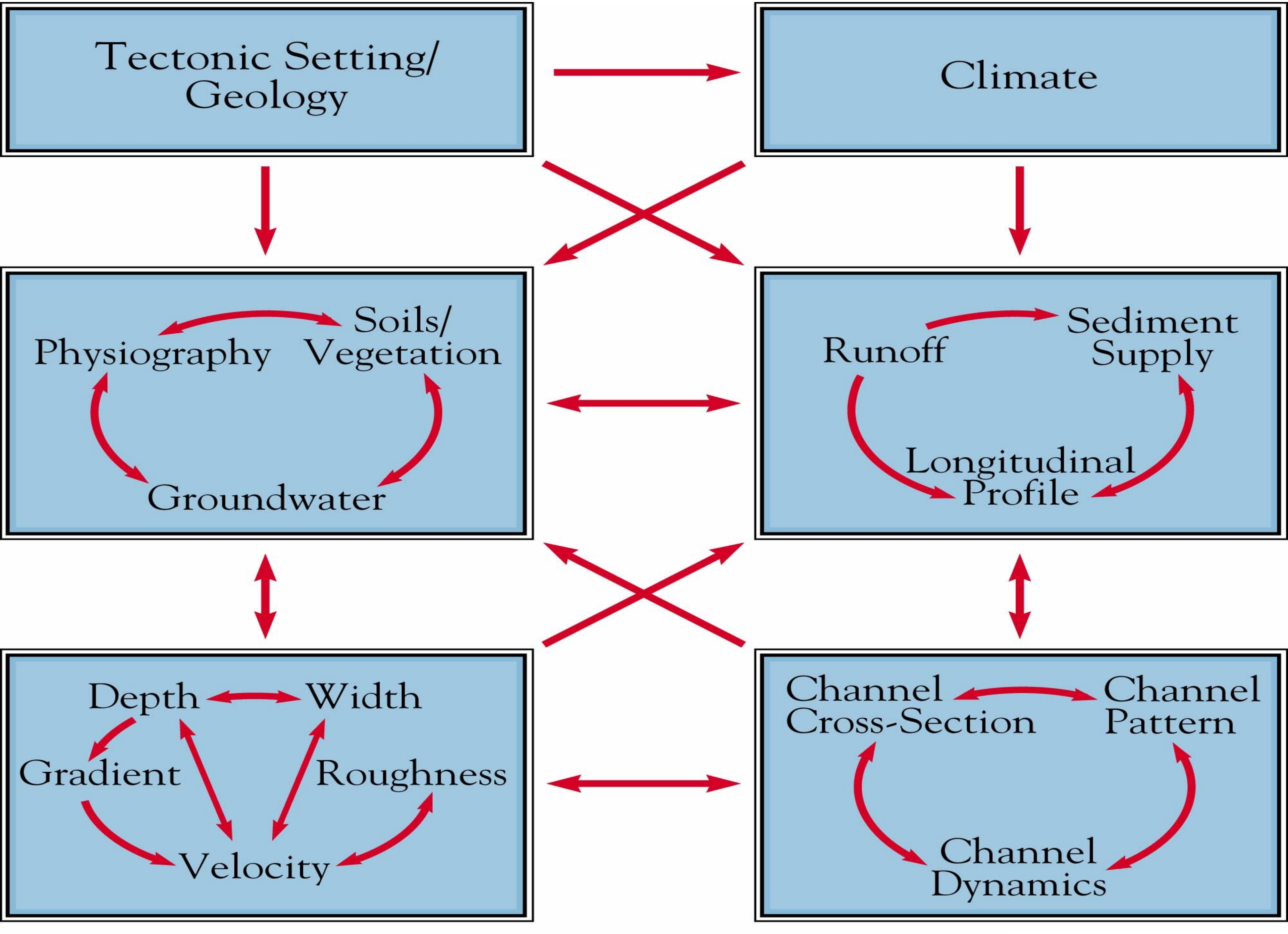
- Controls on Watershed Character
- Neotectonics of British Columbia
- Climate of British Columbia
- Hydrologic setting of the Skeena

Watershed Controls

- Dependent versus independent variables

Tectonic Setting

- Tectonics as a fundamental control on watershed rock type
- Tectonic control on style and rates of uplift
- Tectonic influences on regional and local climate



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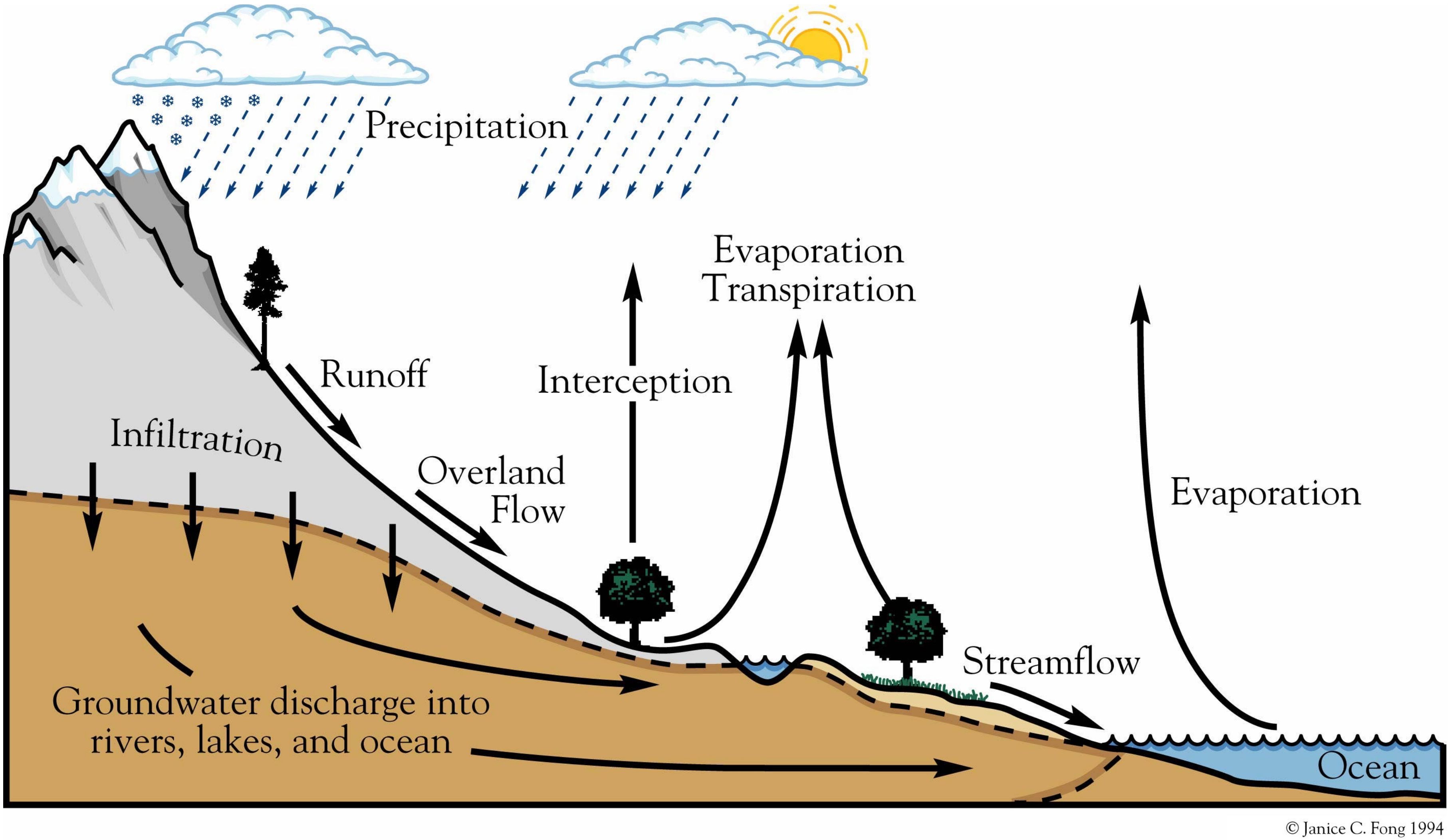
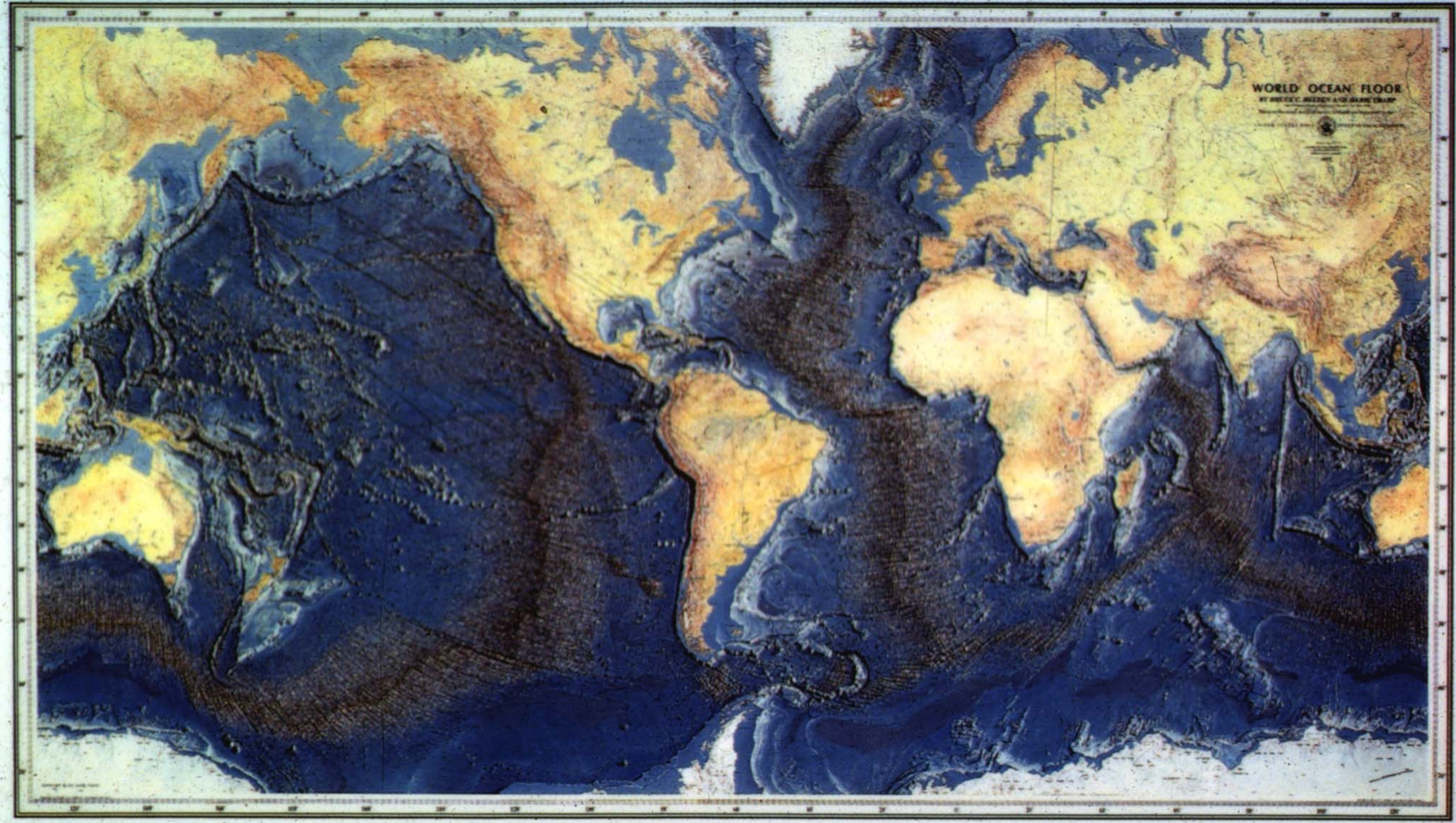
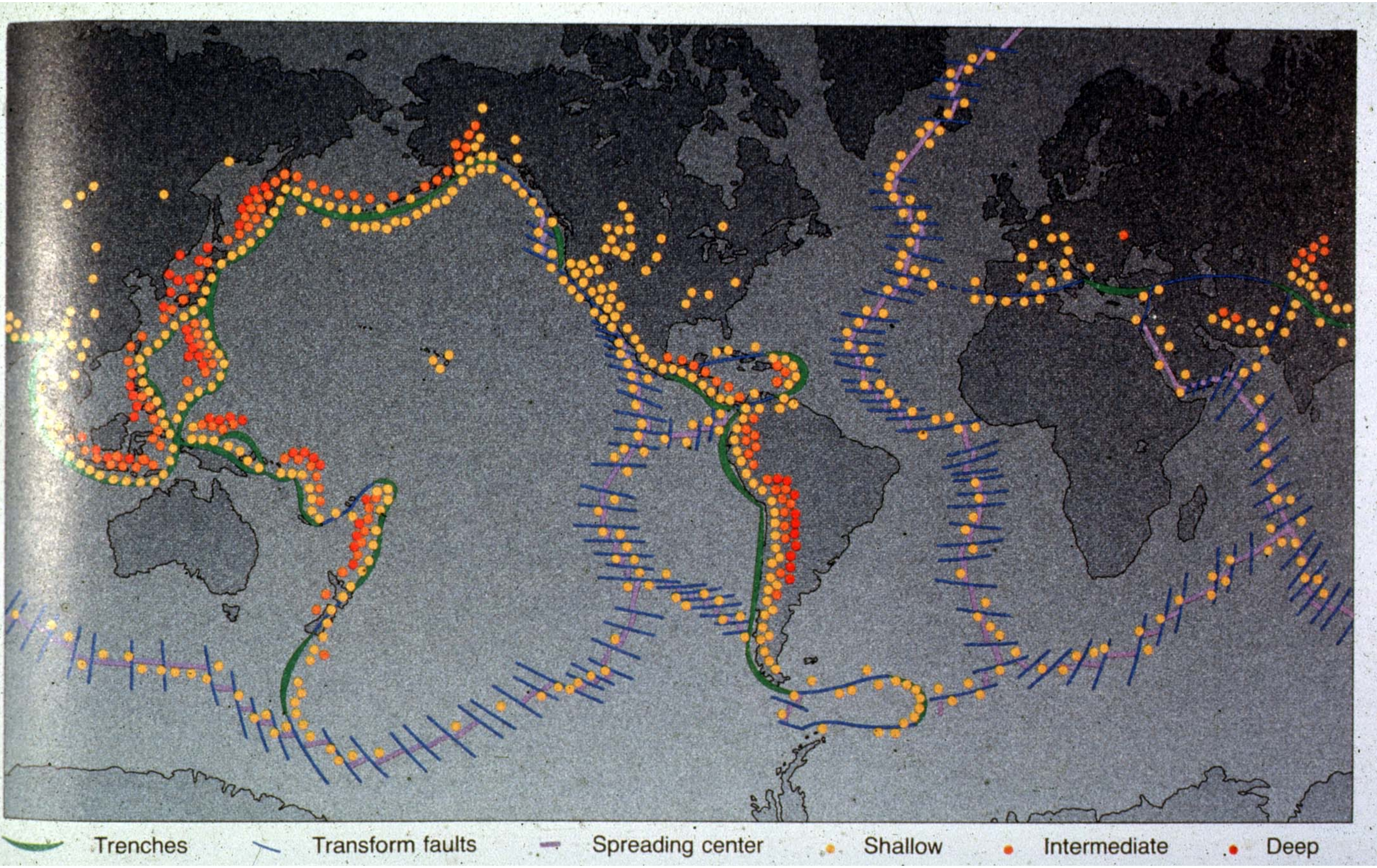
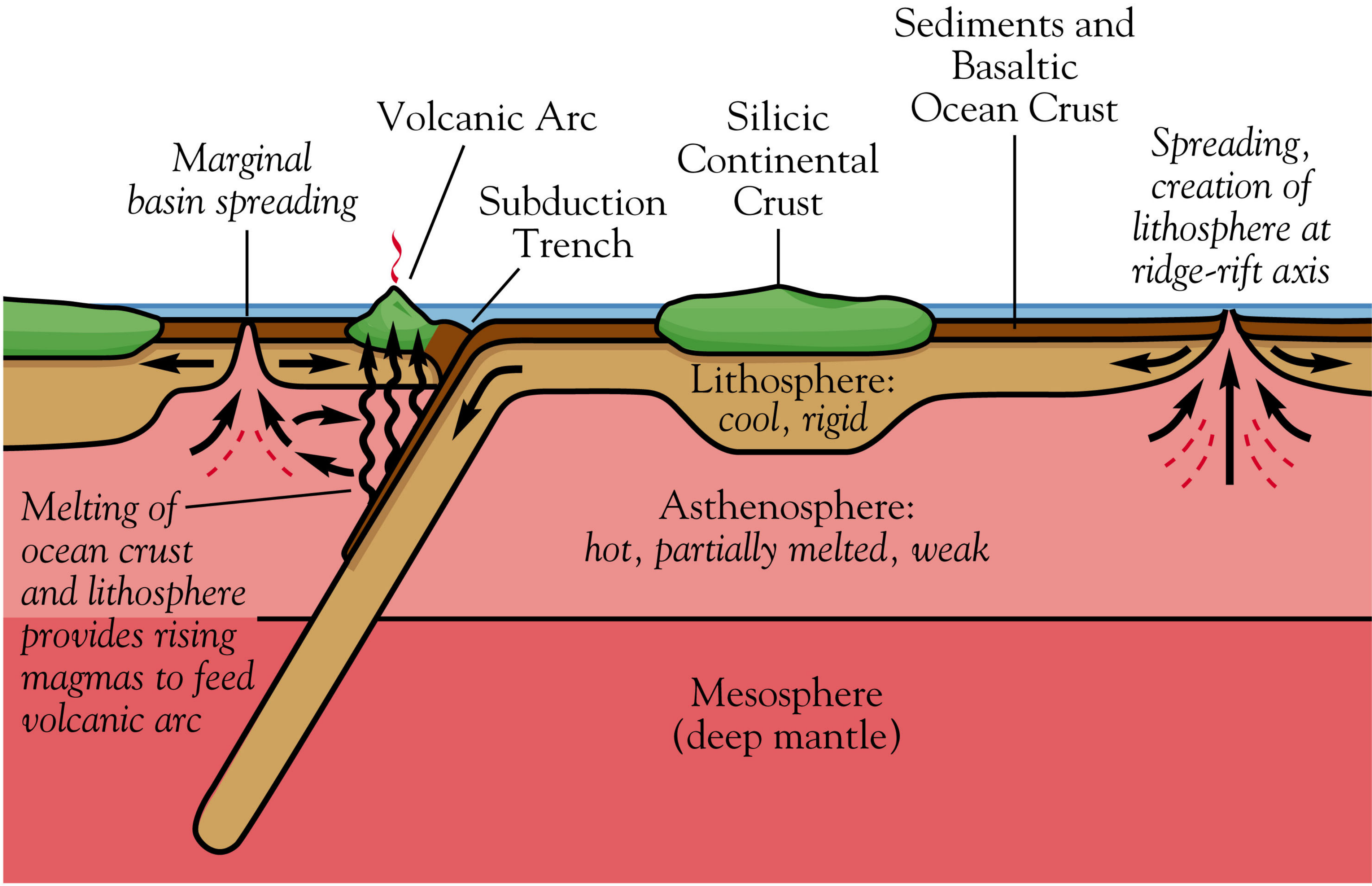


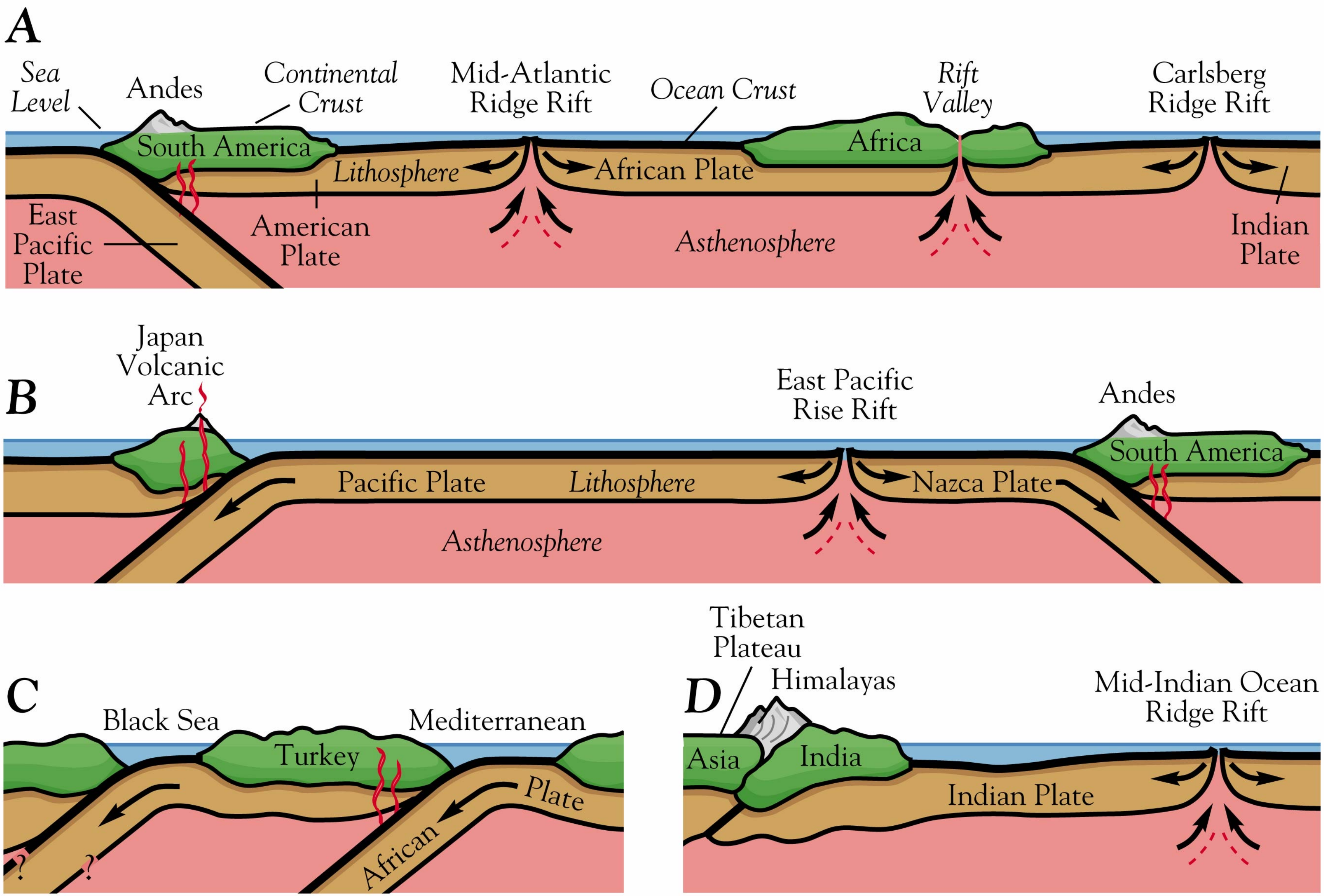
The Hydrologic Cycle


WORLD OCEAN FLOOR


Trenches
Transform faults
Spreading center
Shallow
Intermediate
Deep



Sediments and Basaltic Ocean Crust
Volcanic Arc
Silicic Continental Crust
Marginal basin spreading
Subduction Trench
Spreading, creation of lithosphere at ridge-rift axis
Lithosphere: cool, rigid
Melting of ocean crust and lithosphere provides rising magmas to feed volcanic arc
Asthenosphere: hot, partially melted, weak
Mesosphere (deep mantle)



