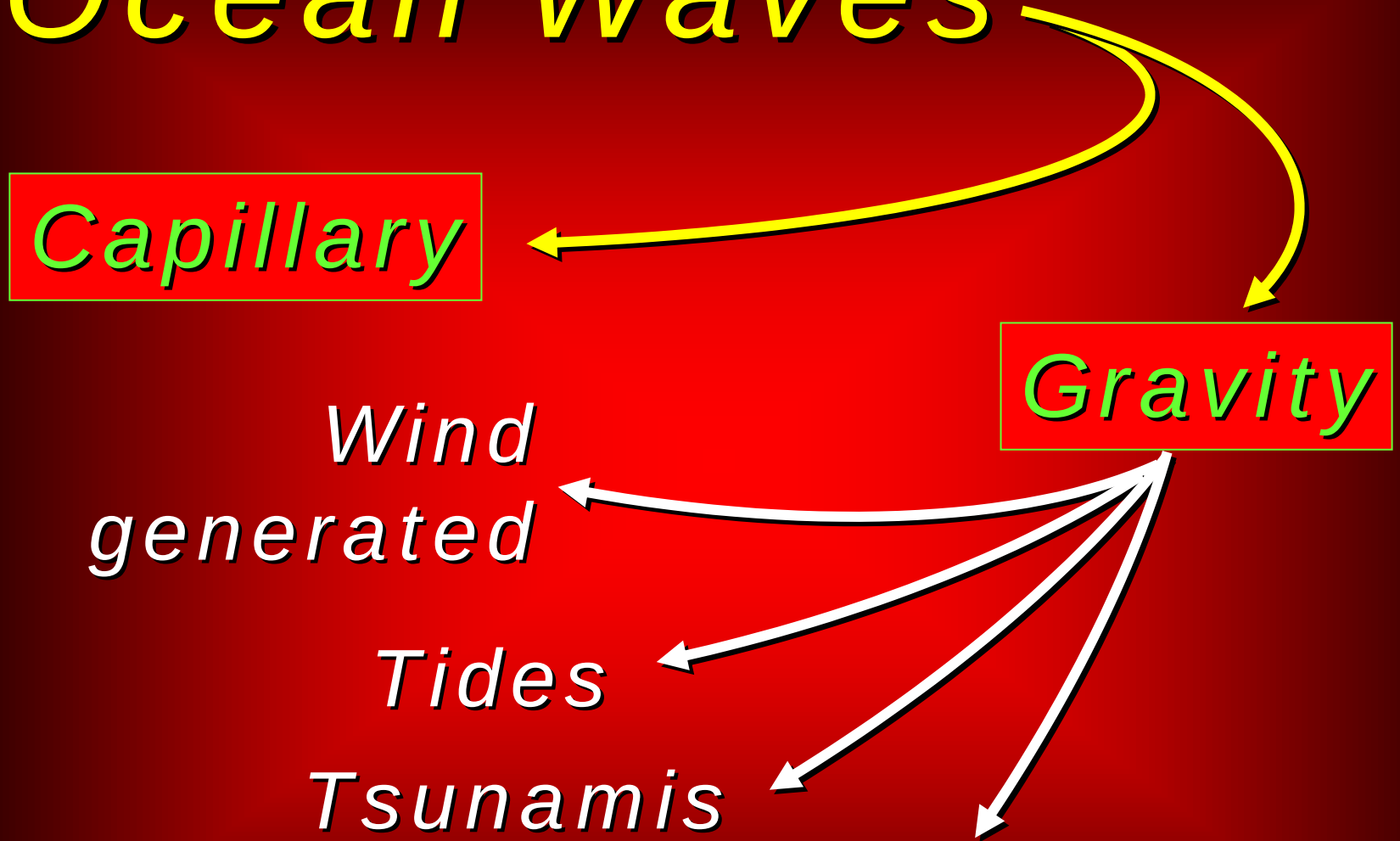
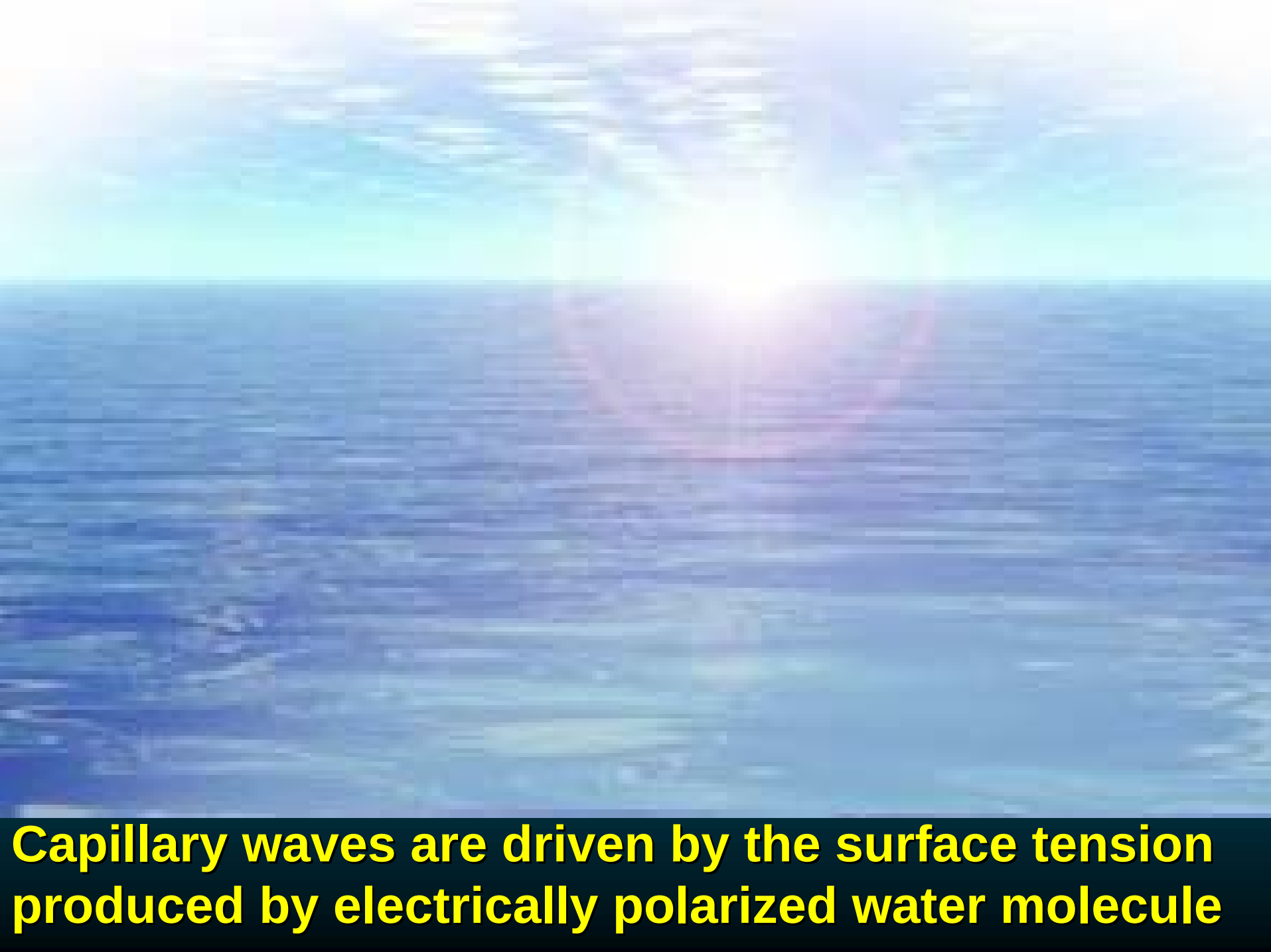
Ocean Waves

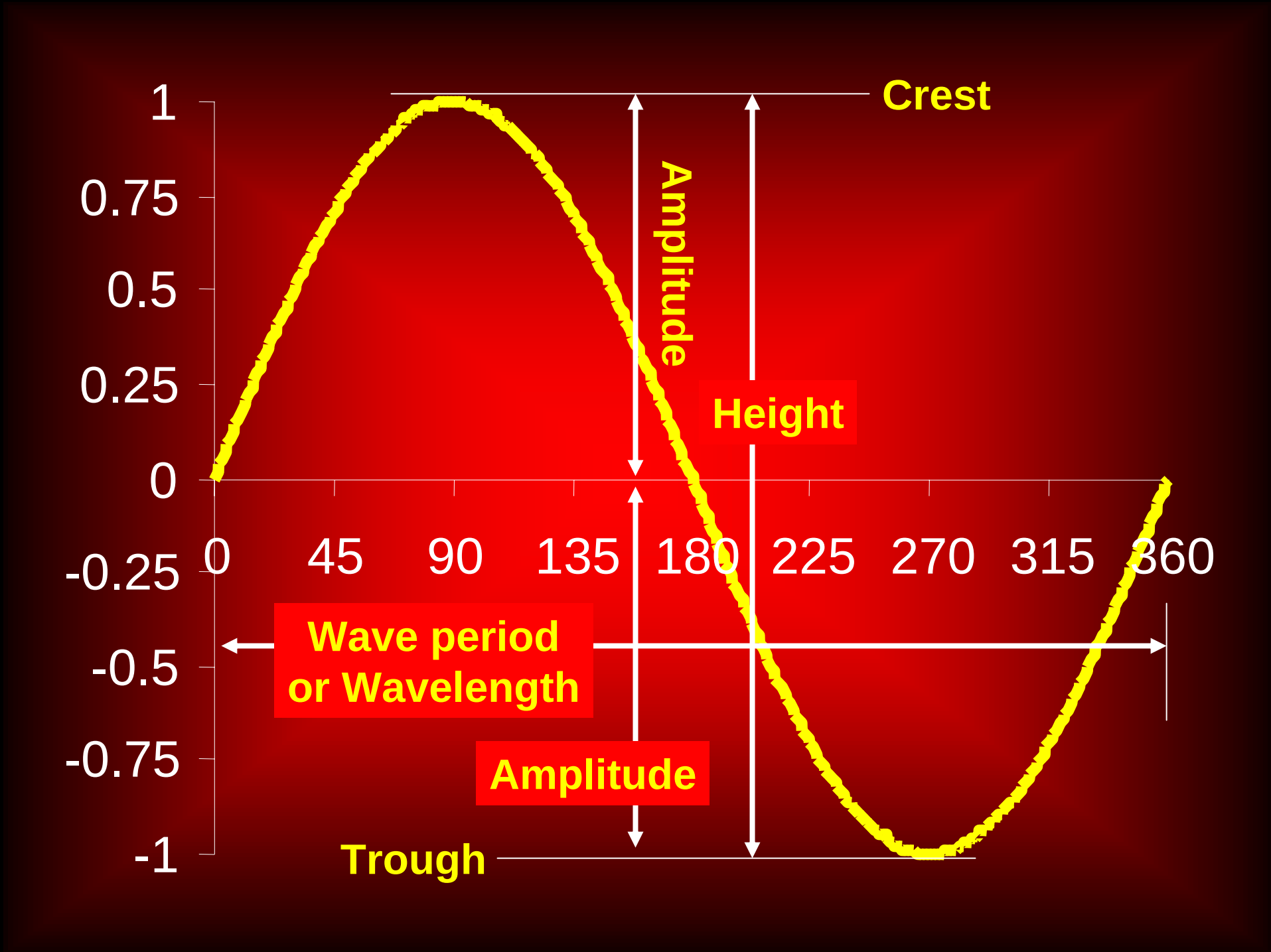



Capillary waves are driven by the surface tension
produced by electrically polarized water molecule


San Pedro Lighthouse

Waves

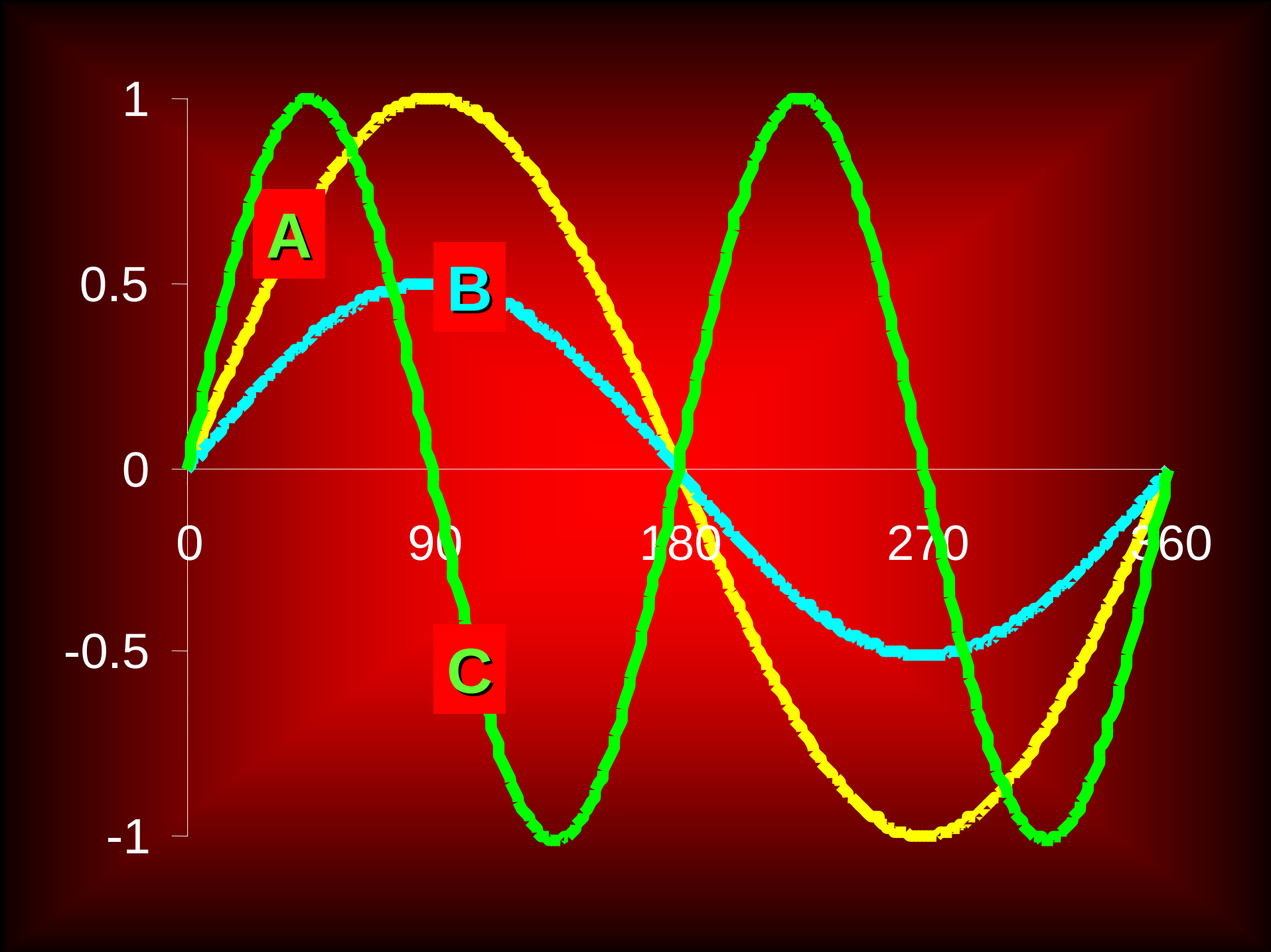
- **are alternate rises and falls, describable as simple/complex sinusoidals**

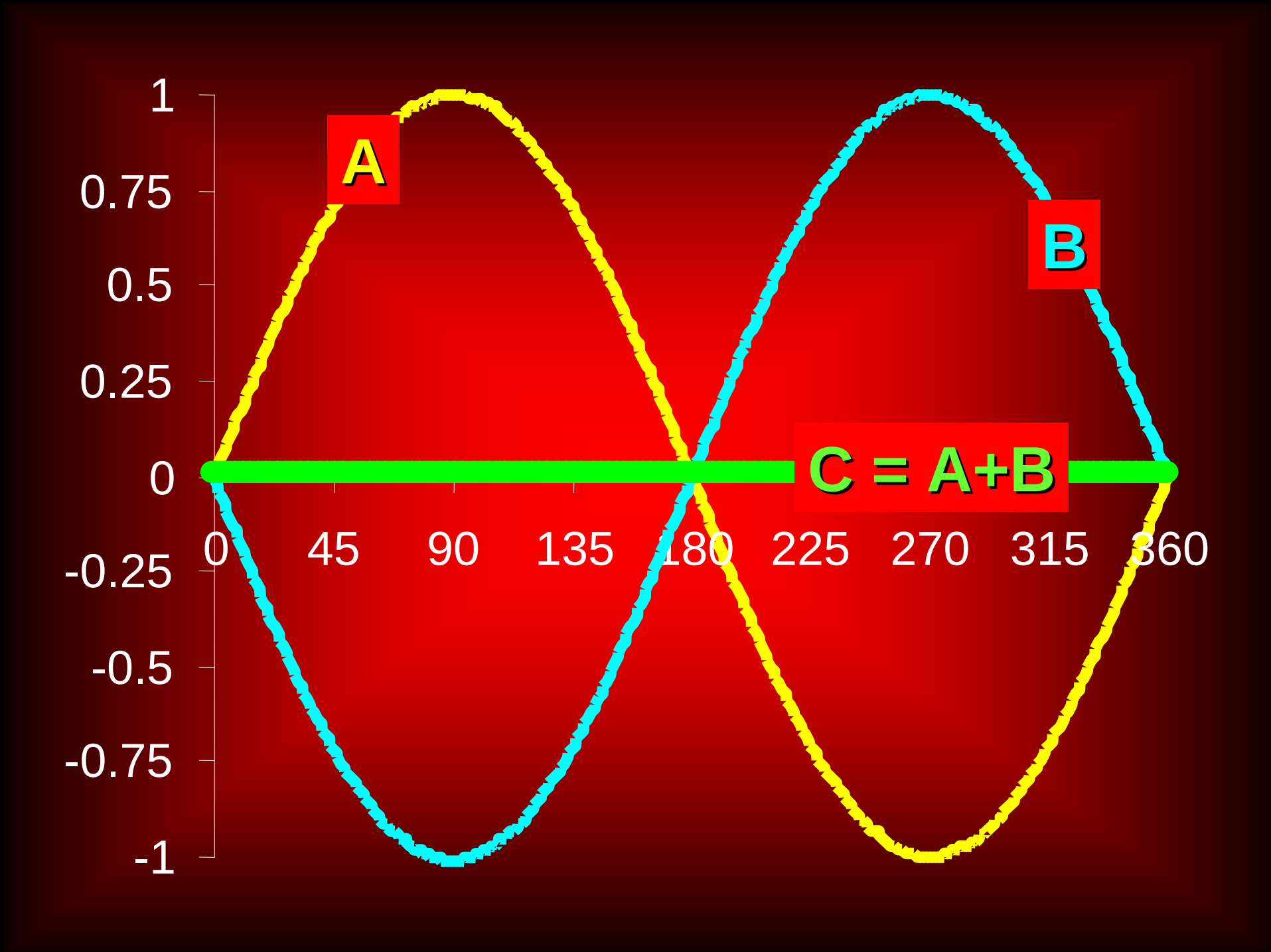

1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
0
45
90
135
180
225
270
315
360
Crest
Amplitude
Height
Wave period
or Wavelength
Amplitude
Trough

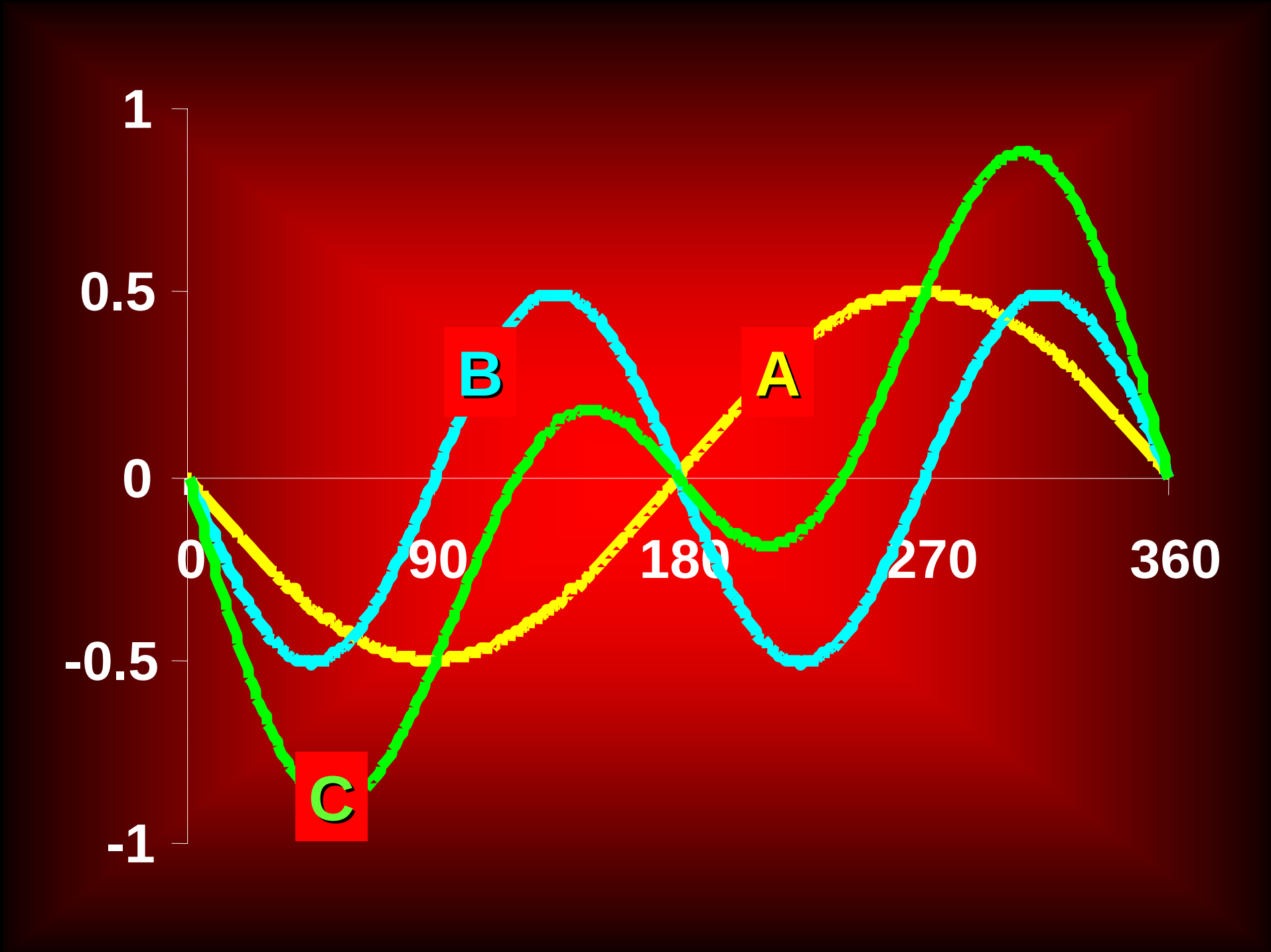
Waves

- **are alternate rises and falls, describable as simple/complex sinusoidals**
- **only add-up, always**

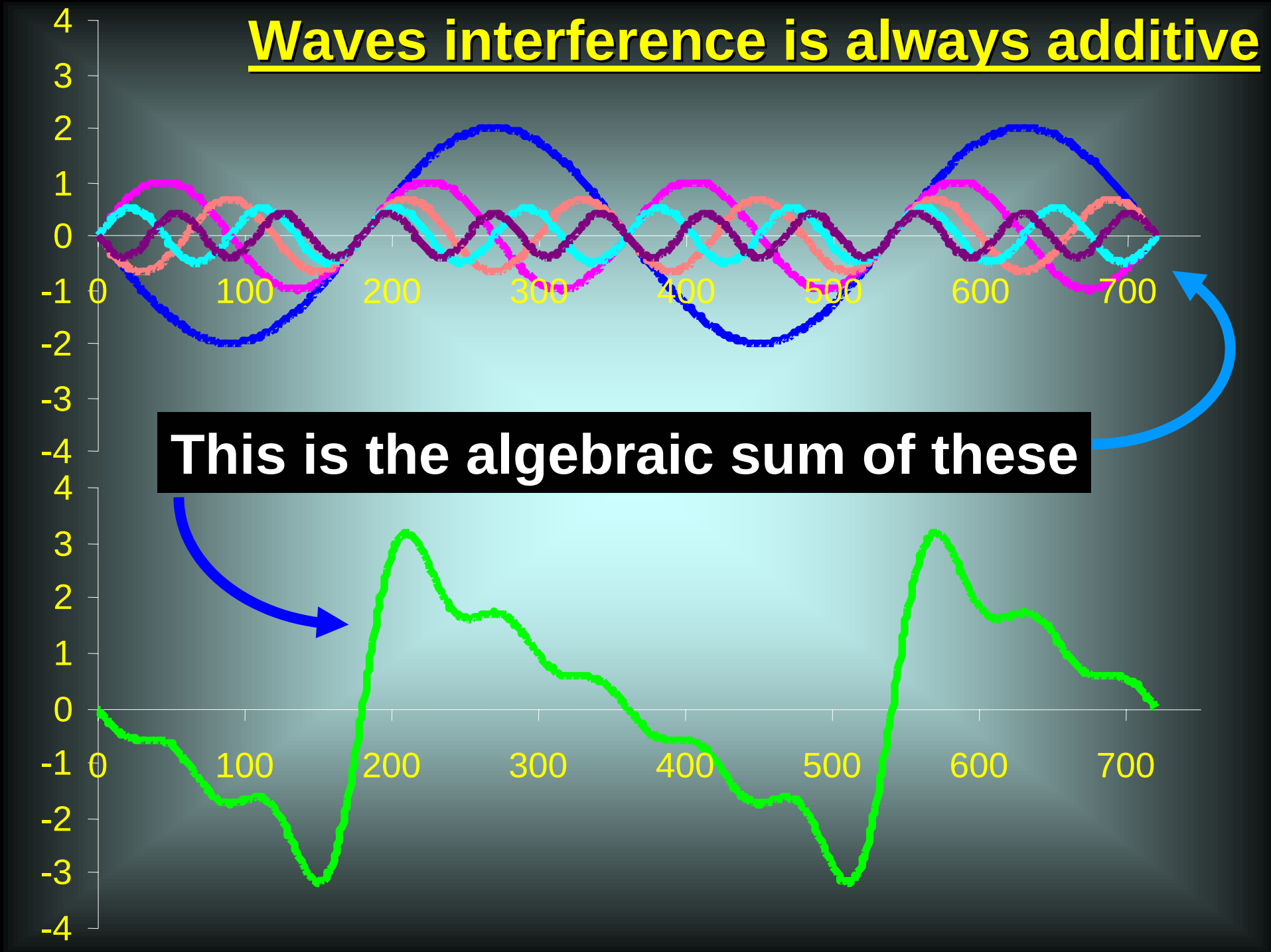
  i.e., wave interference can be constructive and/or destructive


