Geologic Evolution of San Diego County's Coast and Lagoons

Keith Meldahl, Professor of Geology & Oceanography, Mira Costa College

Geologic Evolution of San Diego County's Coast and Lagoons

Lagoons occur where stream valleys meet the sea.

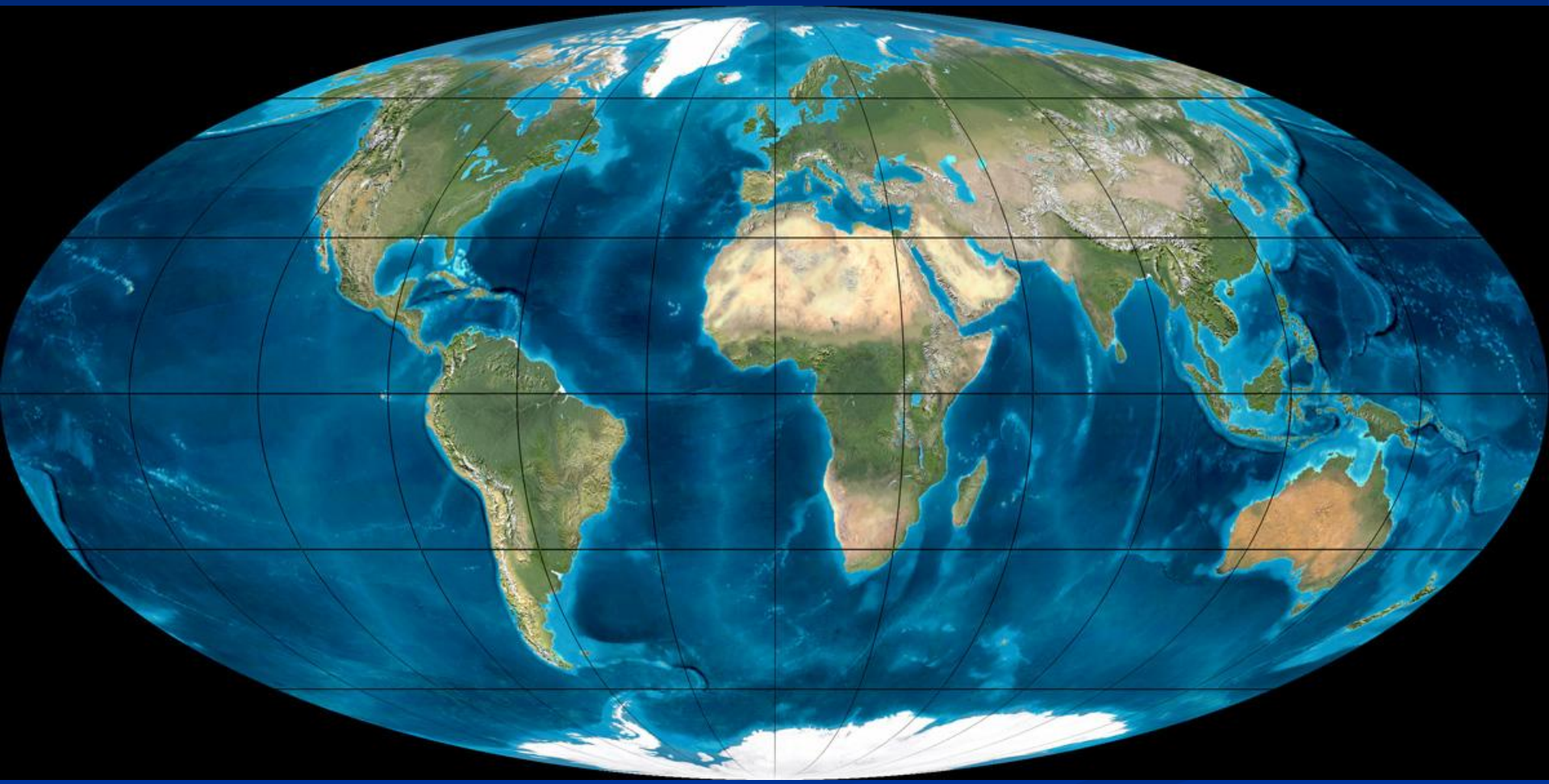
Lagoons occur where stream valleys meet the sea.