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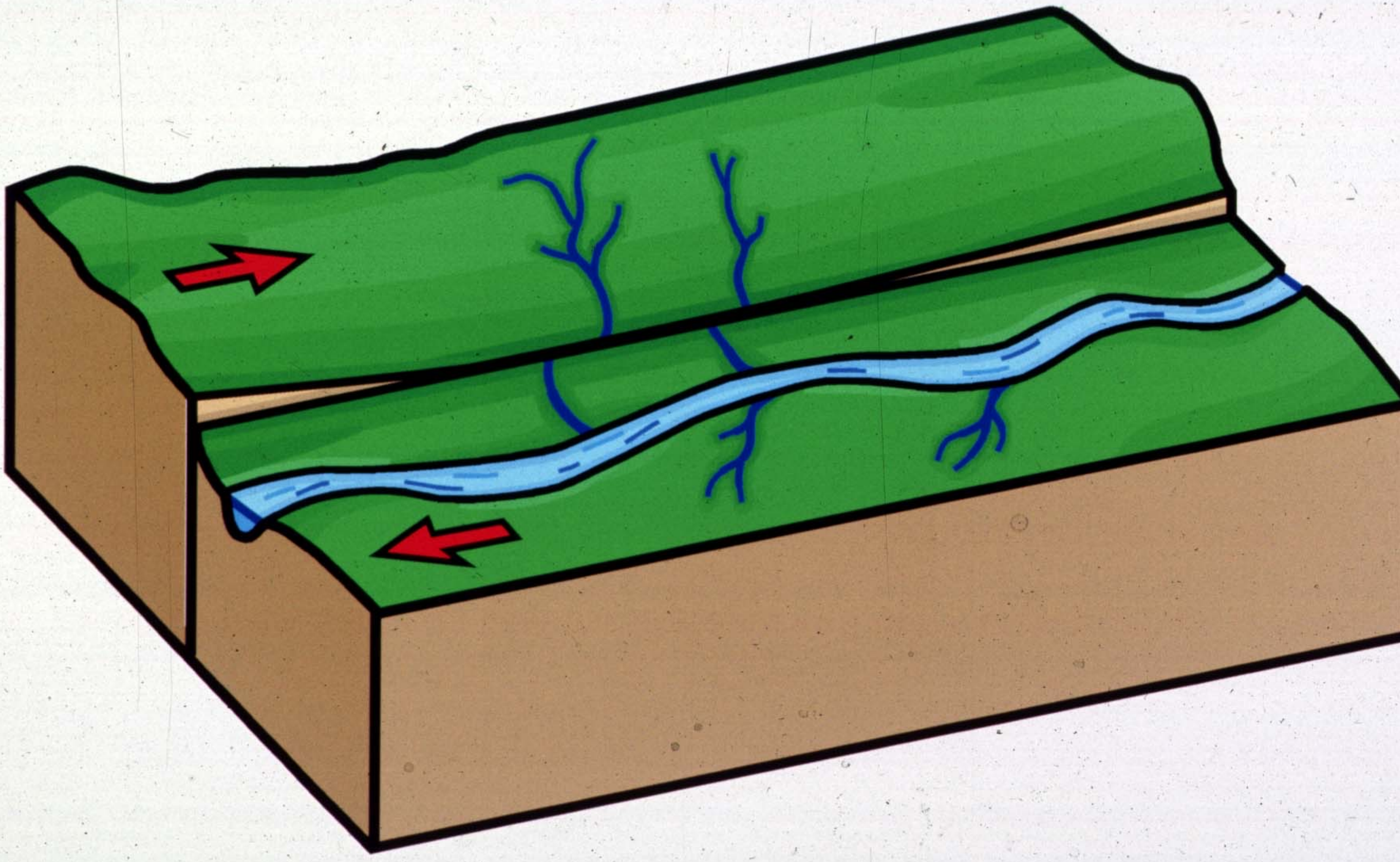

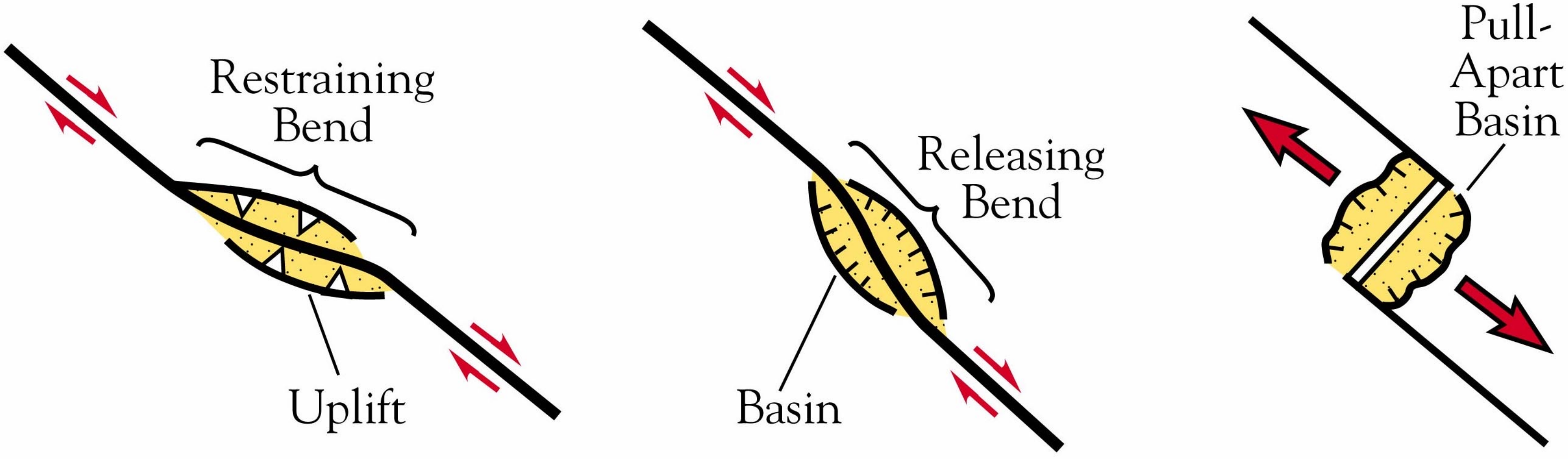

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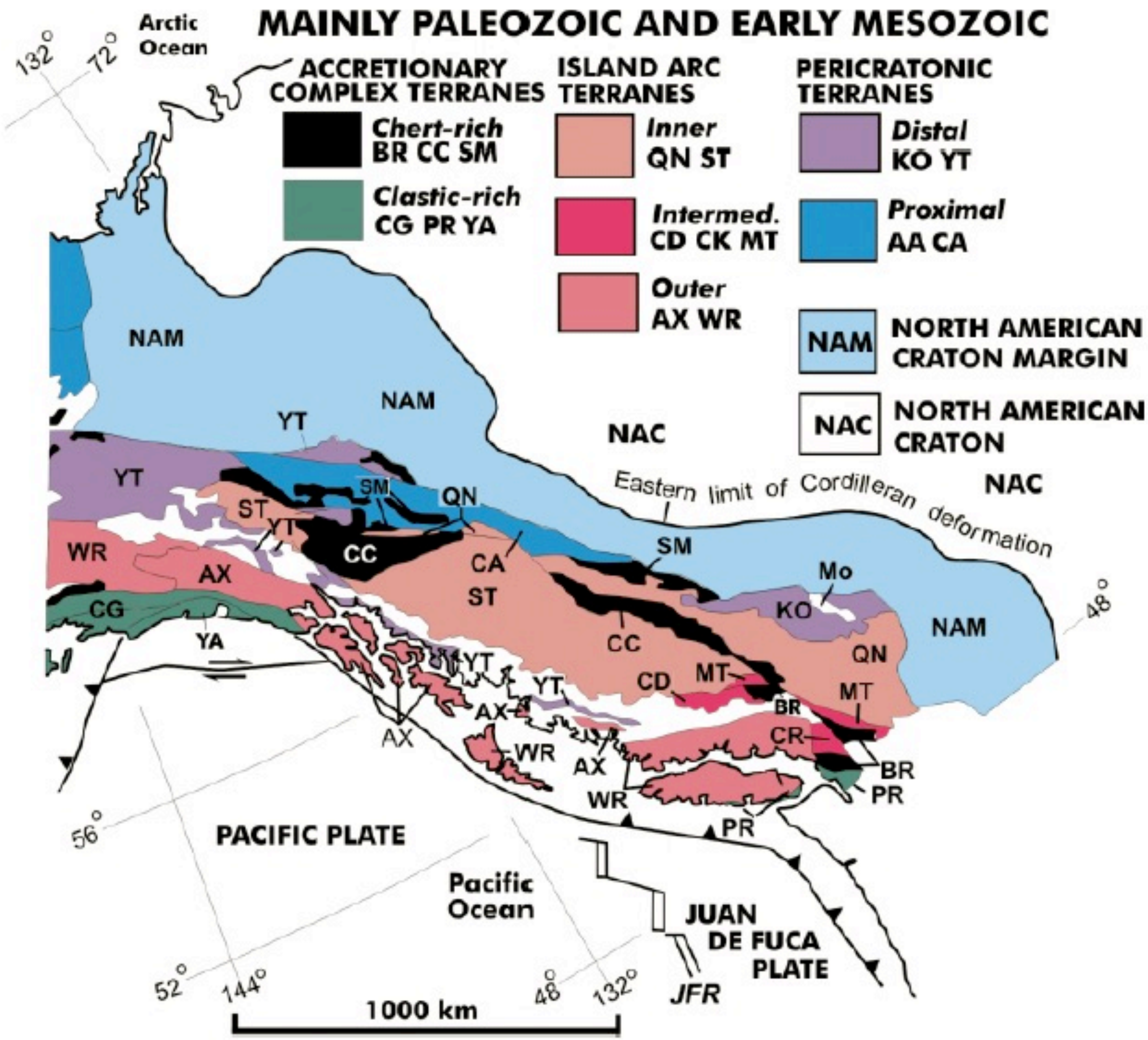
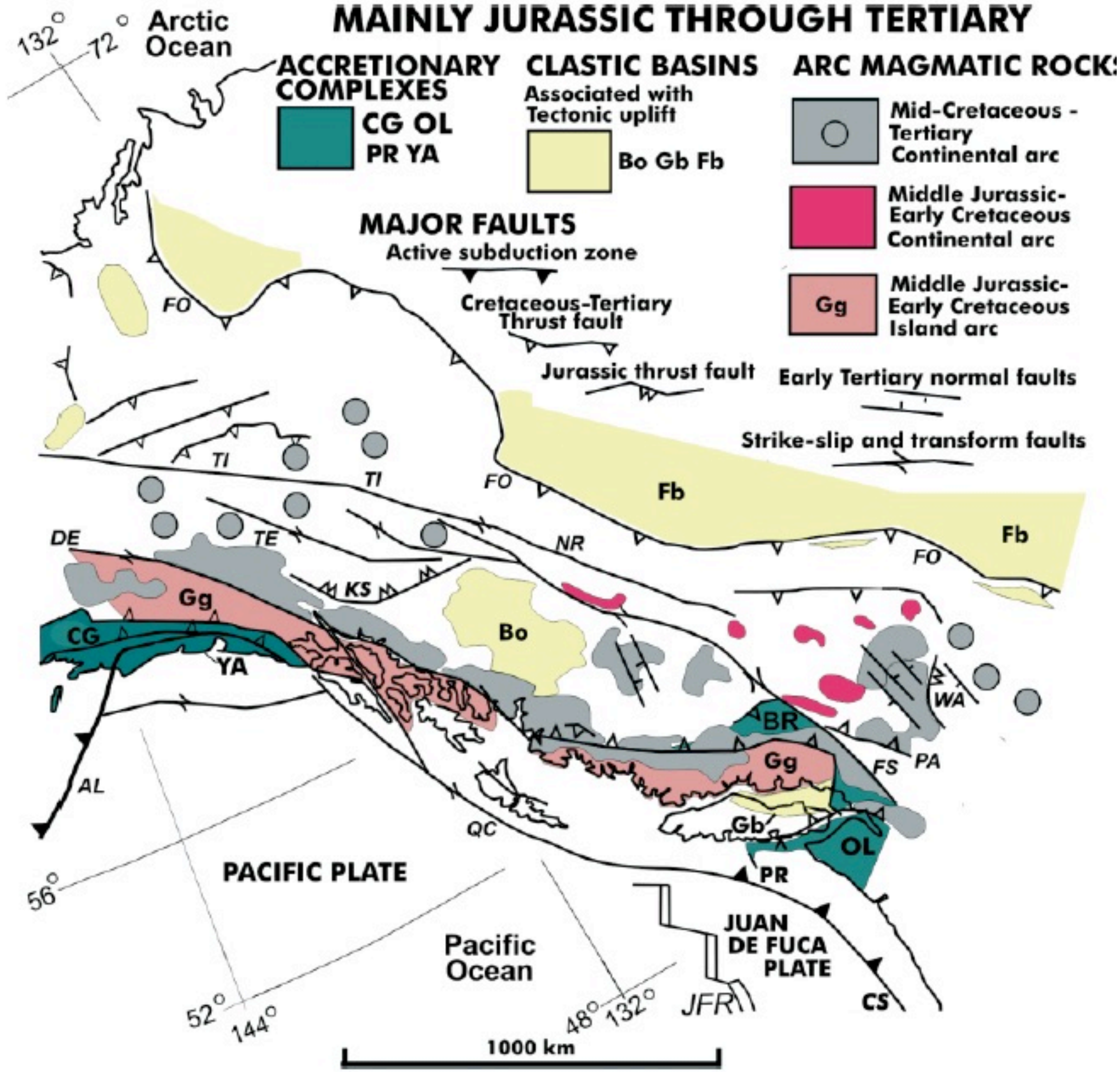
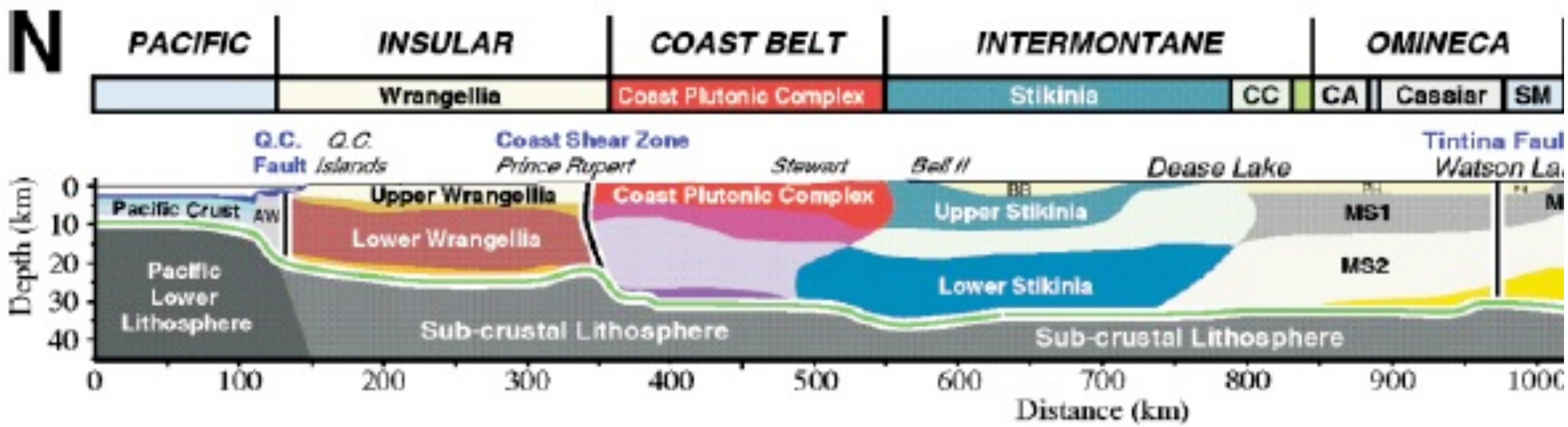
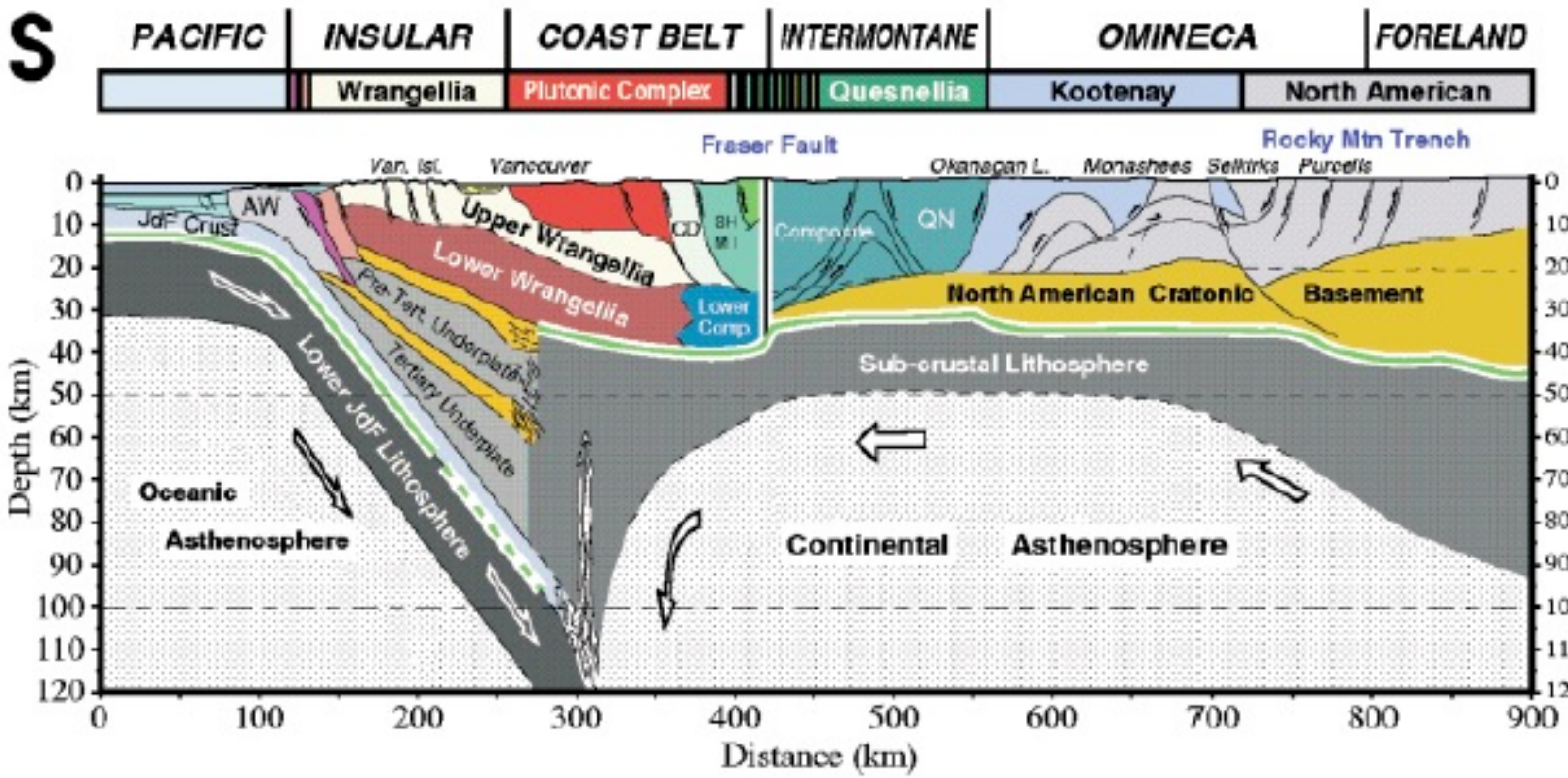
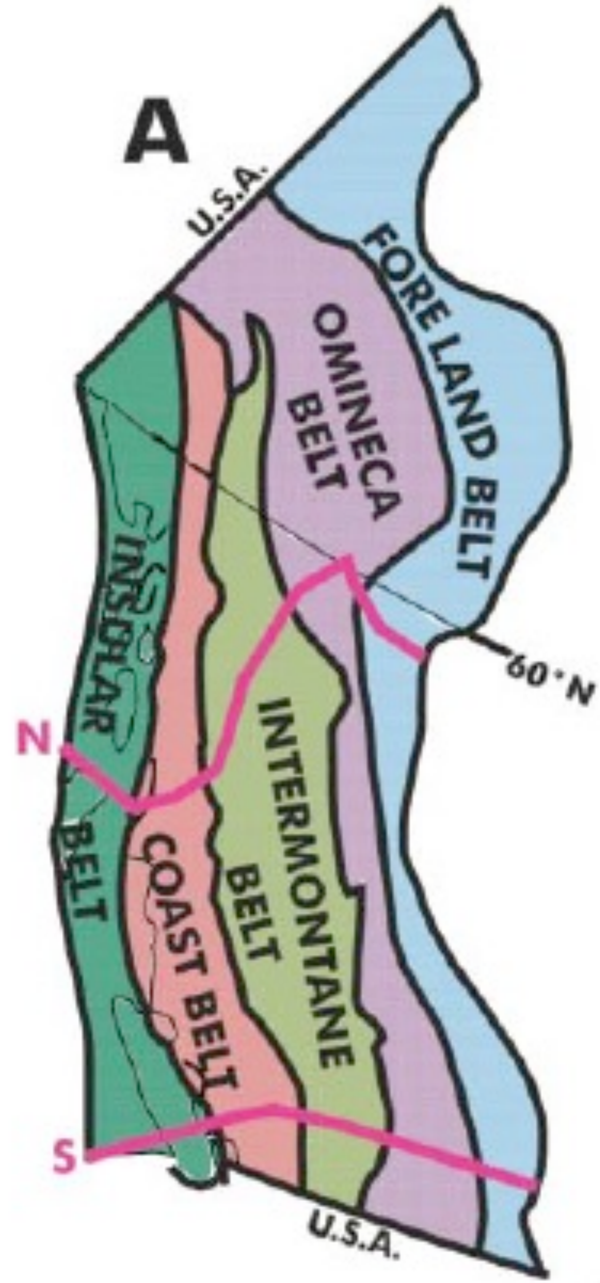