1
0.5
0
-0.5
-1
0
90
180
270
360
A
B
C

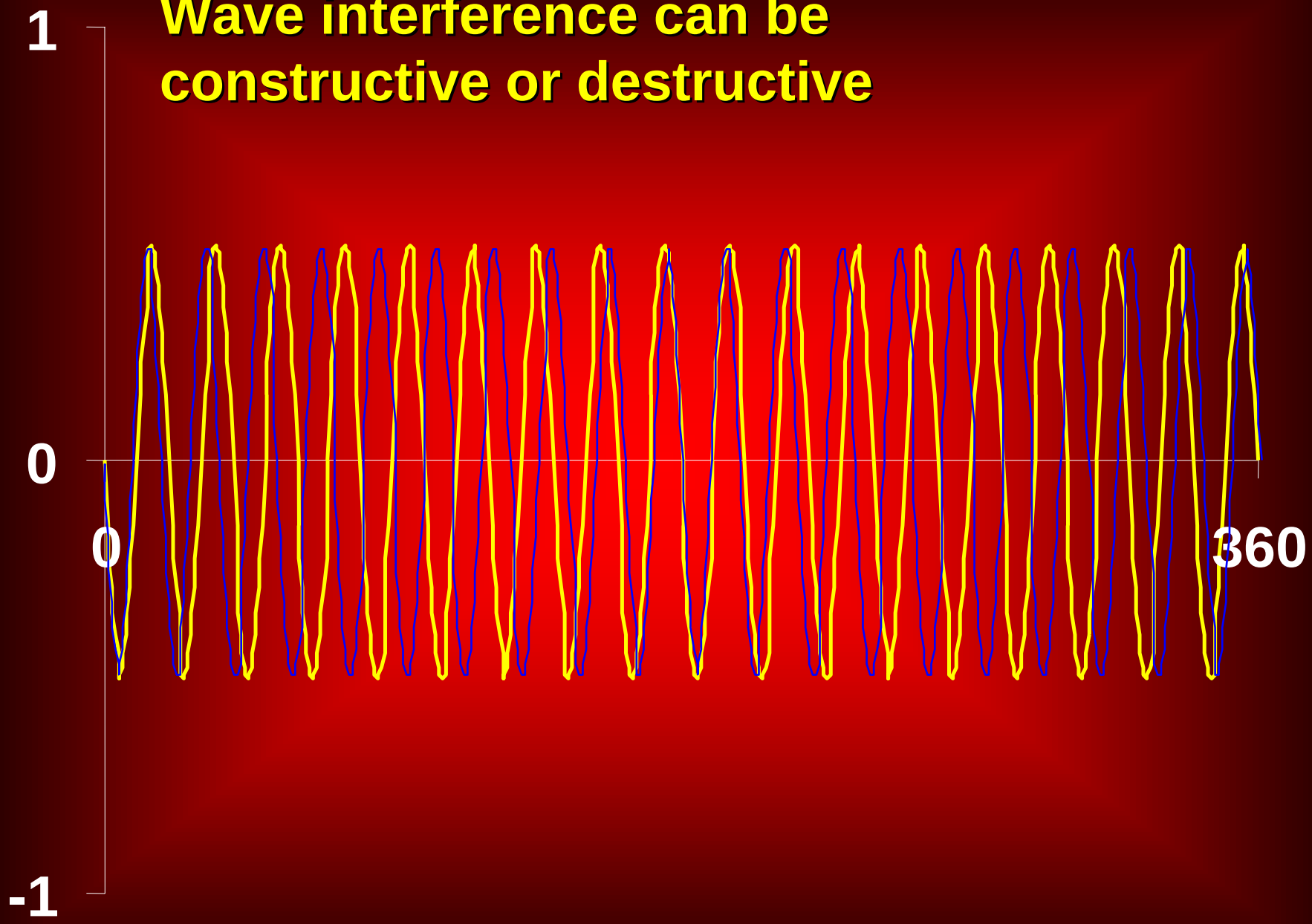

1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
0
45
90
135
180
225
270
315
360
A
B
C = A+B

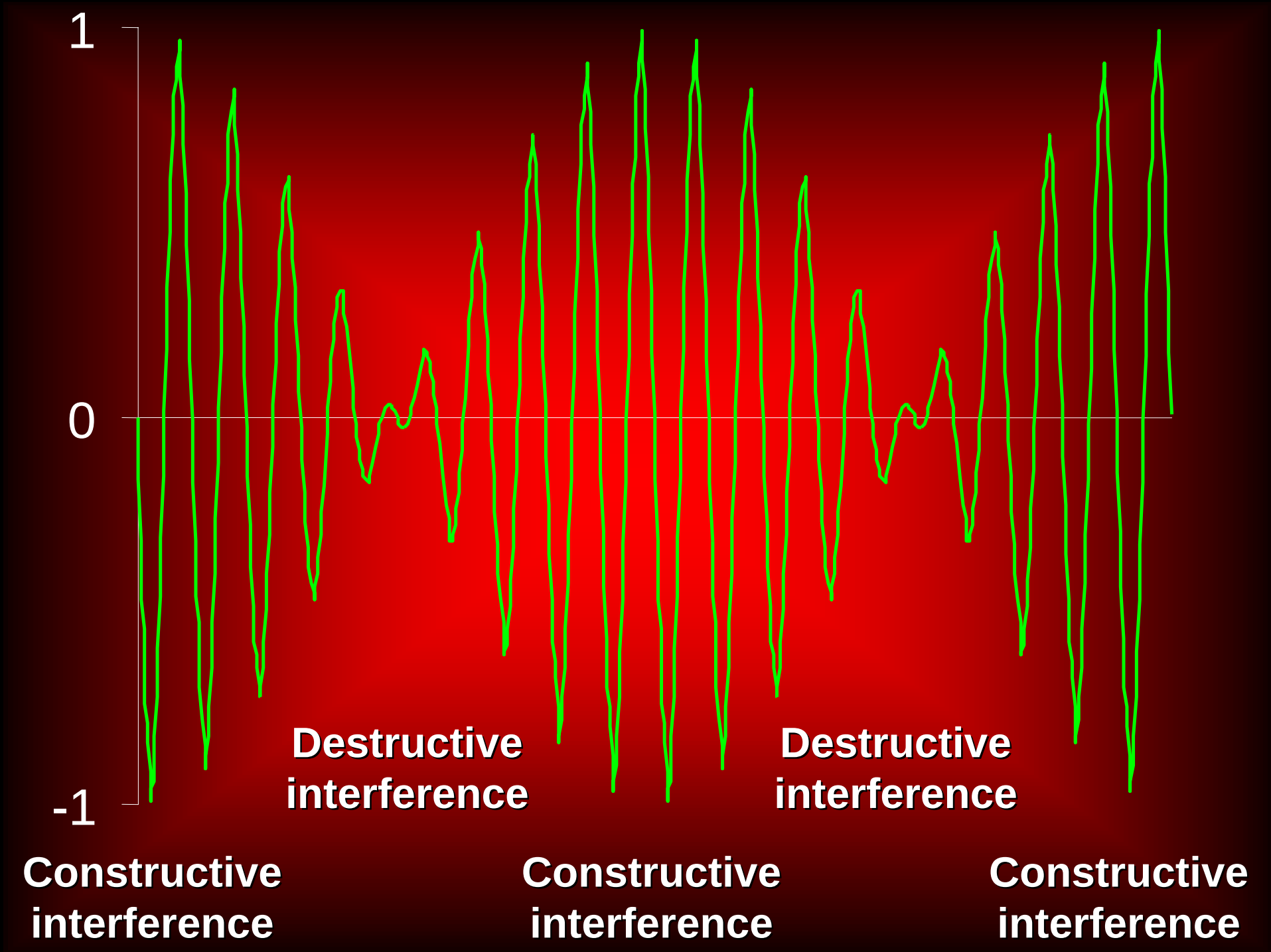

1
0.5
0
-0.5
-1
0
90
180
270
360
A
B
C

Waves interference is always additive



Wave interference can be constructive or destructive



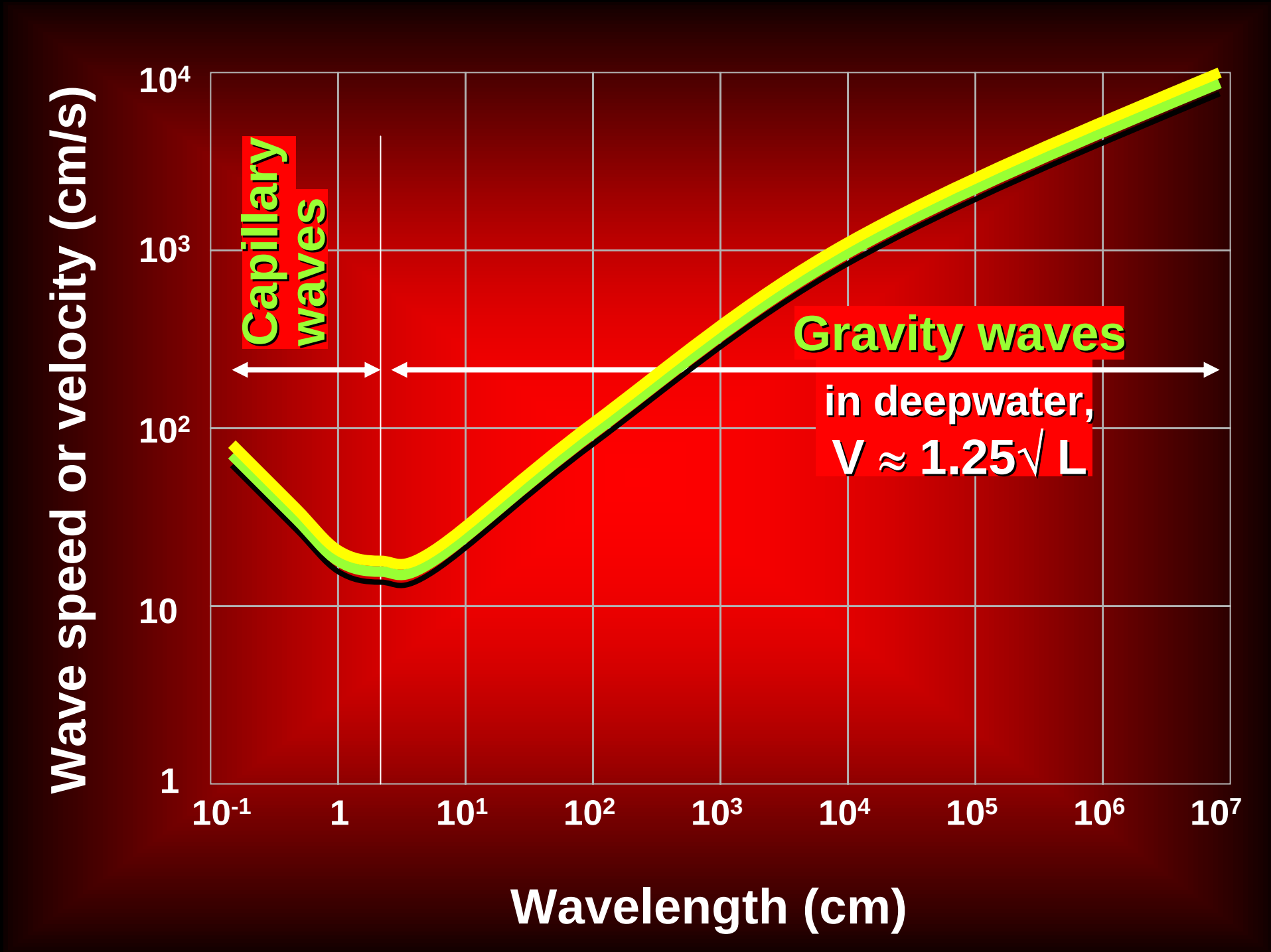

1
0
-1
Destructive interference
Destructive interference
Constructive interference
Constructive interference
Constructive interference

Waves

- are alternate rises and falls, describable as simple/complex sinusoidals
- only add-up, always

  i.e., wave interference can be constructive and/or destructive
- carry energy, not matter

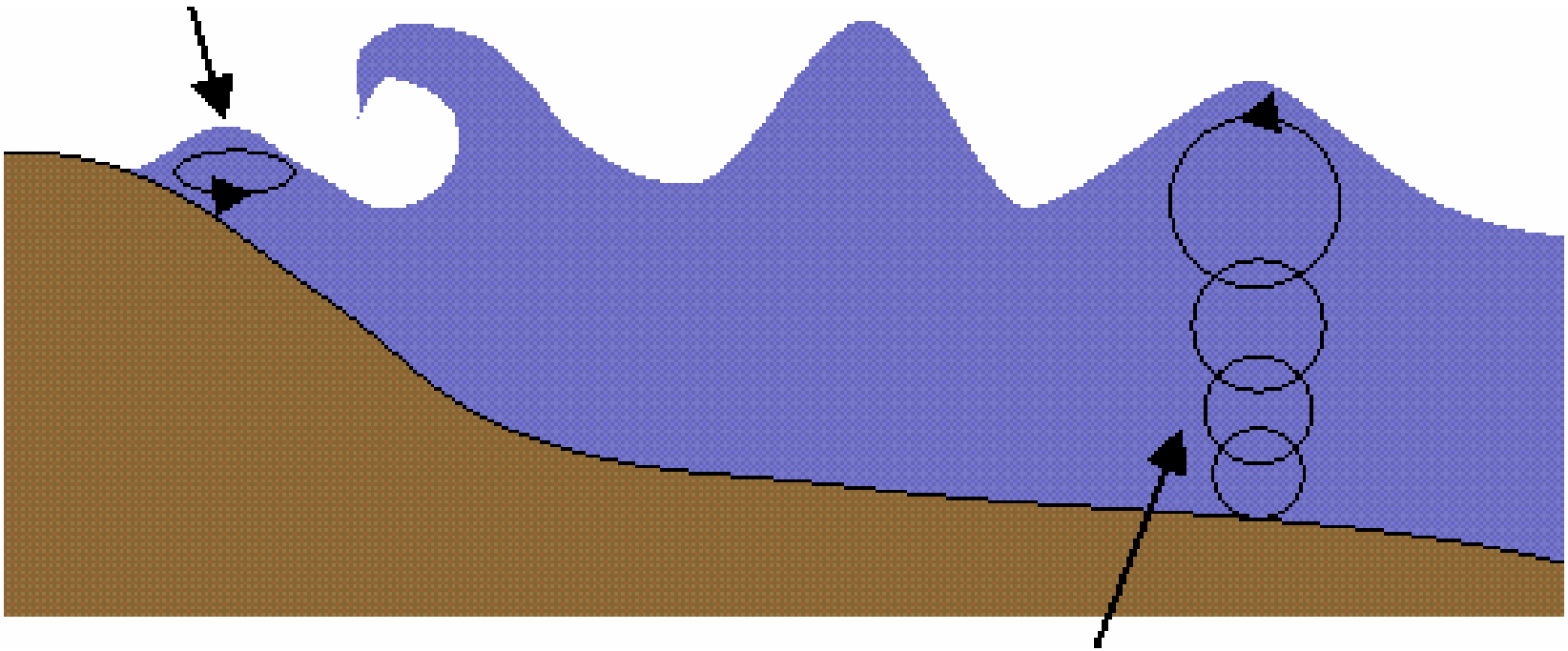
  light is an exception, it travels in waves and as particles


Wave speed or velocity (cm/s)
10^4
10^3
10^2
10
1
Capillary waves
Gravity waves
in deepwater,
V ≈ 1.25√ L
10^-1
1
10^1
10^2
10^3
10^4
10^5
10^6
10^7
Wavelength (cm)

Waves carry energy, not matter

The orbital motion of representative water molecules: orbital size decreases with depth, with negligible water motion at depth ≈ ½ wavelength

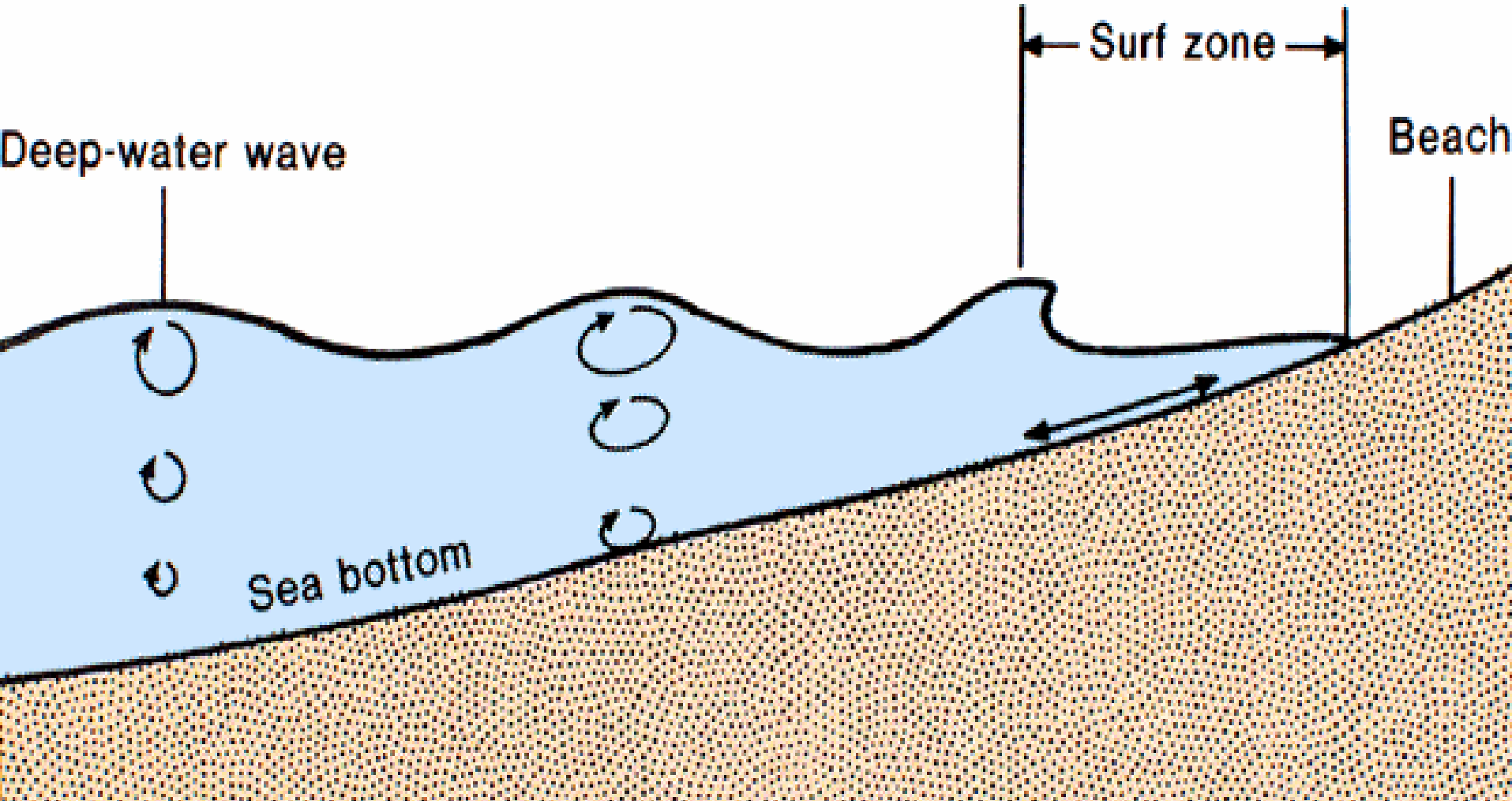
Elliptical path: waves of translation



Circular path: waves of oscillation

Waves break on reaching the shore. Why?

Waves break as the succeeding waves catch up with preceding waves

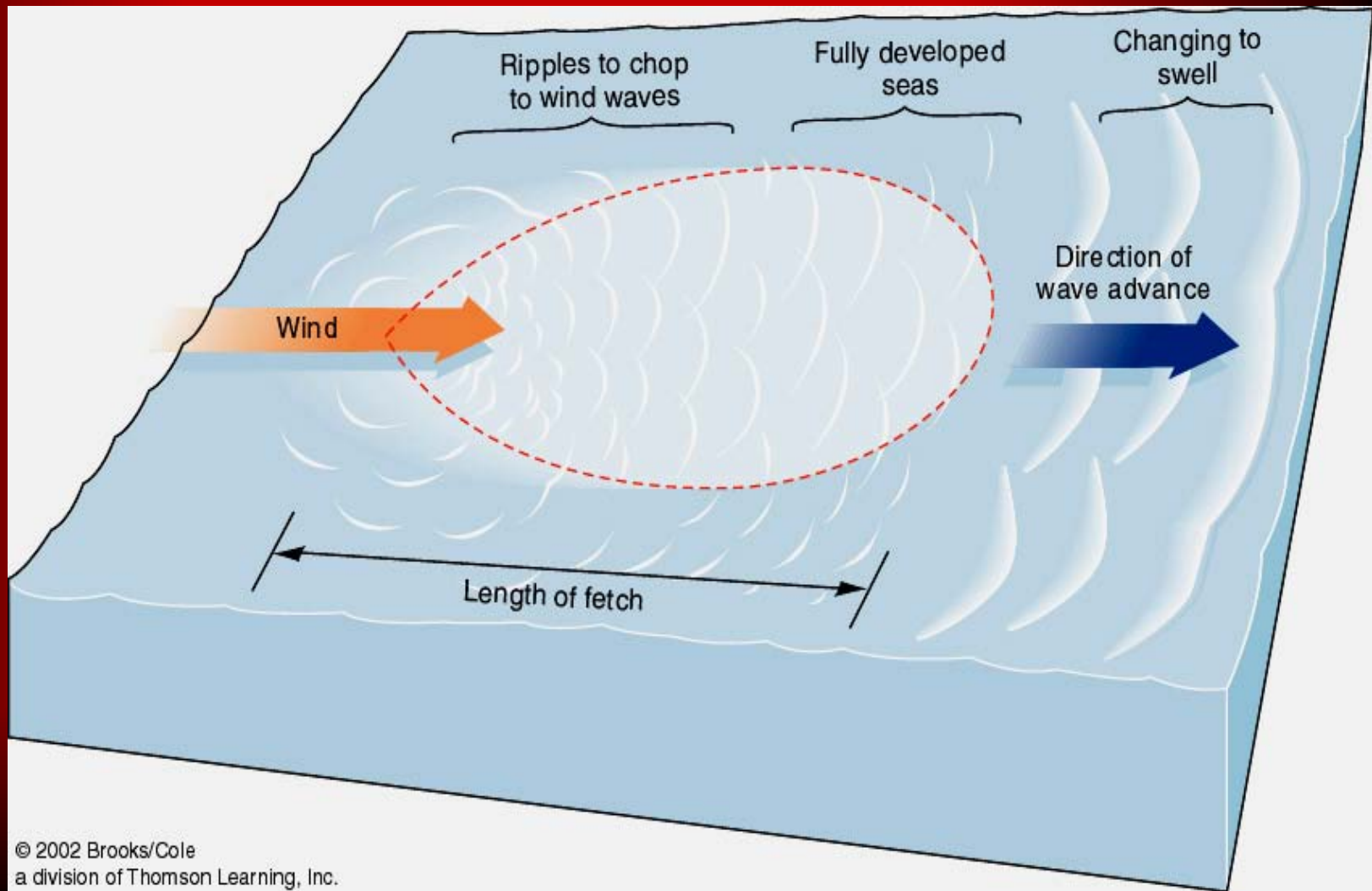



Spilling breakers form when the bottom slopes gradually


Plunging or surging
breakers form when the
bottom slope is steep

Three factors affect wind wave development:

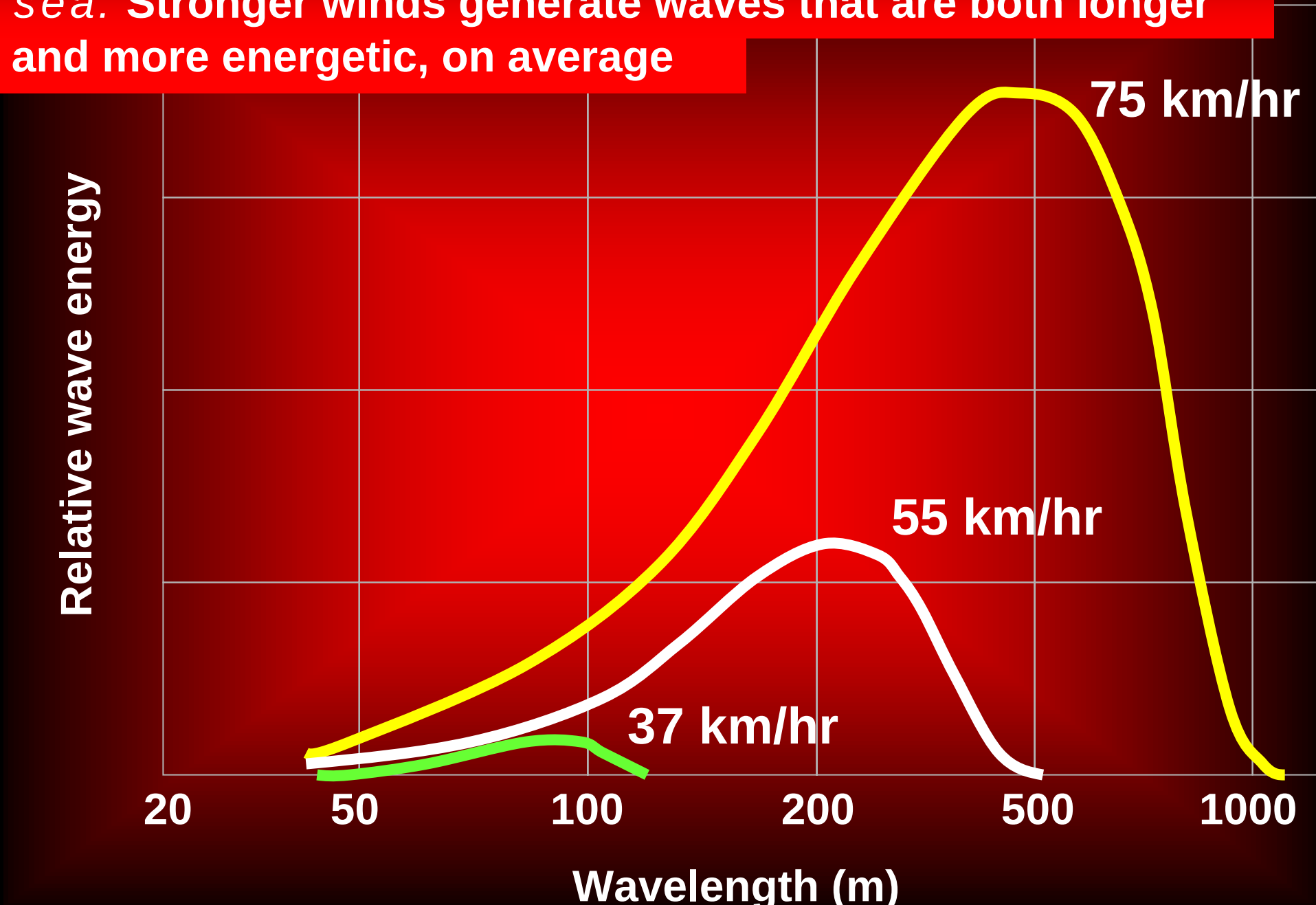
(a) Wind speed, (b) Wind duration, and (c) Fetch

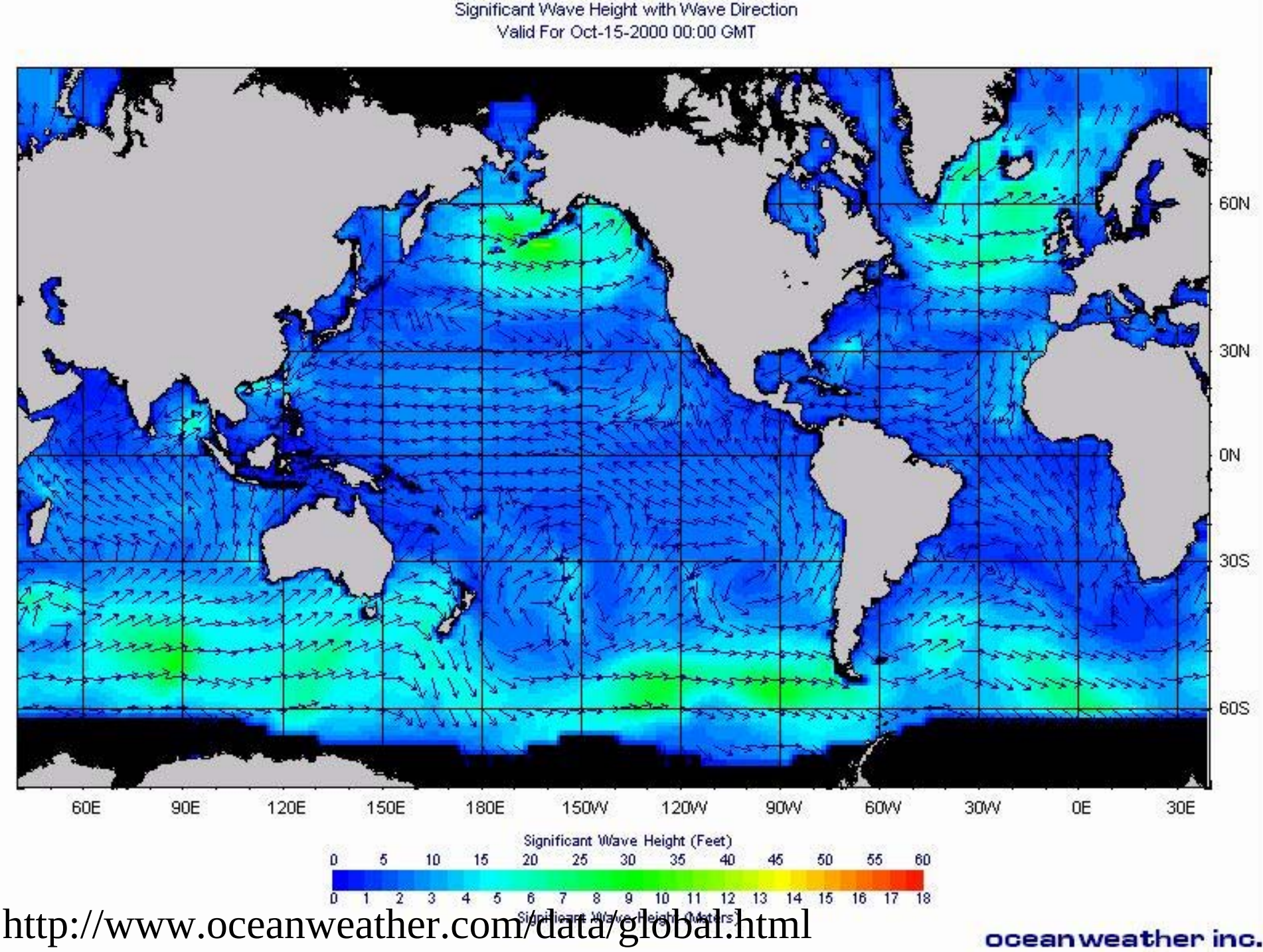


Conditions conducive of a fully developed sea

Wind Conditions			Wave Size		
Wind speed	Fetch	Wind duration	Average height	Average Length	Average period
19 km/hr (10 knots)	19 km	2 hr	0.27 m	8.5 m	3.0 sec
37 km/hr (20 knots)	139 km	10 hr	1.5 m	33.8 m	5.7 sec
56 km/hr (30 knots)	518 km	23 hr	4.1 m	76.5 m	8.6 sec
74 km/hr (40 knots)	1313 km	42 hr	8.5 m	136 m	11.4 sec
92 km/hr (50 knots)	2627 km	69 hr	14.8 m	212 m	14.3 sec

Wave energy versus wavelength for fully developed sea: **Stronger winds generate waves that are both longer and more energetic, on average**

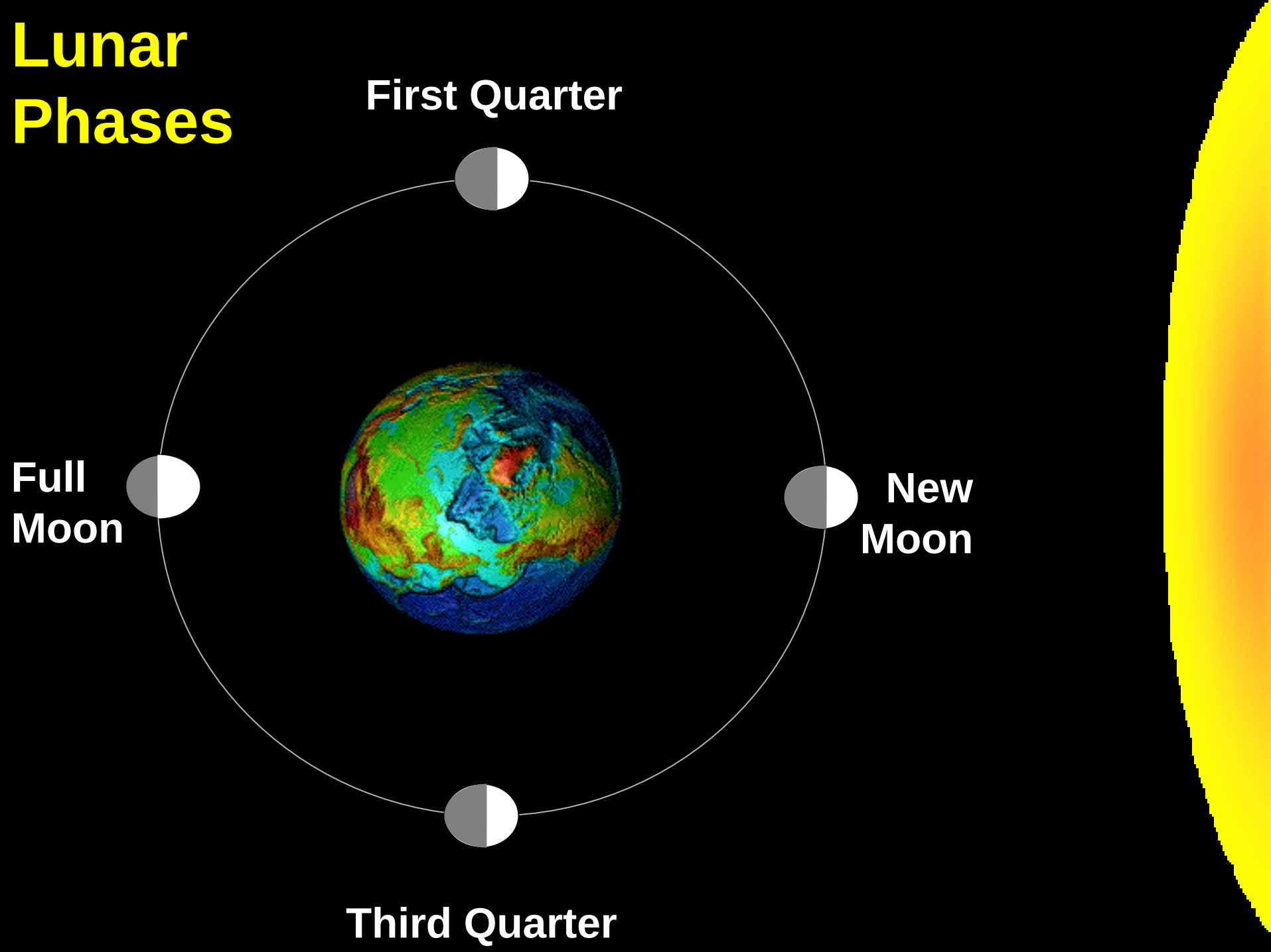




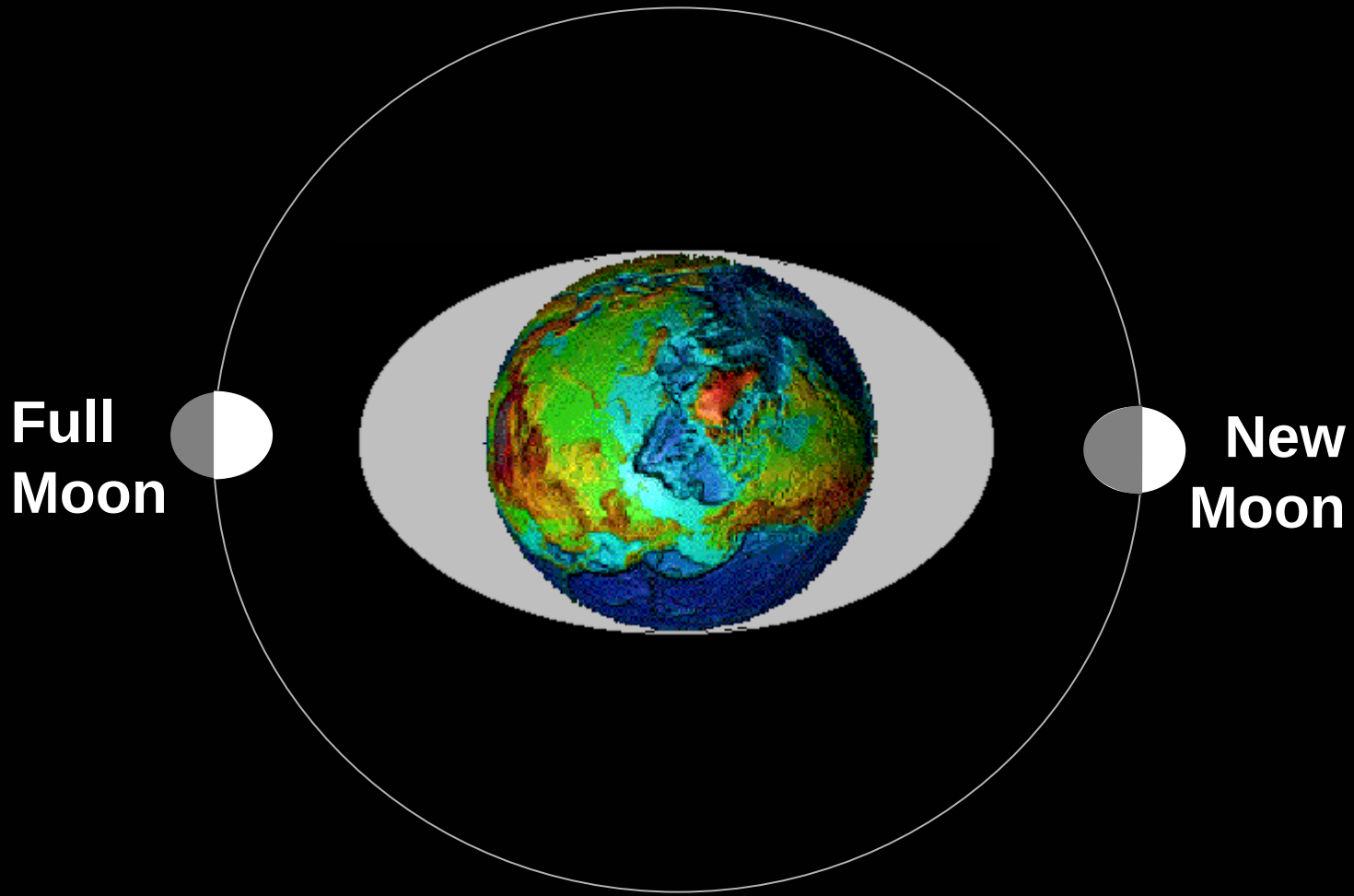
http://www.oceanweather.com/data/global.html

oceanweather inc.

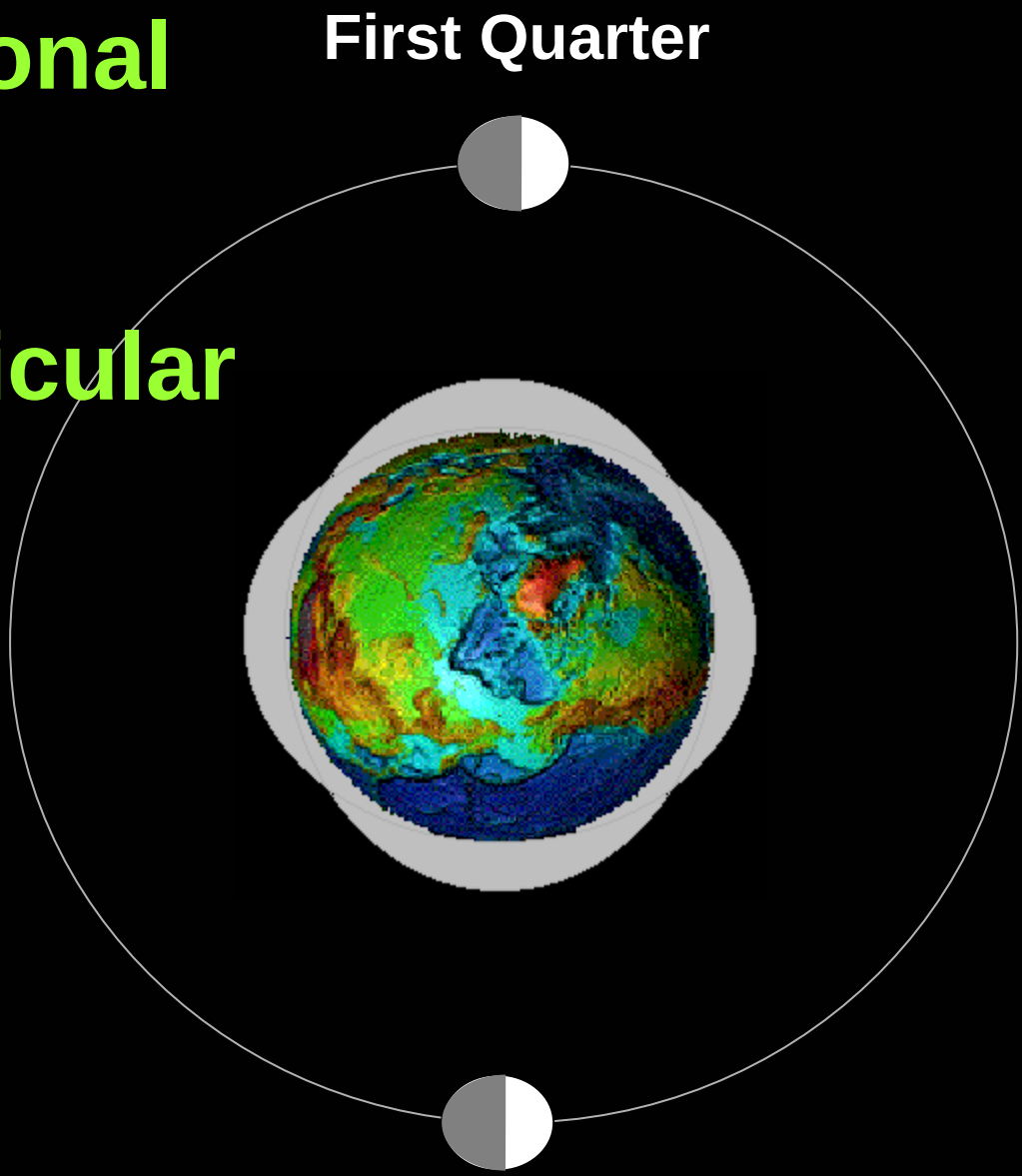
Lunar Phases



Spring Tides occur when the lunar and solar gravitational pulls add up

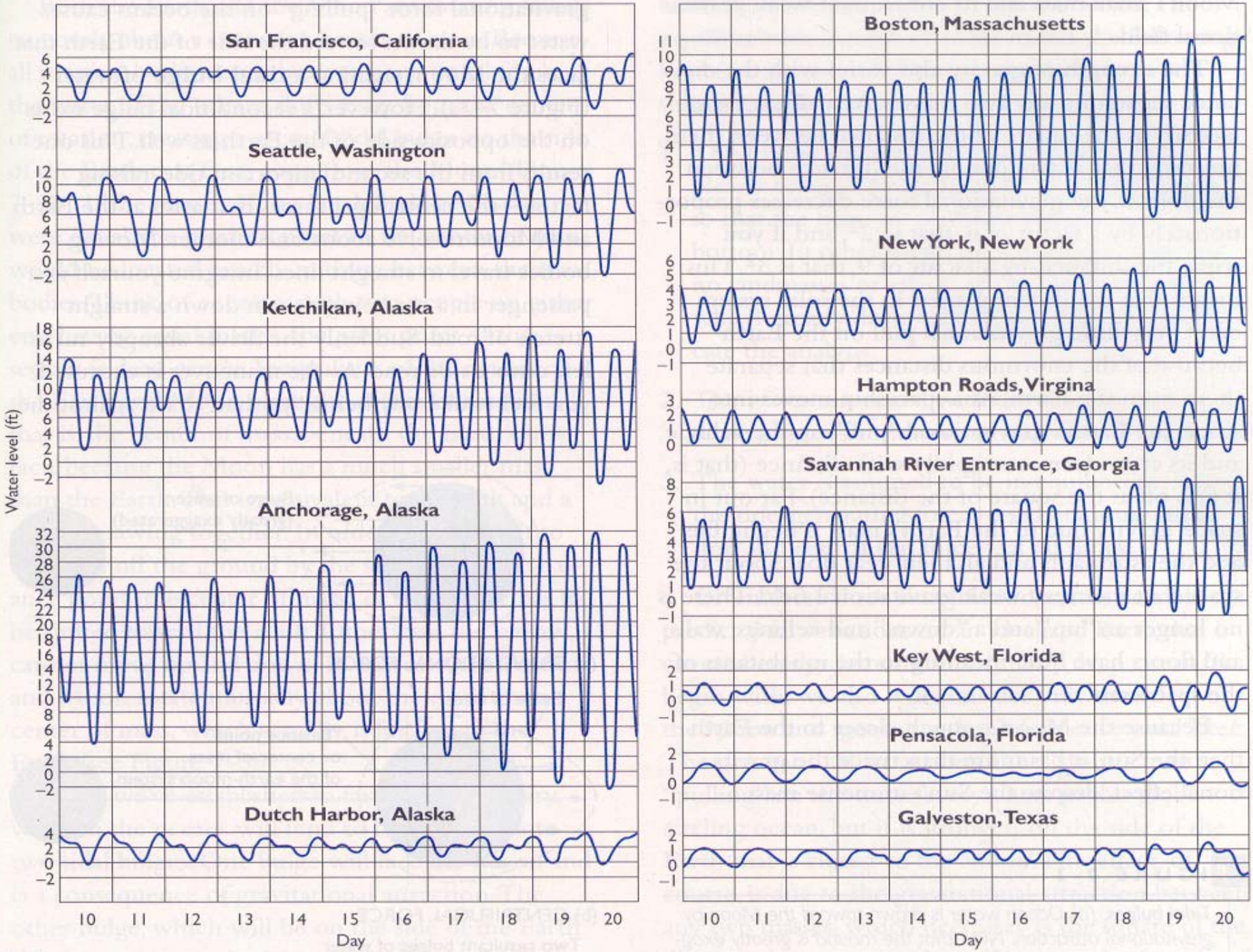


Neap Tides occur when lunar and solar gravitational pulls are mutually perpendicular