Carmel Valley
Los Penasquitos Canyon
Penasquitos Marsh
Torrey Pines State Reserve
Photo by Bruce Perry, Department of Geological Sciences, CSU Long Beach

TOPICS

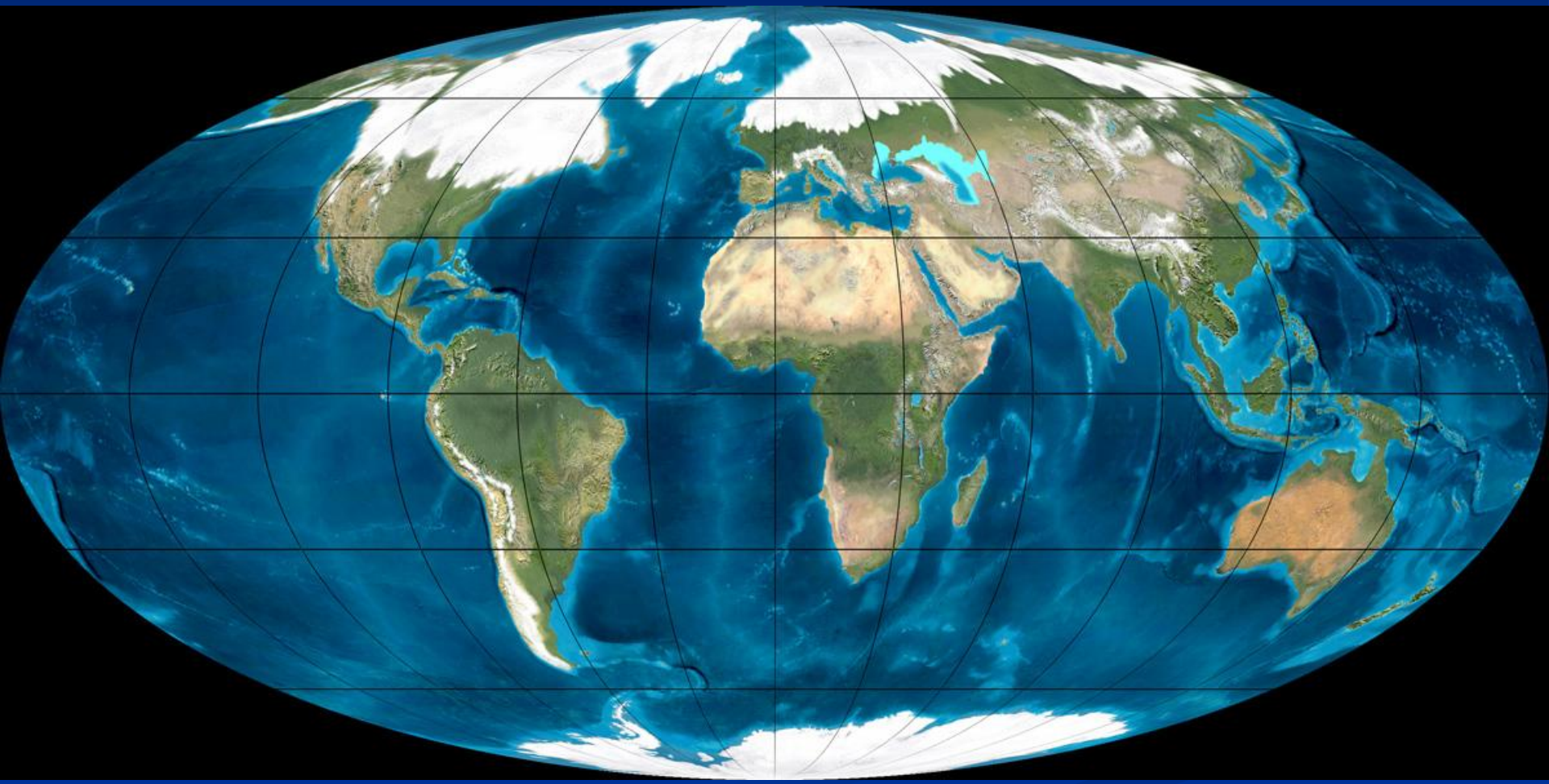
- How our coastal lagoons came to be
  - ice ages & sea level changes
  - formation of lagoons and marine terraces
- Our eroding coastline
  - dwindling sand and rising seas