MAINLY PALEOZOIC AND EARLY MESOZOIC
Arctic Ocean
ACCRETIONARY COMPLEX TERRANES
Chert-rich BR CC SM
Clastic-rich CG PR YA
ISLAND ARC TERRANES
Inner QN ST
Intermed. CD CK MT
Outer AX WR
PERICRATONIC TERRANES
Distal KO YT
Proximal AA CA
NAM NORTH AMERICAN CRATON MARGIN
NAC NORTH AMERICAN CRATON
Eastern limit of Cordilleran deformation
NAM
NAC
YT
SM
QN
ST
CC
CA
WR
AX
CG
YA
KO
Mo
CD
MT
BR
CR
PR
PACIFIC PLATE
Pacific Ocean
JUAN DE FUCA PLATE
JFR
1000 km
132°
72°
48°
56°
52°
144°


MAINLY JURASSIC THROUGH TERTIARY
ACCRETIONARY COMPLEXES
CG OL
PR YA
CLASTIC BASINS
Associated with Tectonic uplift
Bo Gb Fb
ARC MAGMATIC ROCKS
Mid-Cretaceous - Tertiary Continental arc
Middle Jurassic-Early Cretaceous Continental arc
Middle Jurassic-Early Cretaceous Island arc
Gg
MAJOR FAULTS
Active subduction zone
Cretaceous-Tertiary Thrust fault
Jurassic thrust fault
Early Tertiary normal faults
Strike-slip and transform faults
Arctic Ocean
132°
72°
FO
TI
TI
FO
Fb
Fb
NR
FO
DE
TE
KS
Gg
CG
YA
Bo
BR
WA
Gg
FS
PA
AL
QC
Gb
OL
PR
PACIFIC PLATE
56°
Pacific Ocean
JUAN DE FUCA PLATE
52°
144°
48°
132°
JFR
CS
1000 km

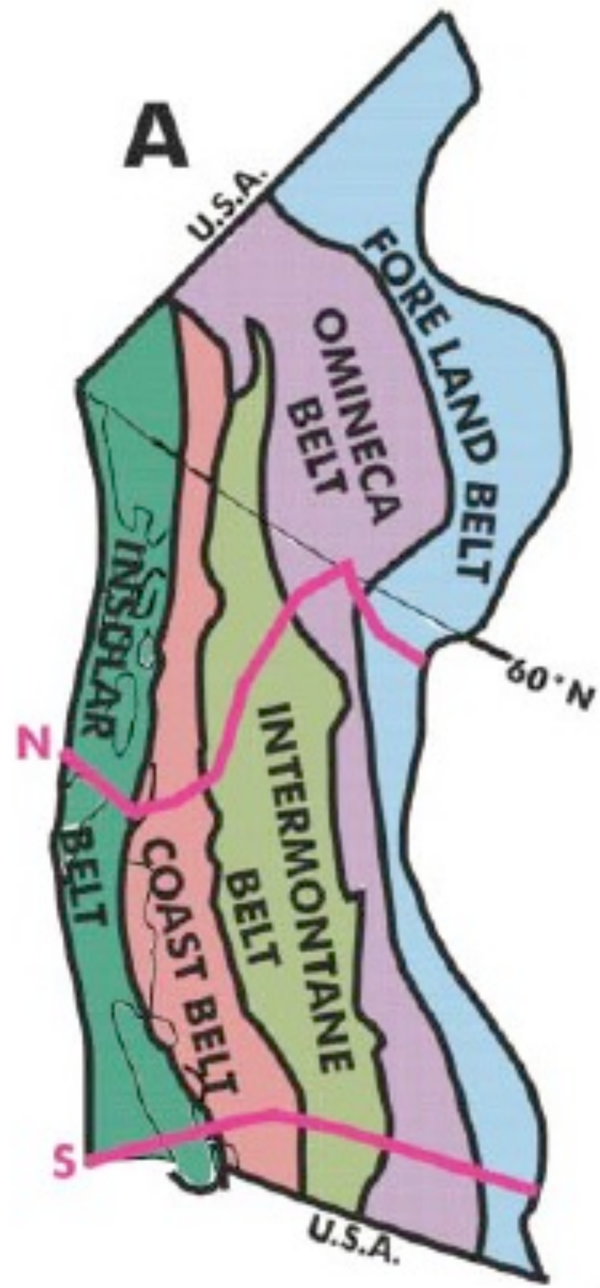


N
PACIFIC
INSULAR
COAST BELT
INTERMONTANE
OMINECA
Wrangellia
Coast Plutonic Complex
Stikinia
CC
CA
Cassiar
SM
Q.C. Fault
Q.C. Islands
Coast Shear Zone
Prince Rupert
Stewart
Bell II
Dease Lake
Watson La
Upper Wrangellia
Lower Wrangellia
Coast Plutonic Complex
Upper Stikinia
Lower Stikinia
Pacific Crust
AW
MS1
MS2
Pacific Lower Lithosphere
Sub-crustal Lithosphere
Sub-crustal Lithosphere
Depth (km)
0
10
20
30
40
0
100
200
300
400
500
600
700
800
900
Distance (km)

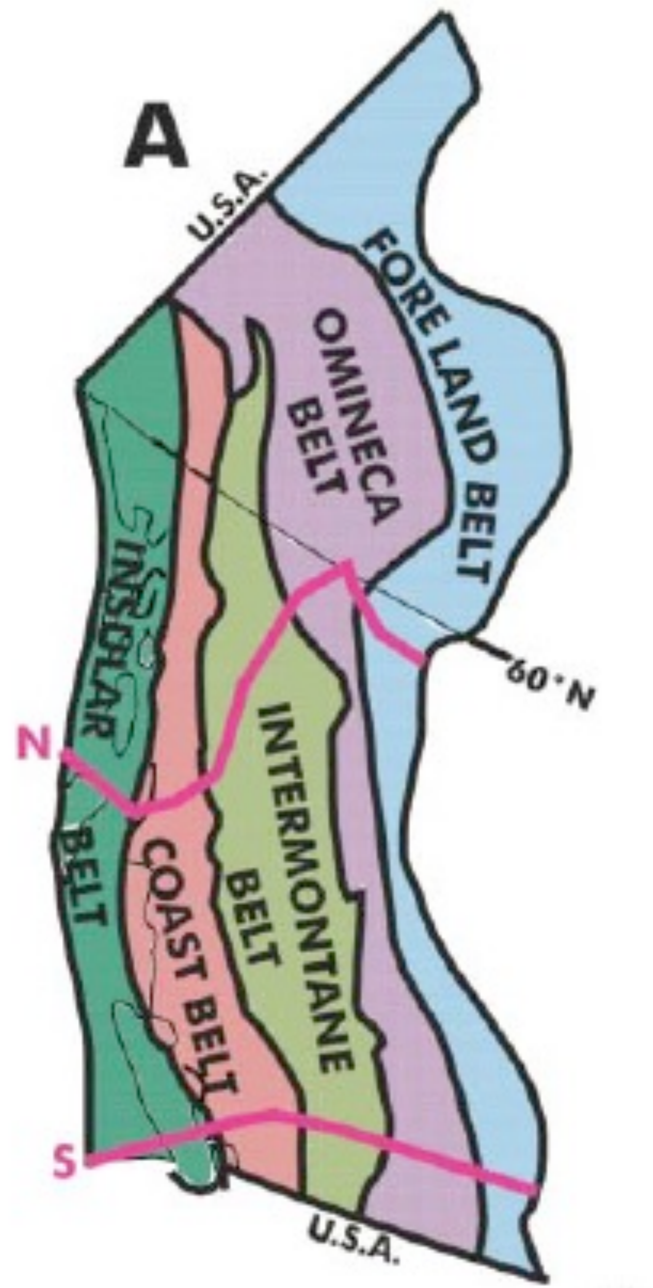

S
PACIFIC
INSULAR
COAST BELT
INTERMONTANE
OMINECA
FORELAND
Wrangellia
Plutonic Complex
Quesnellia
Kootenay
North American
Fraser Fault
Rocky Mtn Trench
Van. Isl.
Vancouver
Okanagan L.
Monashees
Selkirks
Purcells
JdF Crust
AW
Upper Wrangellia
Lower Wrangellia
CD
Lower Comp.
QN
North American Cratonic Basement
Sub-crustal Lithosphere
Pre-Tert. Underplate
Tertiary Underplate
Lower JdF Lithosphere
Oceanic Asthenosphere
Continental Asthenosphere
Depth (km)
Distance (km)
0
10
20
30
40
50
60
70
80
90
100
110
120
0
100
200
300
400
500
600
700
800
900



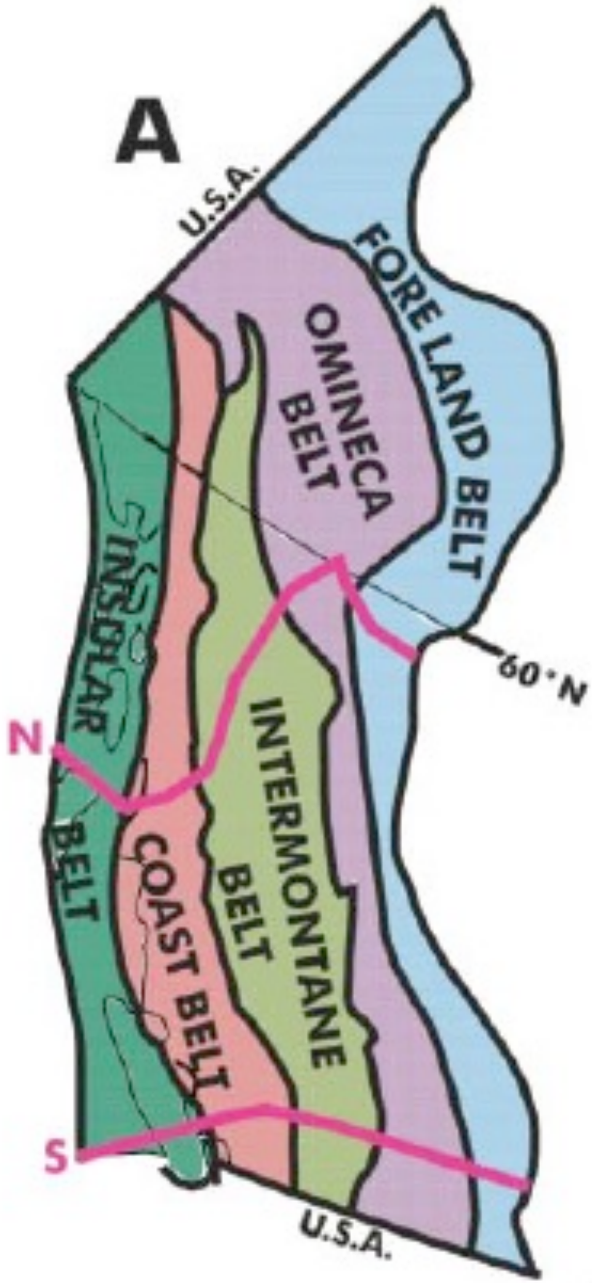
- Five Morphogeologic Belts in Canadian Cordillera
- Each belt with distinctive rock types, landforms
- Belts reflect 750 my of activity at North American Plate margin



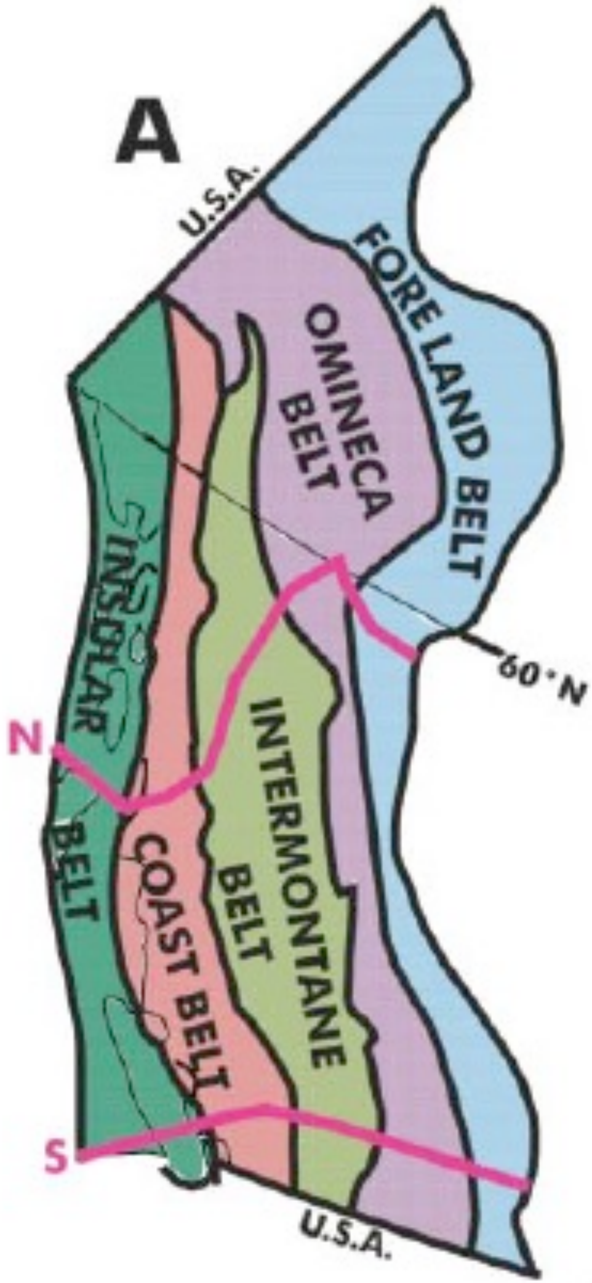
- Foreland Belt: Rocky, Mackenzie and Franklin Mountains
- Precambrian and Paleozoic sedimentary rocks
- Western margin of North America until Jurassic
- Folded and thrust eastward in late Jurassic-Early Tertiary



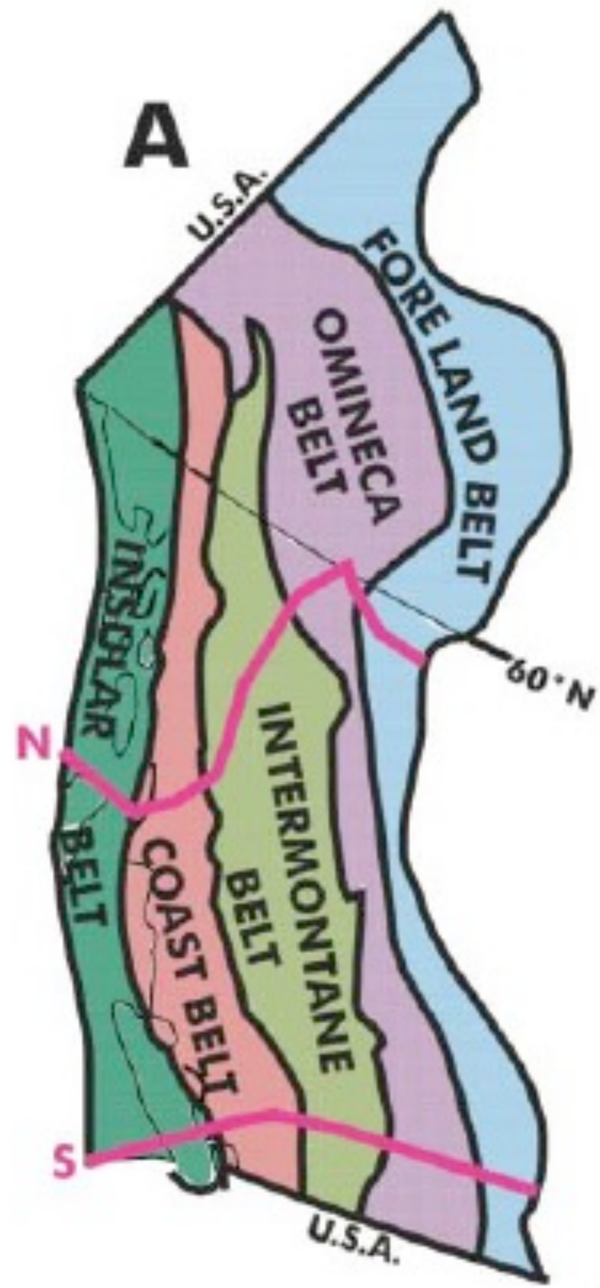
- Omineca Belt: Purcell, Selkirk, Monashee, Cariboo, Omineca, Cassiar and Selwyn Mountains
- Sedimentary, volcanic and granitic rocks
- Accreted terranes
- Granitic/volcanic rocks of arc
- Deforemed in late Jurassic-early Teritary



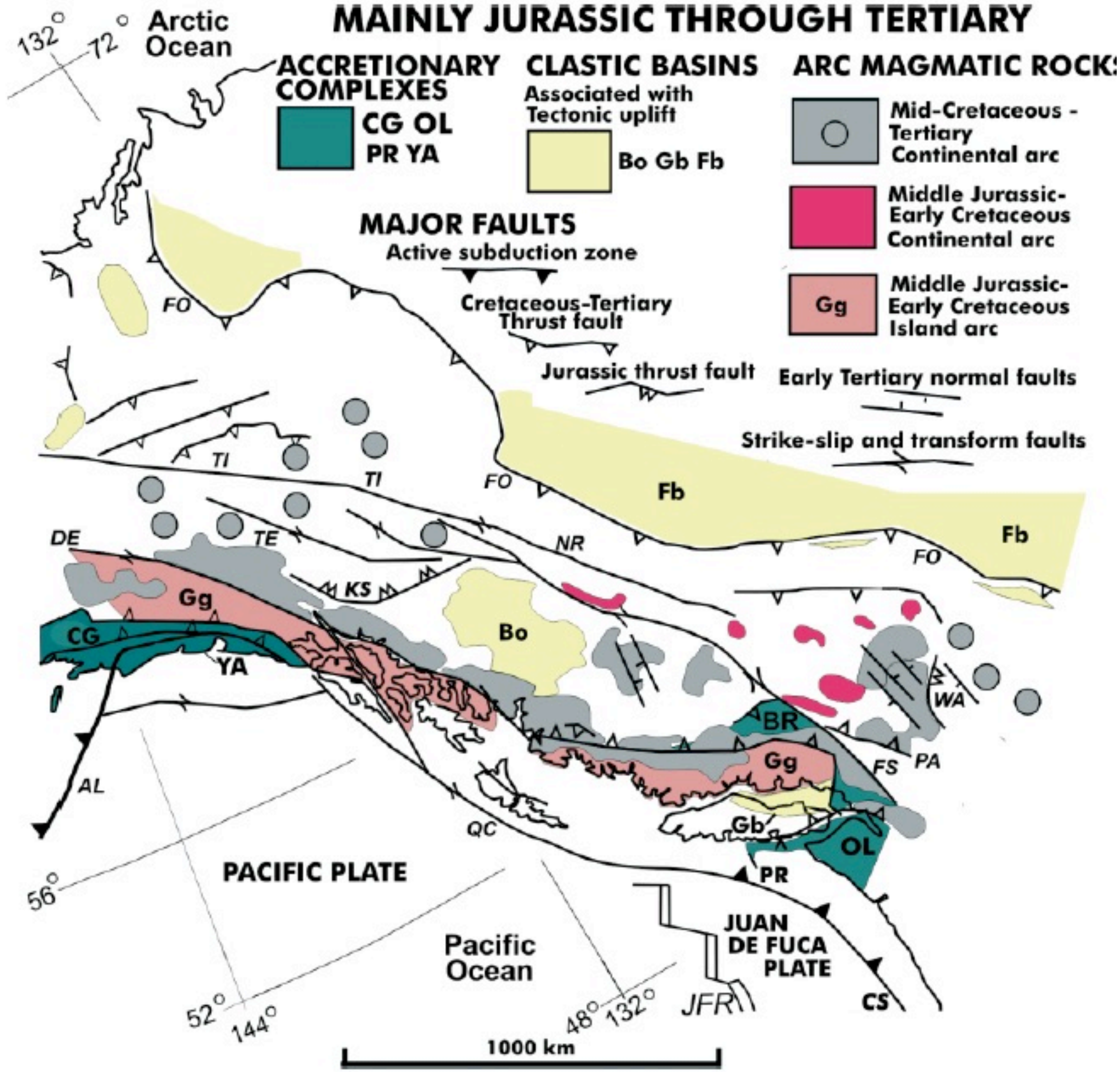
- Intermontane Belt: Interiar, Stikine and Yukon Plateaus and Skeena Mountains
- Volcanic, sedimentary and granitic rocks
- Accreted terranes (Stikine)
- Thick sedimentary deposites of Mesozoic-early Teritiary age (Bowser Basin)
- Extensional basins in Mesozoic and Cenozoic
- Volcanic arcs



- Coast Belt: Coast and Cascade Mountains
- Granitic and volcanic rocks
- Jurassic through present-day volcanic arcs
- Large strike-slip or transform faults
- Local accreted terranes



- Insular Belt: Insular Mountains, Saint Elias Ranges, coastal depressions, islands, continental shelf and slope
- Volcanic, sedimentary and granitic rocks
- Subduction zone accretion
- Volcanic arcs
- Large strike-slip faults