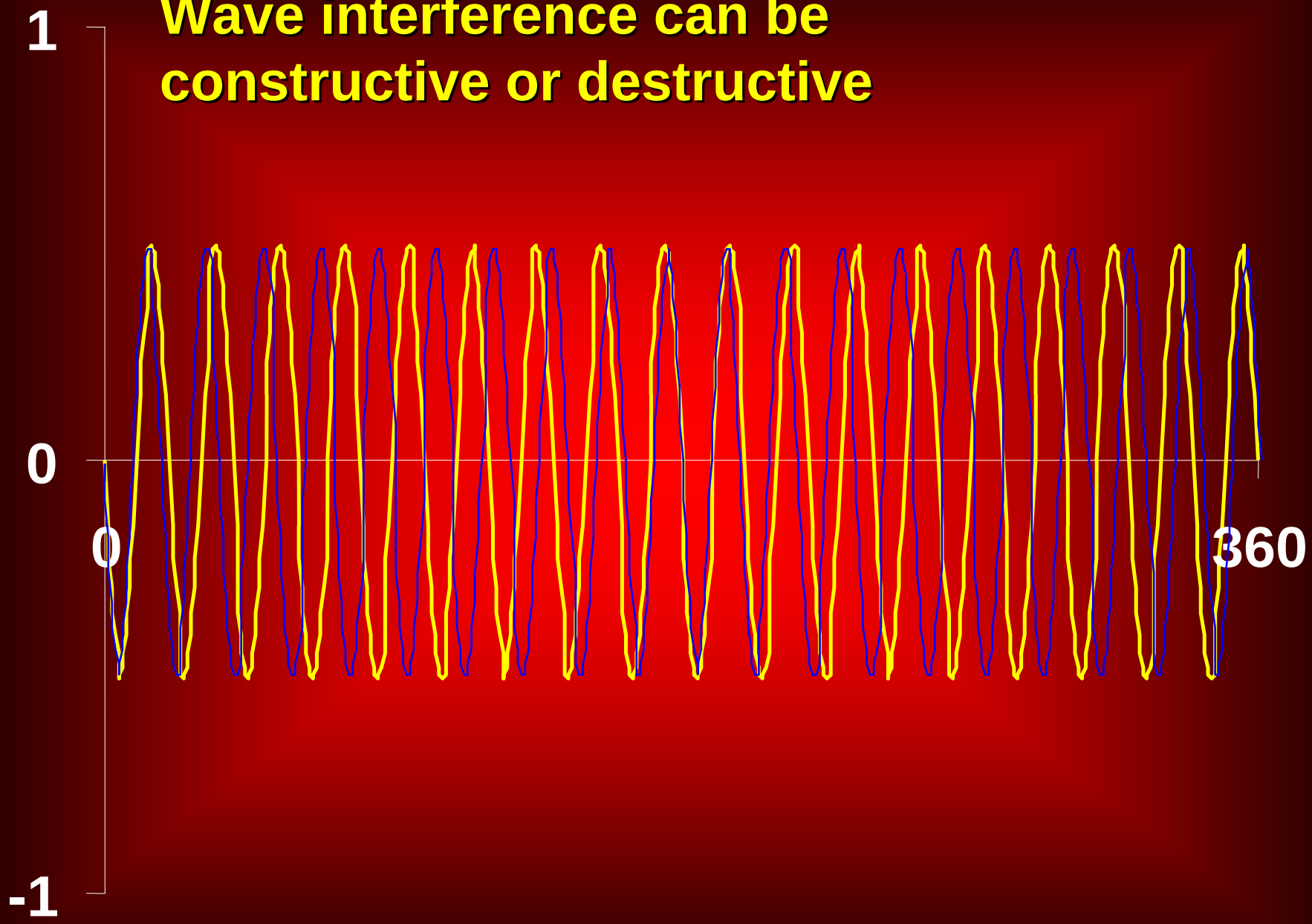


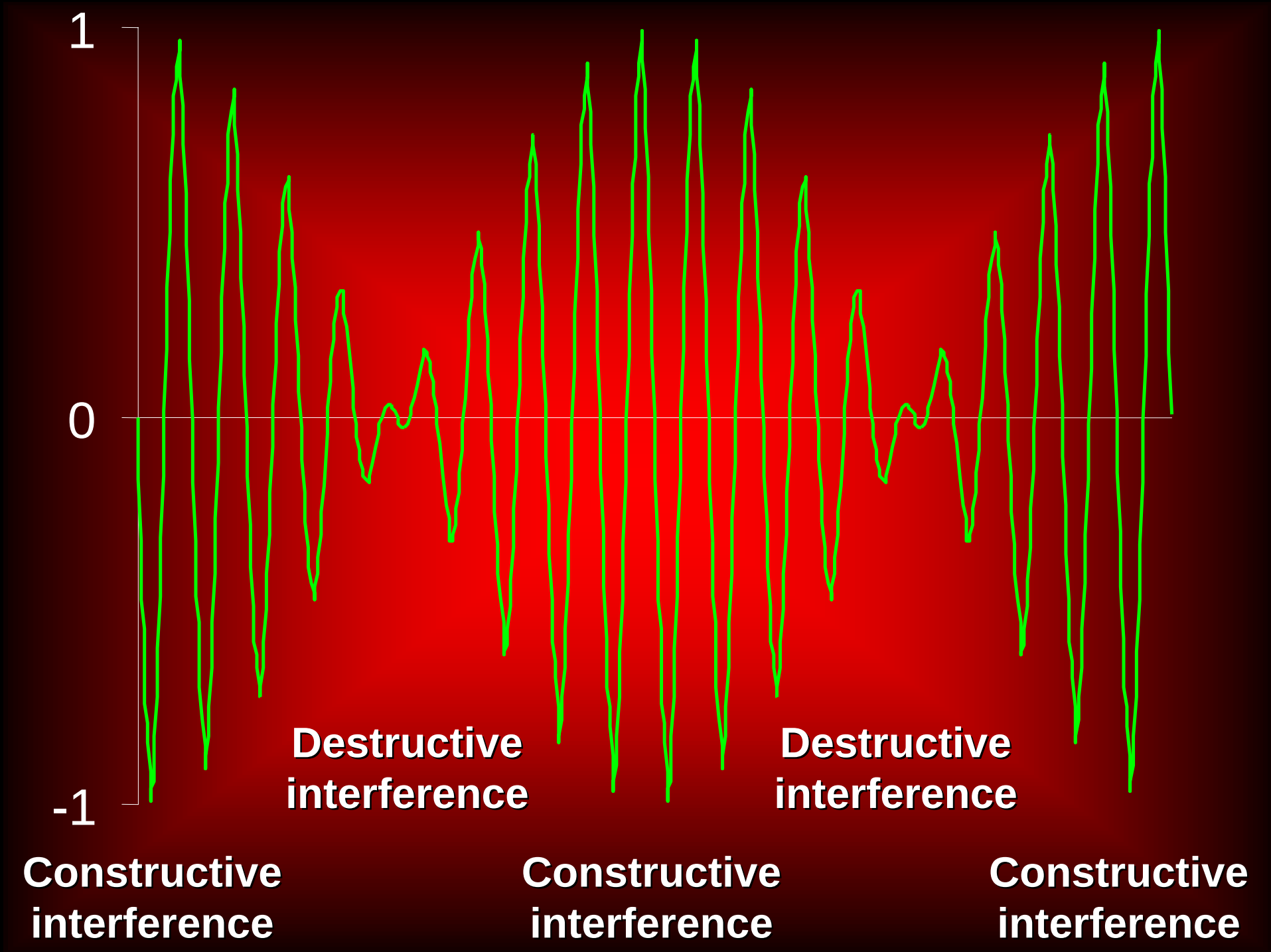
Tides can be

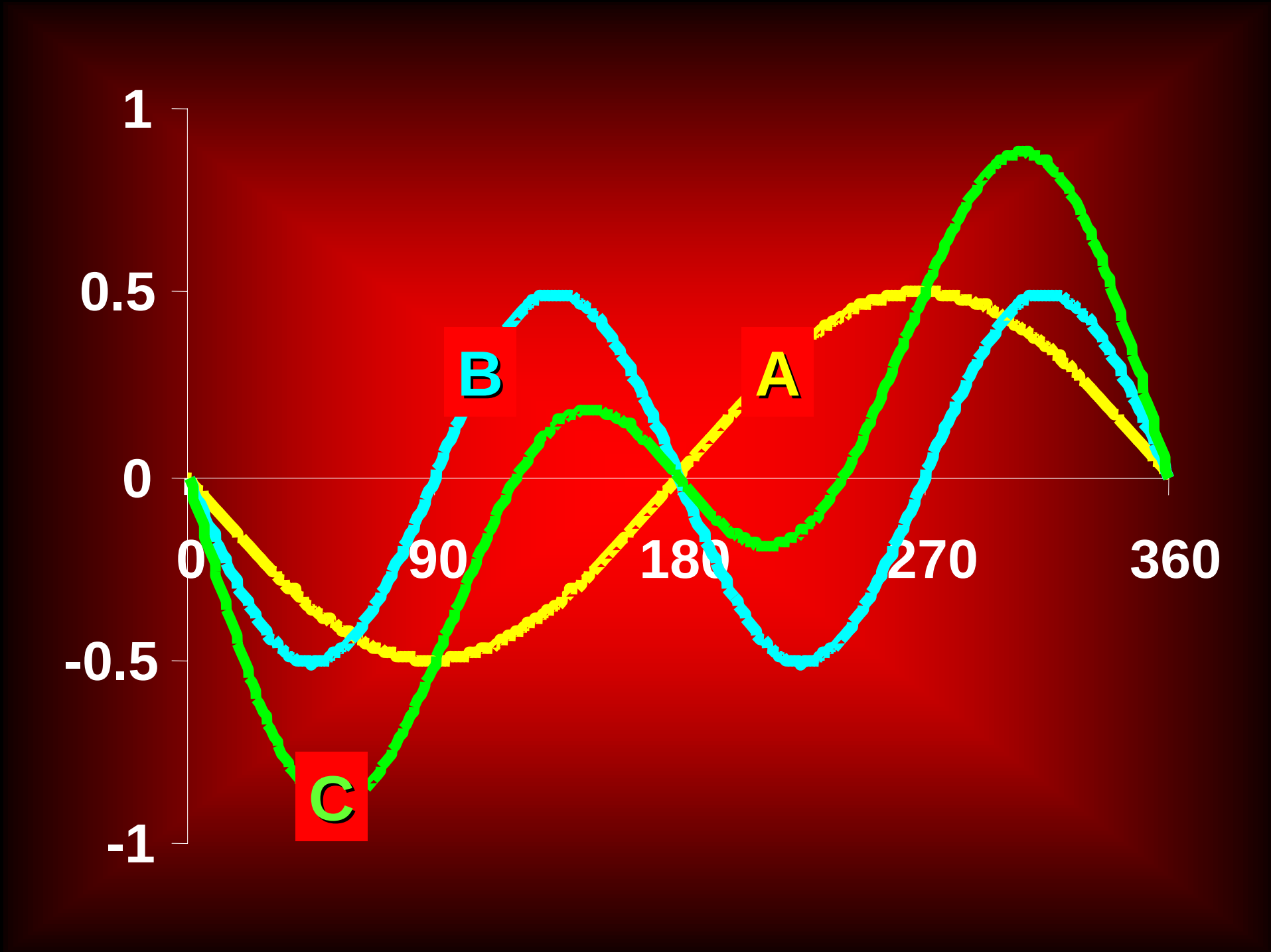
- *SPRING and NEAP, depending on the relative positions of Sun and Moon*
- *DIURNAL, SEMIDIURNAL or MIXED, depending on their daily cycles*

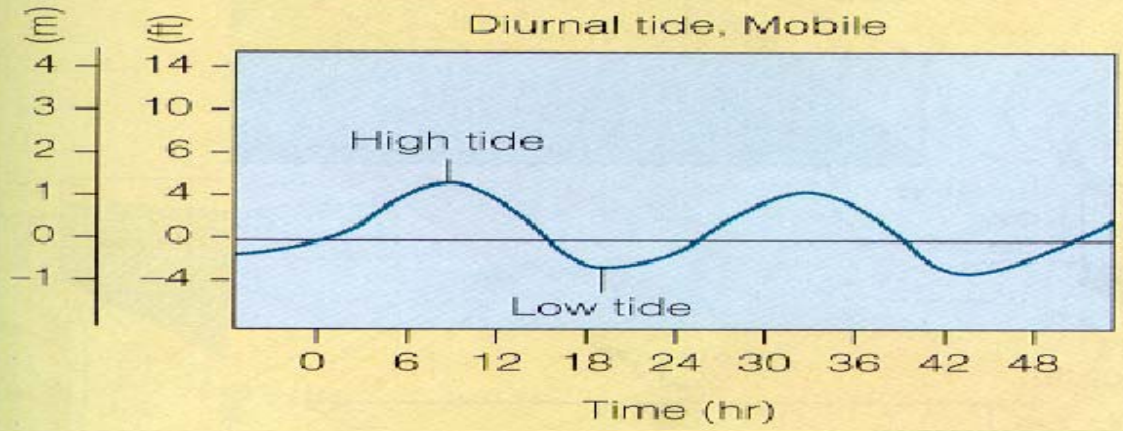

San Francisco, California
Seattle, Washington
Ketchikan, Alaska
Anchorage, Alaska
Dutch Harbor, Alaska
Boston, Massachusetts
New York, New York
Hampton Roads, Virgina
Savannah River Entrance, Georgia
Key West, Florida
Pensacola, Florida
Galveston, Texas
Water level (ft)
Day
Day

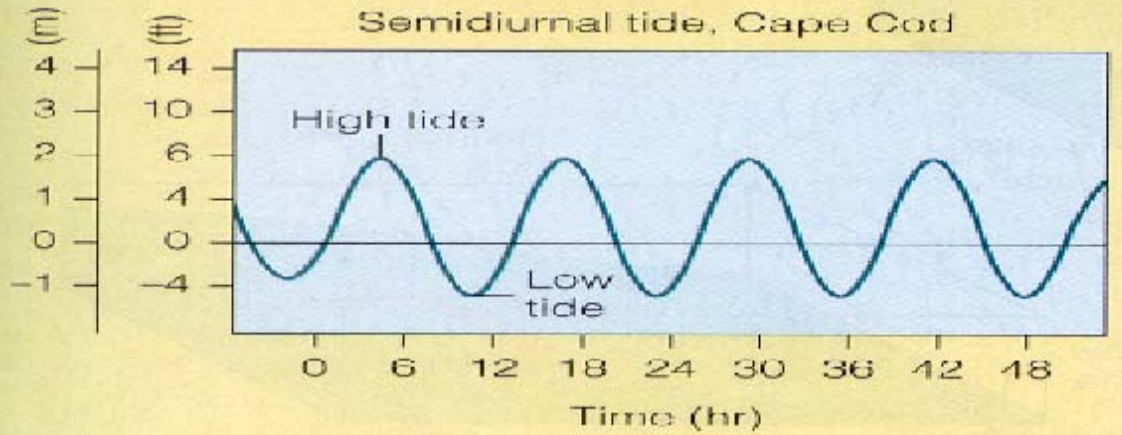
Wave interference can be constructive or destructive

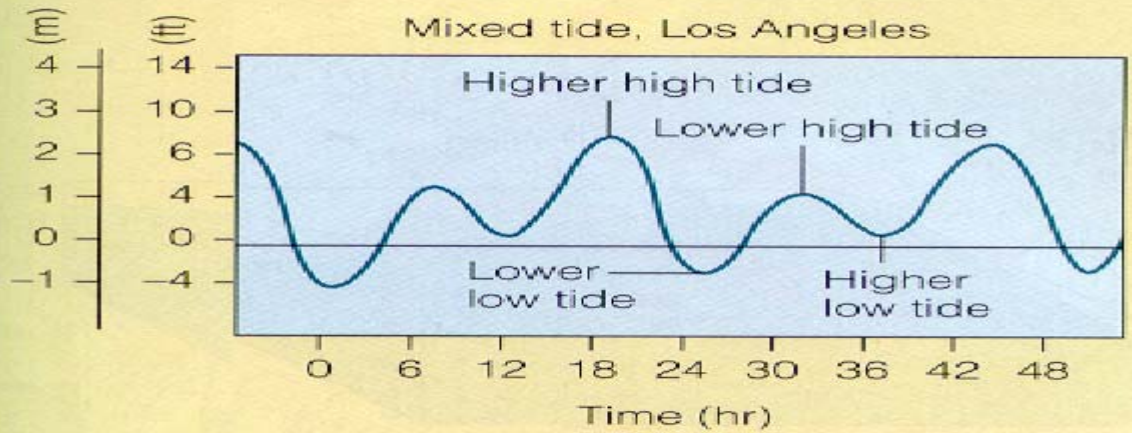



1
0
-1
Destructive interference
Destructive interference
Constructive interference
Constructive interference
Constructive interference


1
0.5
0
-0.5
-1
0
90
180
270
360
A
B
C







Tides can be

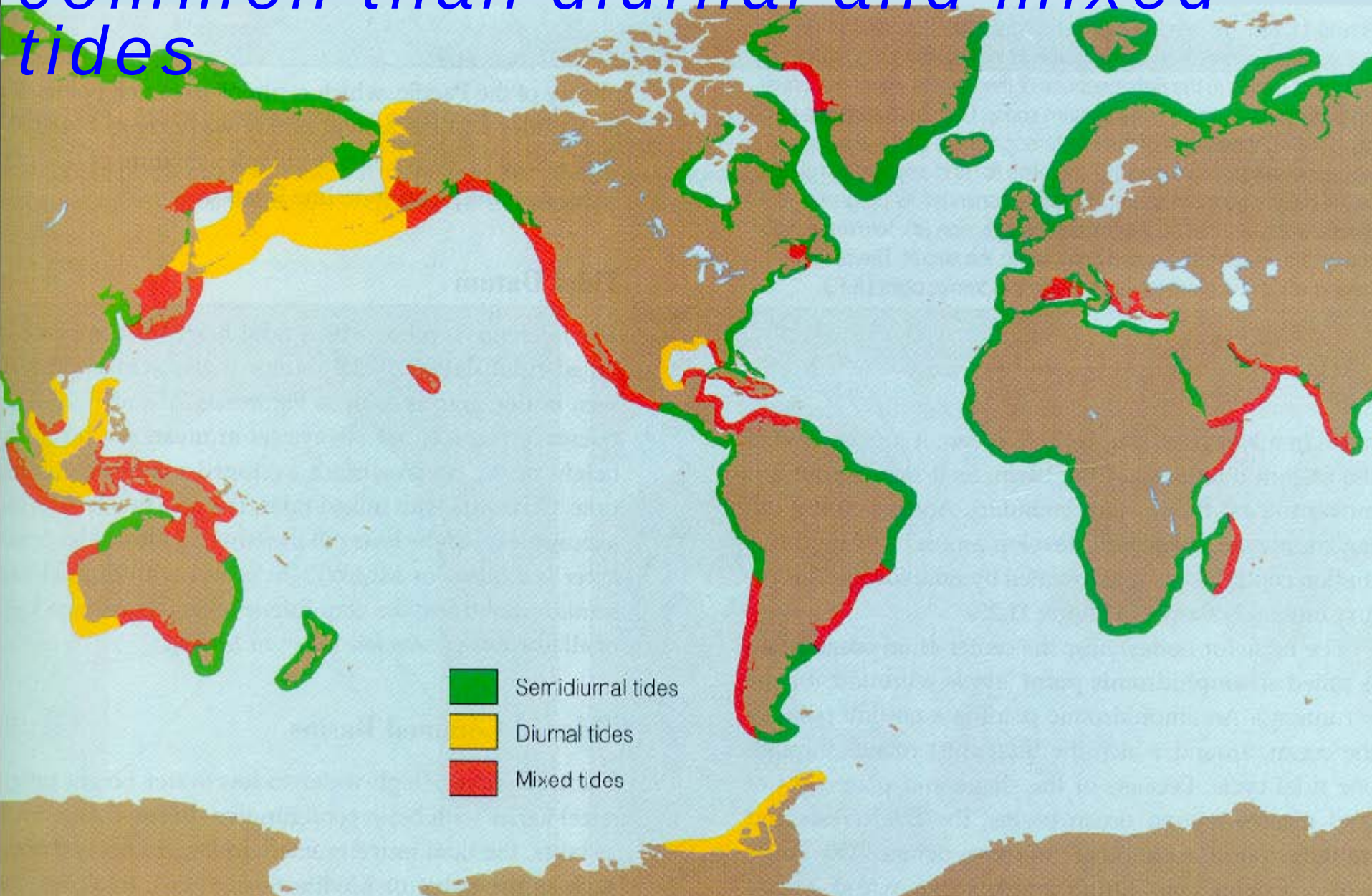
1. Diurnal: or once daily

2. Semidiurnal or twice daily

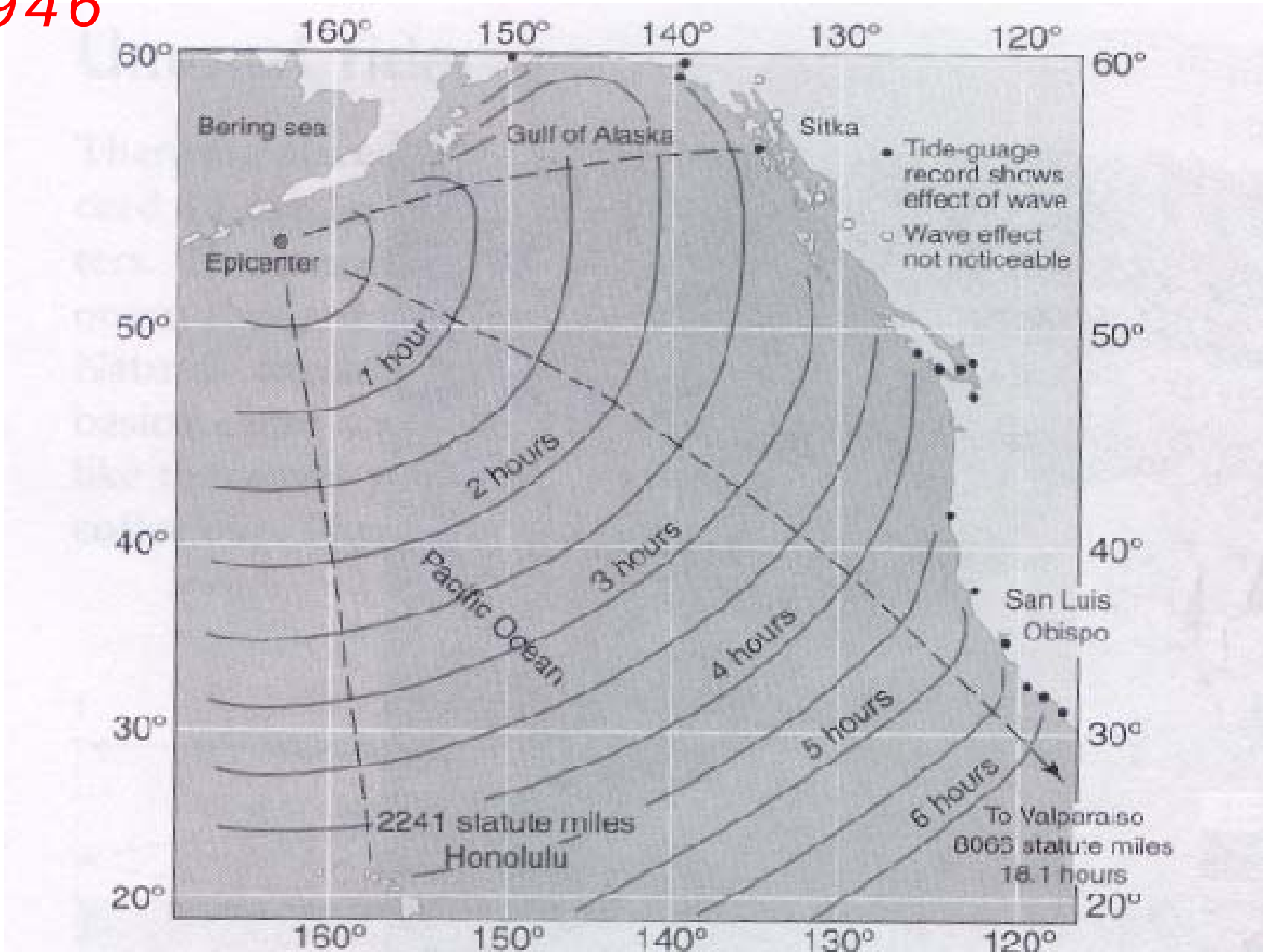
and

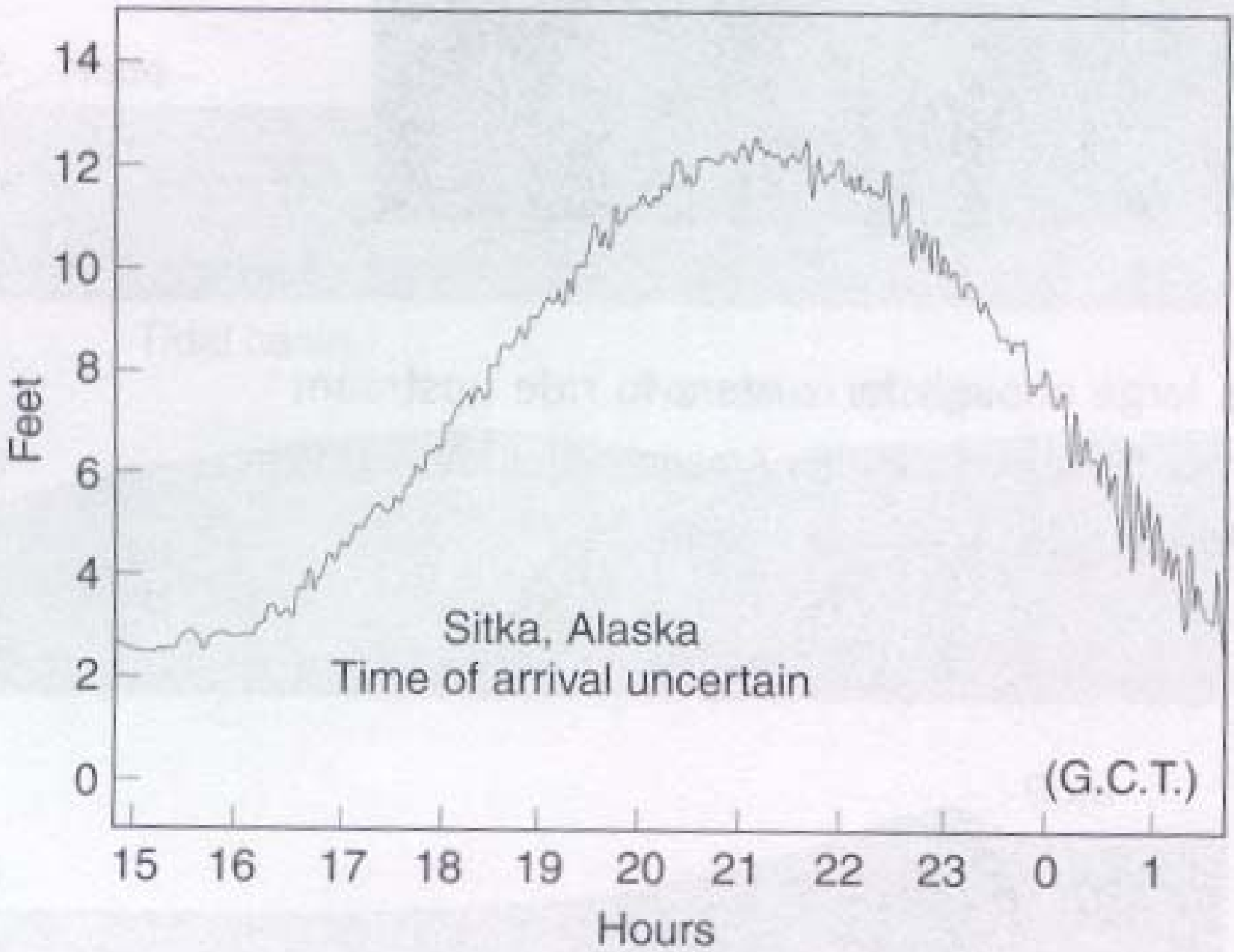
3. Mixed

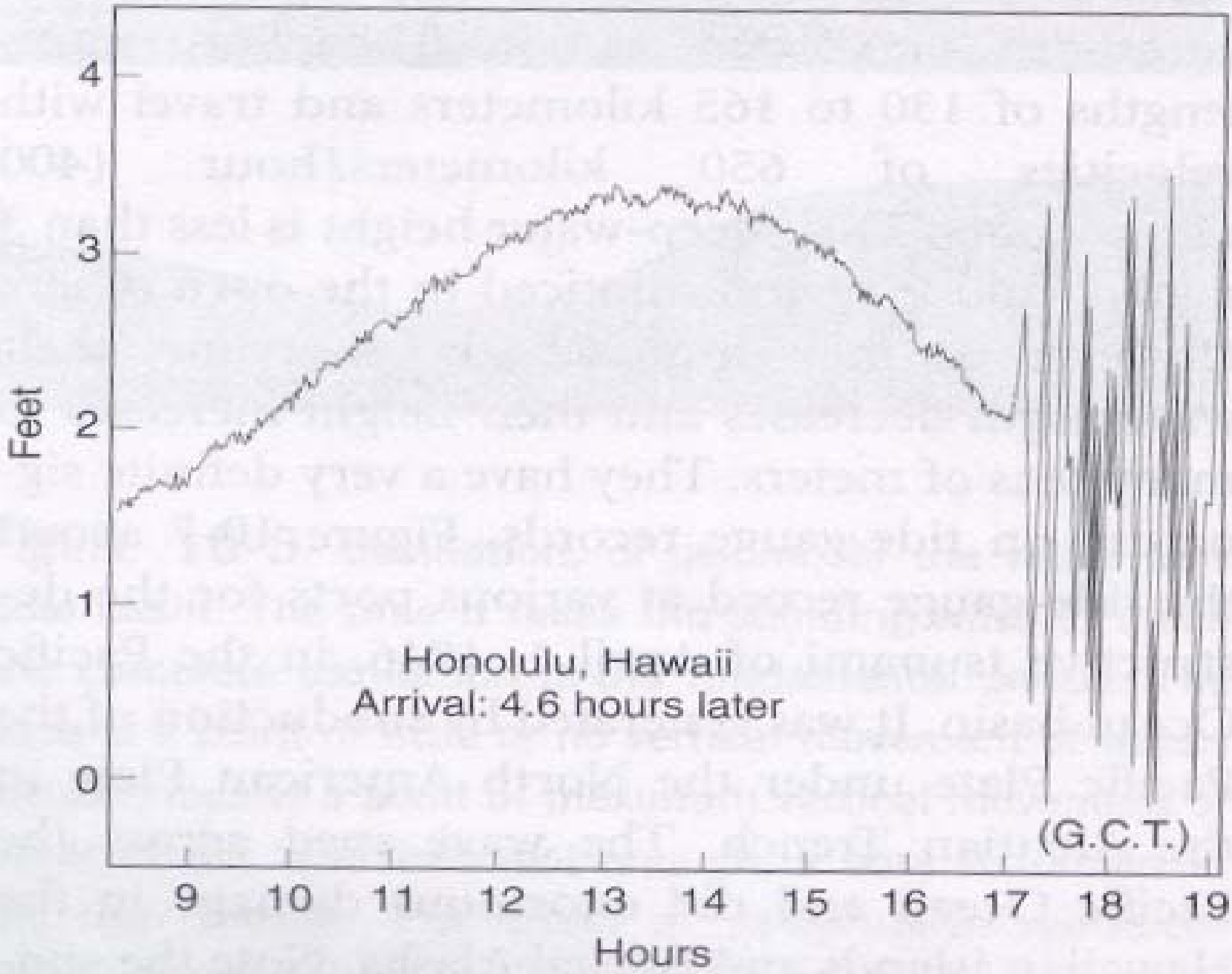
Semidiurnal tides are more common than diurnal and mixed tides