Earth Today



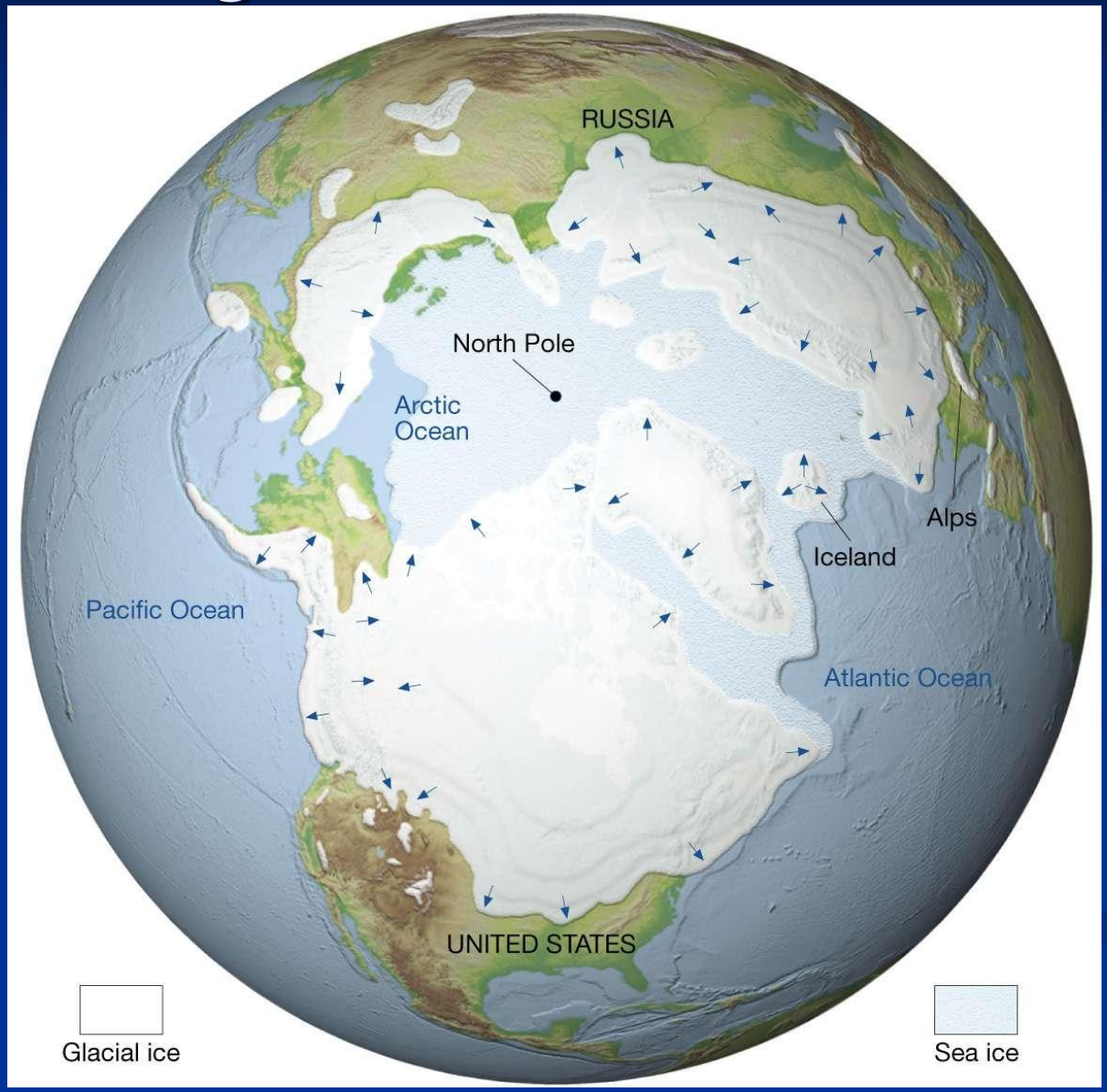
Ron Blakey, Northern Arizona University

Earth about 18,000 years ago
during the Last Glacial Maximum



Ron Blakey, Northern Arizona University

Earth about 18,000 years ago
during the Last Glacial Maximum