MAINLY JURASSIC THROUGH TERTIARY
ACCRETIONARY COMPLEXES
CG OL
PR YA
CLASTIC BASINS
Associated with Tectonic uplift
Bo Gb Fb
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Jurassic thrust fault
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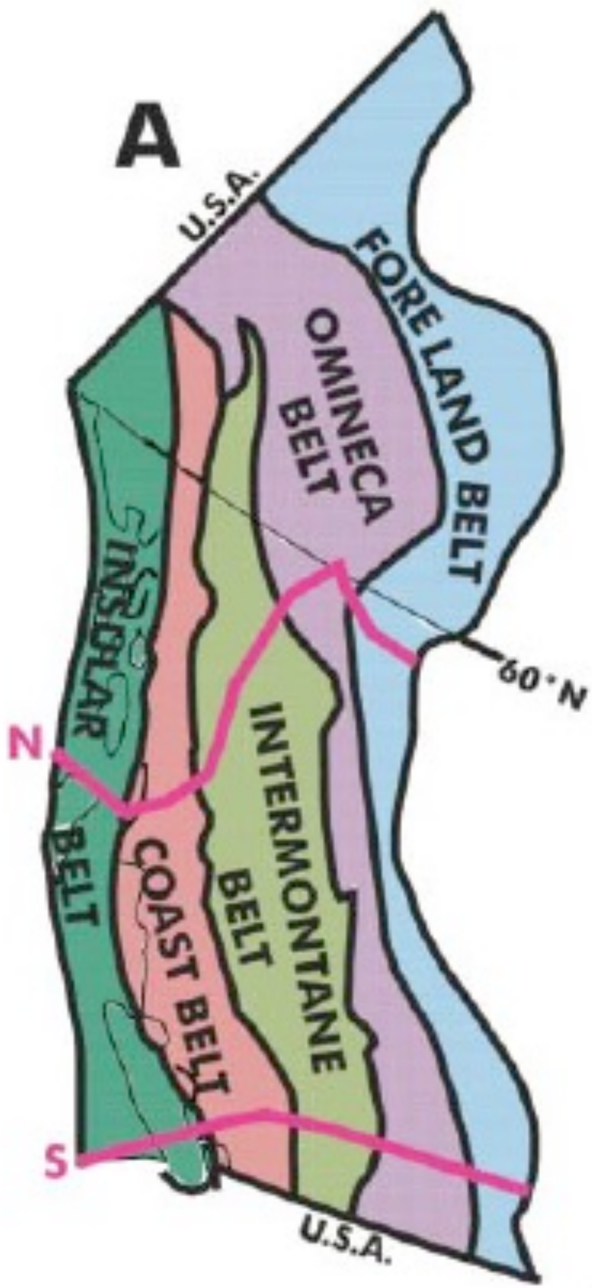
Strike-slip and transform faults
Arctic Ocean
132°
72°
FO
TI
TI
FO
Fb
Fb
NR
FO
DE
TE
KS
Gg
CG
YA
Bo
BR
WA
Gg
FS
PA
Gb
OL
PR
AL
QC
PACIFIC PLATE
Pacific Ocean
JUAN DE FUCA PLATE
JFR
CS
56°
52°
144°
48°
132°
1000 km



Skeena Watershed:

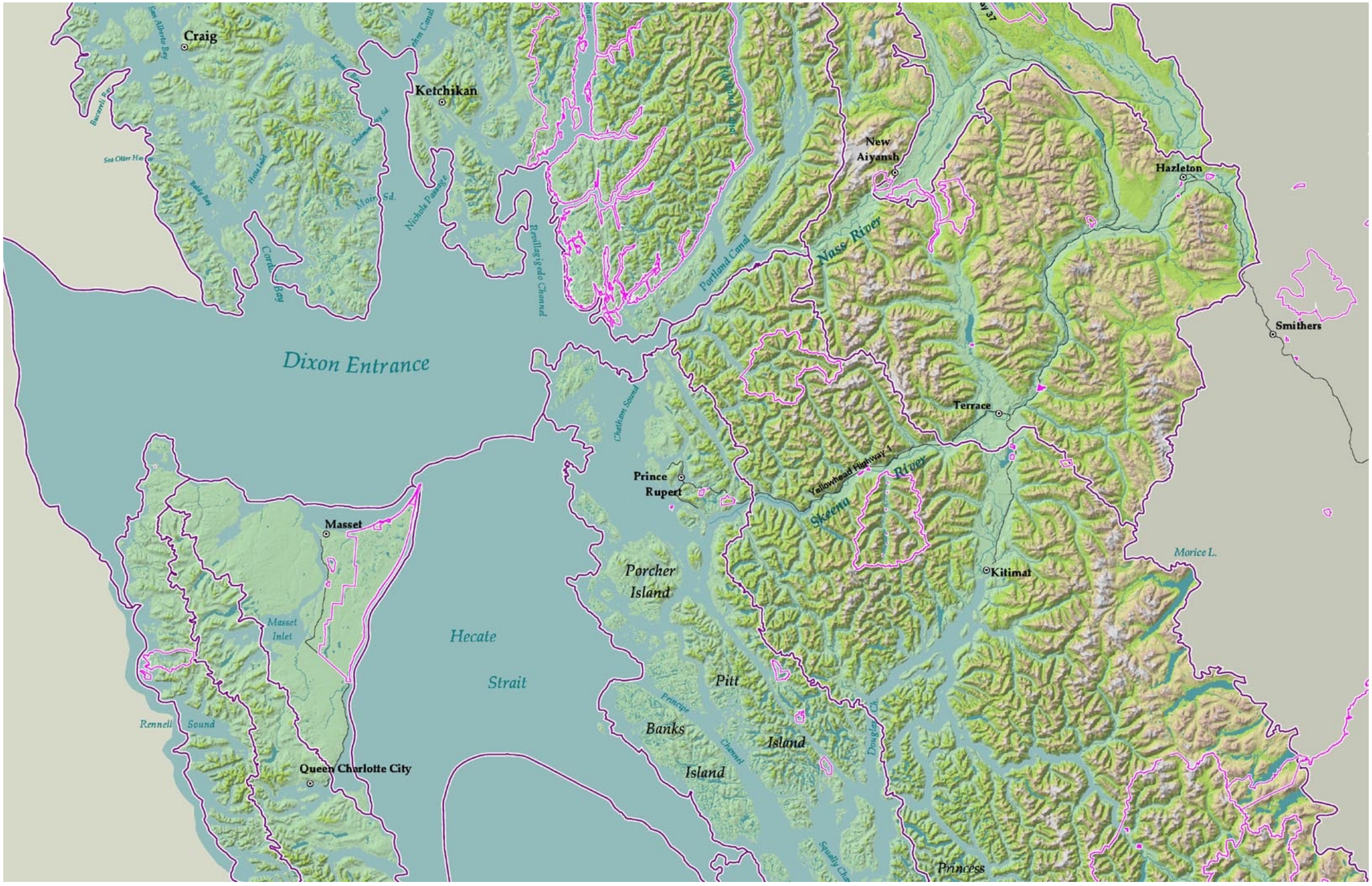
- Coast Belt and Intermontane Belt
- High rates of uplift in Coast Belt/Coast Mountains
- Intermontane Belt is extensional (pull-apart) with broad uplift


Cassiar
NORTHERN BOREAL MOUNTAINS
Fort Nelson
TAIGA PLAINS
BOREAL PLAINS
Fort St John
SUB-BOREAL INTERIOR
Prince Rupert
Prince George
Queen Charlotte City
Quesnel
CENTRAL INTERIOR
COAST AND MOUNTAINS
SOUTHERN INTERIOR MOUNTAINS
NORTHEAST PACIFIC
Kamloops
SOUTHERN INTERIOR
GEORGIA DEPRESSION
Nelson
Vancouver
Victoria


Coastal Forest and Mountains
Alaska, US
Yukon, Canada
Alaska
British
Columbia
Canada
United States

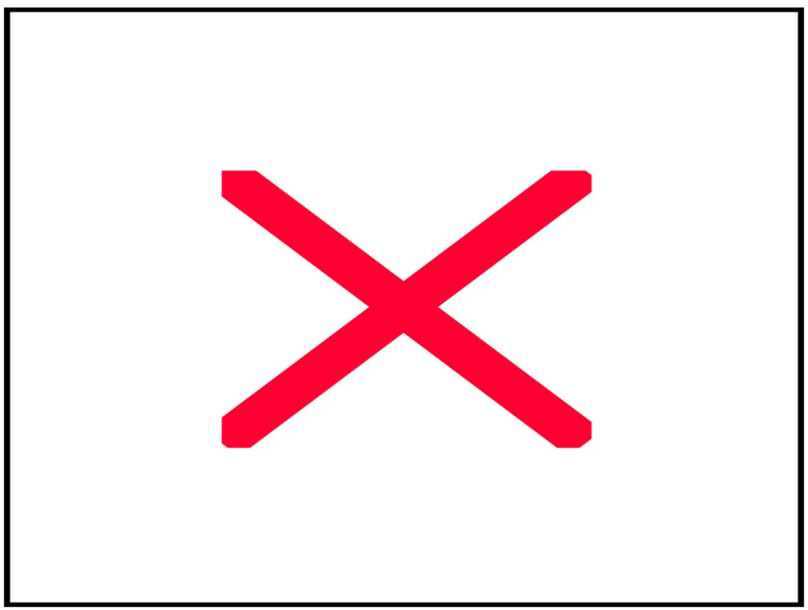
Coast Mountains

- Extensive range in coastal BC
- Uplift began 10 MA at 220m/MA
- Accelerated to 400+m/MA 2.5 MA
- Causes of accelerated uplift due to glacial exhumation?
- Dominant influence on climate during the Pleistocene and Holocene



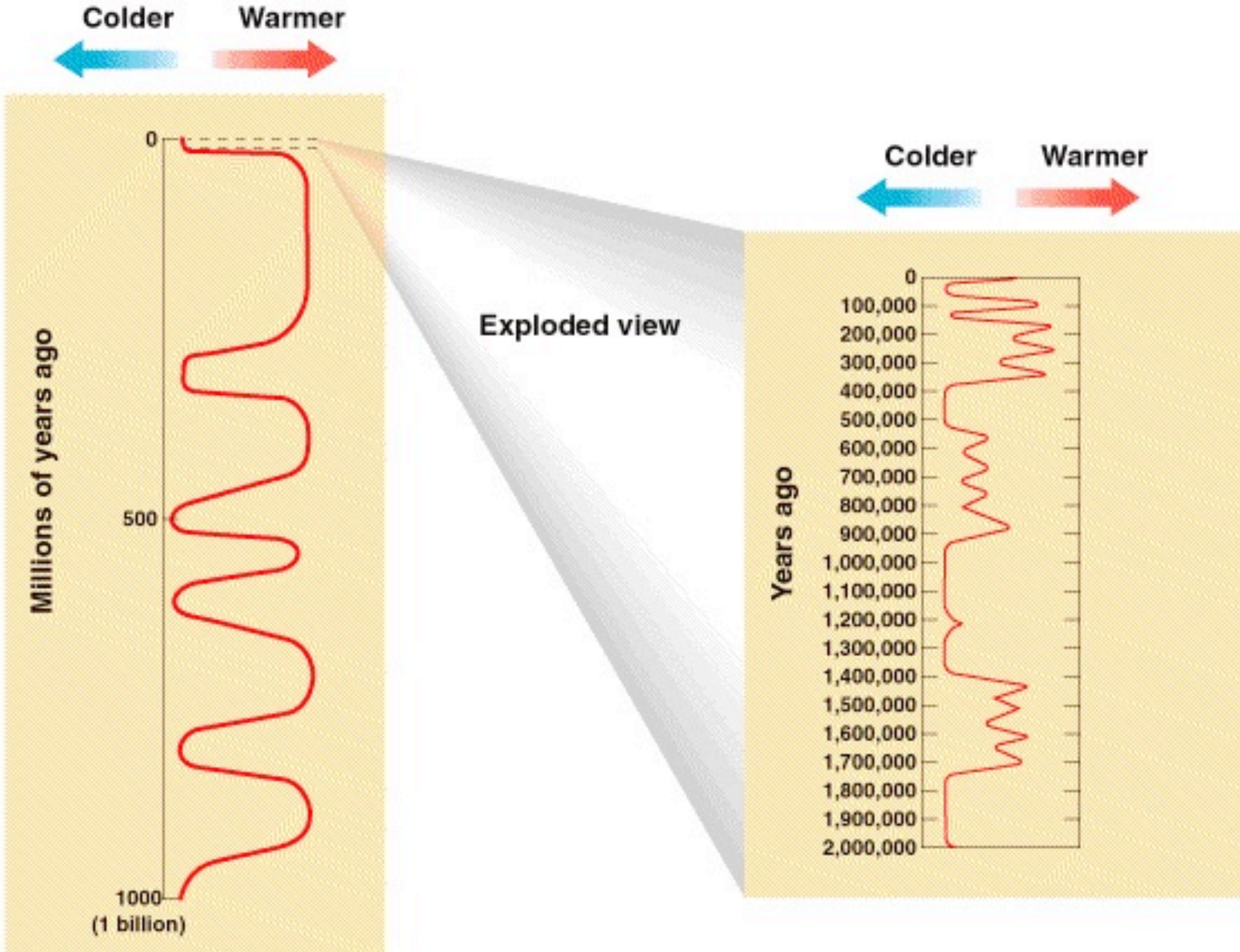
Craig
Ketchikan
New Aiyansh
Hazleton
Nass River
Portland Canal
Revillagigedo Channel
Nichols Passage
Cordova Bay
Dixon Entrance
Smithers
Terrace
Chatham Sound
Prince Rupert
Yellowhead Highway 1
Skeena River
Masset
Kitimat
Morice L.
Porcher Island
Masset Inlet
Hecate Strait
Pitt Island
Banks Island
Rennell Sound
Queen Charlotte City
Principe Channel
Douglas Ch.
Princess

Cordilleran Ice Sheet



- Extensive Pleistocene ice sheet that coveren most of North America
- Multiple expansions and retreats of ice sheets
- Significant, but disputed impacts in British Columbia

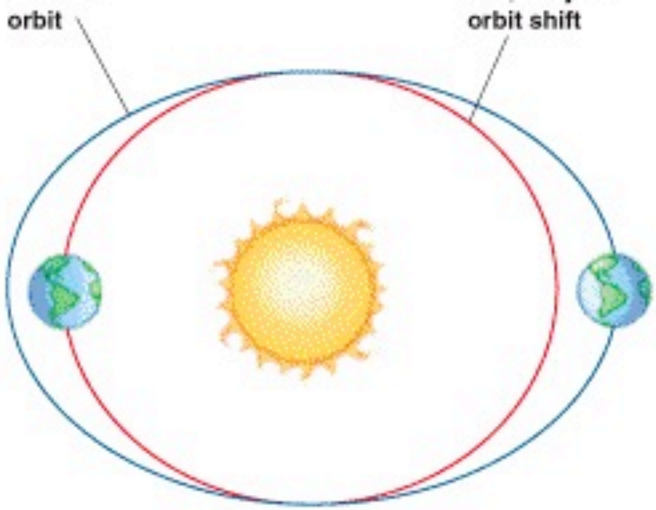
Thompson and Turk: Earth Science and the Environment, 2/e
Figure 11.29