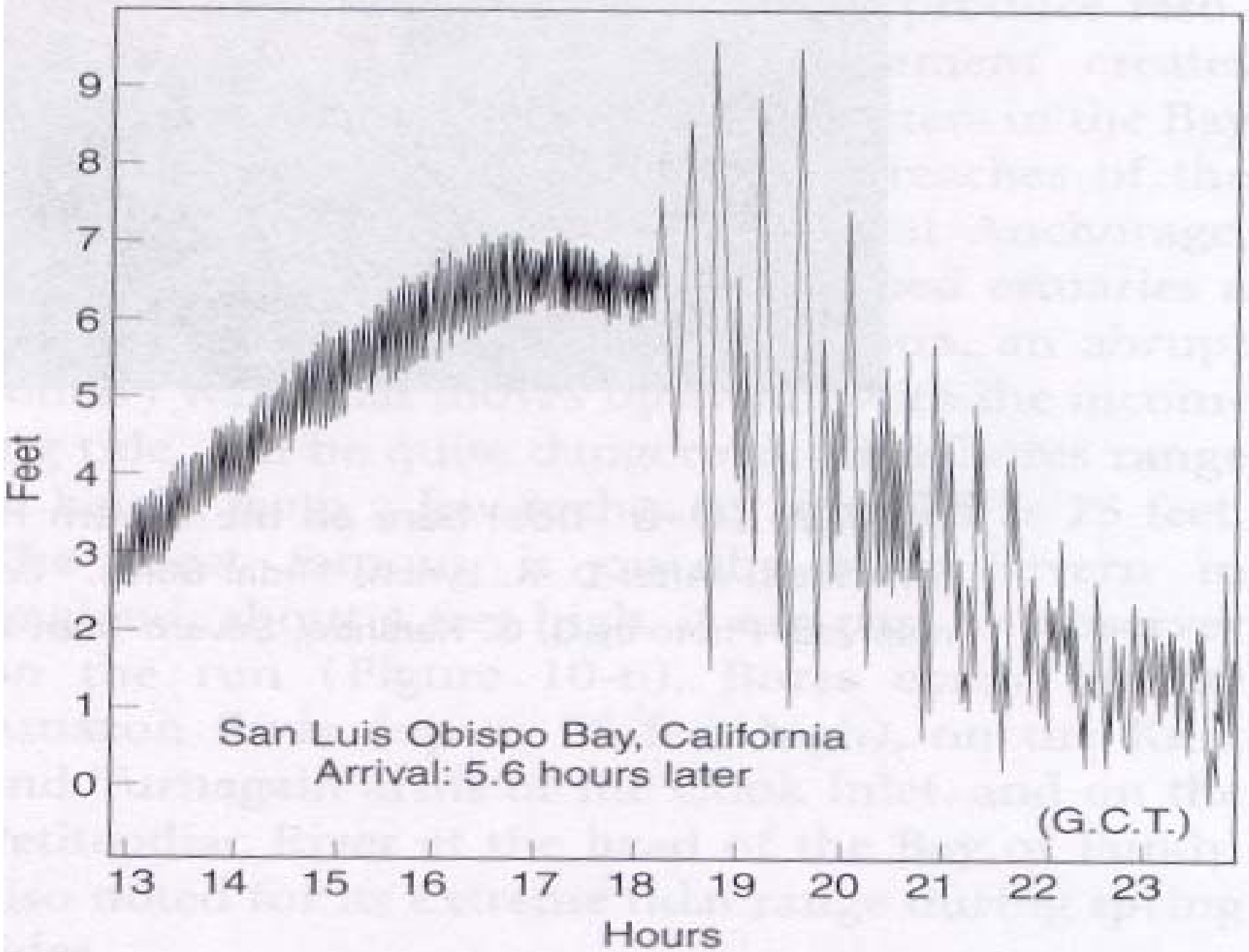


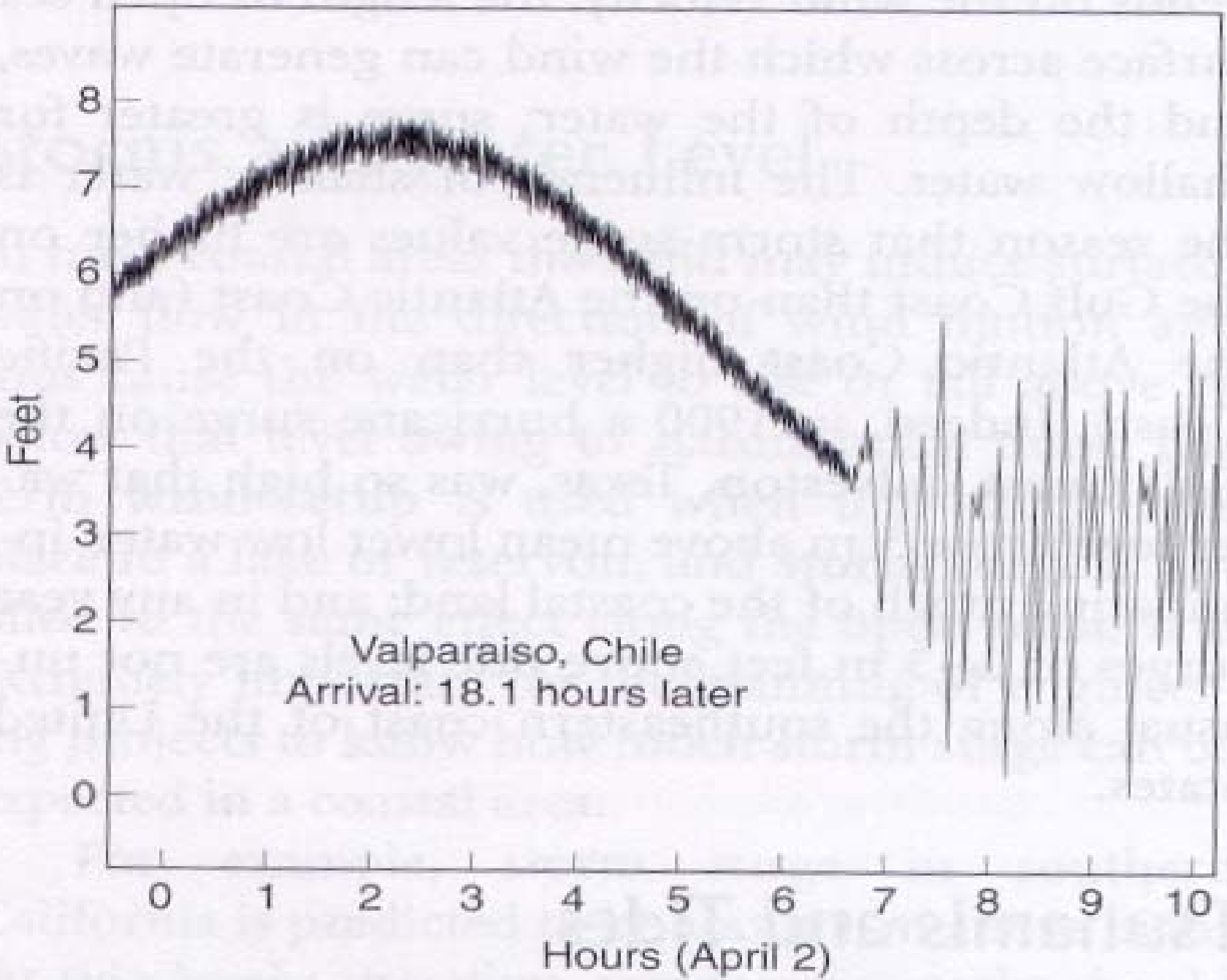
The travel-path of the tsunami of April 1, 1946

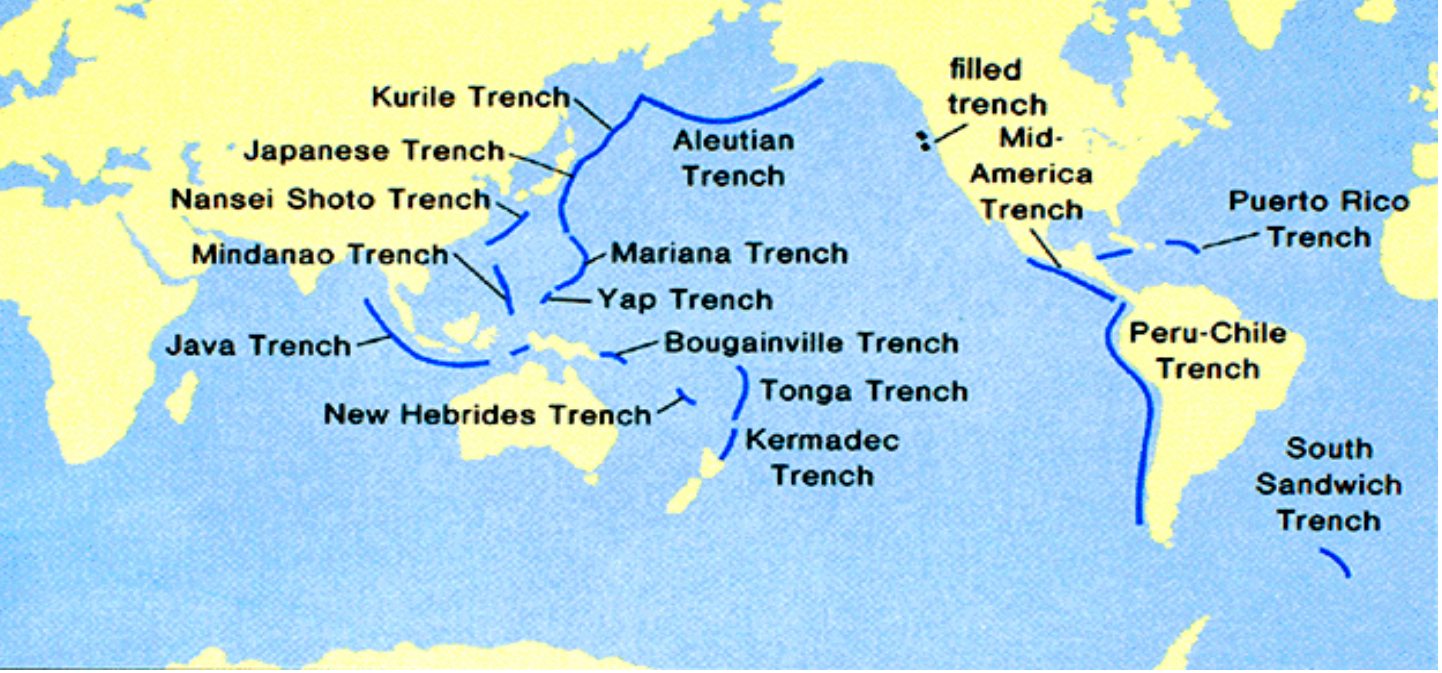


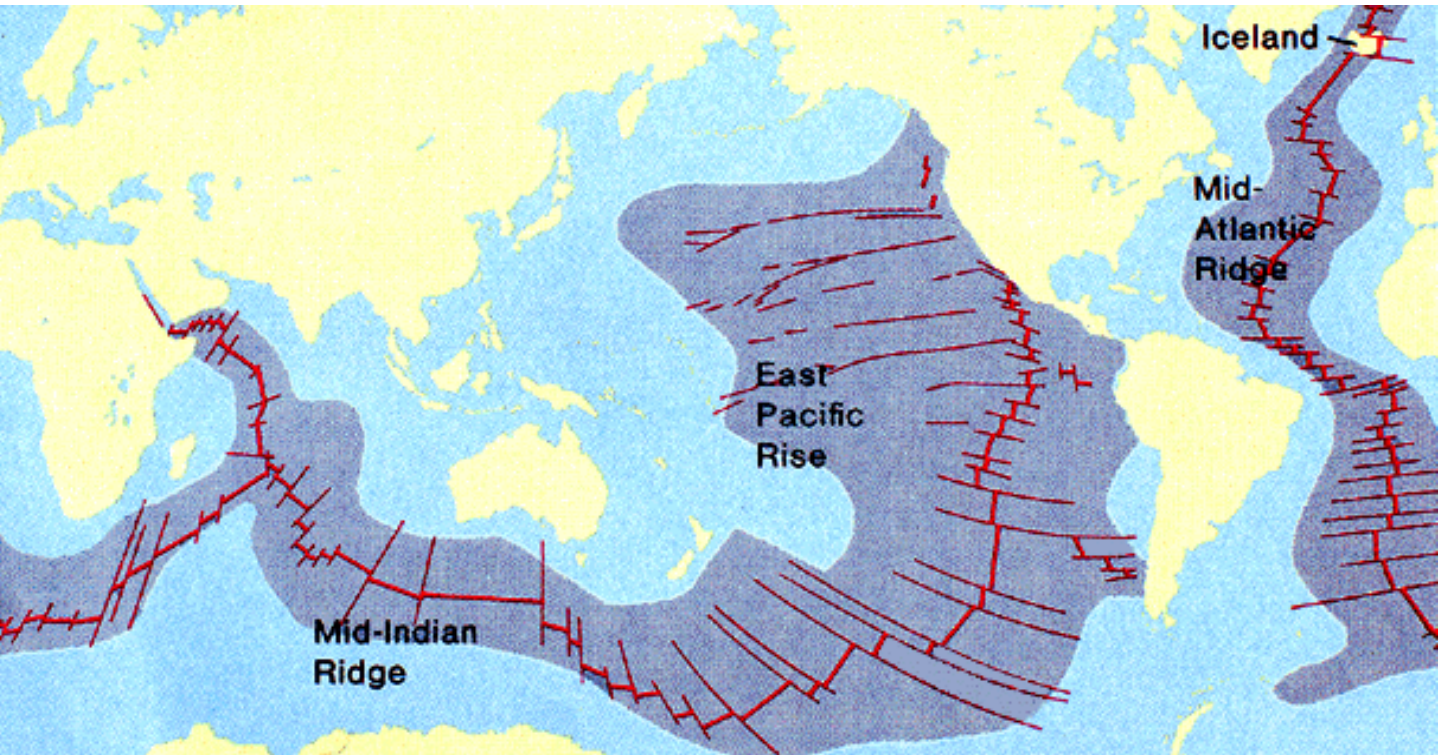

14
12
10
8
6
4
2
0
Feet
Sitka, Alaska
Time of arrival uncertain
(G.C.T.)
15
16
17
18
19
20
21
22
23
0
1
Hours


Feet
4
3
2
1
0
Honolulu, Hawaii
Arrival: 4.6 hours later
(G.C.T.)
9
10
11
12
13
14
15
16
17
18
19
Hours


Feet
9
8
7
6
5
4
3
2
1
0
San Luis Obispo Bay, California
Arrival: 5.6 hours later
(G.C.T.)
13
14
15
16
17
18
19
20
21
22
23
Hours

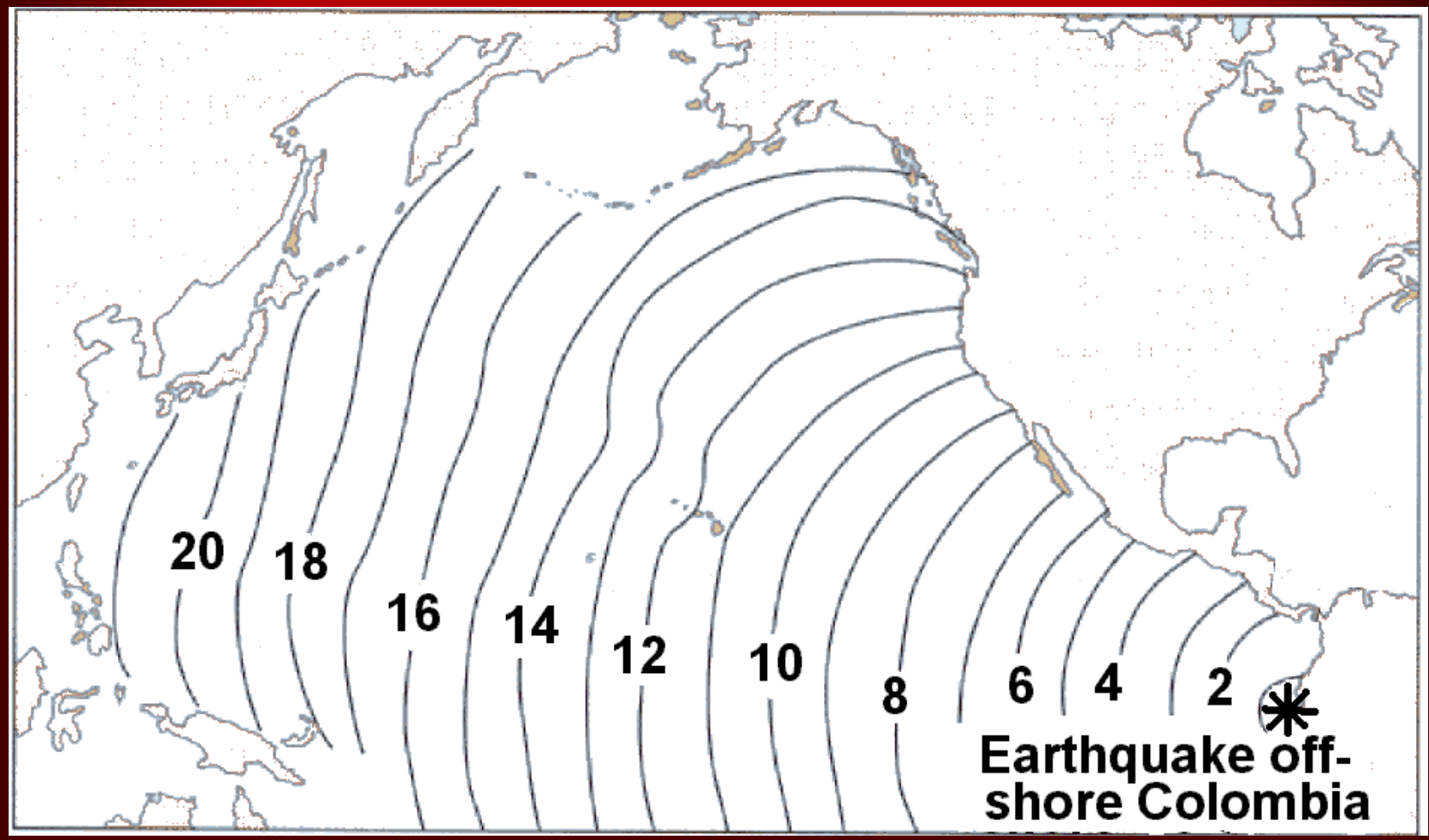

Feet
8
7
6
5
4
3
2
1
0
Valparaiso, Chile
Arrival: 18.1 hours later
0
1
2
3
4
5
6
7
8
9
10
Hours (April 2)





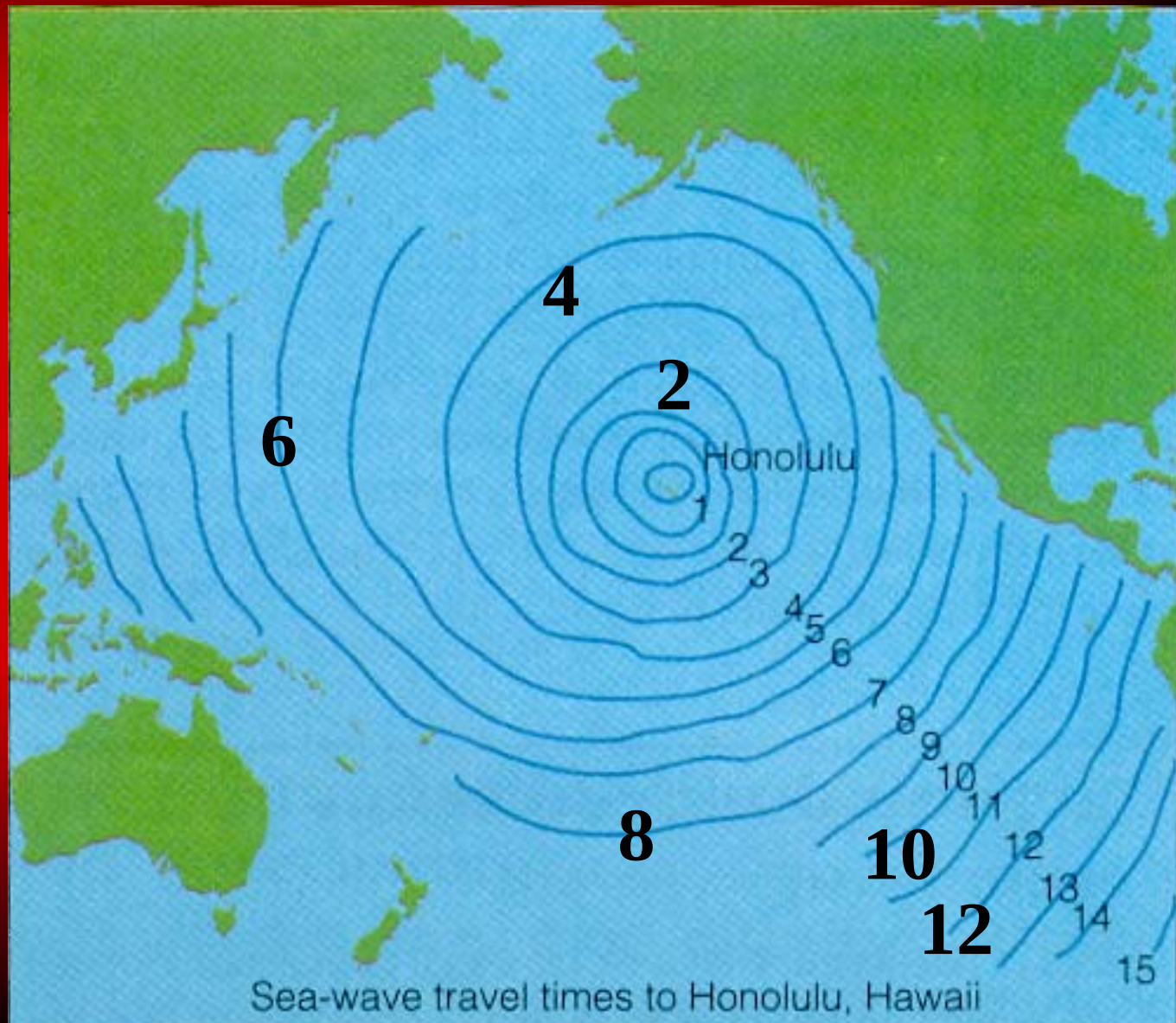
Active ocean-continent margins should expect tsunamis more frequently than the passive ones

The map below shows the position of the leading wave of a tsunami generated by a 1979 earthquake offshore Colombia, South America*. These contours are for the tsunami arrival times in hours.