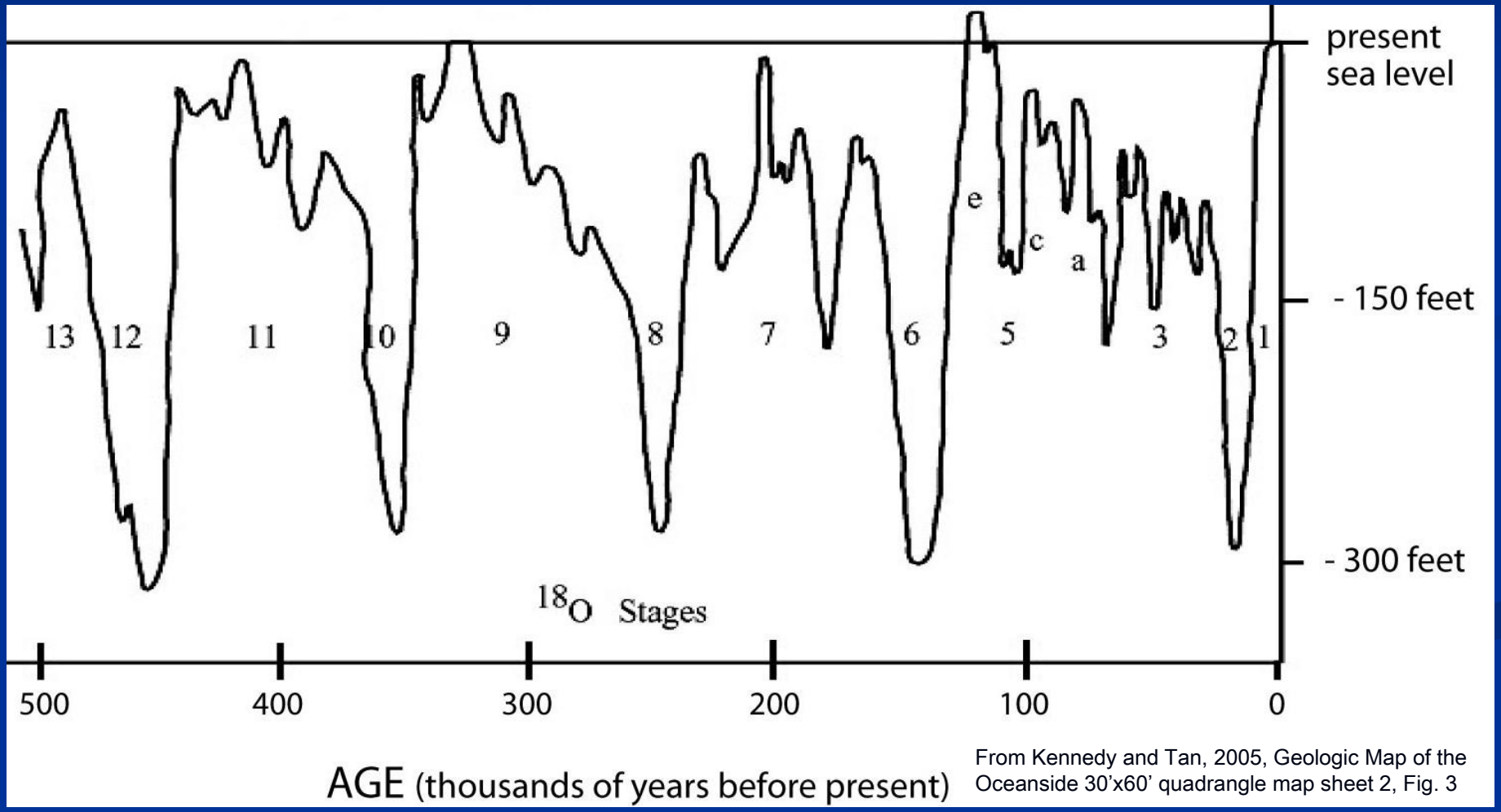


18,000 years ago, the sea was 330 feet lower, and the beach lay two miles to the west!

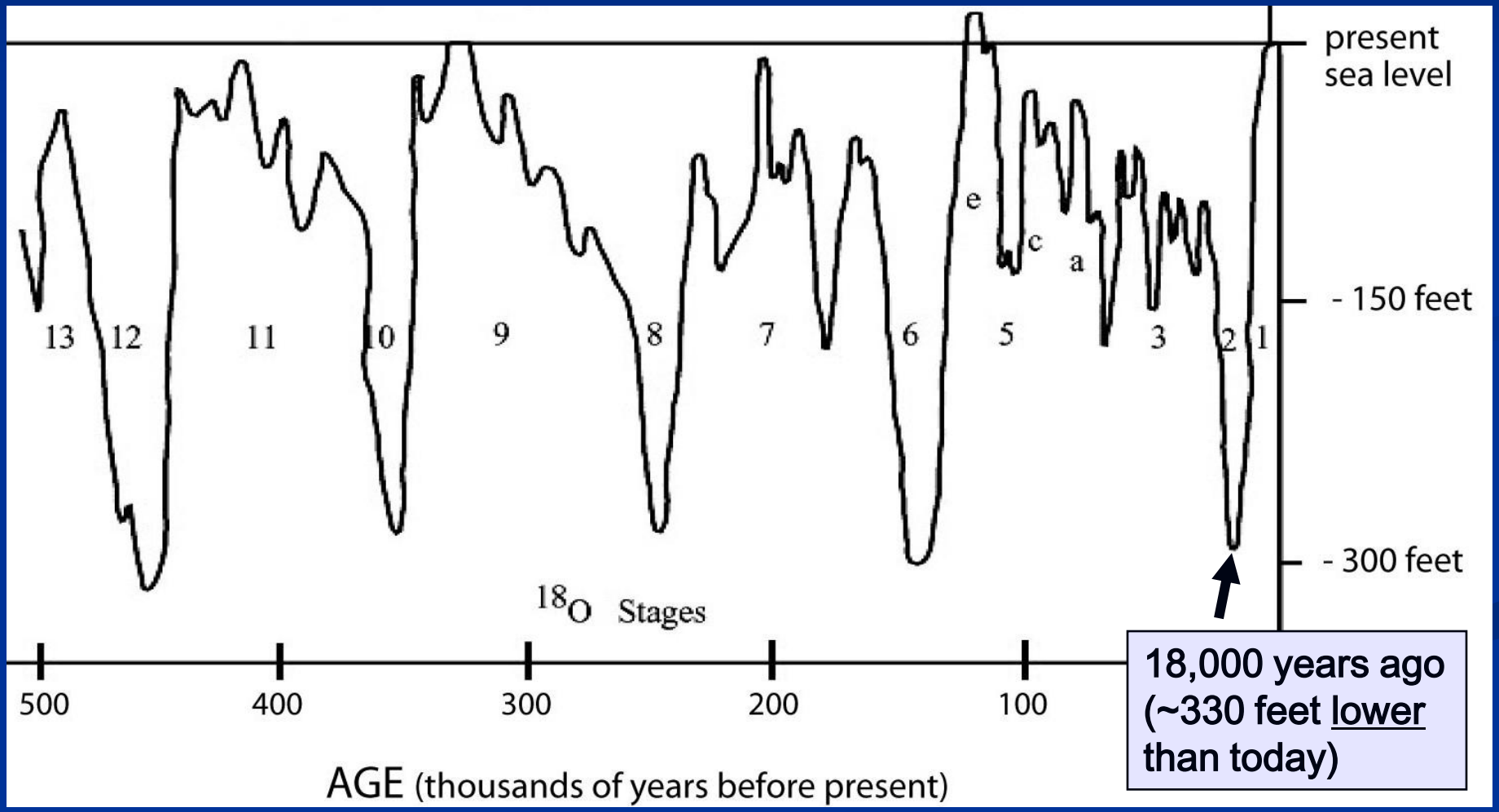
Since 18,000 years ago, the sea has risen to its present level (a rise of more than 300 feet).