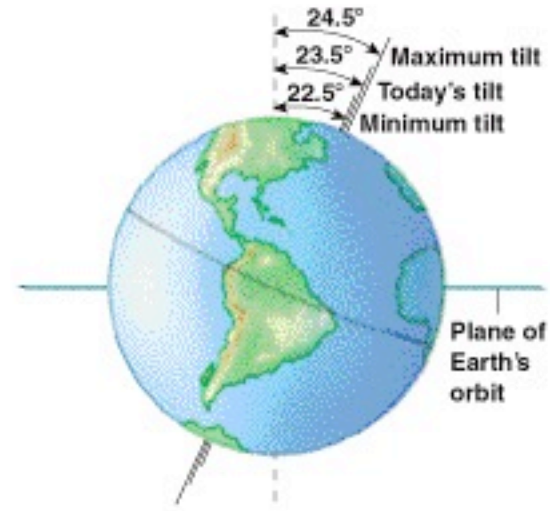
A

B

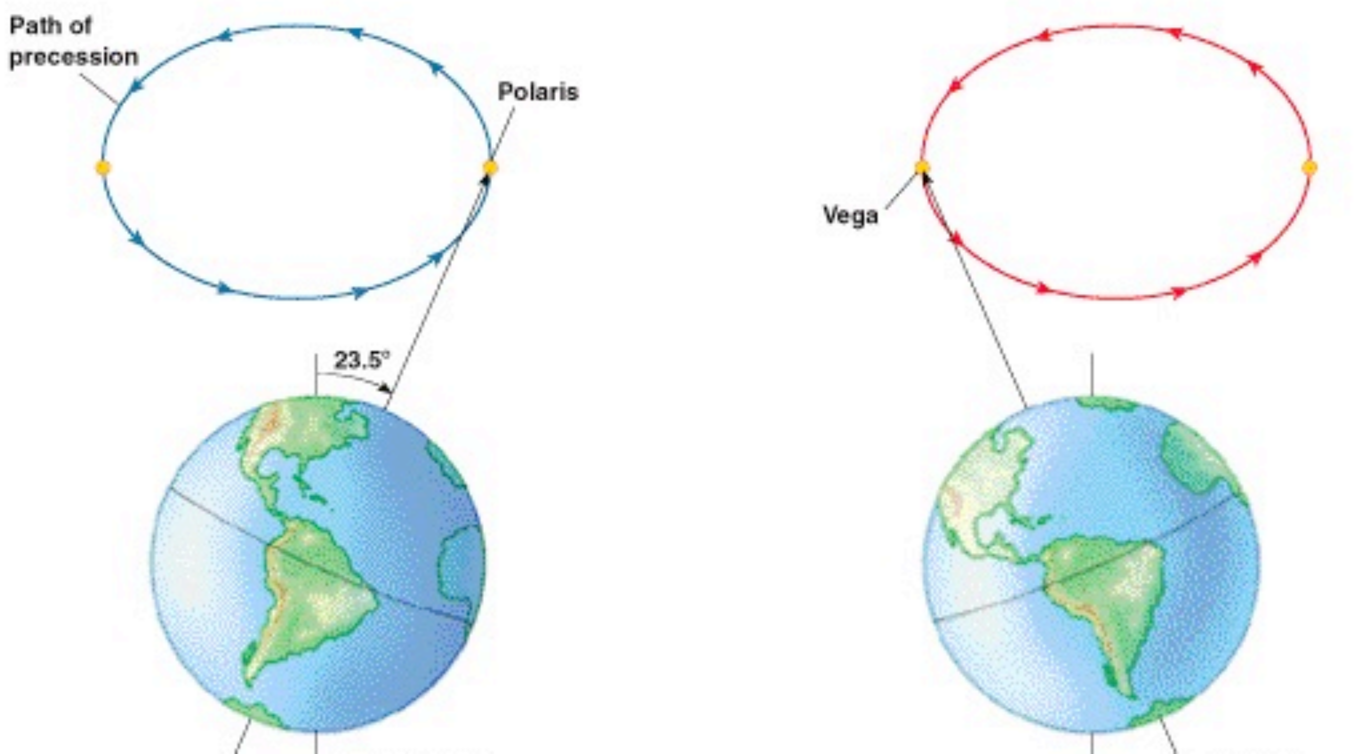
Saunders College Publishing



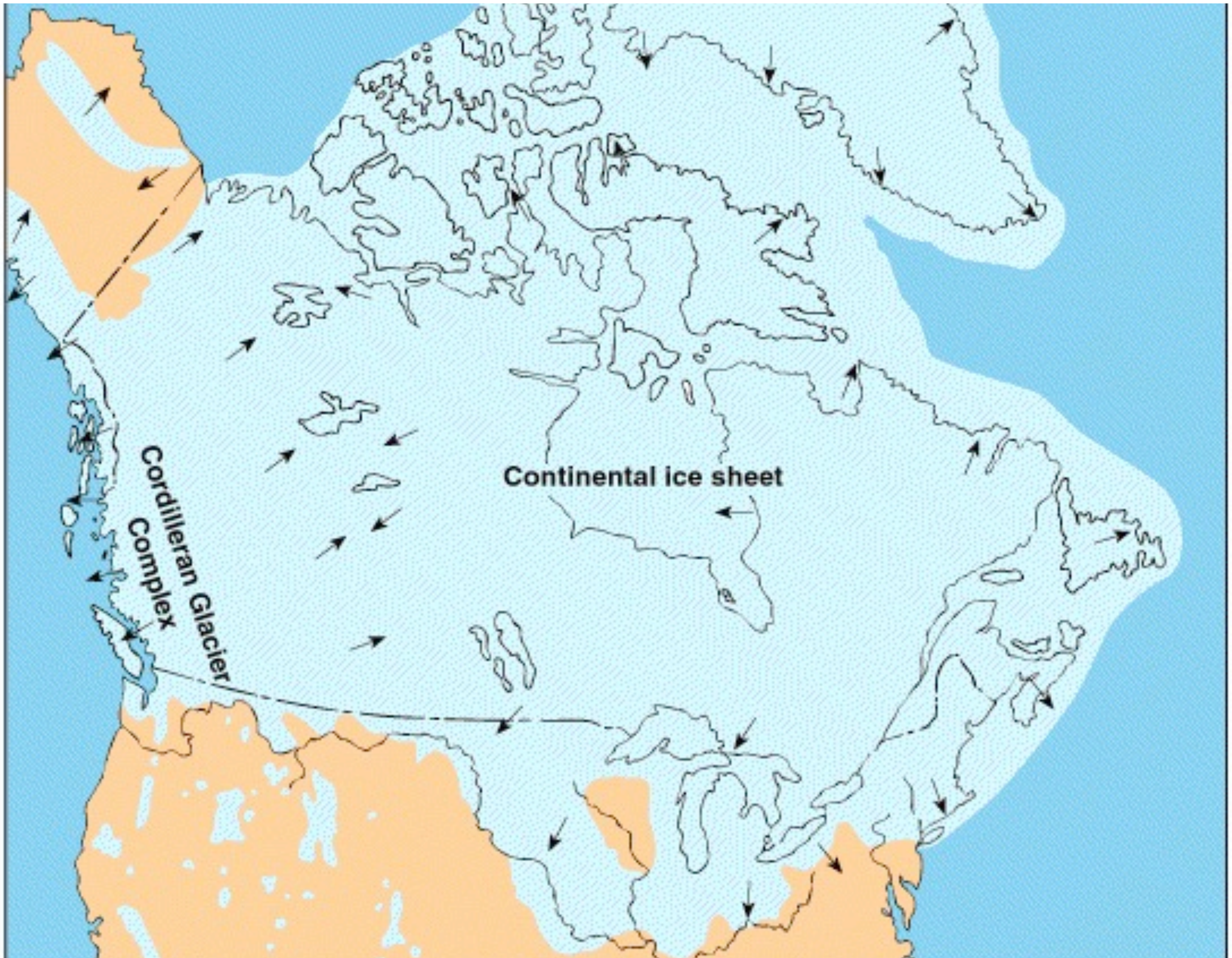
A Orbital eccentricity



B Axis shift



Maximum extent of continental glaciation 18,000 years ago

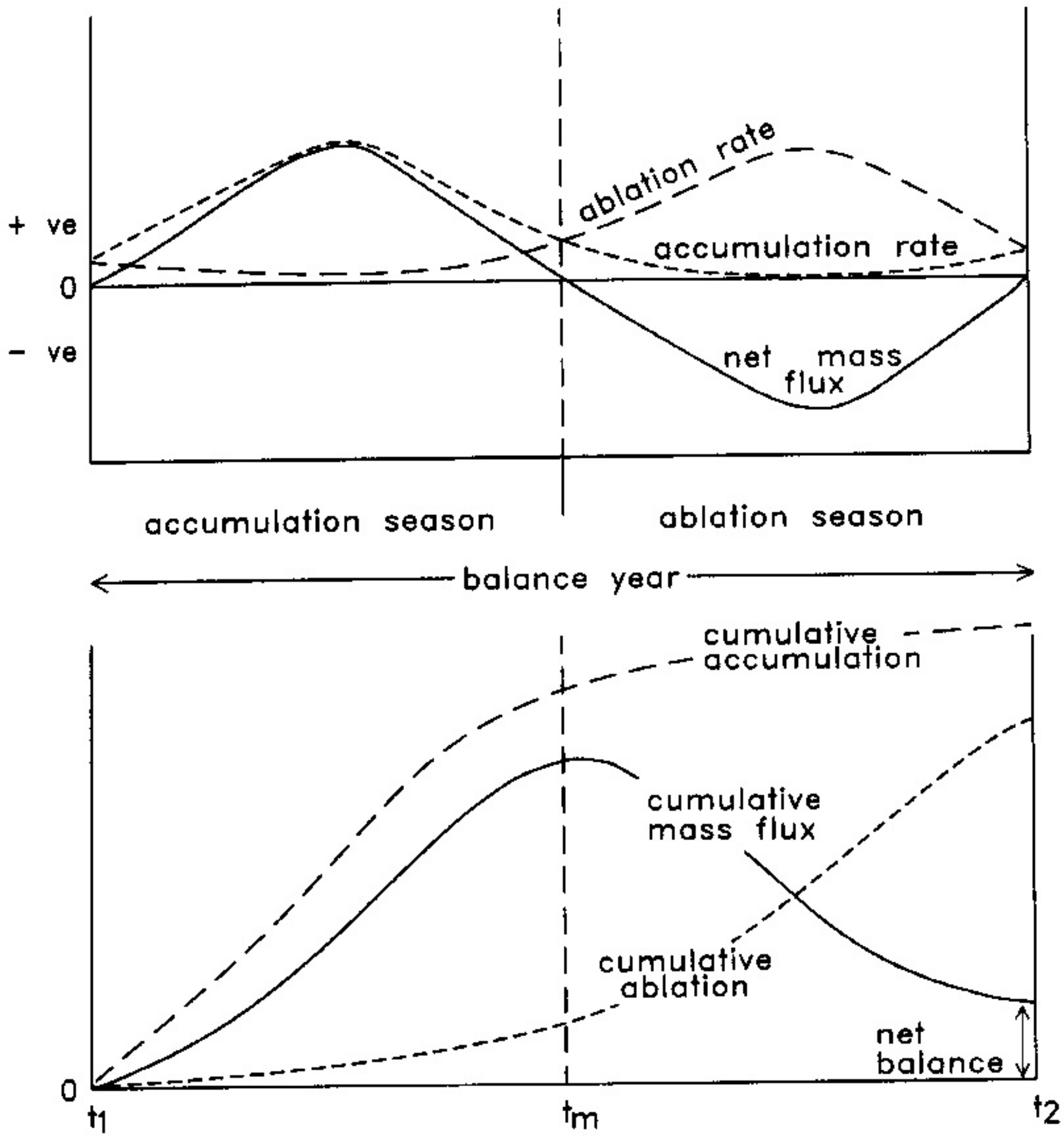


Feedbacks

- Climate controls glacier mass balance, temperature, size, thermal regime, movement and geomorphic activity
- Glaciers influence albedo, surface energy balance, atmospheric and oceanic circulation
- Elevation controls rates of accumulation and ablation in glaciers
- Uplift controls rate of accumulation and rate of erosion

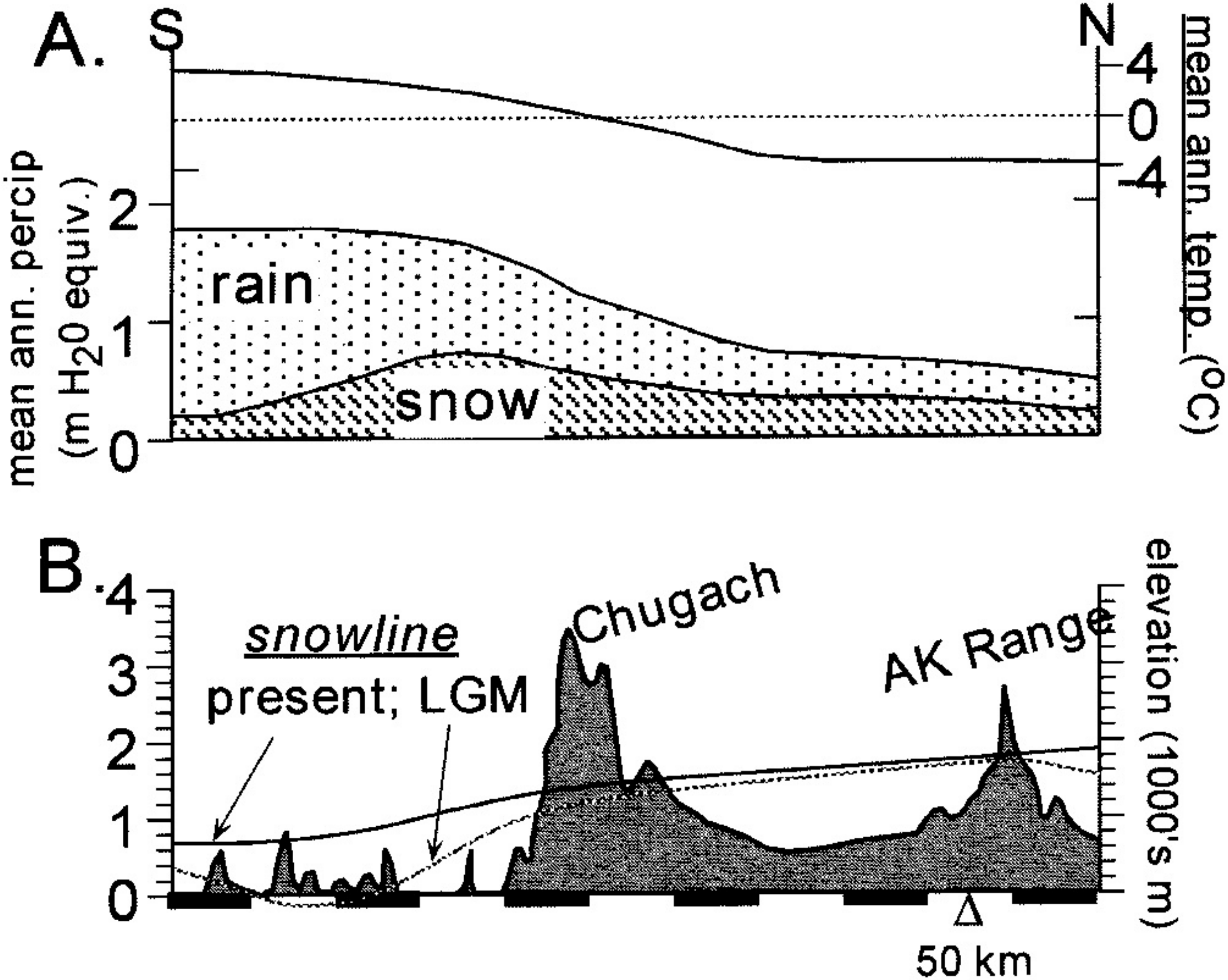
Mass Balance in Glaciers

- Mass balance is a function of:
  - Inputs (accumulation)
  - Throughputs (transport)
  - Outputs (ablation)
- Links climate change, uplift and glacial variation



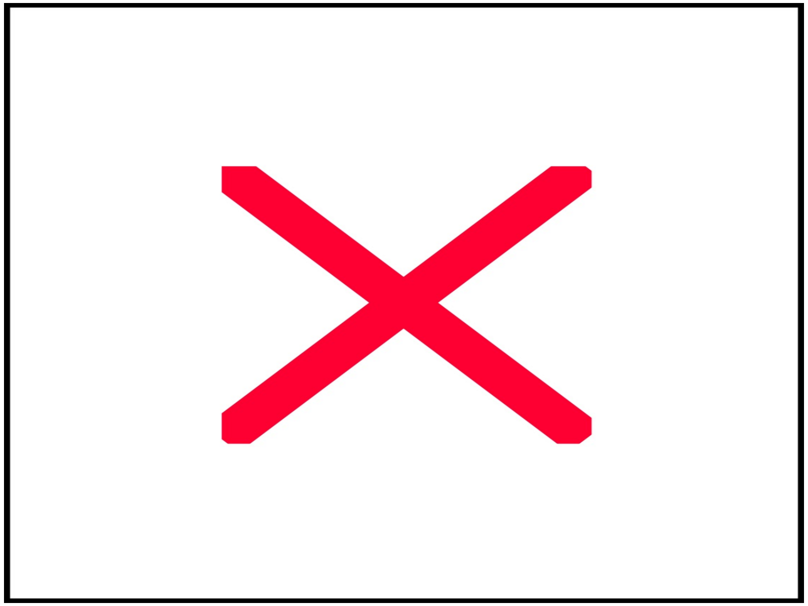
Mass balance components:

- ablation
- accumulation
- mass flux



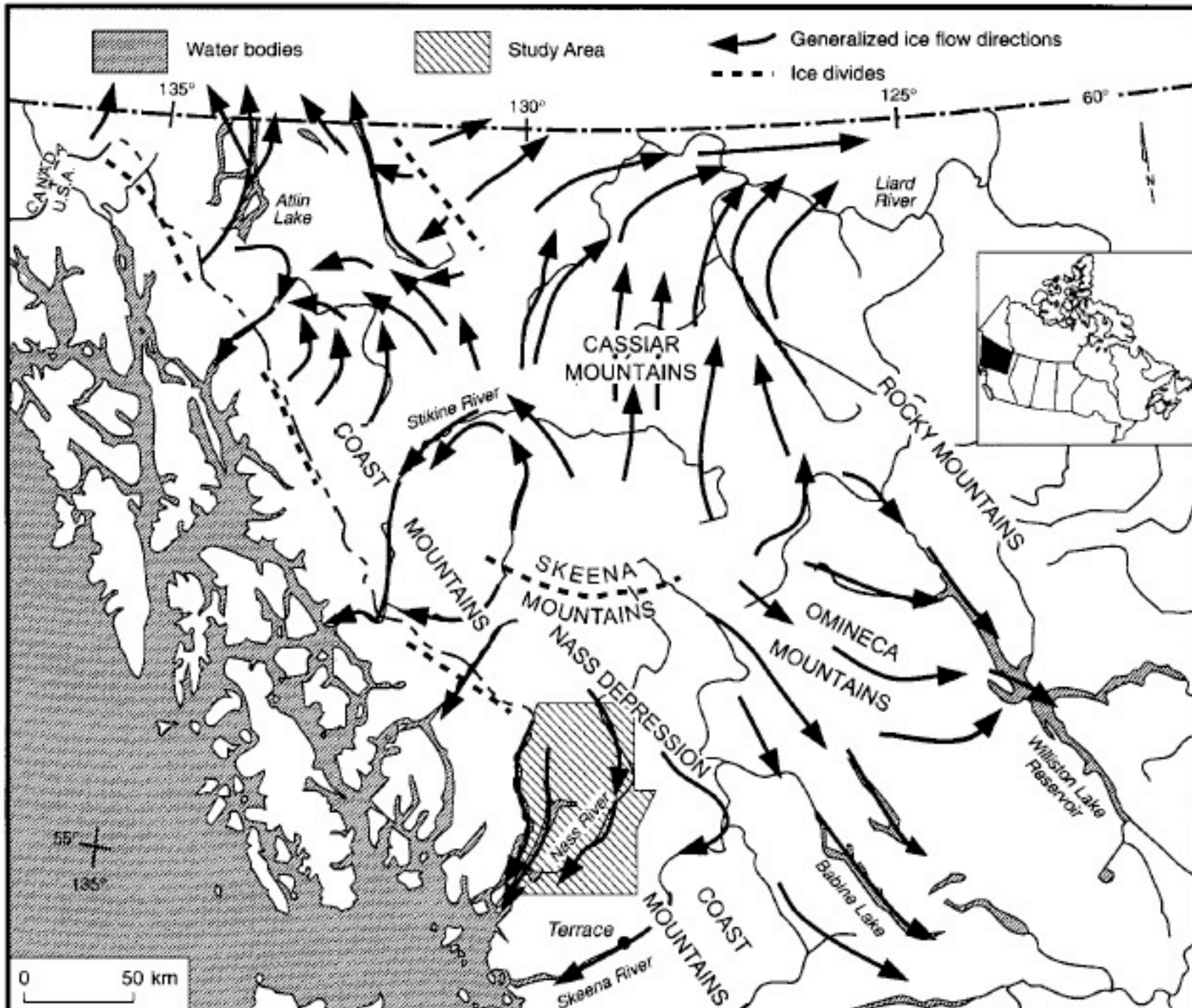
A.
S
N
mean ann. temp. (°C)
4
0
-4
mean ann. percip (m $H_2$0 equiv.)
2
1
0
rain
snow
B.
4
3
2
1
0
snowline
present; LGM
Chugach
AK Range
elevation (1000's m)
50 km

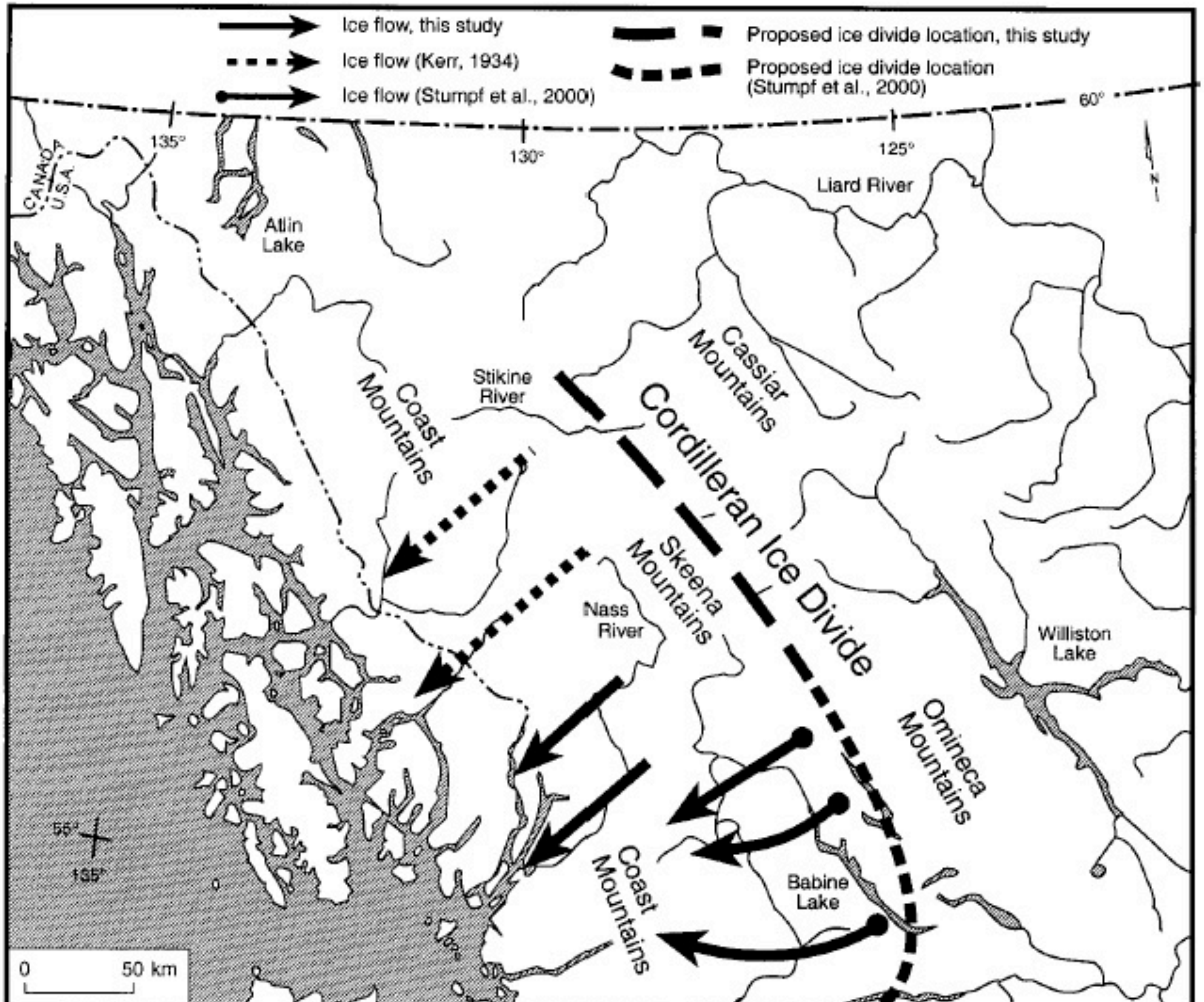
Phases of Ice Flow



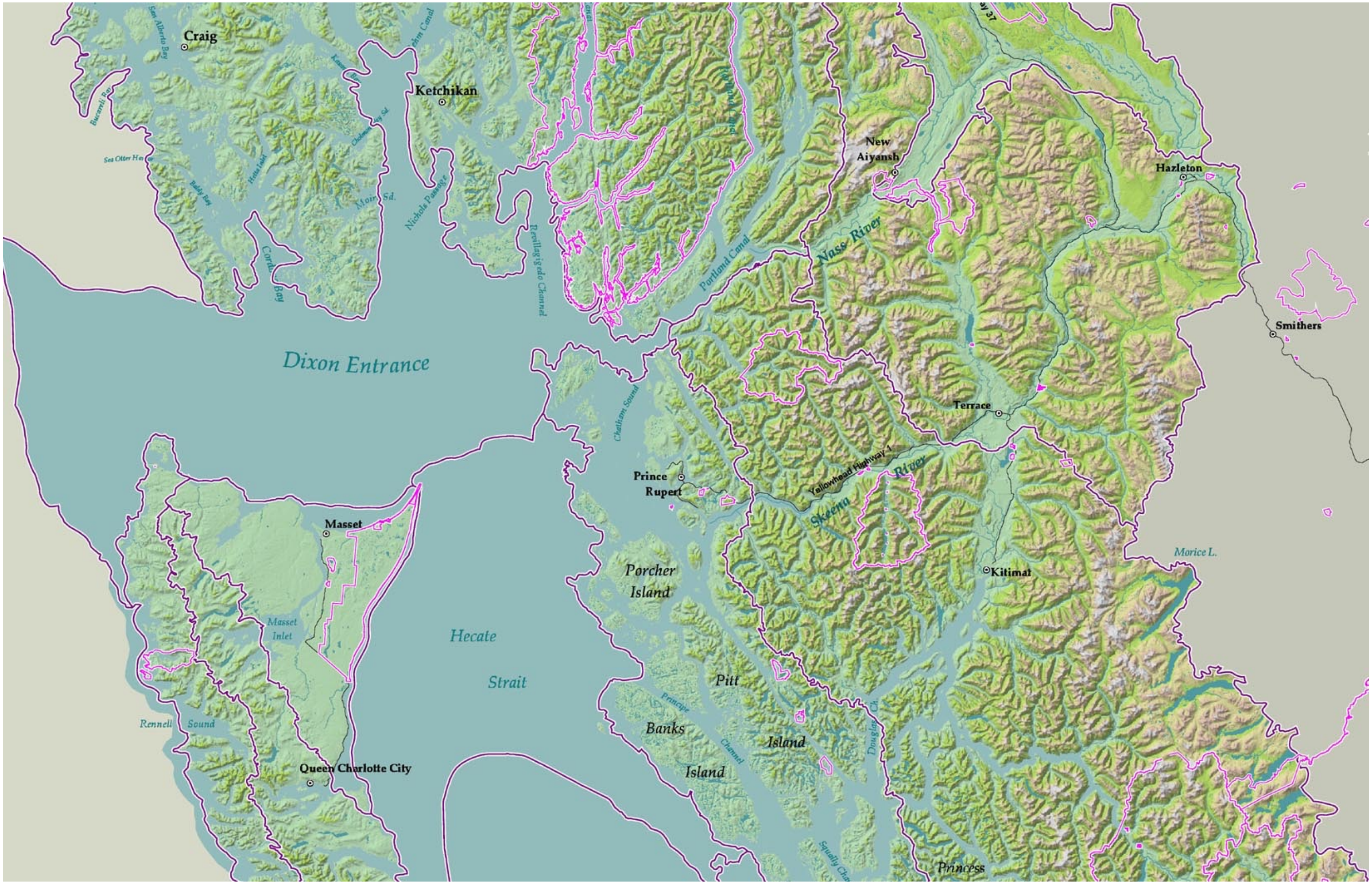
- Ice Expansion: controlled by local accumulation and topography
- Maximum: uncontrolled by topography
- Late: topographic control during retreat