*K. Ida & T. Iwasaki (Ed.): Tsunamis: Their Science and Engineering (D. Reidel, Boston MA, 1983)

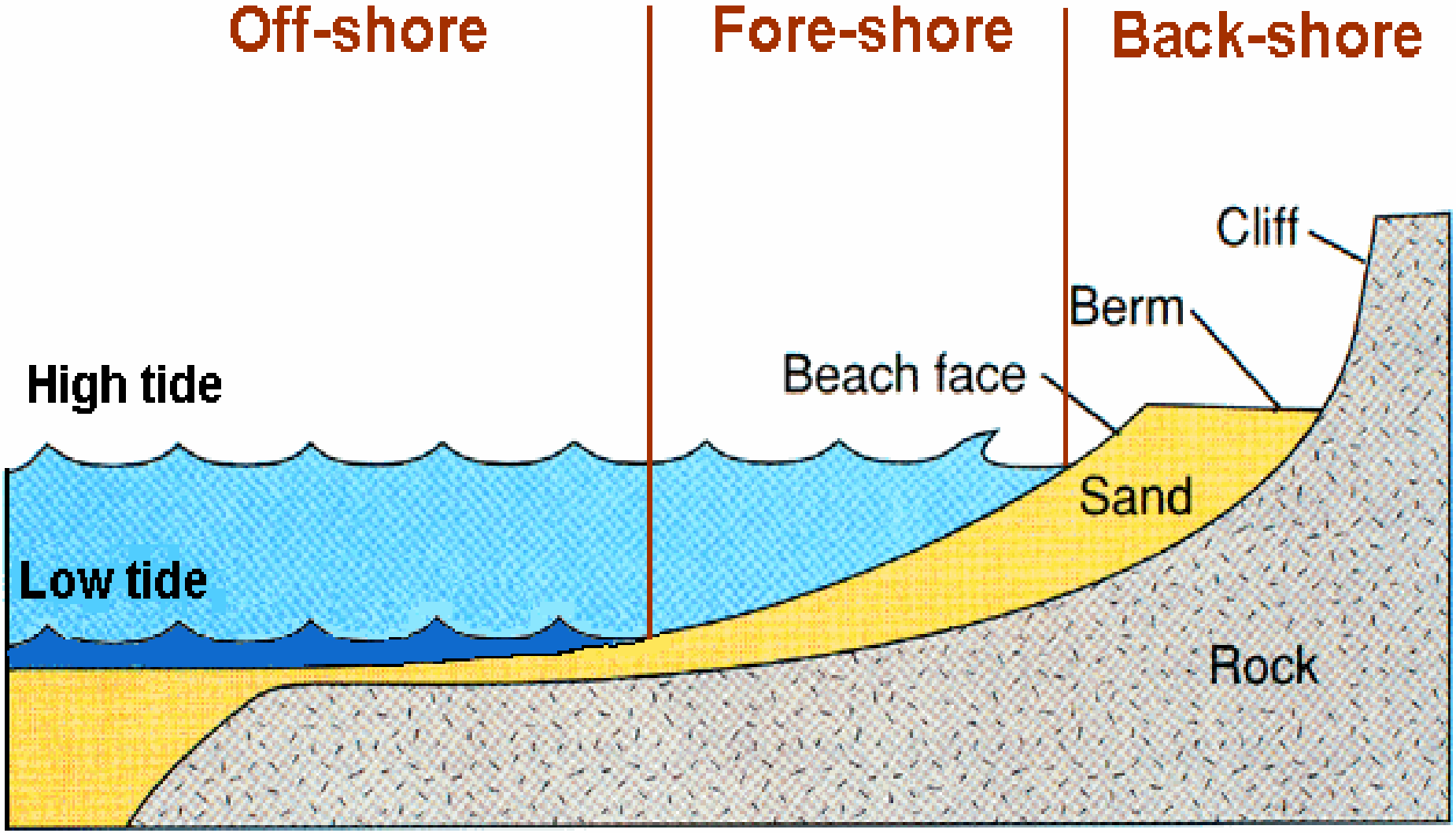
Consider an earthquake with its epicenter at Honolulu, Hawaii. The corresponding tsunami travel times (in hours) from Hawaii are given in this map of the Pacific Ocean.

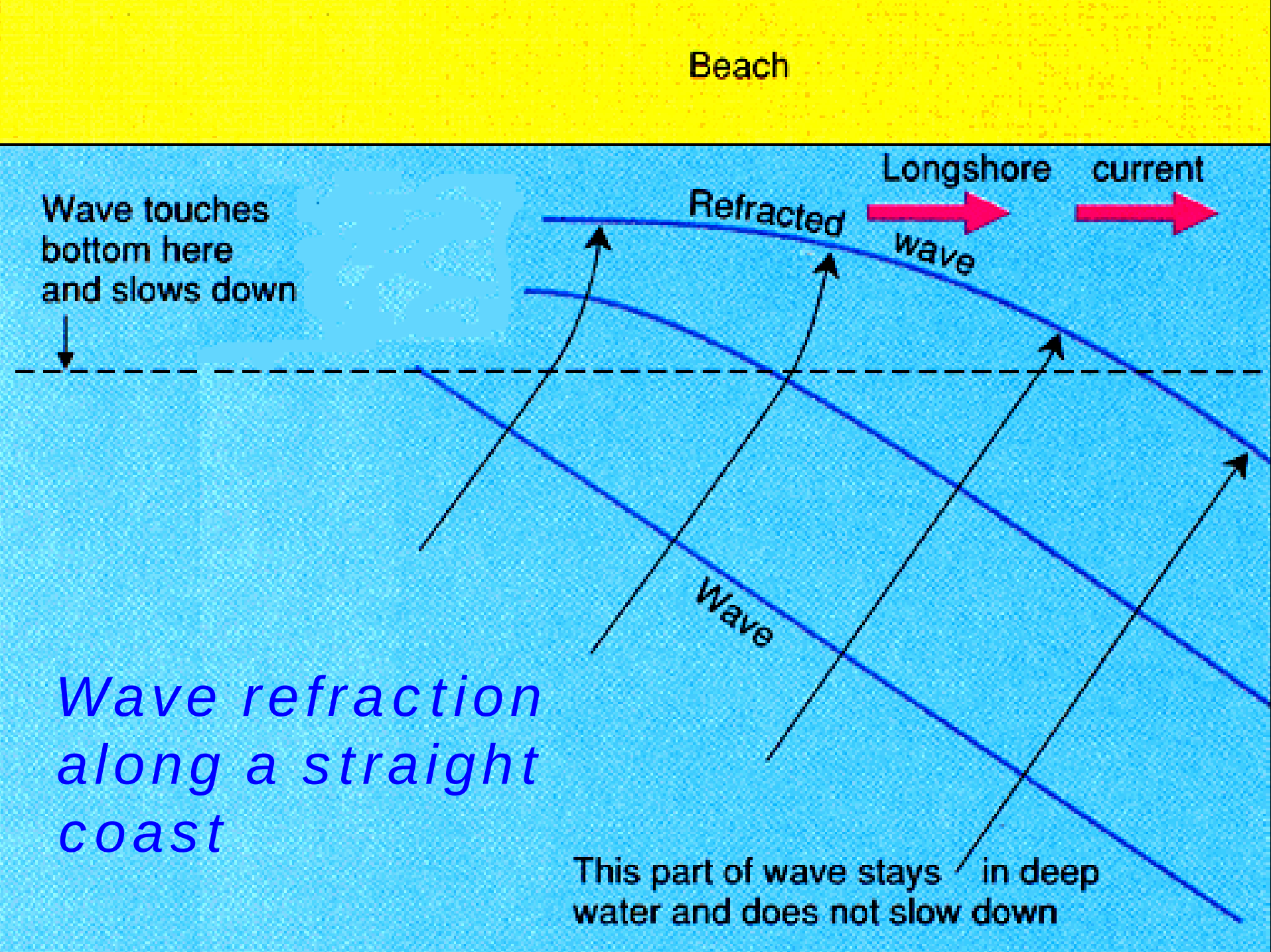


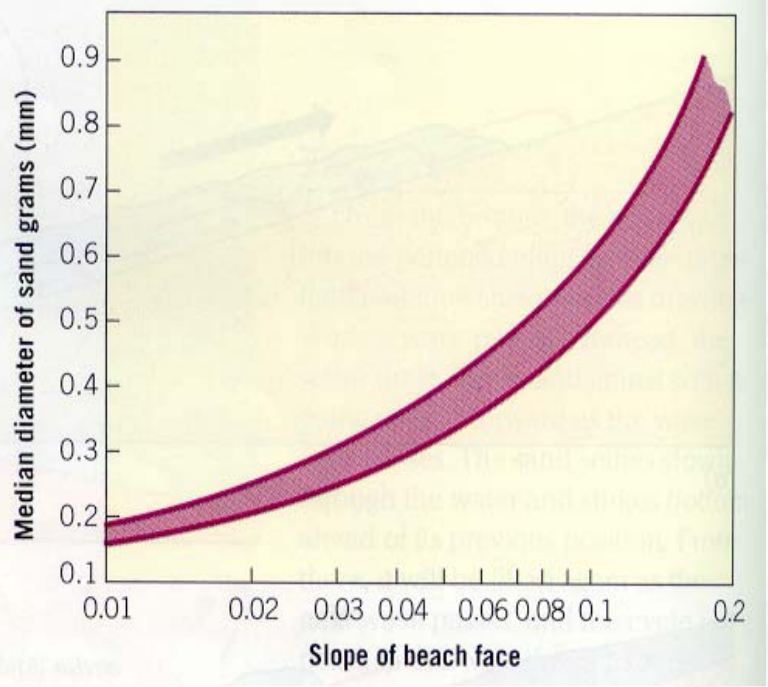
Coasts can be

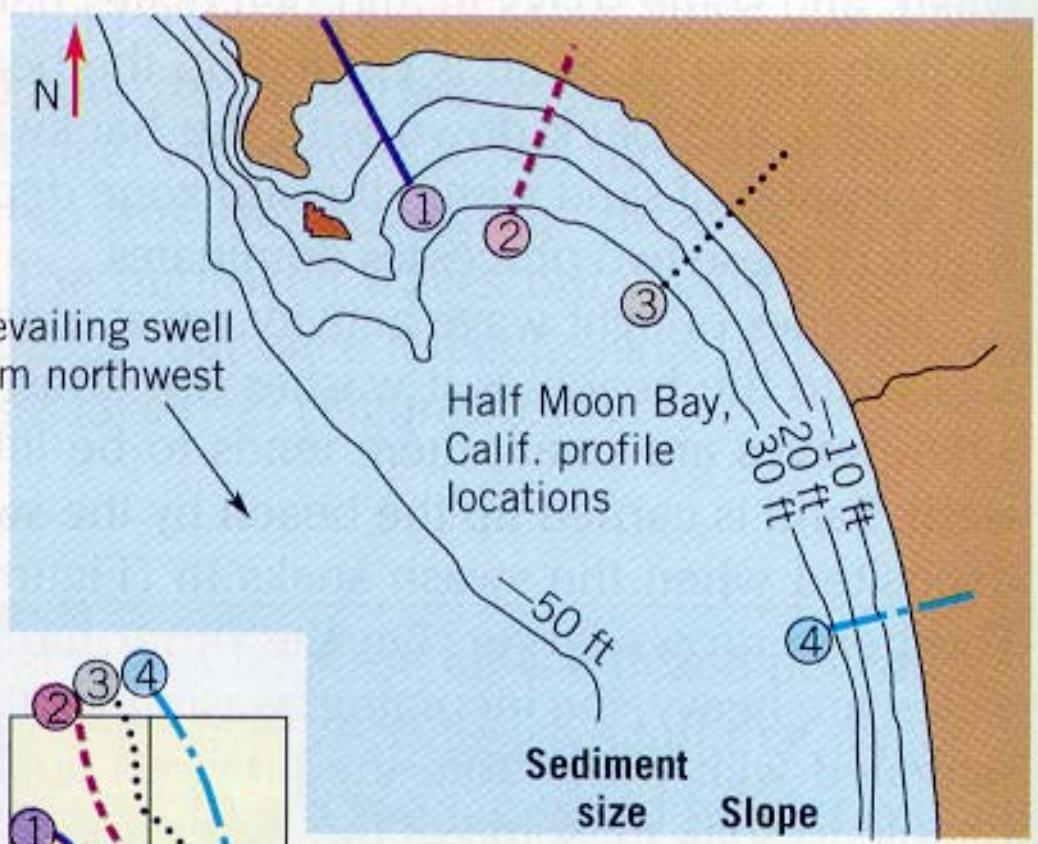
- *active or passive*
- *erosional or depositional*

Parts of a beach

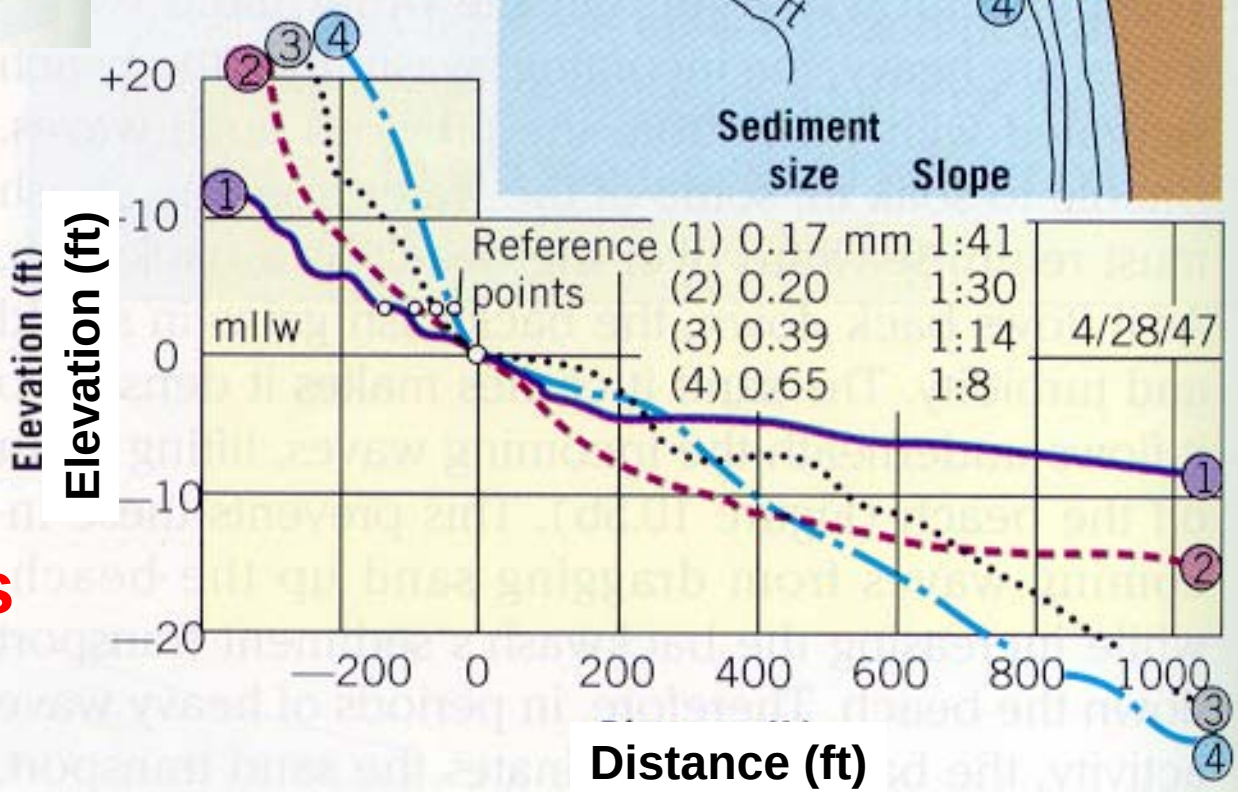


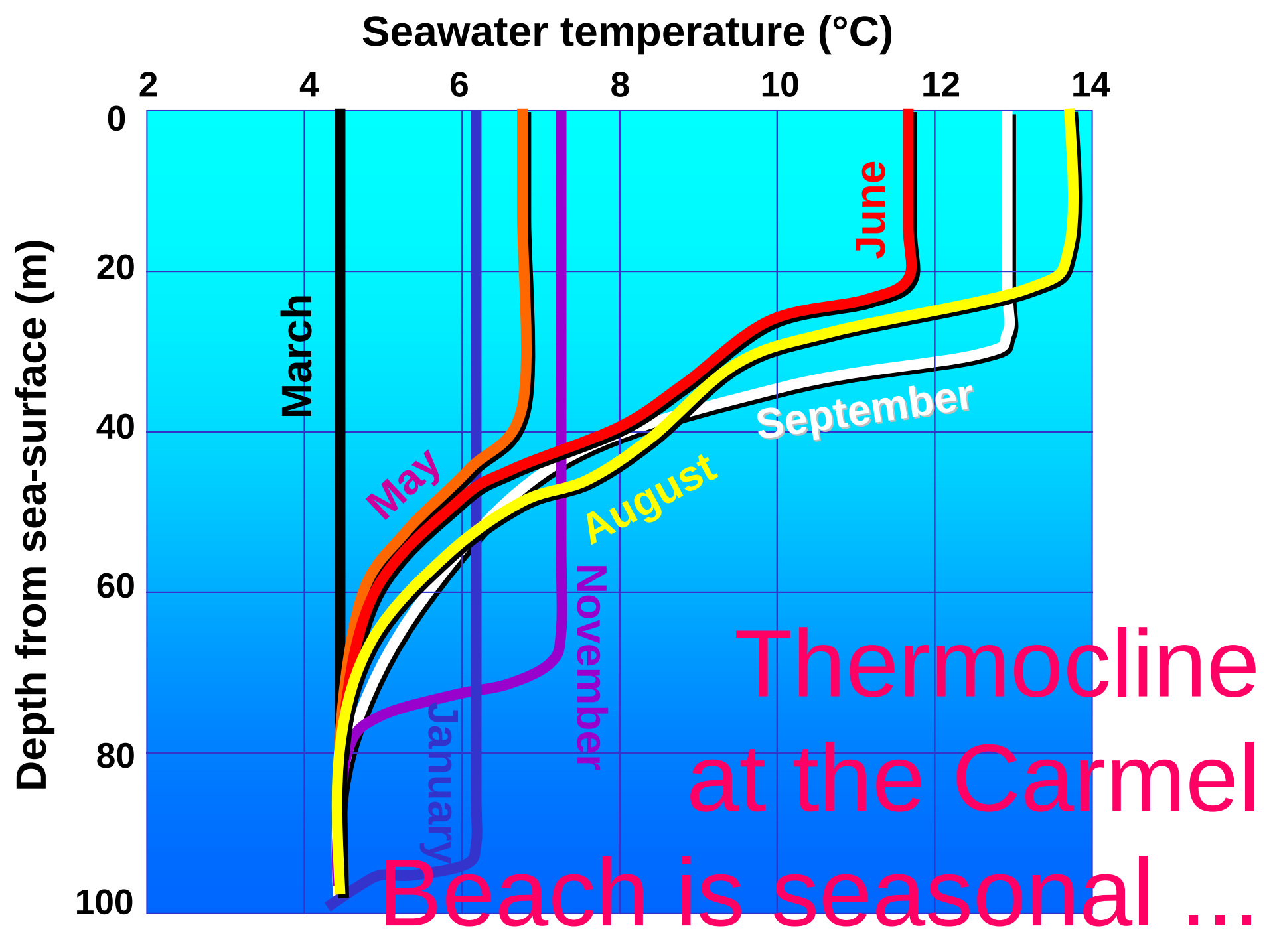

Beach
Longshore current
Refracted wave
Wave touches bottom here and slows down
Wave
Wave refraction along a straight coast
This part of wave stays in deep water and does not slow down

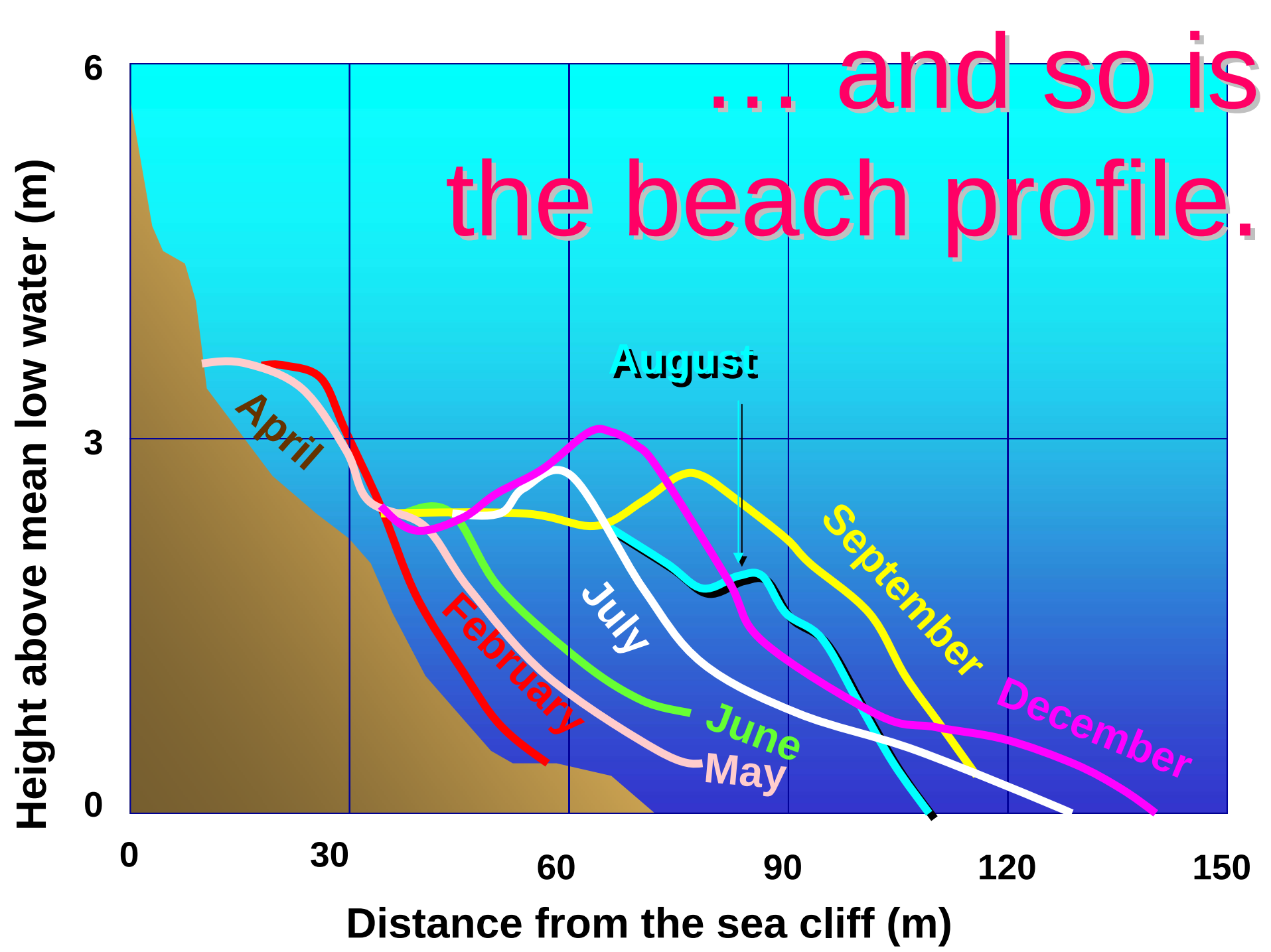


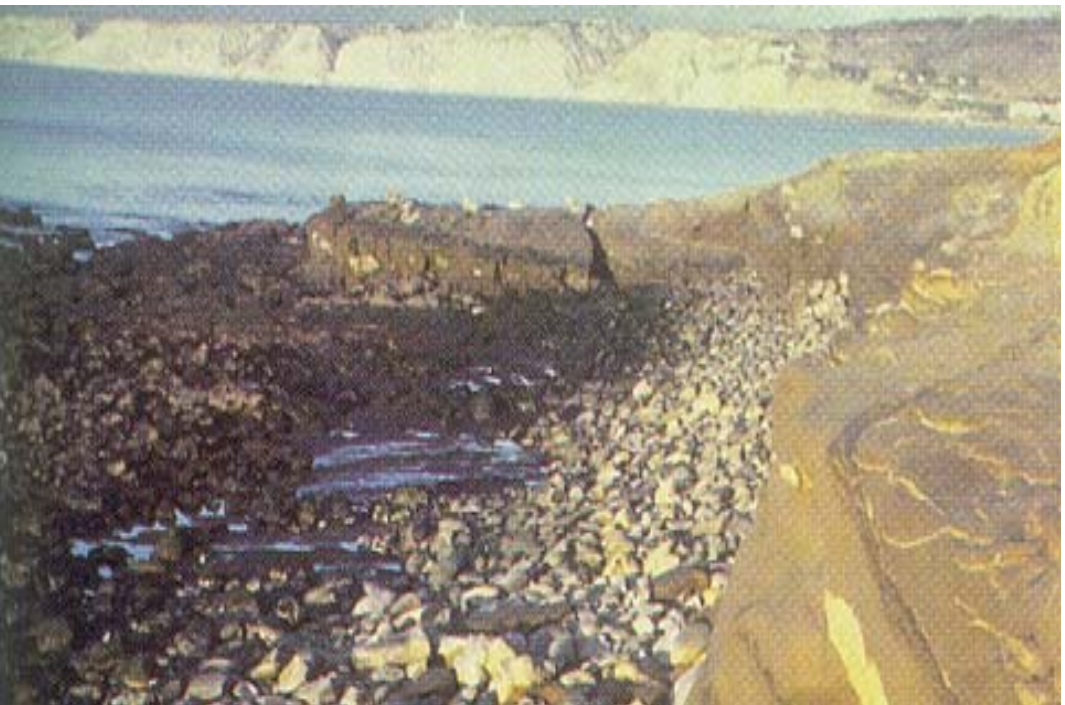


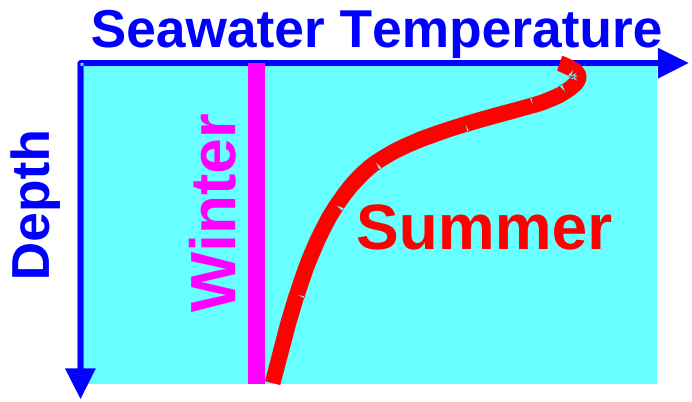
The gentler the beach slope, the finer the beach sediments tend to be, as can be seen from these profiles of the Half Moon Bay, California.