The Earth has been through many glacial-interglacial cycles during the past several hundred thousand years.

As the glaciers have come and gone, the sea has gone up & down.

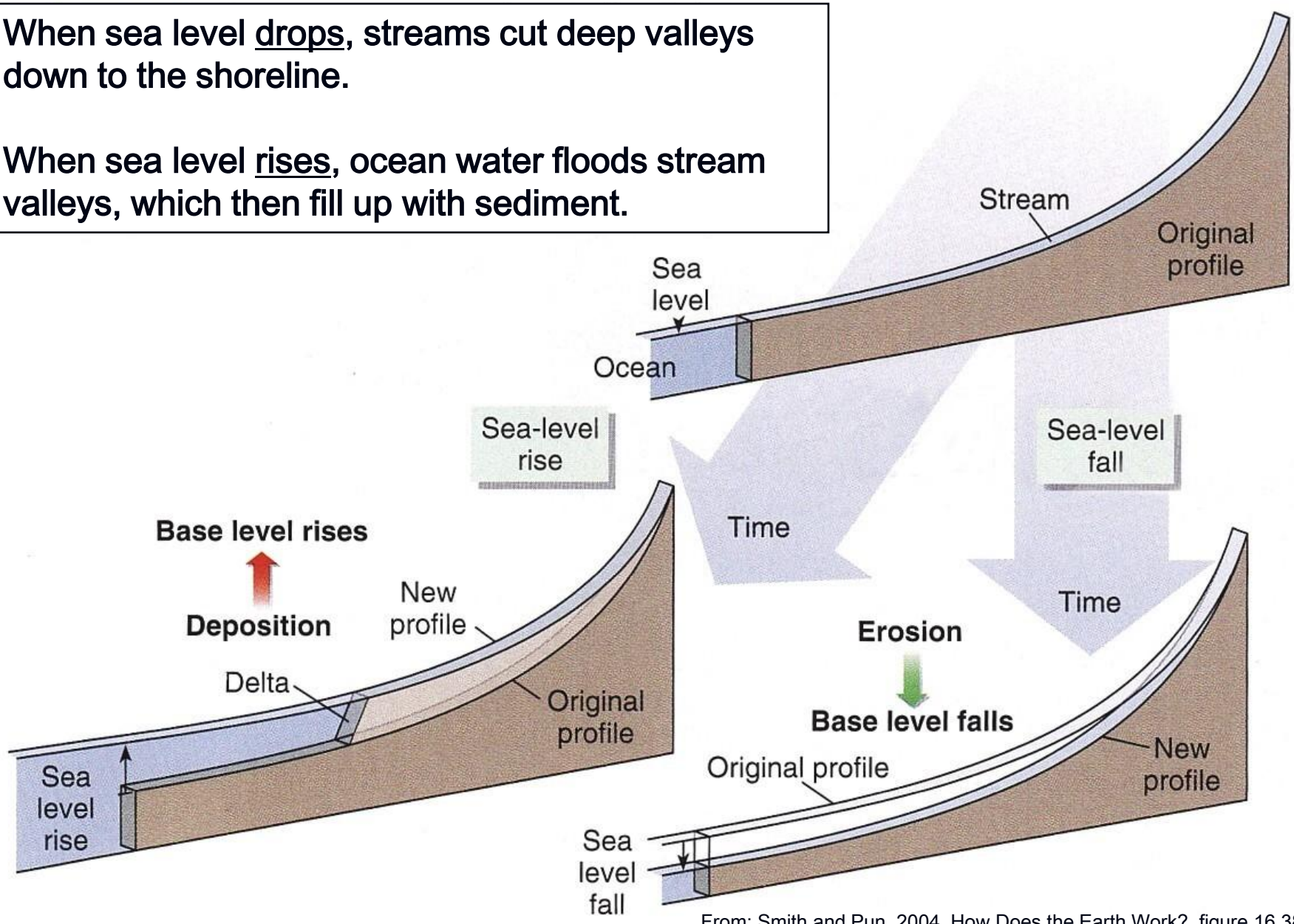


From Kennedy and Tan, 2005, Geologic Map of the Oceanside 30'x60' quadrangle map sheet 2, Fig. 3


125,000 years ago
(~ 20 feet higher
than today)
present
sea level
- 150 feet
- 300 feet
13
12
11
10
9
8
7
6
5
e
c
a
3
2
1
^{18}O Stages
500
400
300
200
100
18,000 years ago
(~330 feet lower
than today)
AGE (thousands of years before present)

When sea level drops, streams cut deep valleys down to the shoreline.