Historical understanding of last glacial maxima in BC



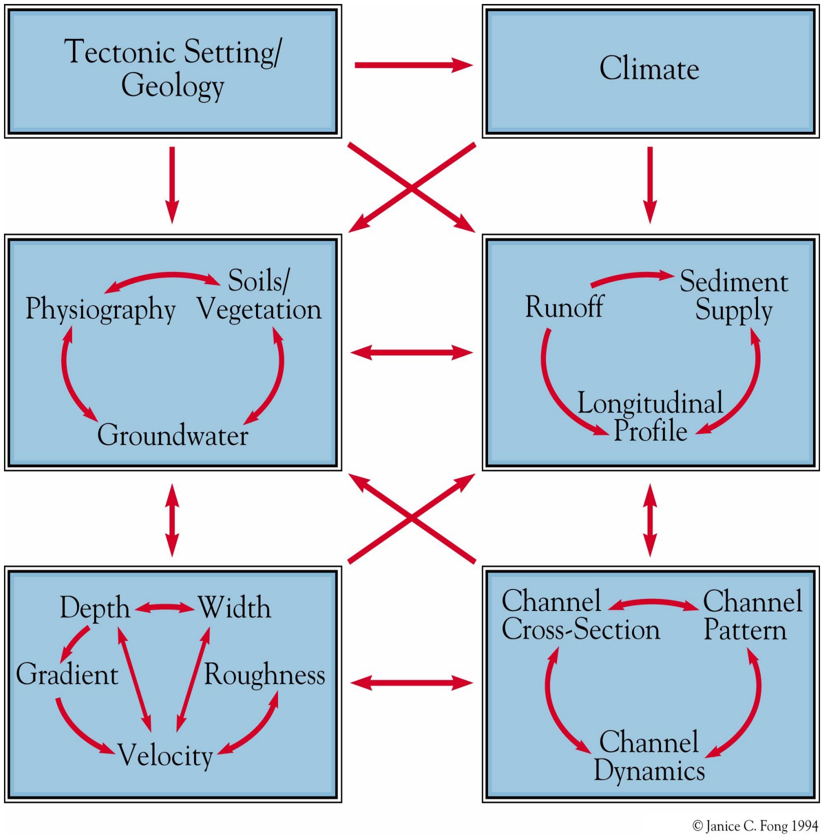


From: McCuaig and Roberts, 2002

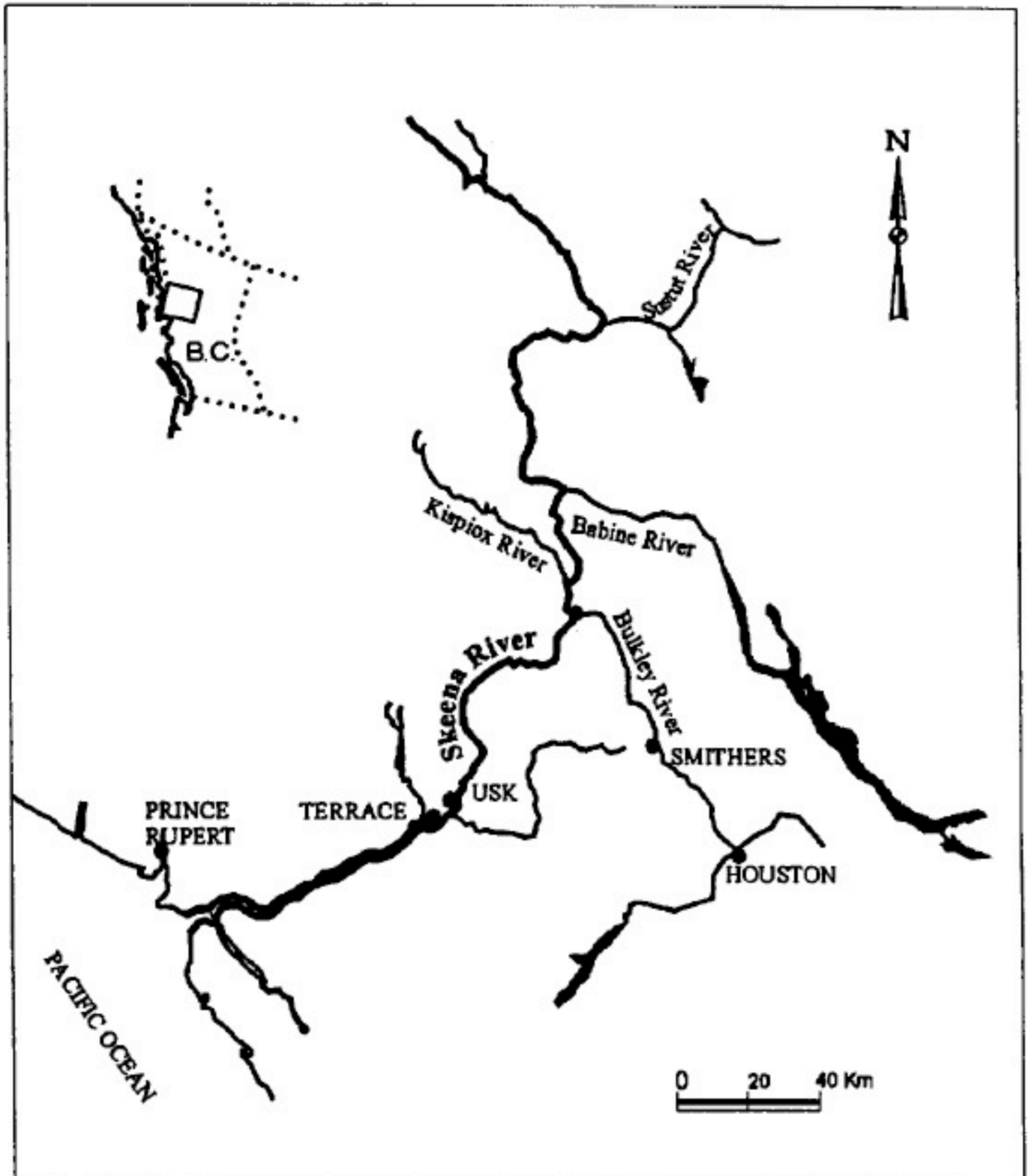


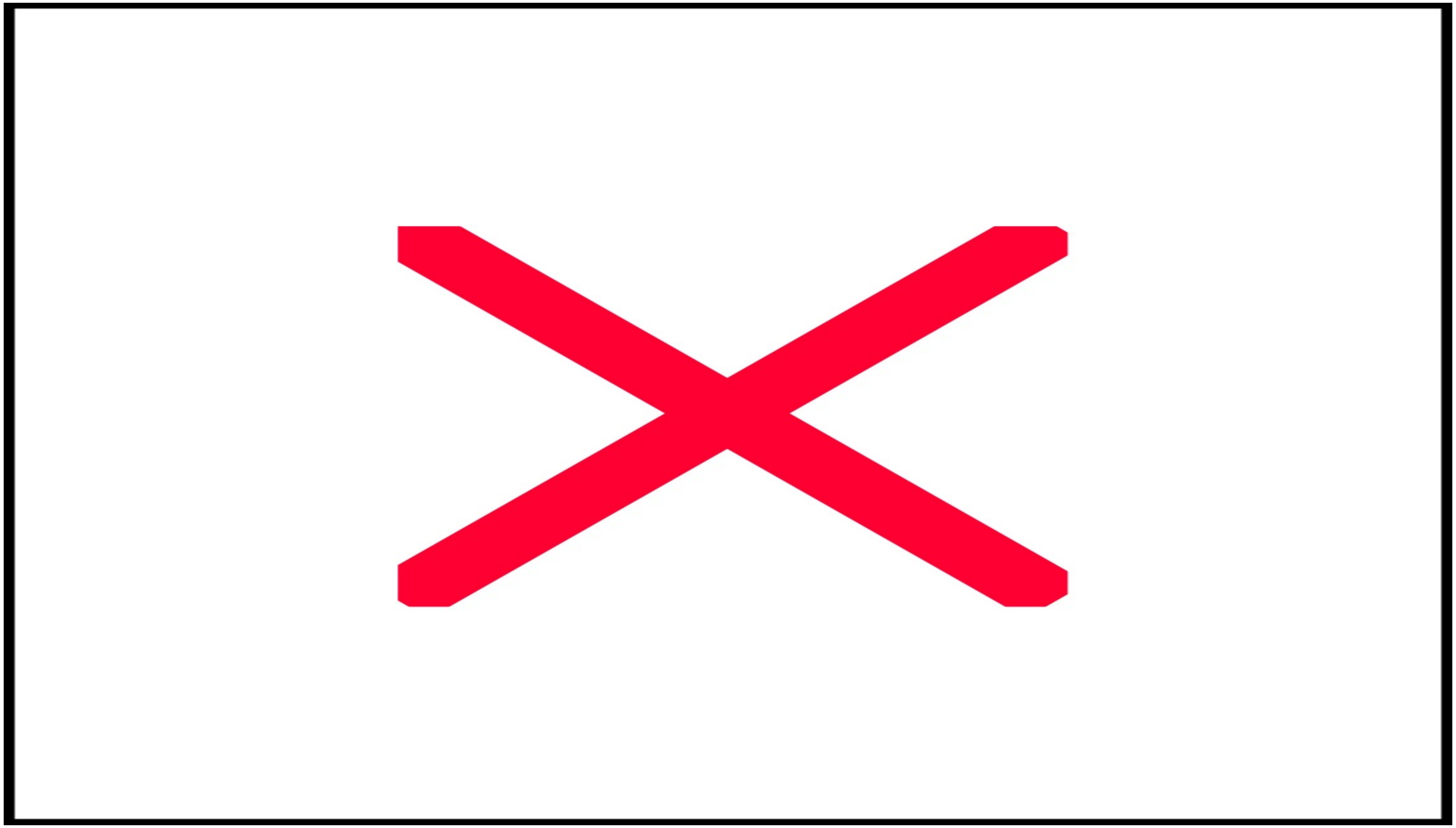
Craig
San Alberto Bay
Ketchikan
Bucareli Bay
Sea Otter Hbr
Moira Sd.
Nichols Passage
Cordova Bay
Revillagigedo Channel
Portland Canal
Nass River
New Aiyansh
Hazleton
Smithers
Dixon Entrance
Chatham Sound
Terrace
Prince Rupert
Yellowhead Highway 16
Skeena River
Masset
Kitimat
Morice L.
Porcher Island
Masset Inlet
Hecate Strait
Pitt Island
Rennell Sound
Principe Channel
Banks Island
Douglas Ch.
Queen Charlotte City
Princess

Climate



- Climate in the Skeena Watershed a function of tectonic setting and its interactions with ocean/atmospheric circulation patterns
- Multiple time scales of variation, including seasonal, interannual, decadal….


N
B.C.
Sustut River
Kispiox River
Babine River
Skeena River
Bulkley River
SMITHERS
USK
PRINCE
RUPERT
TERRACE
HOUSTON
PACIFIC OCEAN
0
20
40 Km



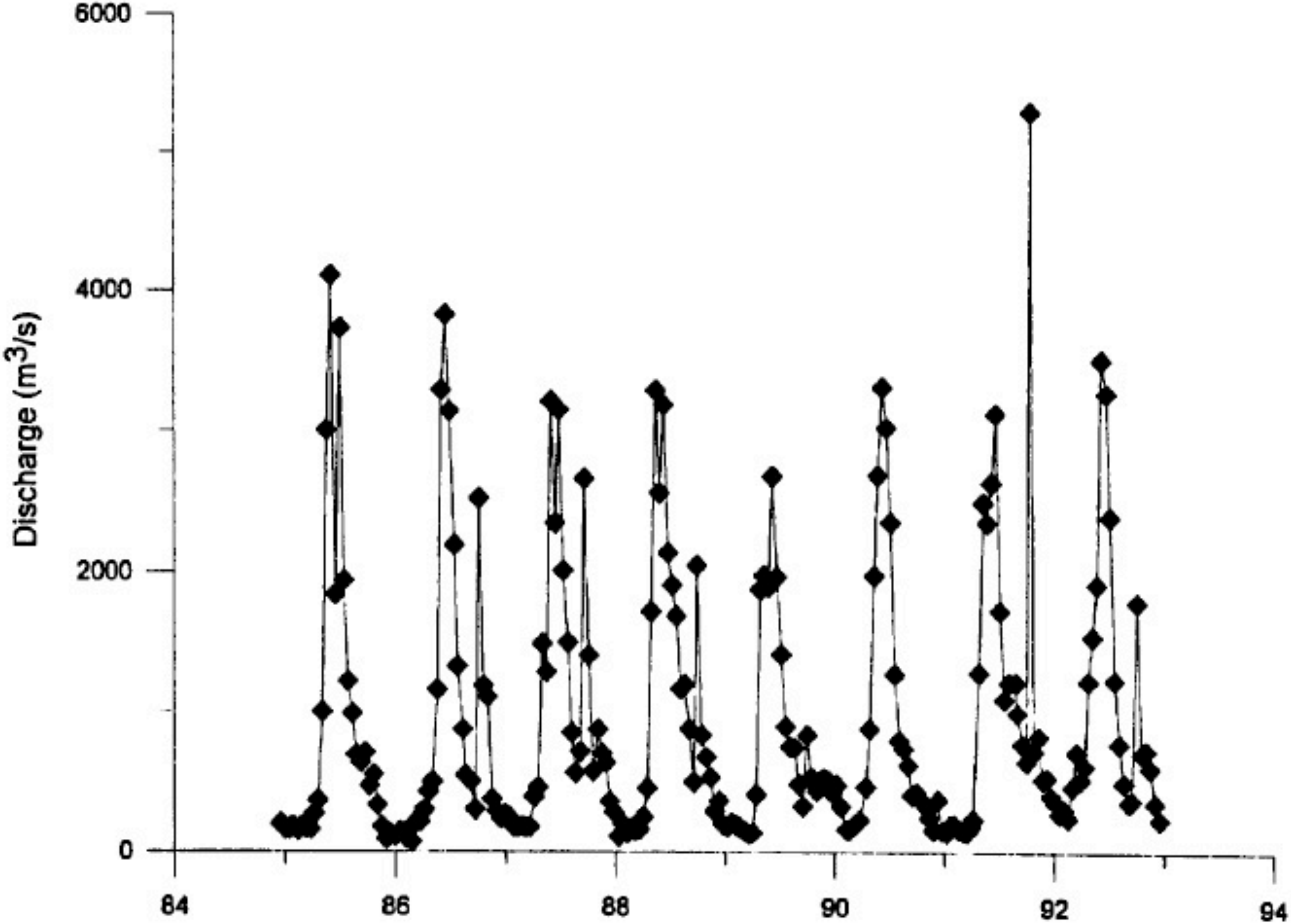
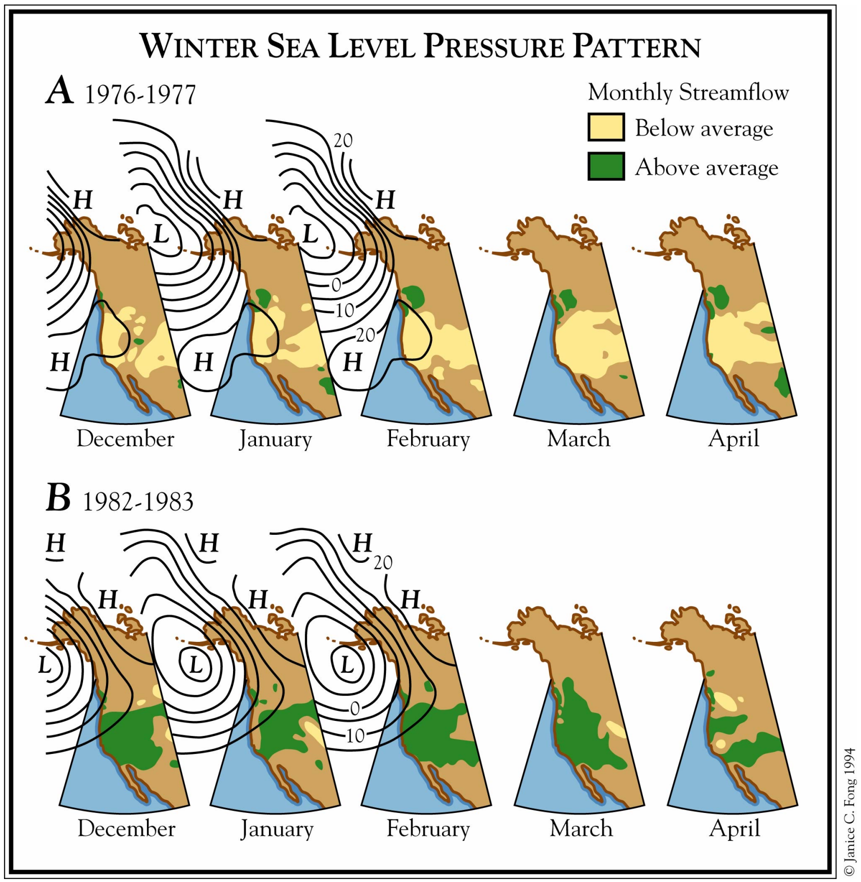


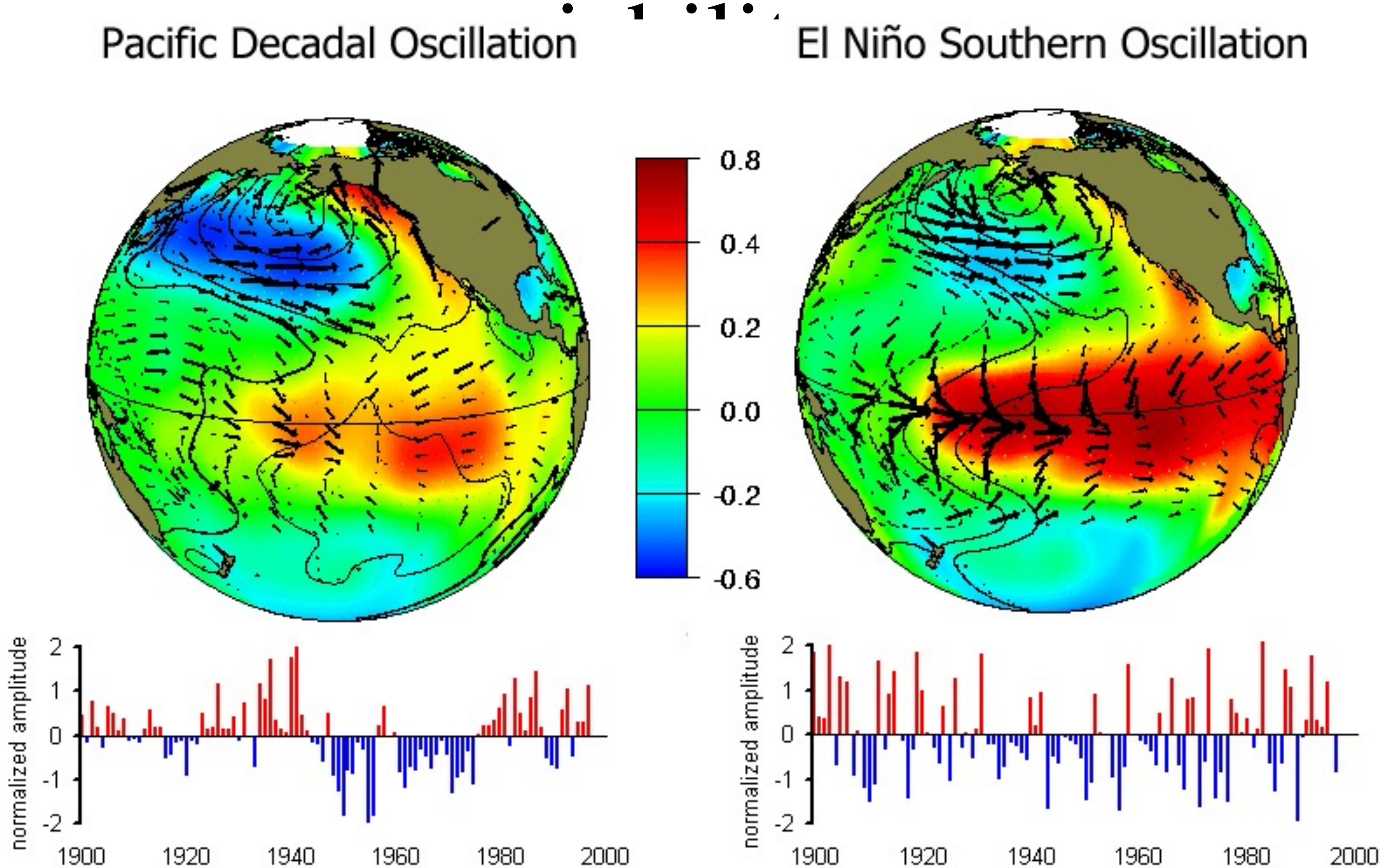
Fig. 4. Time-series plot of discharge (m^3/s) from the Skeena River at Usk from 1985 to 1993.