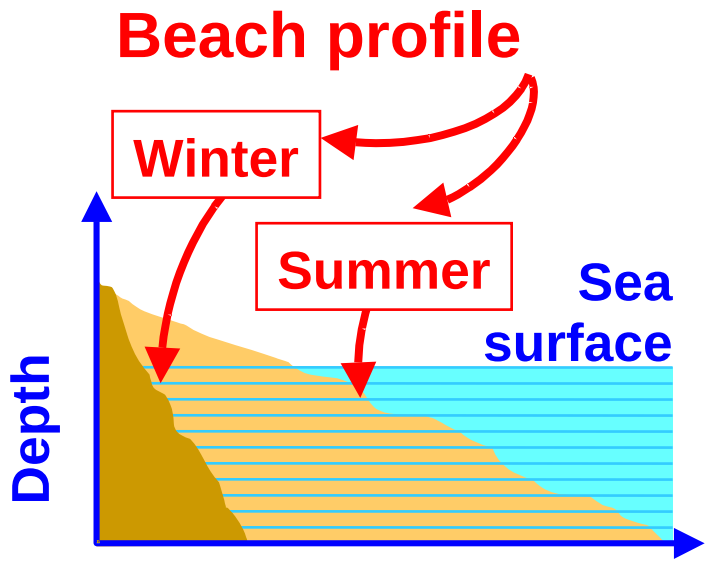



Seawater temperature (°C)
2
4
6
8
10
12
14
Depth from sea-surface (m)
0
20
40
60
80
100
March
May
June
August
September
November
January
Thermocline
at the Carmel
Beach is seasonal …

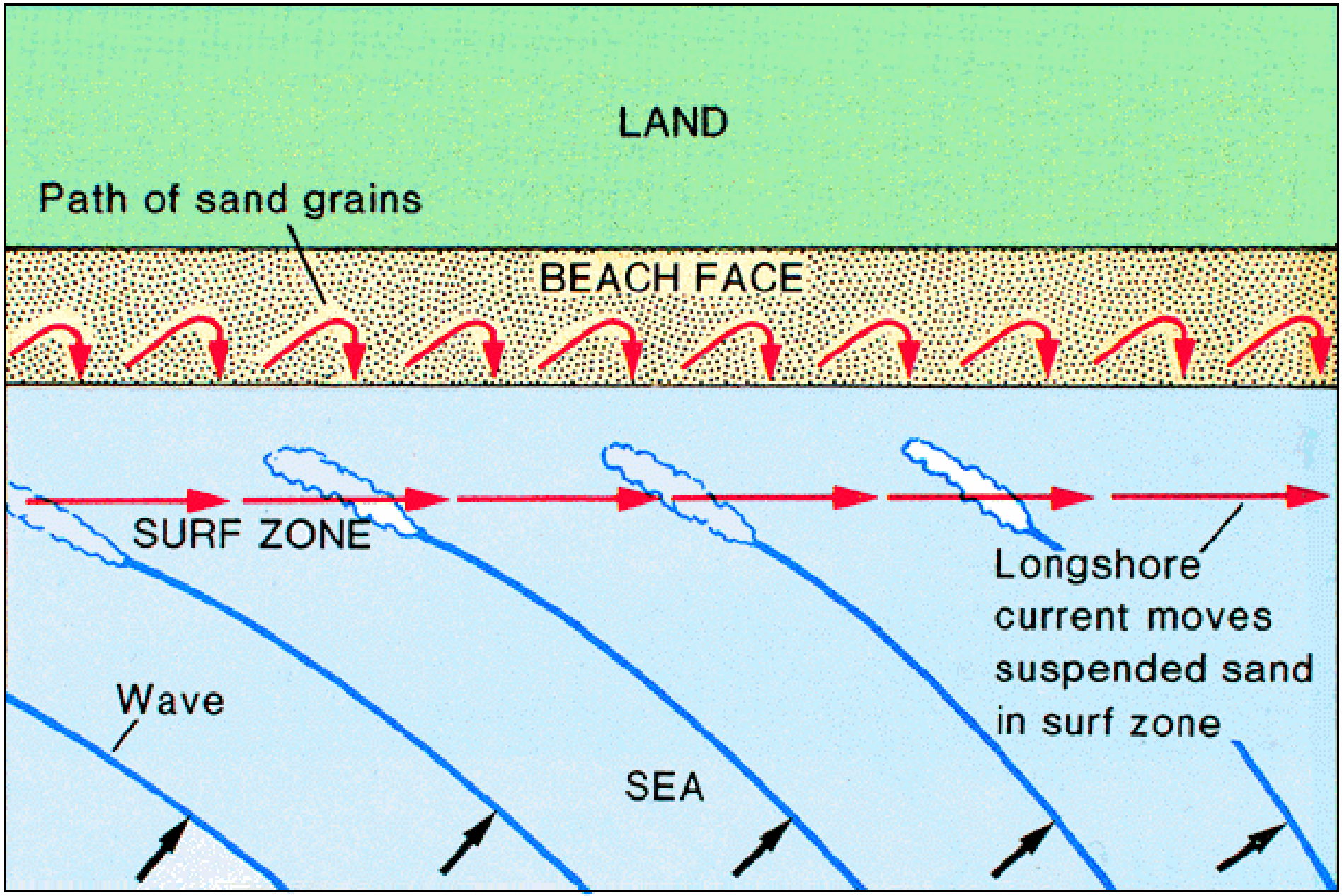

... and so is the beach profile.
Height above mean low water (m)
6
3
0
0
30
60
90
120
150
Distance from the sea cliff (m)
April
August
February
July
June
May
September
December

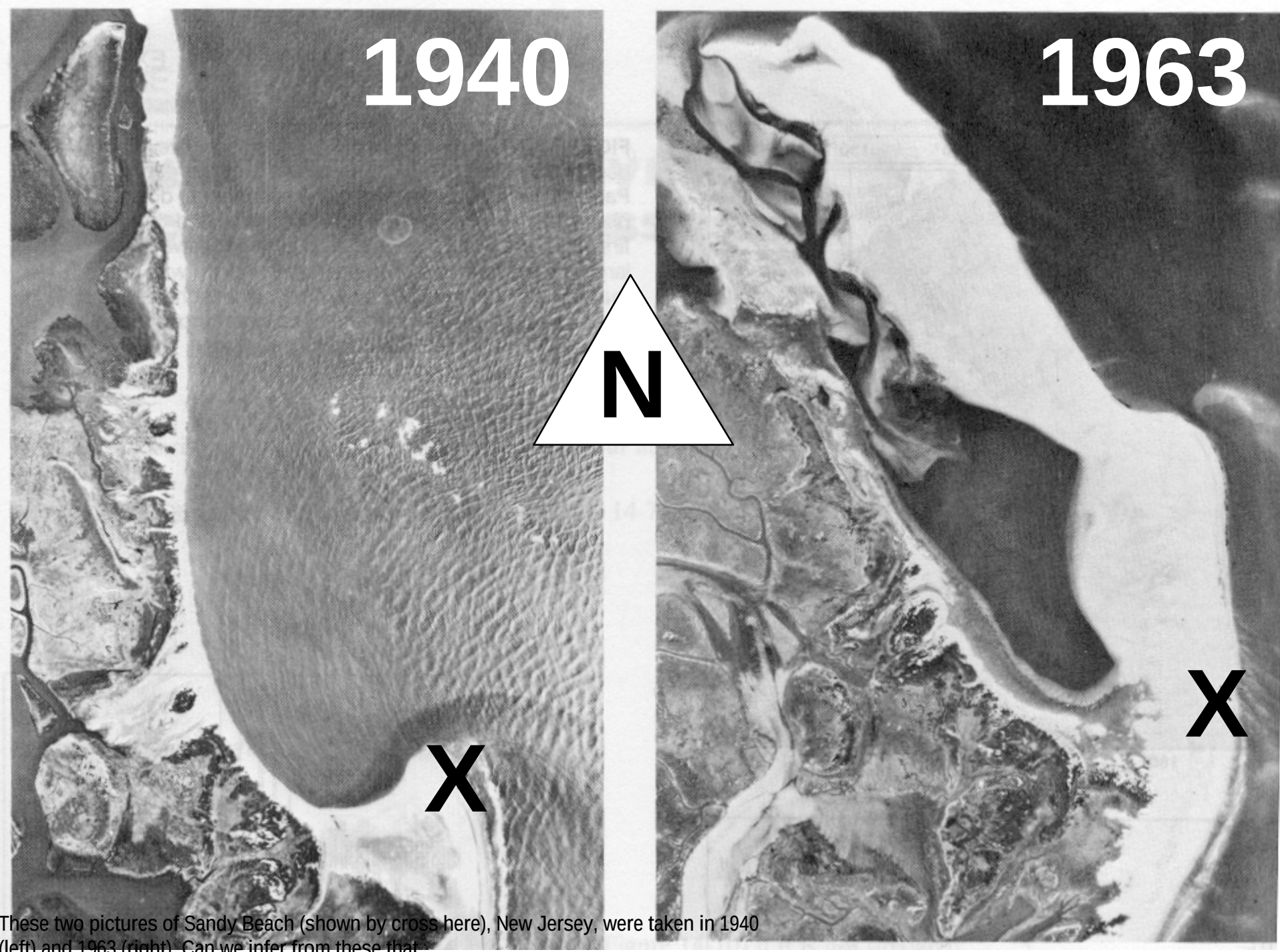



Seawater Temperature
Depth
Winter
Summer


Beach profile
Winter
Summer
Sea surface
Depth

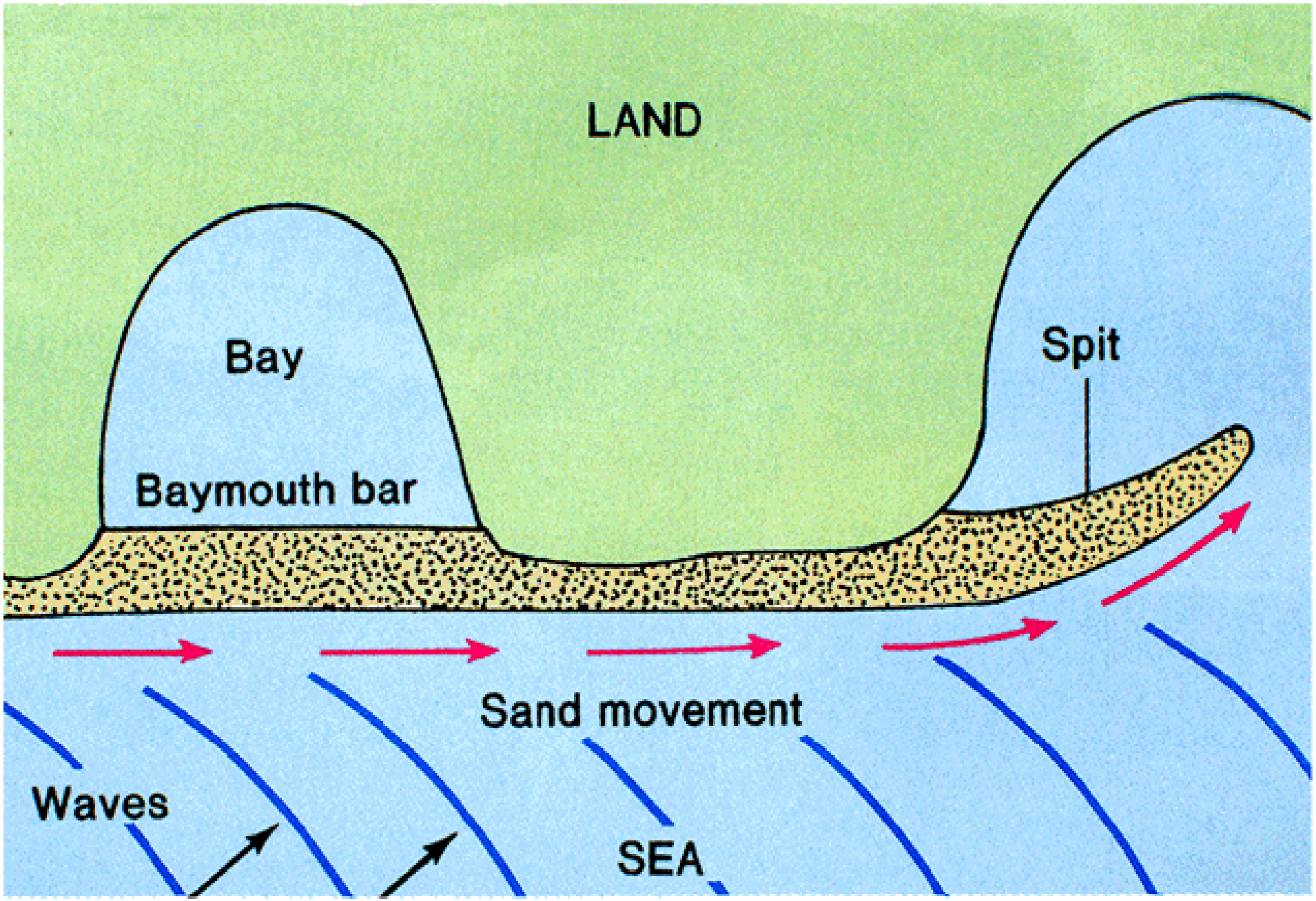
Longshore current and littoral drift



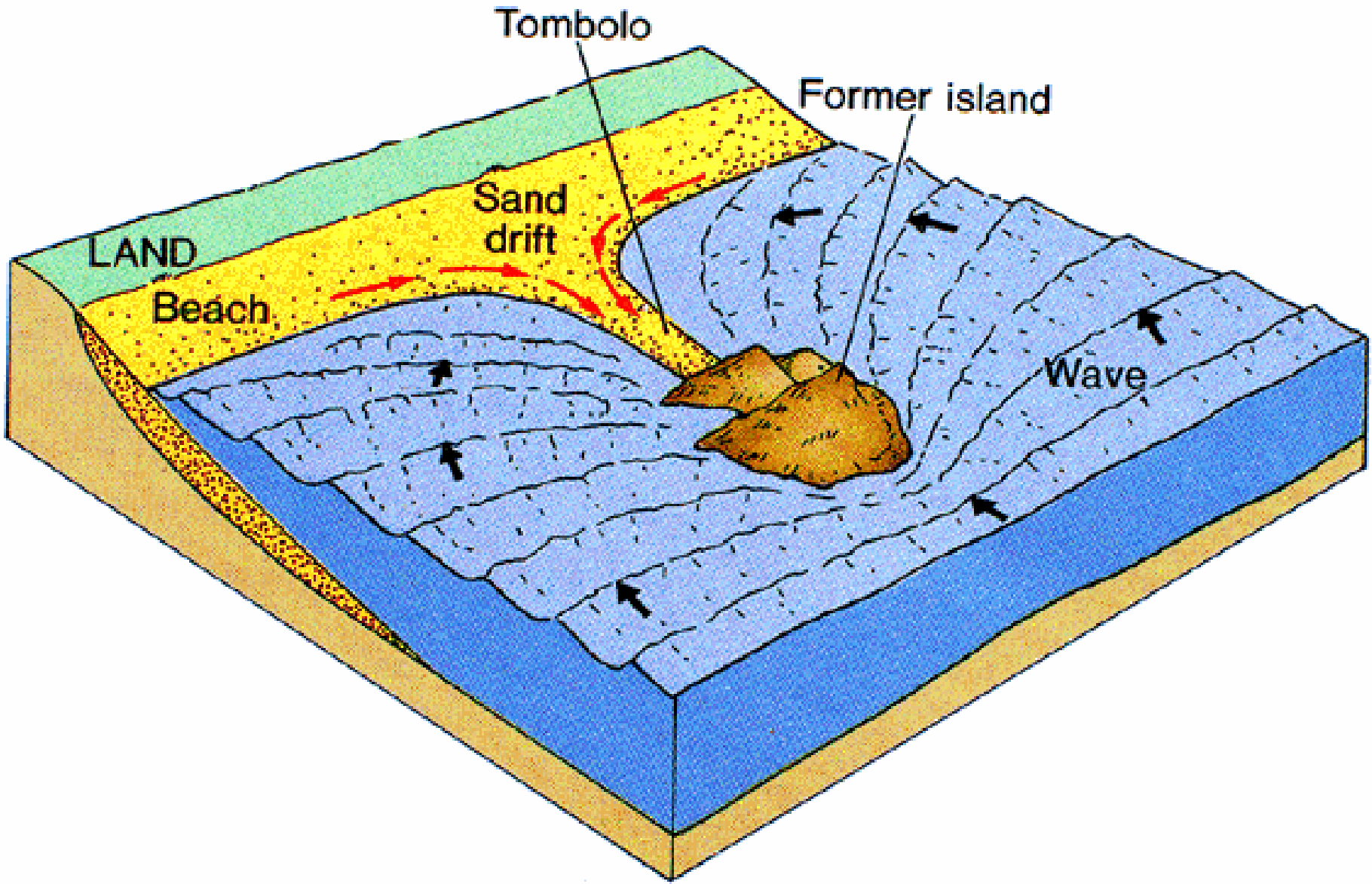


These two pictures of Sandy Beach (shown by cross here), New Jersey, were taken in 1940 (left) and 1963 (right). Can we infer from these that