When sea level rises, ocean water floods stream valleys, which then fill up with sediment.

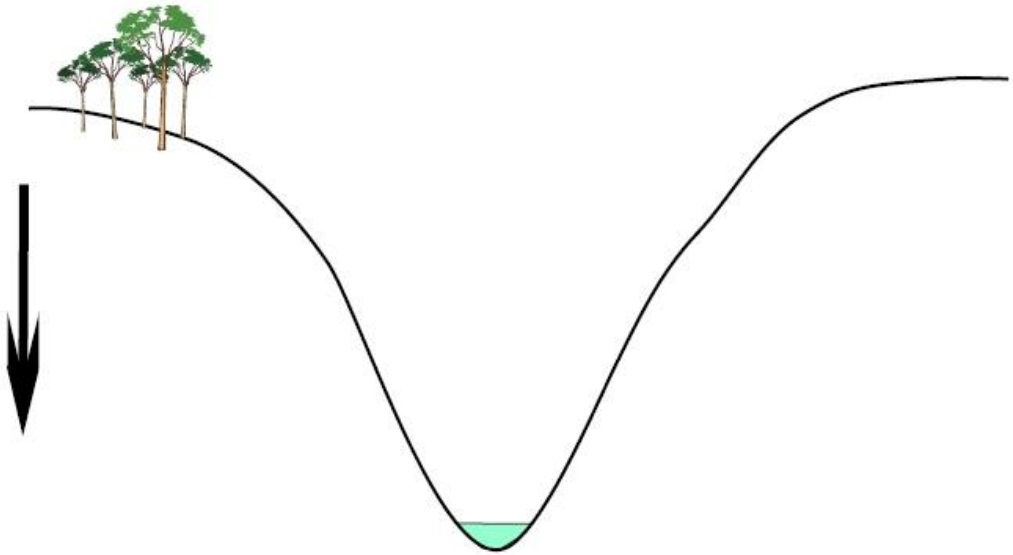


From: Smith and Pun, 2004, How Does the Earth Work?, figure 16.38

How stream erosion and changing sea levels made San Diego County's coastal lagoons

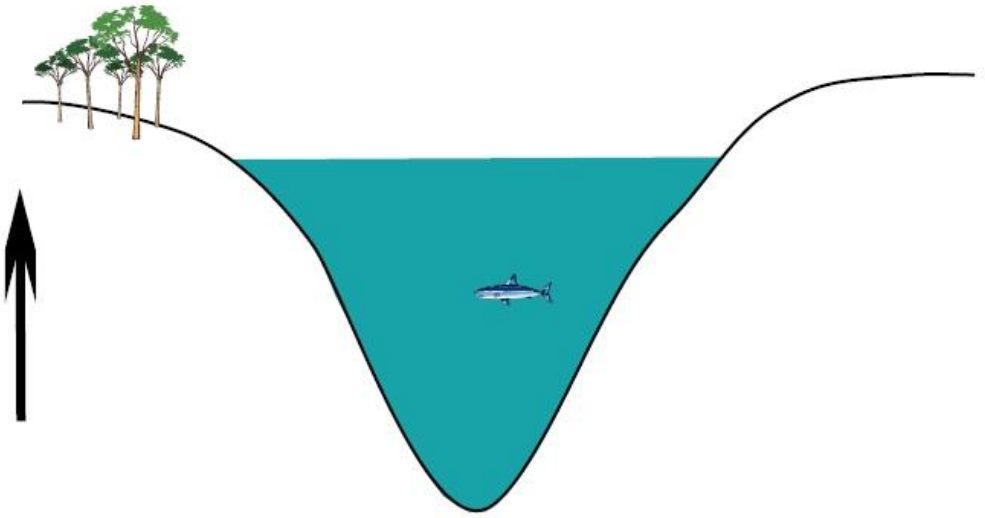
1. Stream flowing toward the sea (toward viewer).