El Niño and Pacific Decadal Oscillations

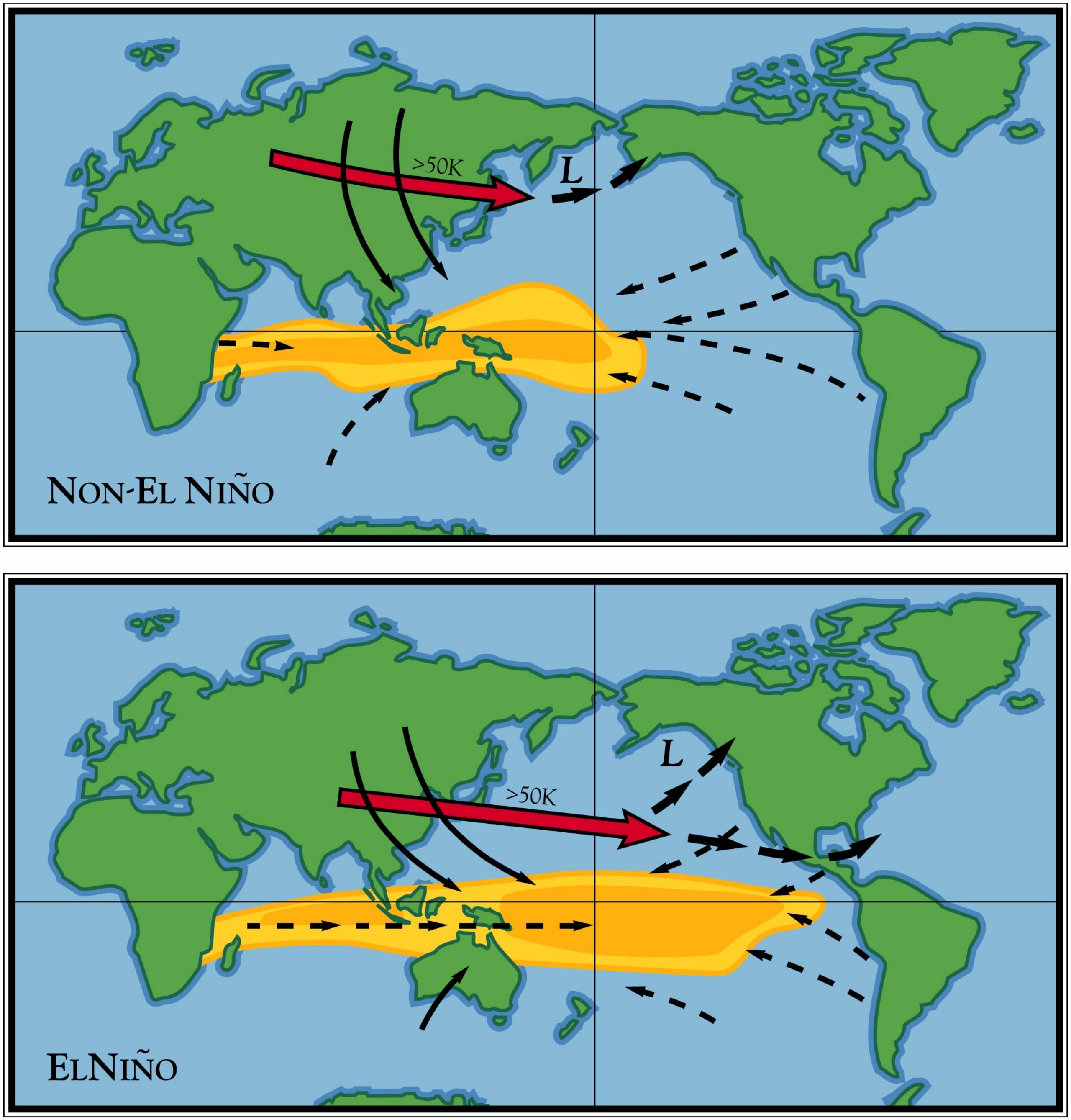


- Evidence for fluctuations in sea surface temps at various timescales.
- El Niño events vary from 6 -18 months
- Pacific Decadal Oscillation events vary from 20-30 years

Modes of Pacific climate



From: Mantua et al. 1997. Bull. Amer. Soc. 78: 1069-1079



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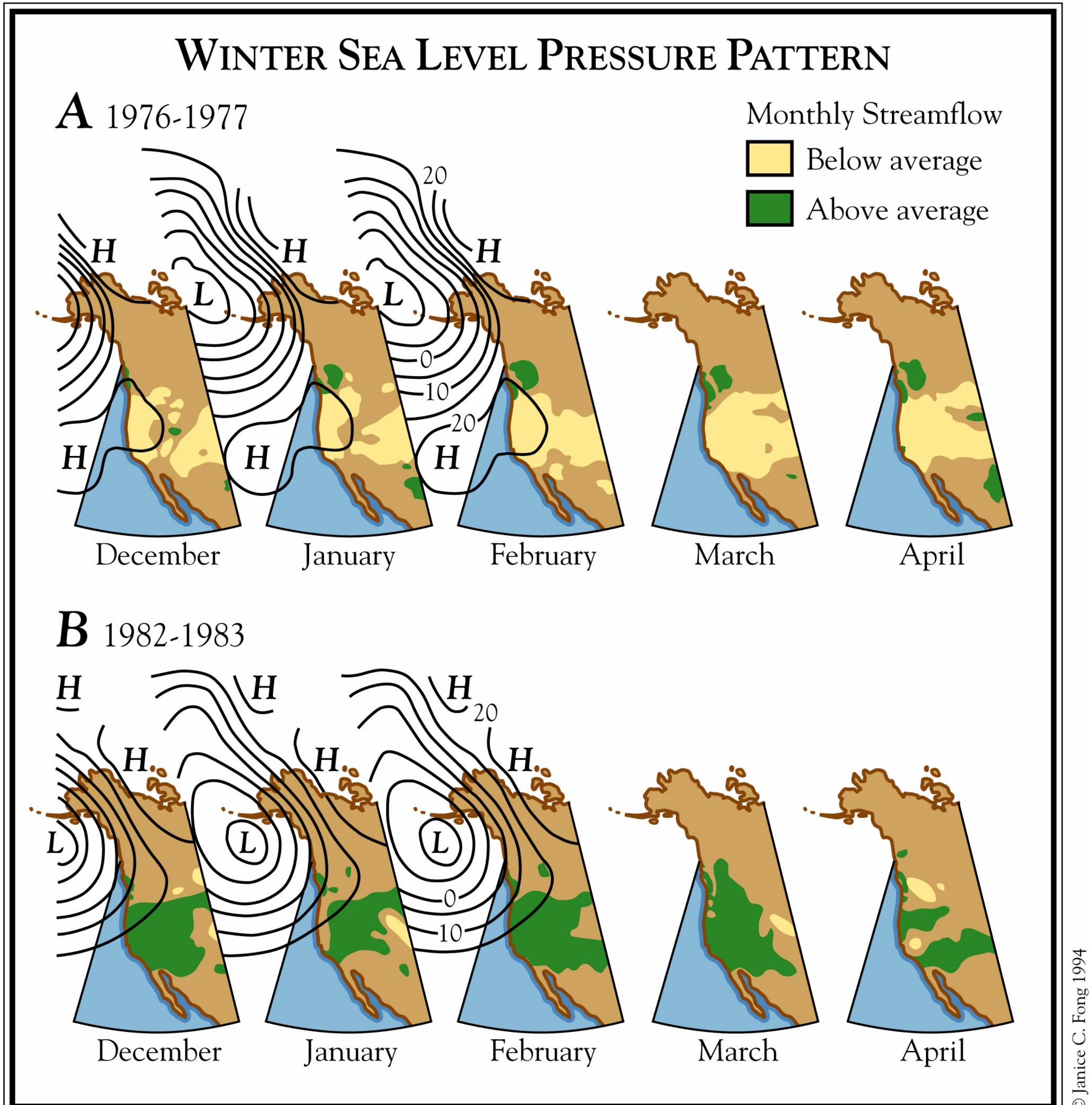
WINTER SEA LEVEL PRESSURE PATTERN
A 1976-1977
Monthly Streamflow
Below average
Above average
H
L
0
10
20
December
January
February
March
April
B 1982-1983
December
January
February
March
April
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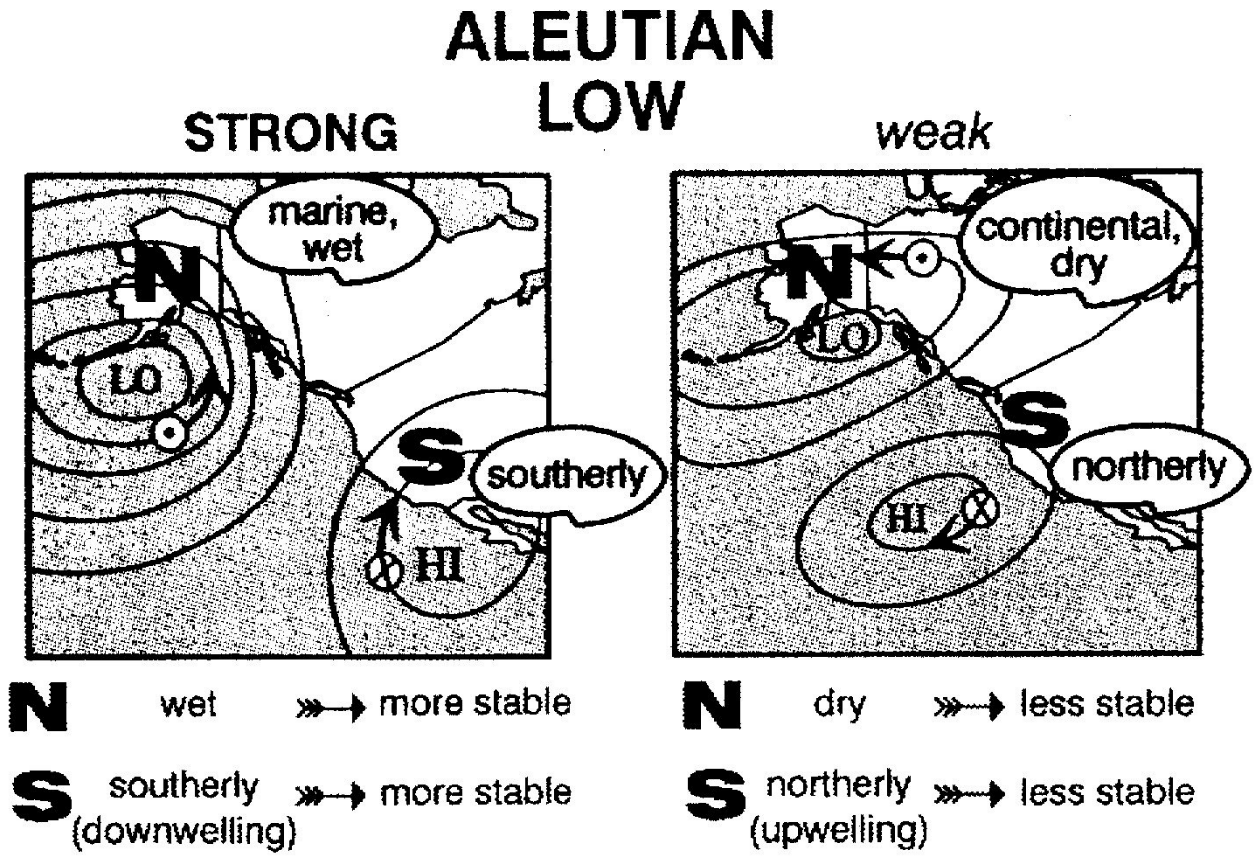
Intensity and Location of the Aleutian Low

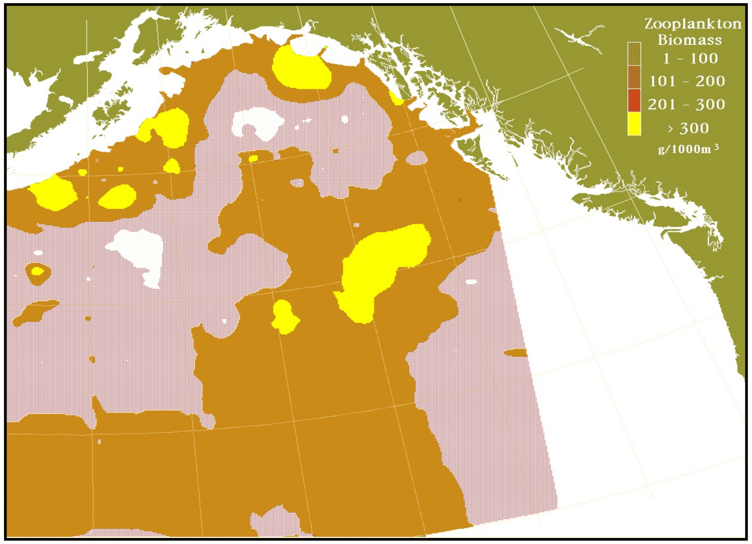


From: Gargett: Fish. Oceanogr. 6: 109-117

Gulf of Alaska Zooplankton Biomass

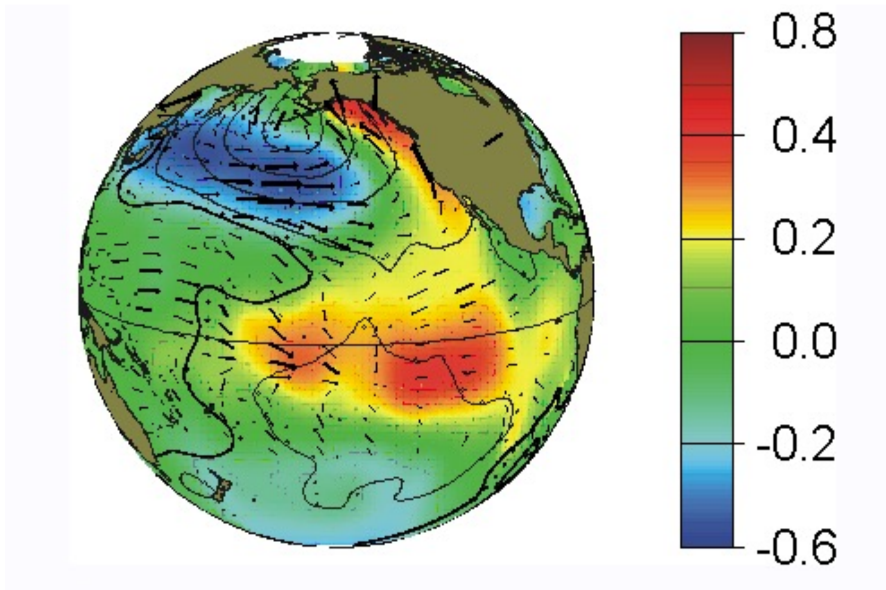
1956-1962

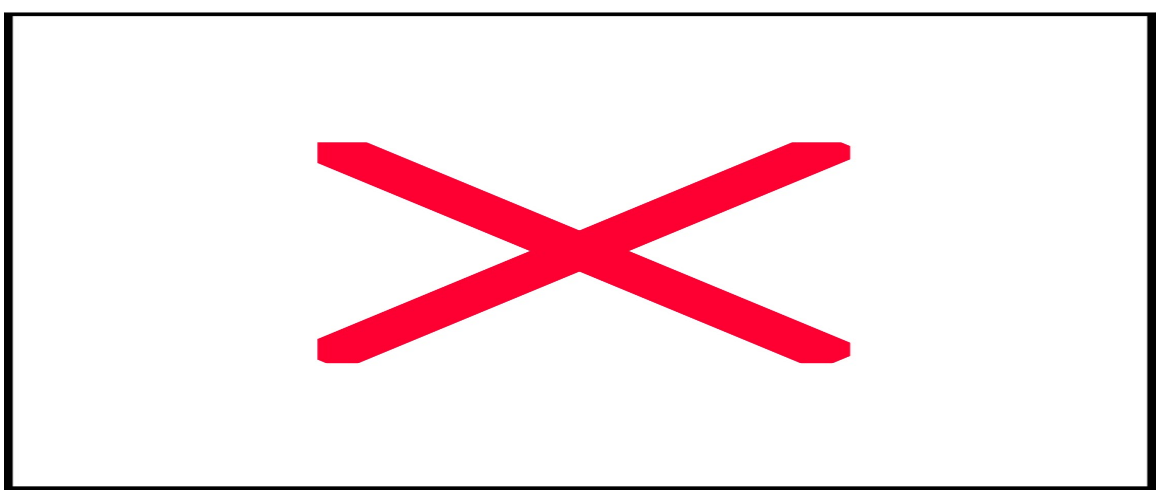
1980-1989

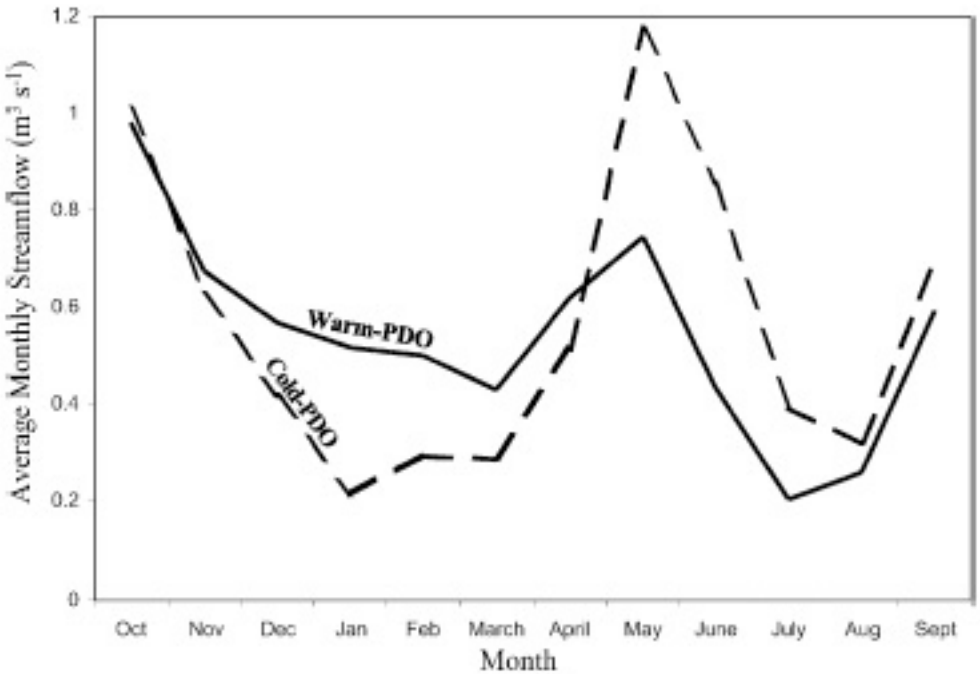


From: Brodeur and Ware (1992) Fish. Oceanogr. 1: 32-38

PDO turns sharply negative in mid 1998







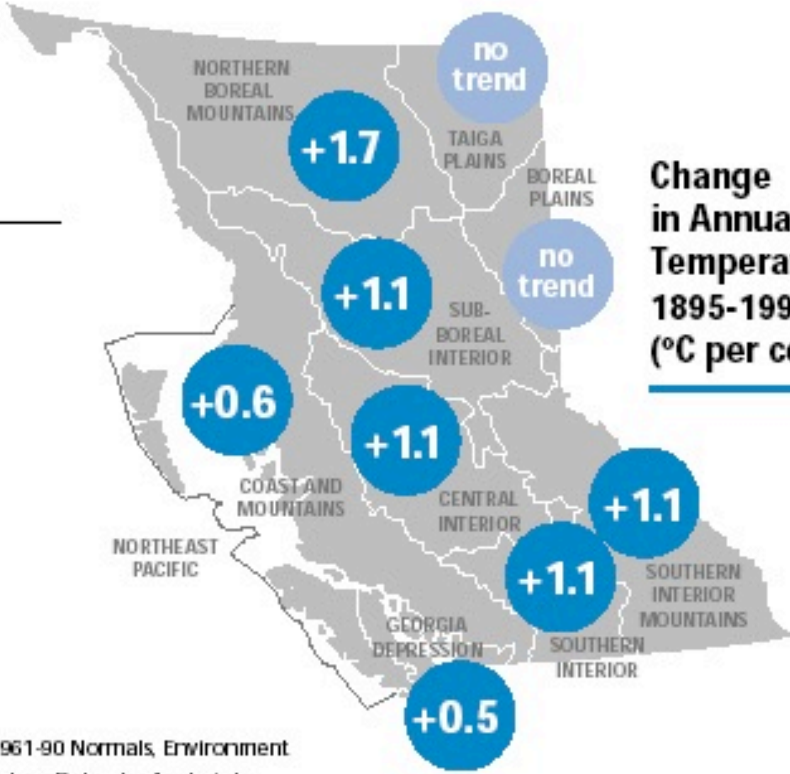
Average Monthly Streamflow ($m^3 s^{-1}$)
1.2
1
0.8
0.6
0.4
0.2
0
Warm-PDO
Cold-PDO
Oct
Nov
Dec
Jan
Feb
March
April
May
June
July
Aug
Sept
Month

Climate Change in British Columbia According to Ministry of Water, Land and Air

- **Average annual temperature warmed by 0.6ºC on the coast, 1.1ºC in the interior, and 1.7ºC in northern BC.**
- **Night-time temperatures increased across most of BC in spring and summer.**
- **Precipitation increased in southern BC by 2 to 4 percent per decade.**
- **Lakes and rivers become free of ice earlier in the spring.**
- **Sea surface temperatures increased by 0.9ºC to 1.8ºC along the BC coast.**
- **Sea level rose by 4 to 12 centimetres along most of the BC coast.**
- **Two large BC glaciers retreated by more than a kilometre each.**
- **The Fraser River discharges more of its total annual flow earlier in the year.**
- **Water in the Fraser River is warmer in summer.**
- **More heat energy is available for plant and insect growth.**

AVERAGE TEMPERATURE

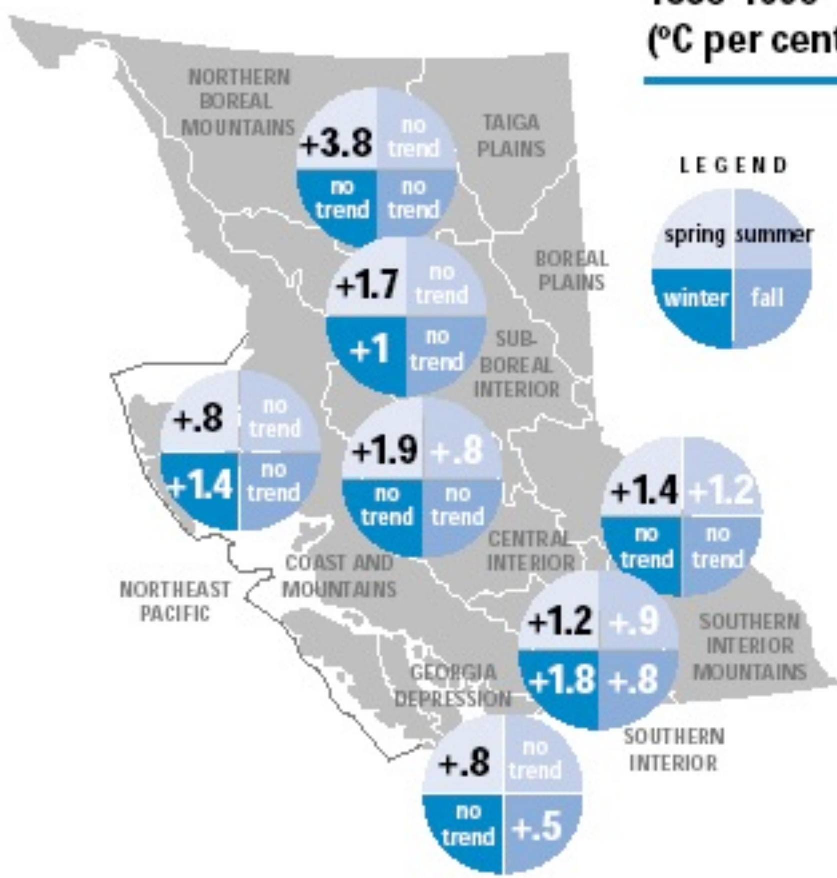
Average temperature increased over most of BC during the 20th century. Spring is warmer on average than it was 100 years ago. Higher temperatures drive other changes in climate systems and affect physical and biological systems in BC. They can have both positive and negative impacts on human activities.