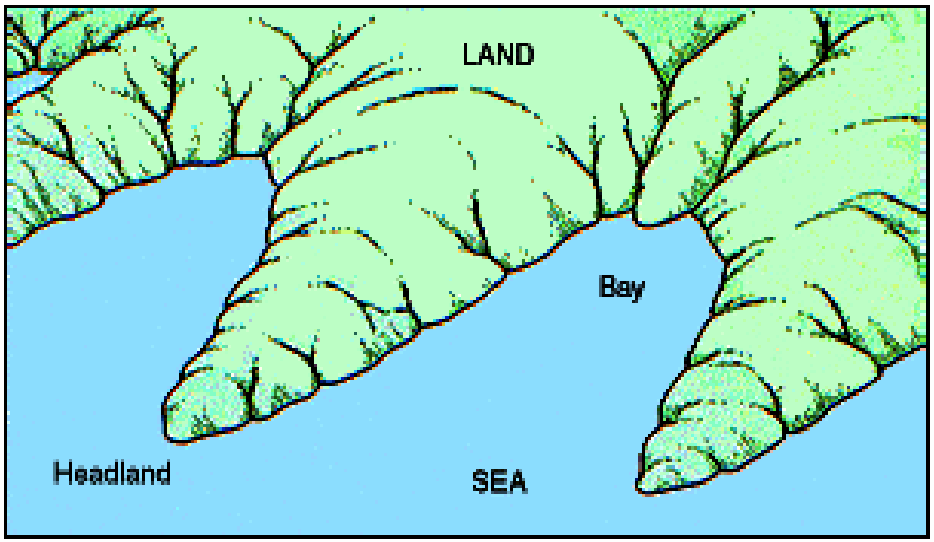
How baymouth bars and spits form



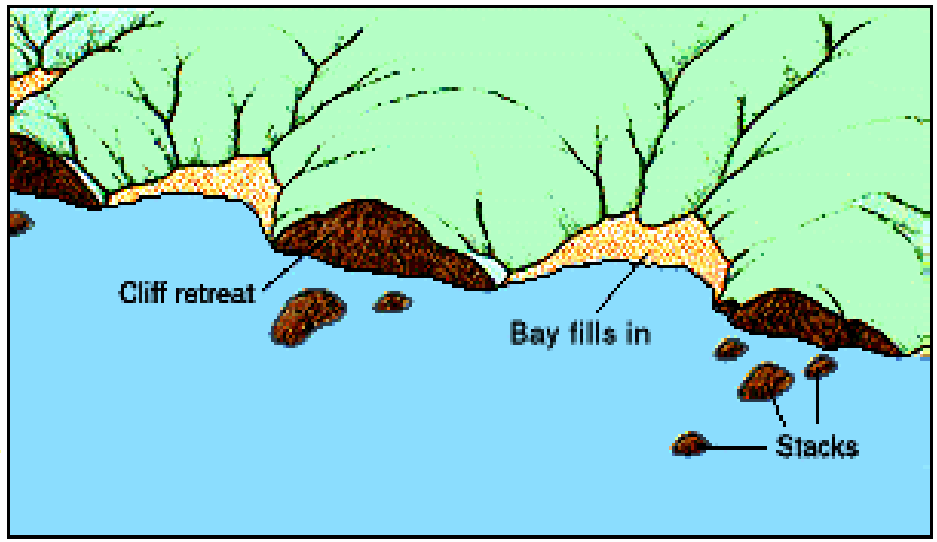
Formation of a tambolo



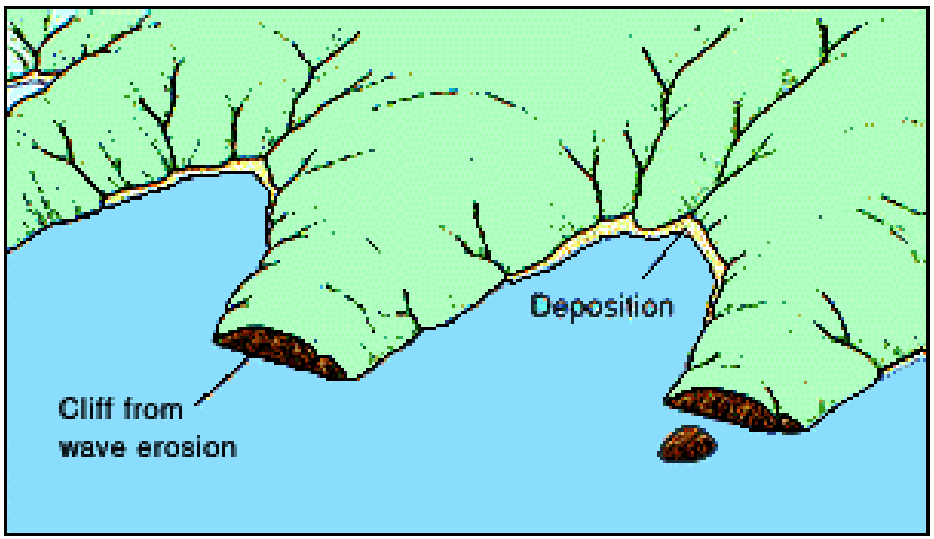
Coastal straightening by wave-erosion



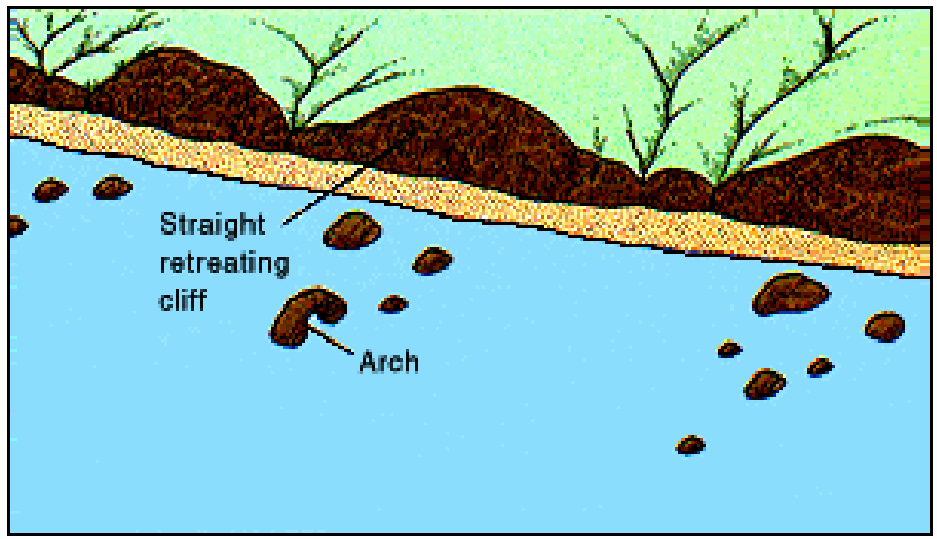
A



C

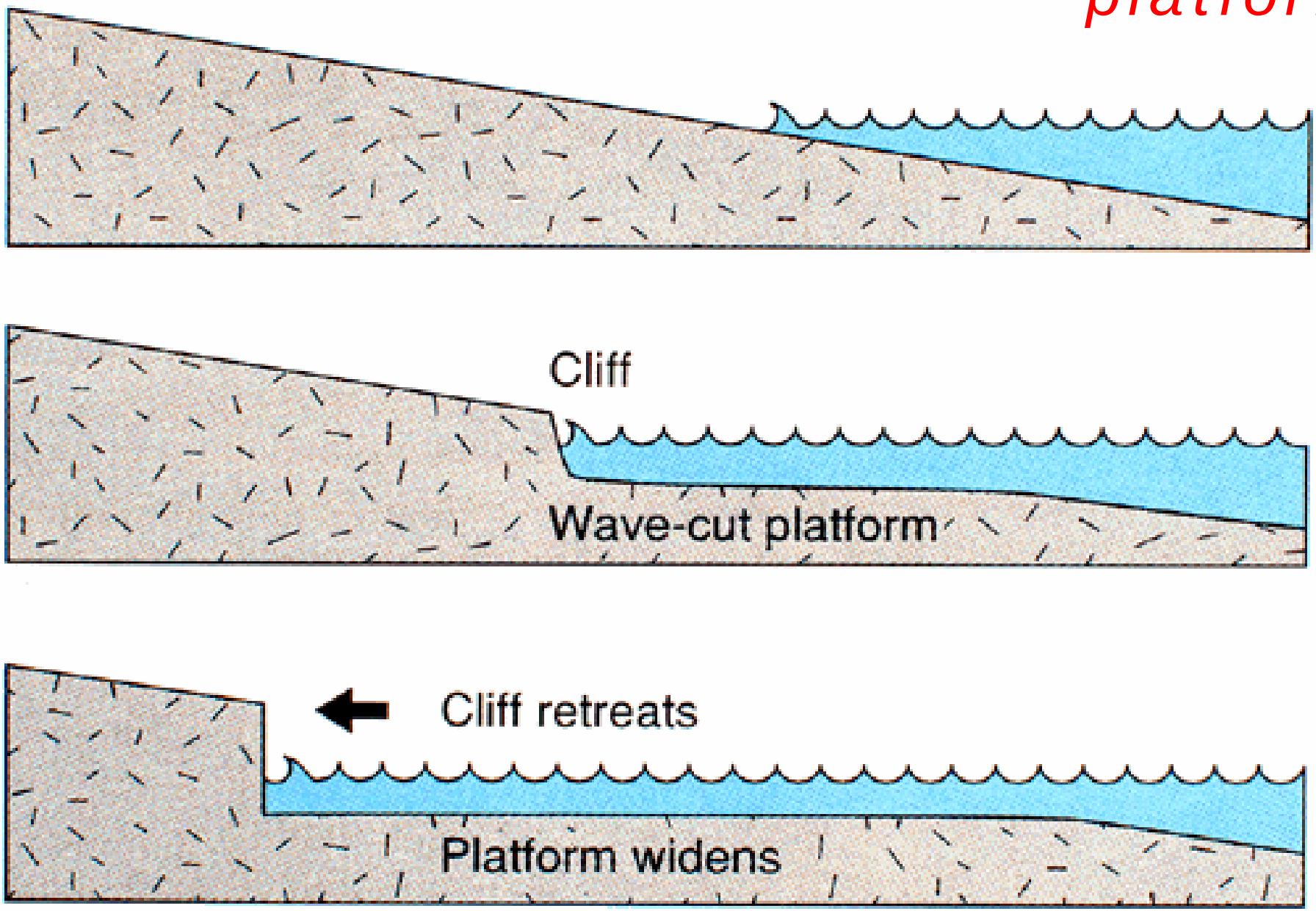


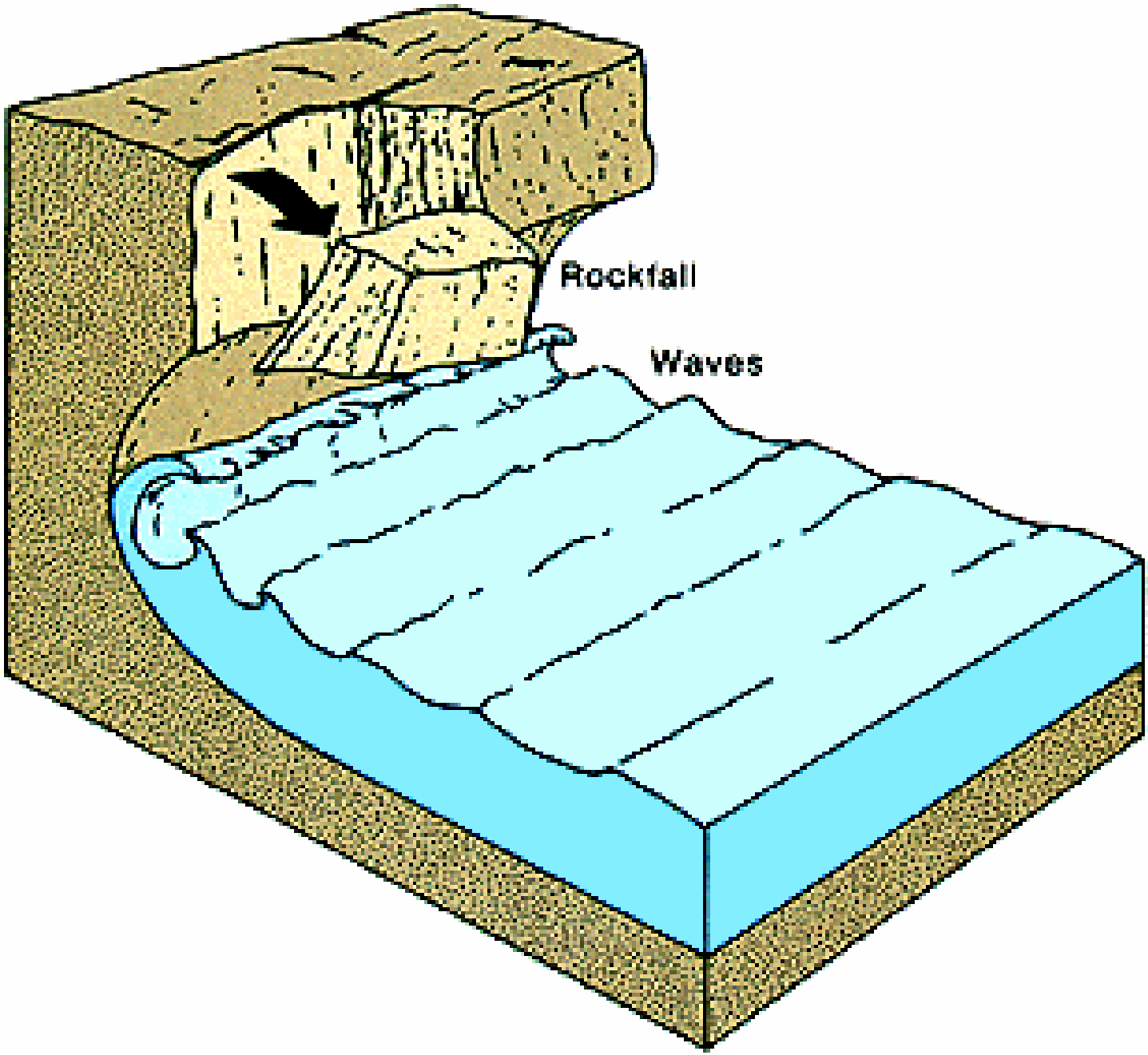
B

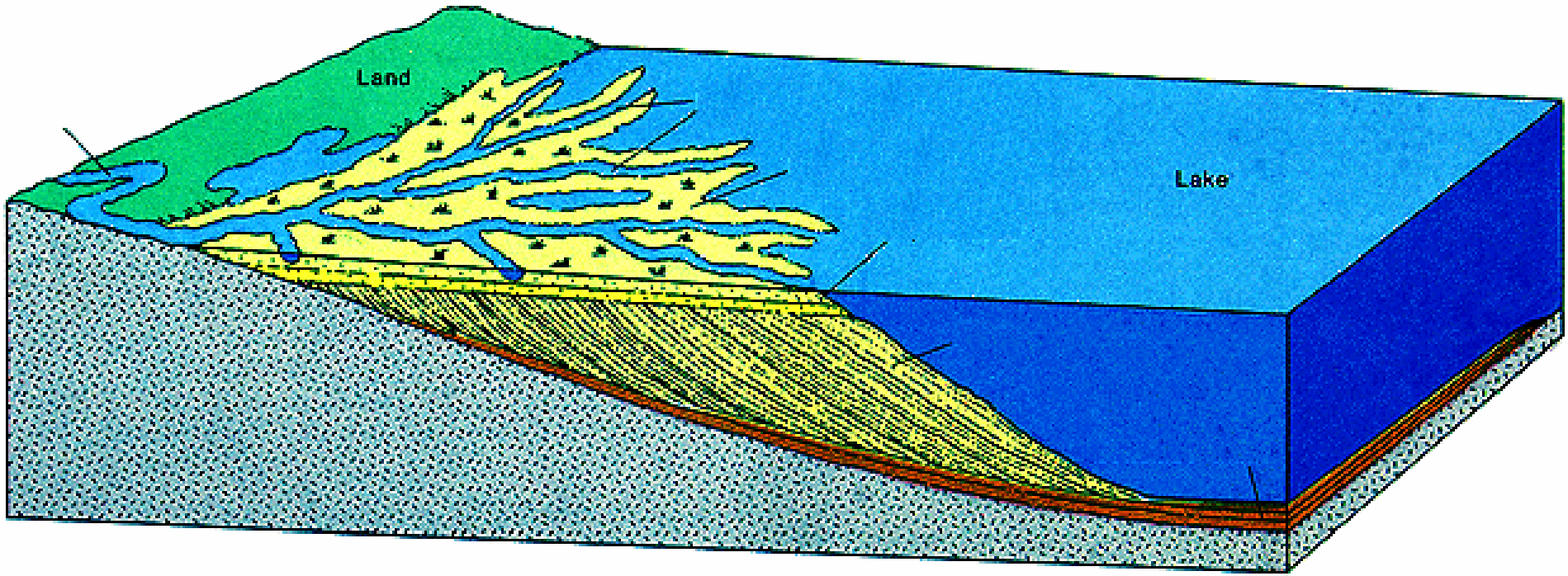


D

The development of a wave-cut platform

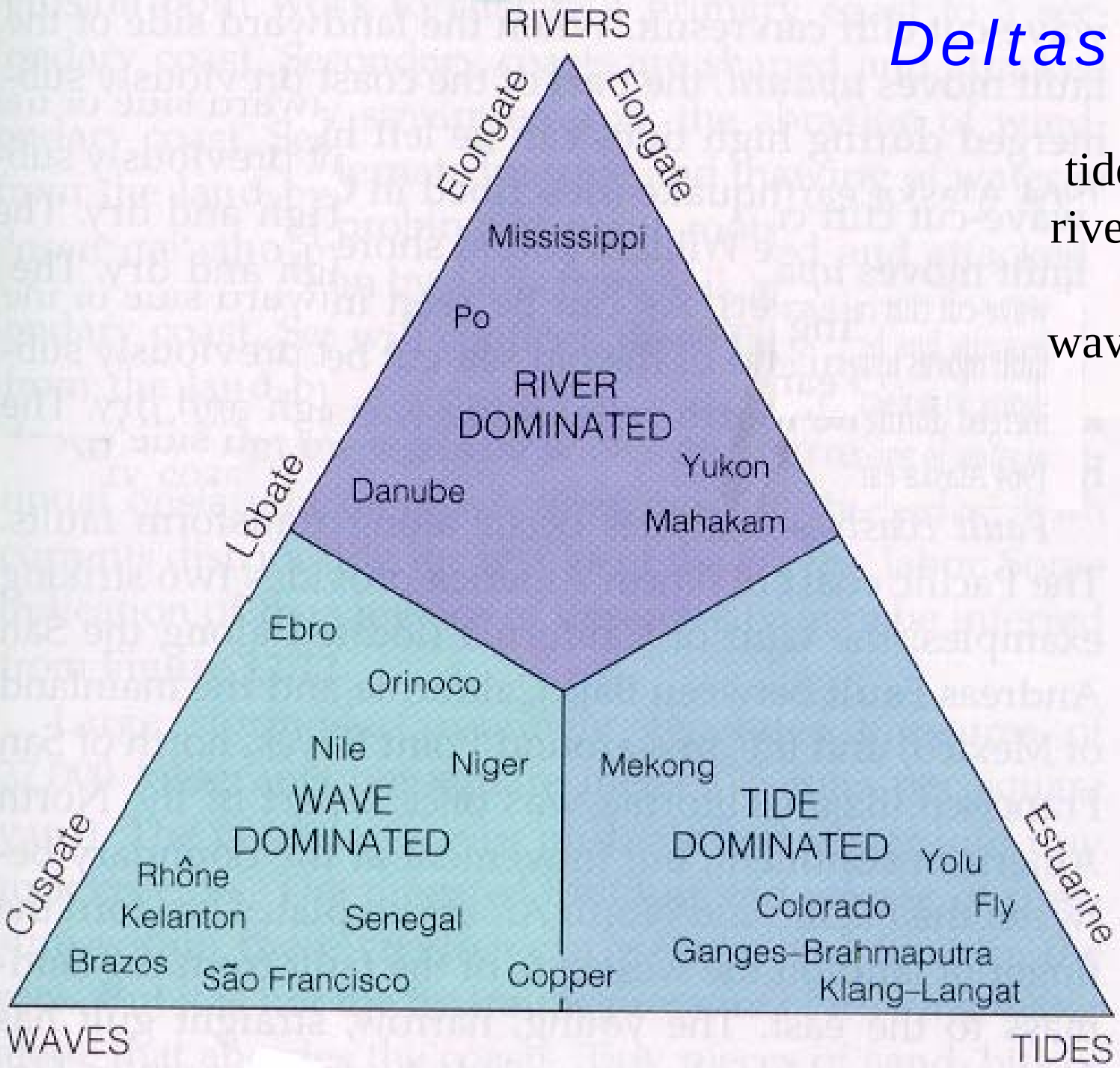


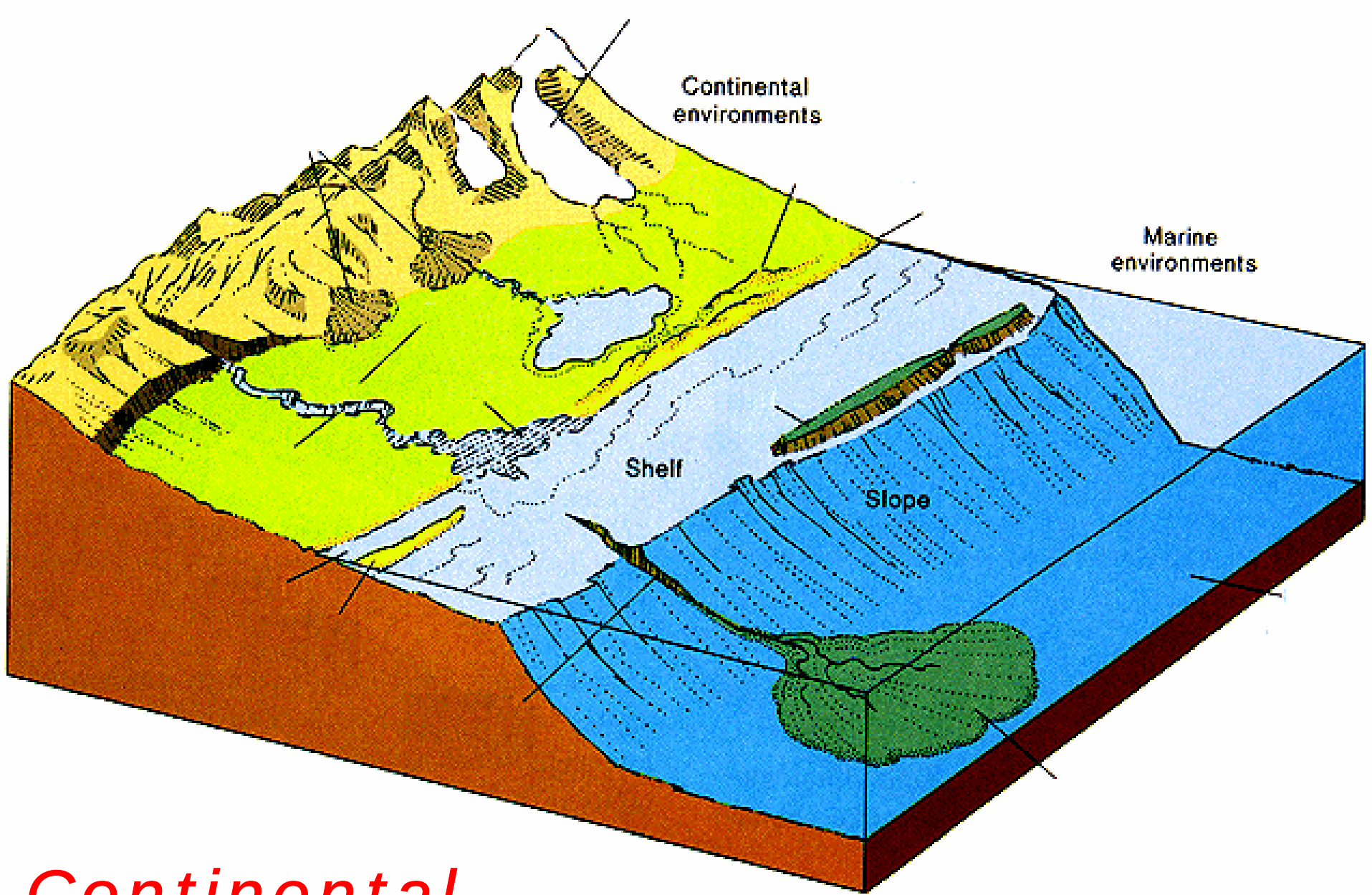

Rockfall
Waves


Land
Lake

Deltas can be

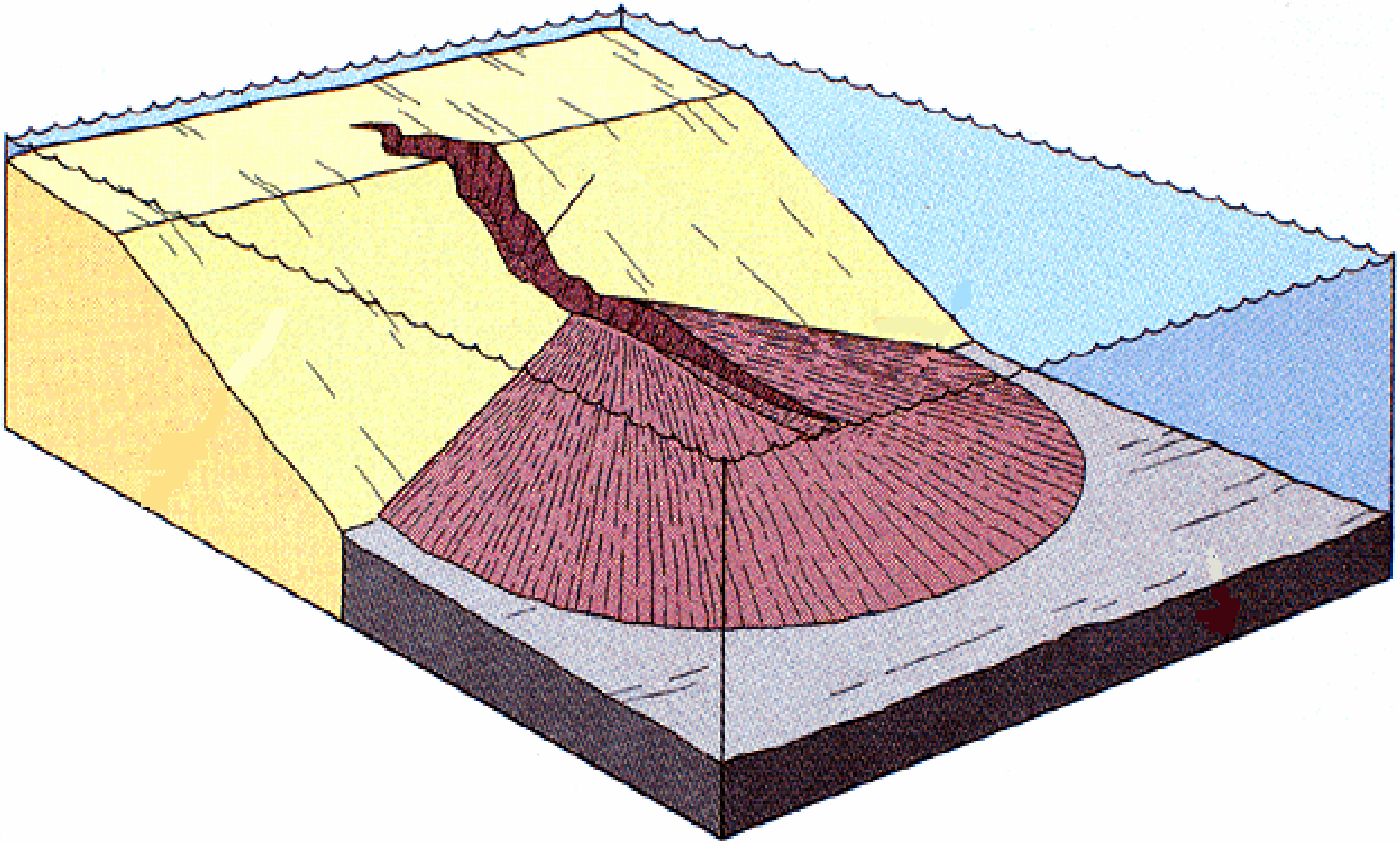
1. tide-dominated, river dominated, and wave-dominated

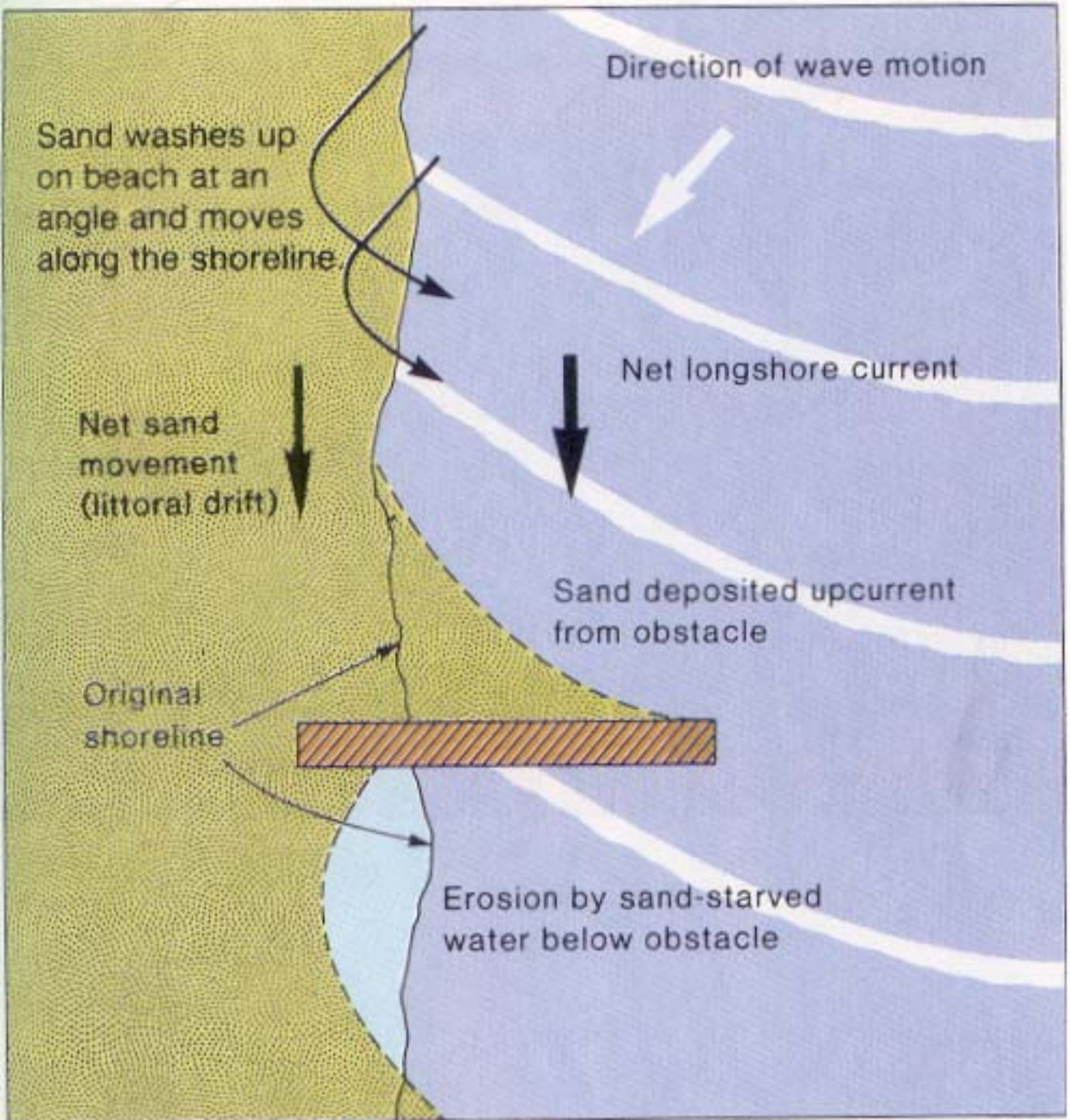




Continental shelf, slope, and submarine canyon

A submarine canyon is a collapsed river channel



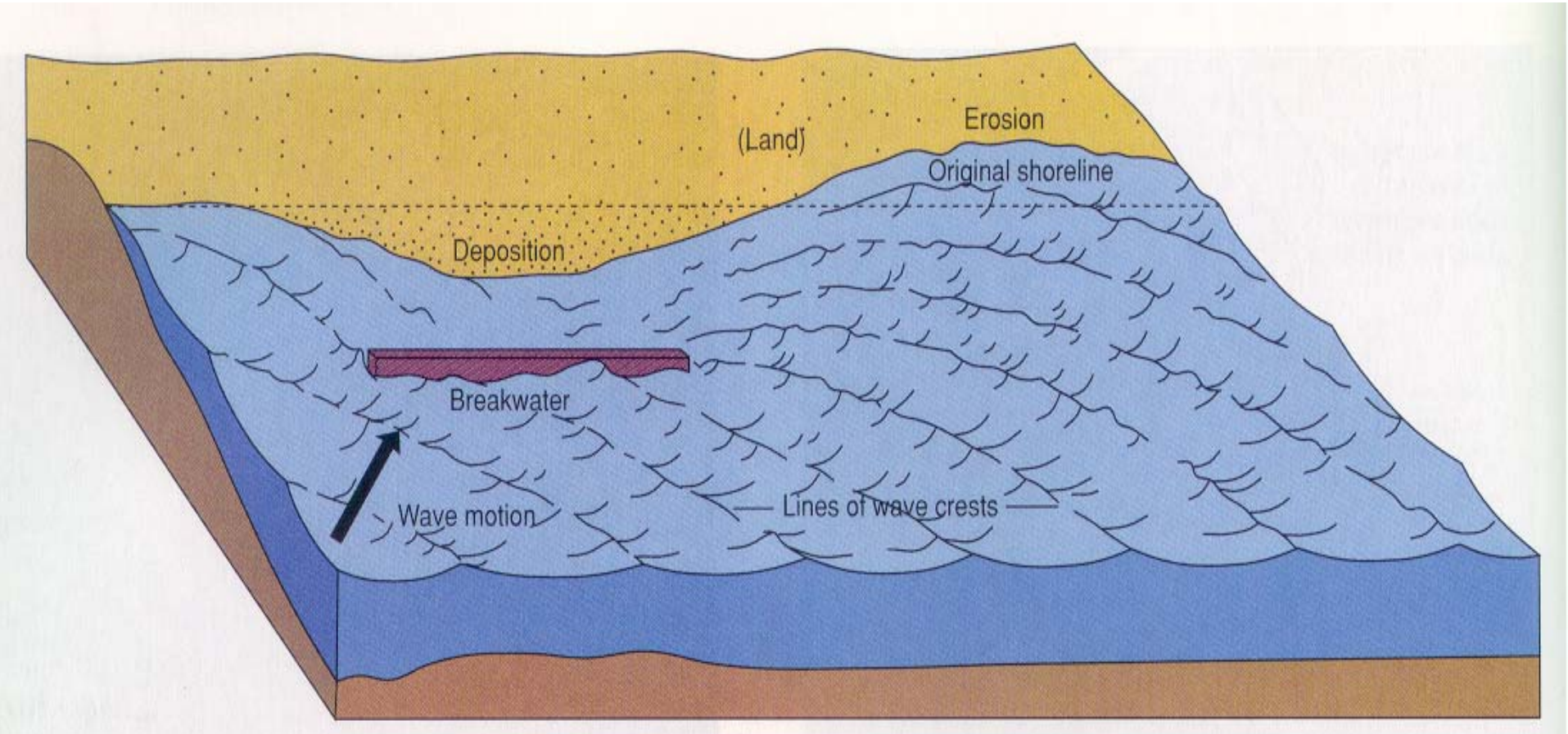


How construction modifies the shoreline:

- **The constructing a groin or a pier, i.e., a structure perpendicular to the shoreline**

How construction modifies the shoreline:

- **Constructing a breakwater wall means sand pile-up right behind the breakwater wall and erosion downstream**




Santa Barbara Harbor