2. Sea level drops; stream cuts a deep valley in response.

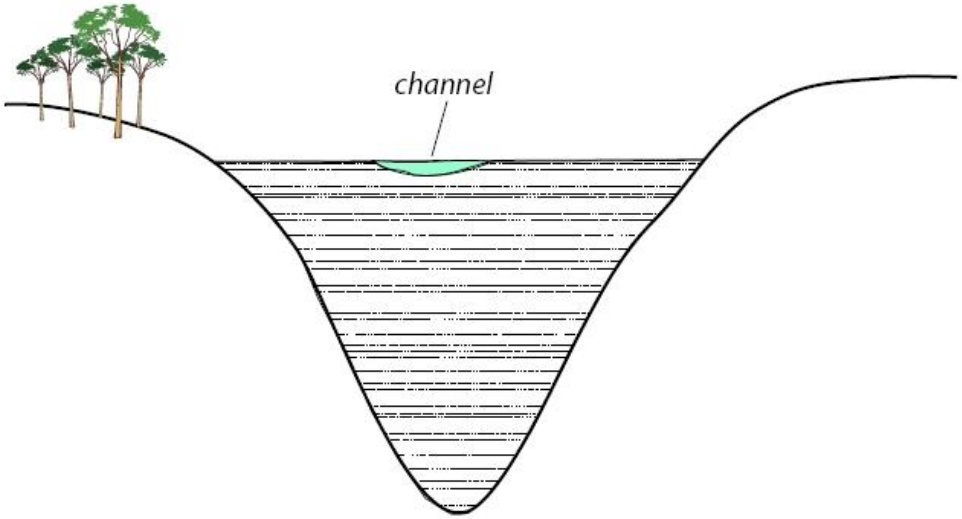


How stream erosion and changing sea levels made San Diego County's coastal lagoons

3. Sea rises; ocean water floods the valley forming a deep-water estuary.

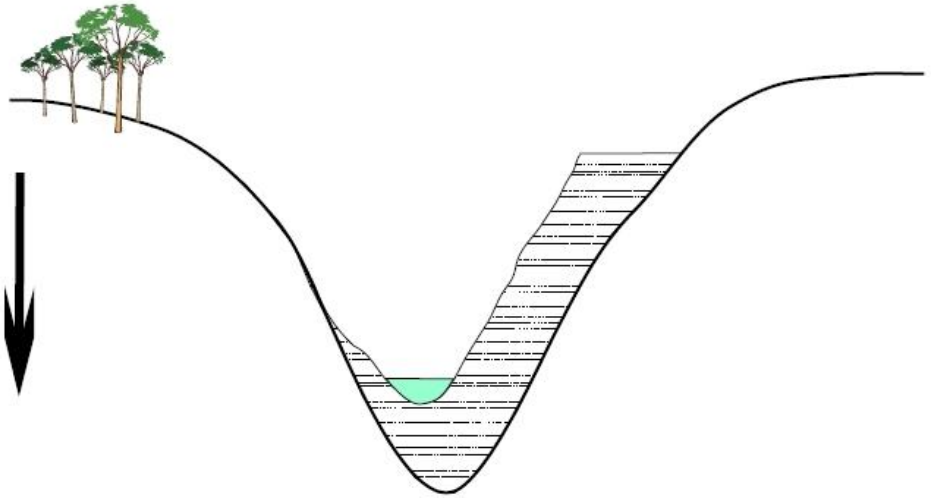


4. Valley gradually fills up with sediment; tidal channels connect stream to ocean.

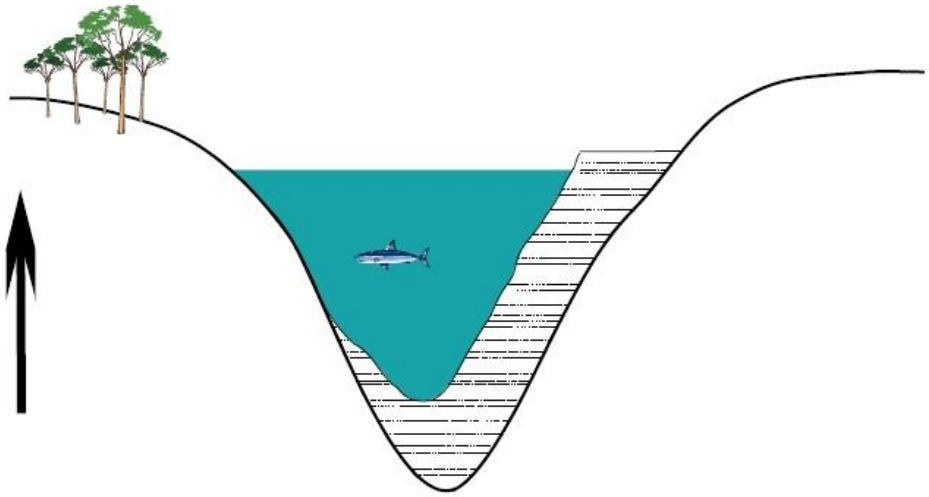


How stream erosion and changing sea levels made San Diego County's coastal lagoons