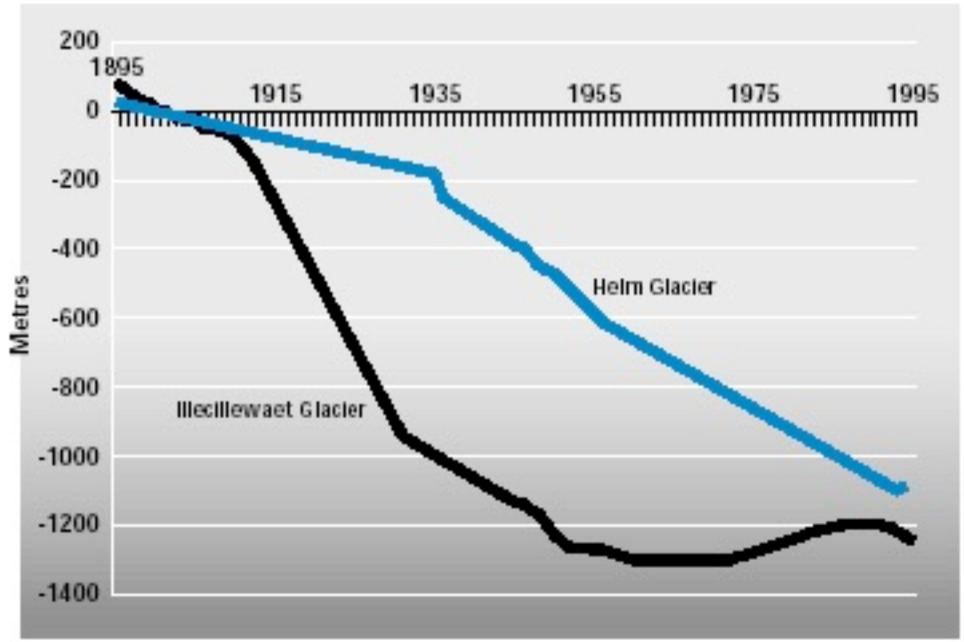
Change in Annual Temperature, 1895-1995 (°C per century)

SOURCE: Data from Archive of Monthly Climate Data and 1961-90 Normals, Environment Canada, and Canadian Historical and Homogenized Temperature Datasets. Analysis by Canadian Institute for Climate Studies, 1999 for BC Ministry of Water, Land and Air Protection. NOTES: A positive sign indicates a warming trend.

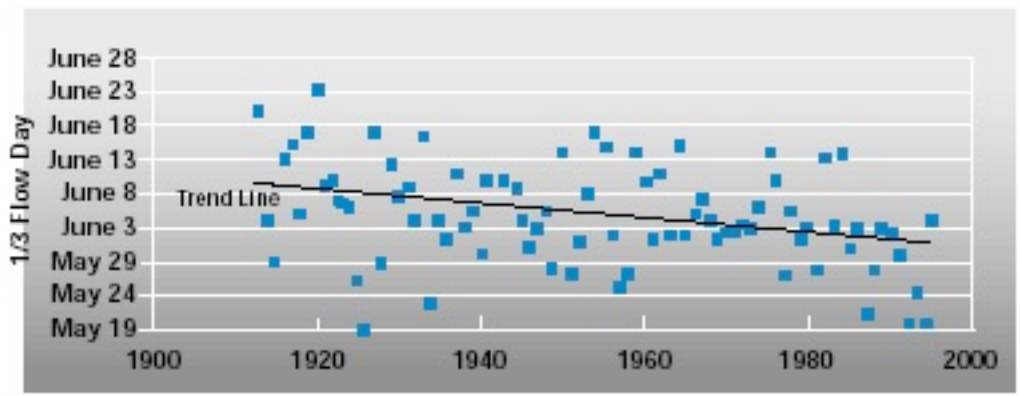
Change in Seasonal Temperature, 1895-1995 (°C per century)

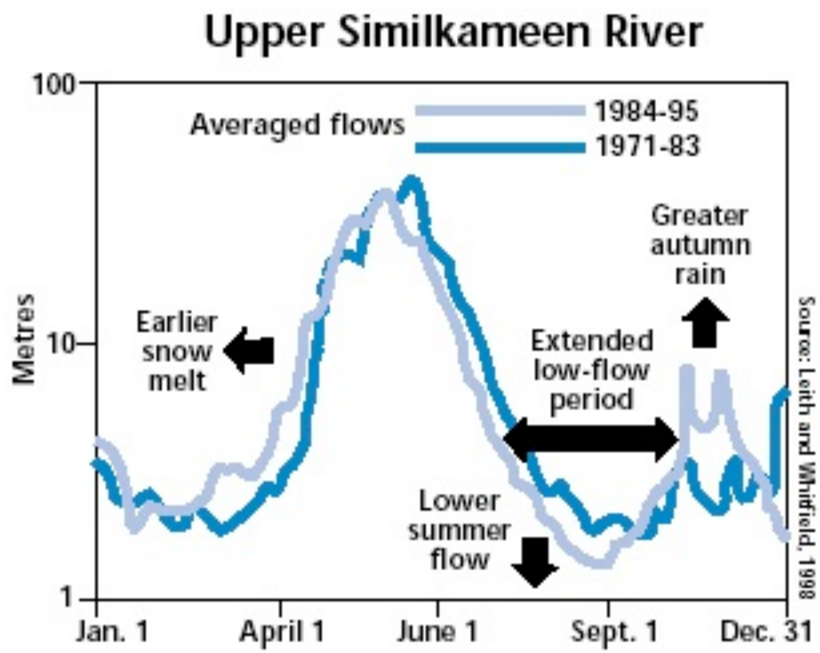


Change in Glacier Terminus Position, 1895-1995

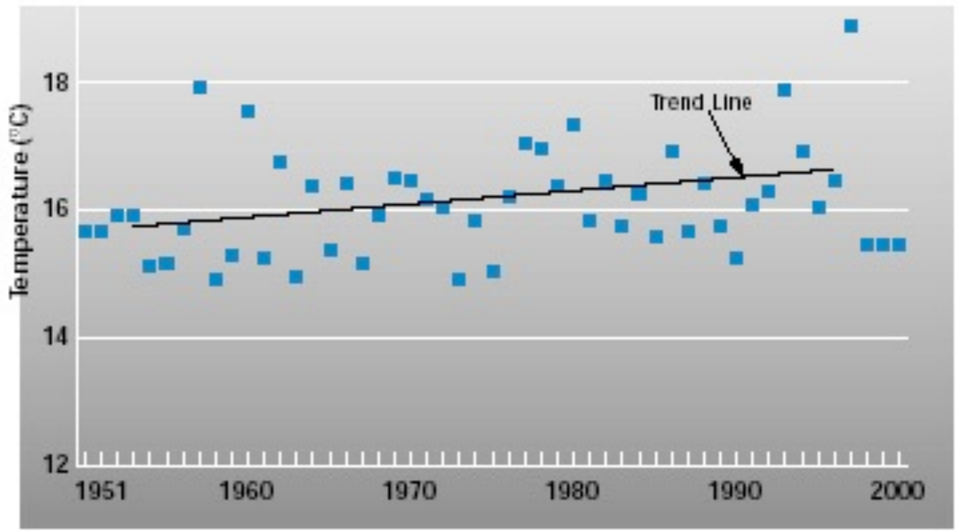


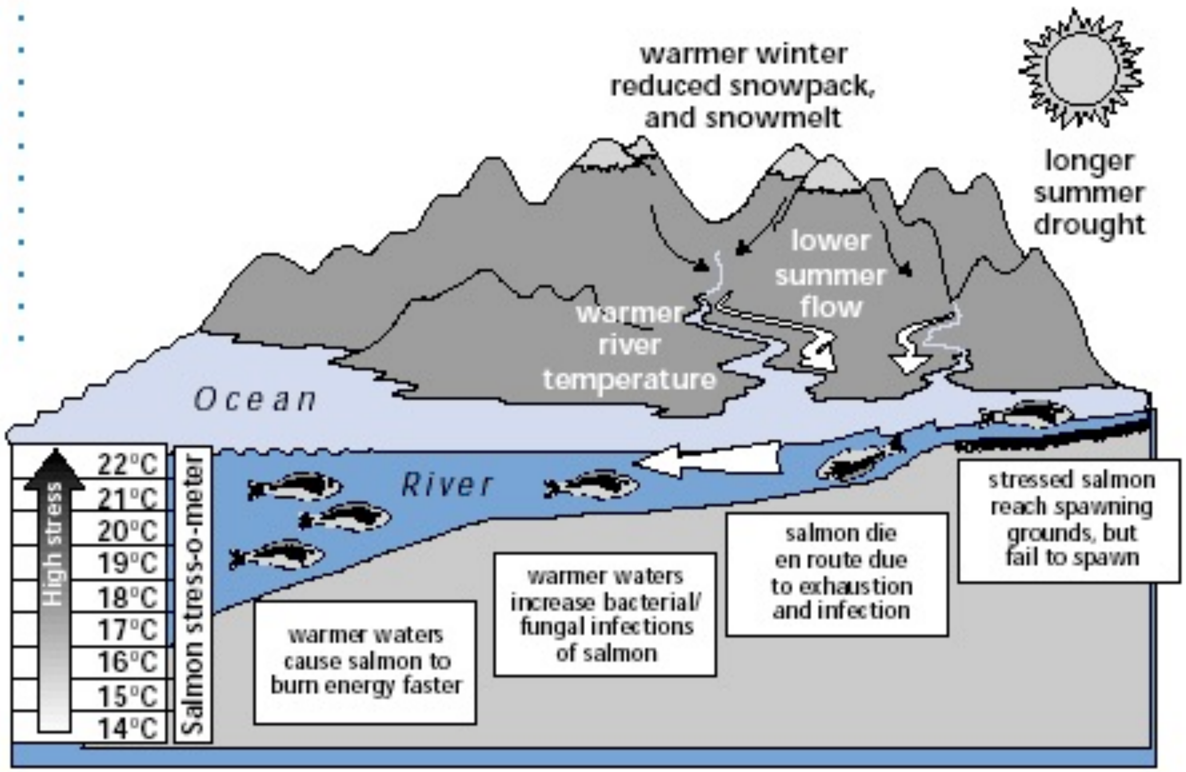
Change in Timing of One-third of Fraser River Annual Flow, 1912-1998




Upper Similkameen River
100
10
1
Metres
Averaged flows
1984-95
1971-83
Earlier snow melt
Greater autumn rain
Extended low-flow period
Lower summer flow
Jan. 1
April 1
June 1
Sept. 1
Dec. 31
Source: Leith and Whitfield, 1998

Change in Average Fraser River Temperature, 1953-1998



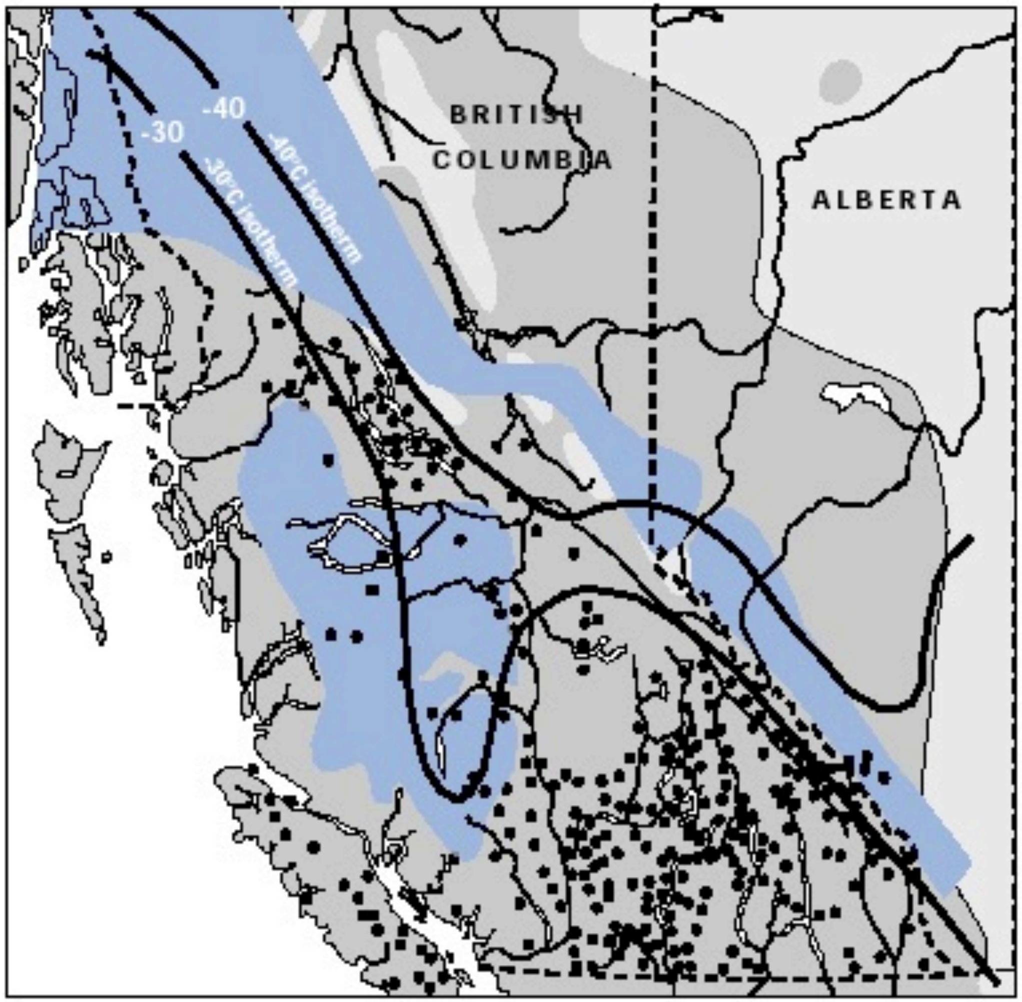


SOURCE: Burghner, R.L. 1991. Life History of Sockeye Salmon. *In* Pacific Salmon Life Histories. University of British Columbia, p.3-117. Graphic from Temperature Rising: Climate Change in Southwestern British Columbia, 1999.

MOUNTAIN PINE BEETLE RANGE

SOURCE: Canadian Forest Service

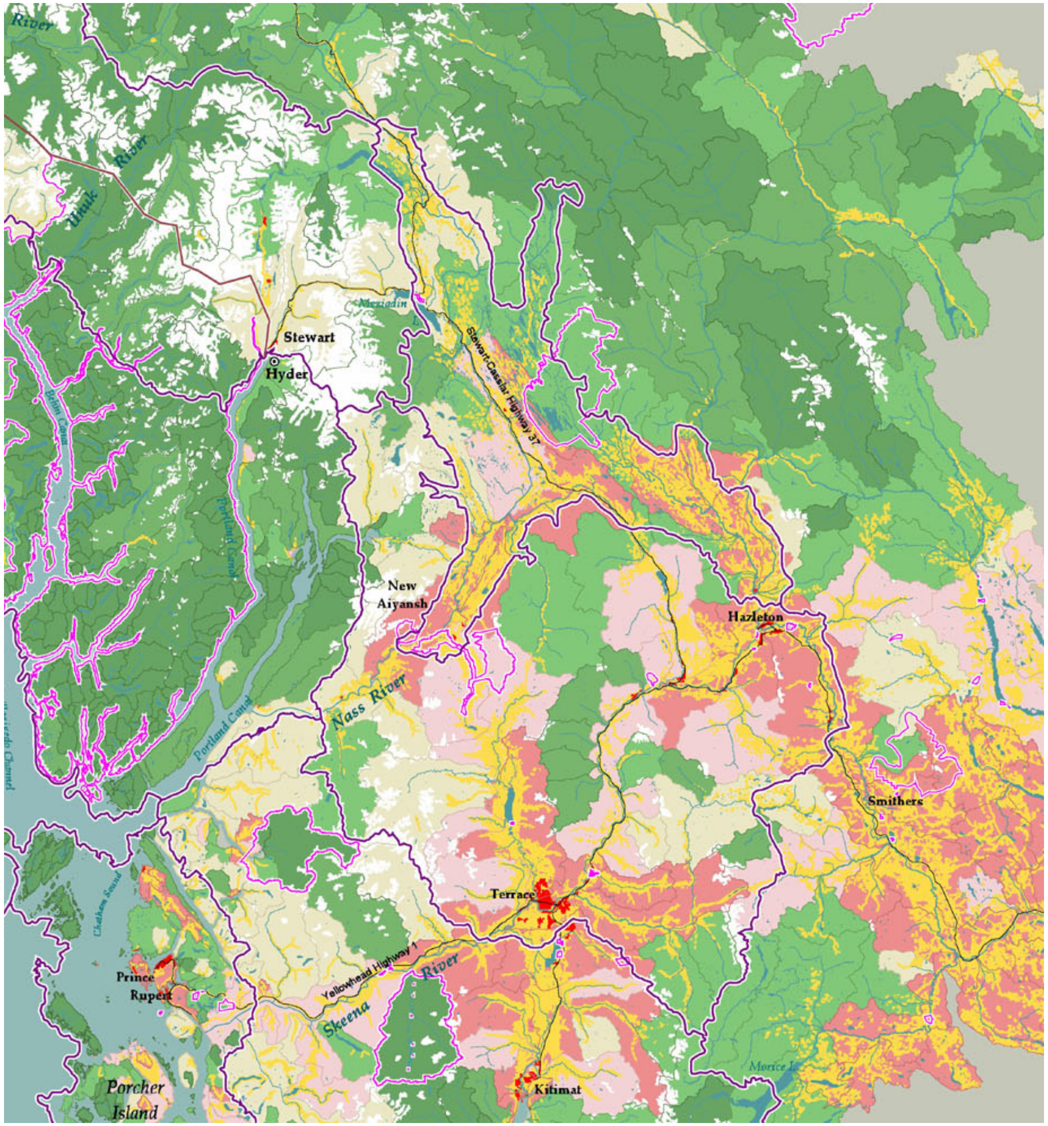
Distribution of Mountain Pine Beetle Infestations, 1910-1970



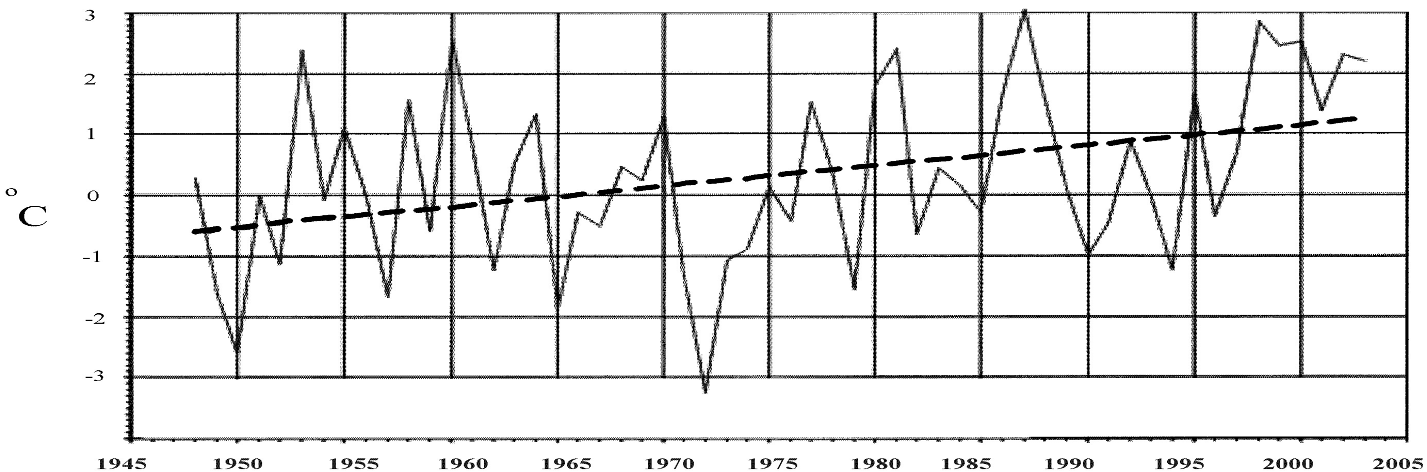
LEGEND

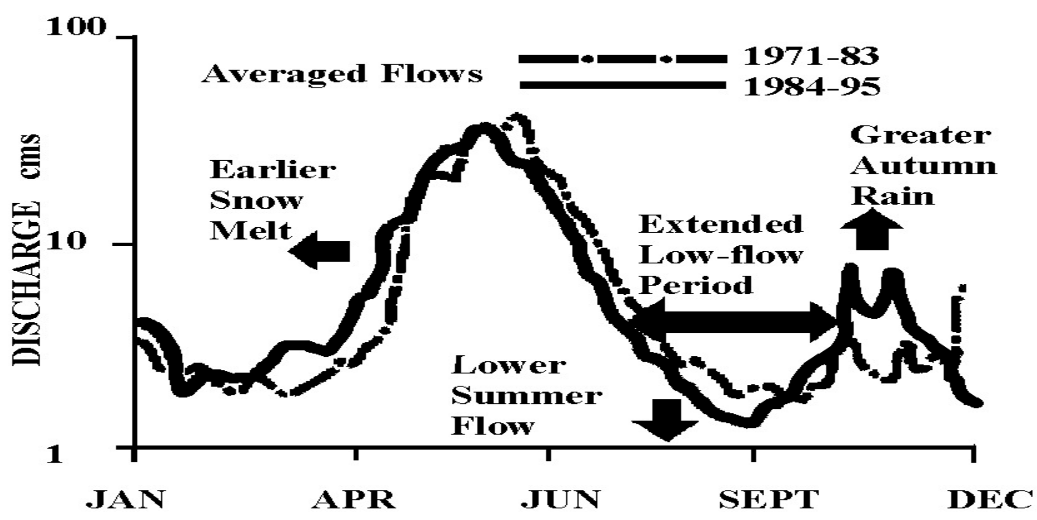
Areas where there is not enough accumulated heat for beetles to complete development on a one-year cycle. (i.e. average degree-day accumulation <833 above 5.6°C)

Range of lodgepole pine

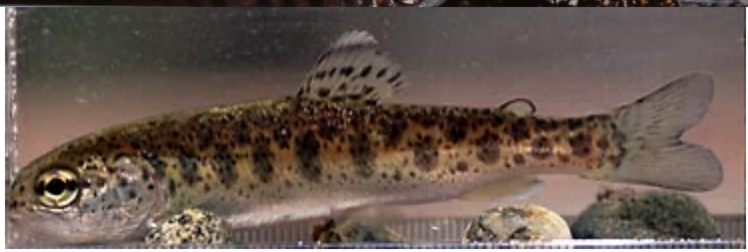


Unuk River
Stewart
Hyder
Stewart-Cassiar Highway 37
New Aiyansh
Hazleton
Nass River
Smithers
Terrace
Skeena River
Prince Rupert
Kitimat
Porcher Island


3
2
1
0
-1
-2
-3
°C
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005


100
10
1
DISCHARGE cms
Averaged Flows
1971-83
1984-95
Earlier
Snow
Melt
Greater
Autumn
Rain
Extended
Low-flow
Period
Lower
Summer
Flow
JAN
APR
JUN
SEPT
DEC

Impacted by Summer Rearing Habitat



Steelhead