5. Sea level drops; stream cuts a new valley through the sedimentary fill, but leaves some behind.

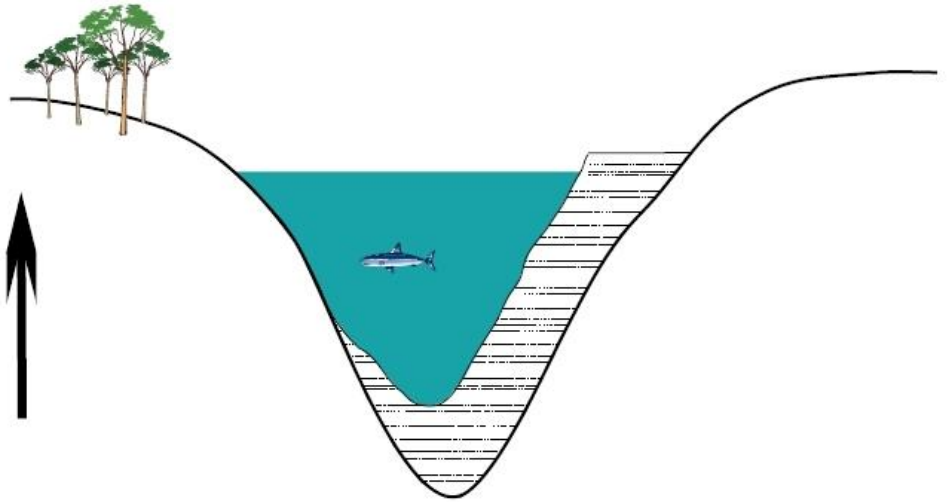


6. Sea rises again, but not as high as before; ocean water floods the valley.

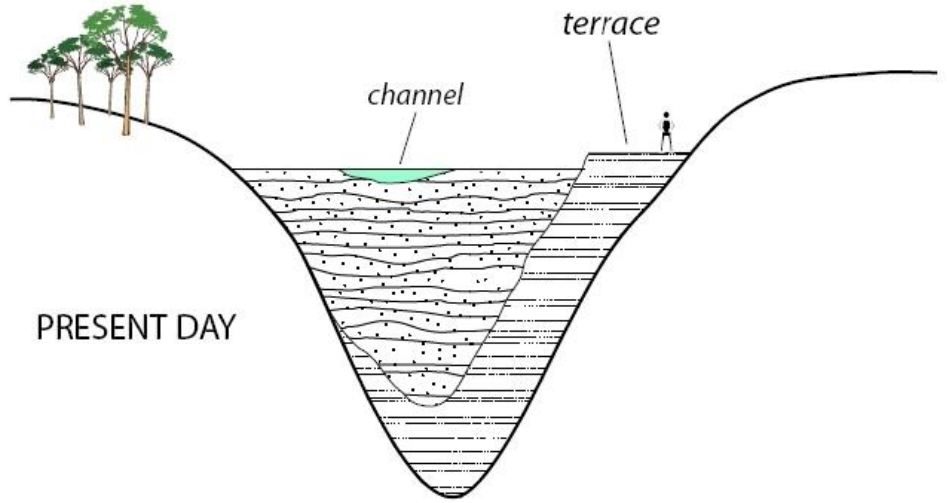


How stream erosion and changing sea levels made San Diego County's coastal lagoons

6. Sea rises again, but not as high as before; ocean water floods the valley.



7. Valley fills up with sediment; tidal channels again connect stream to ocean.

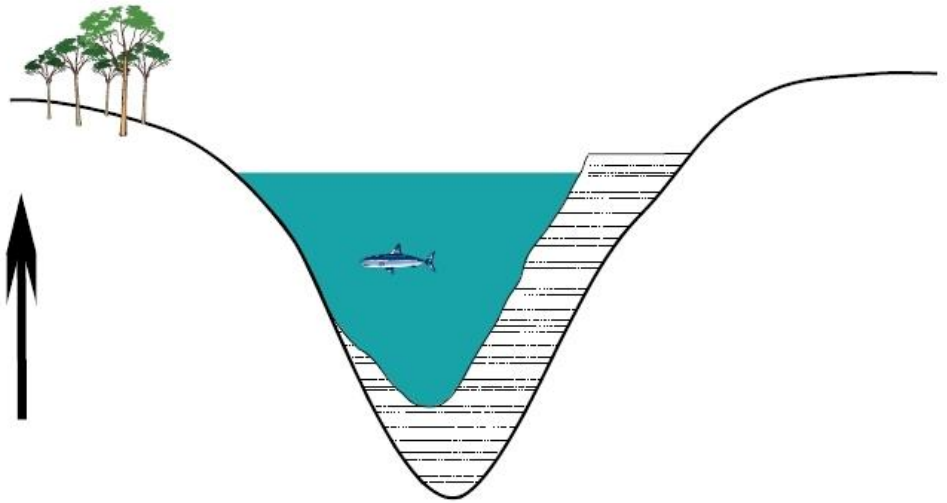


Stream valleys drowned by rising sea levels in New England.

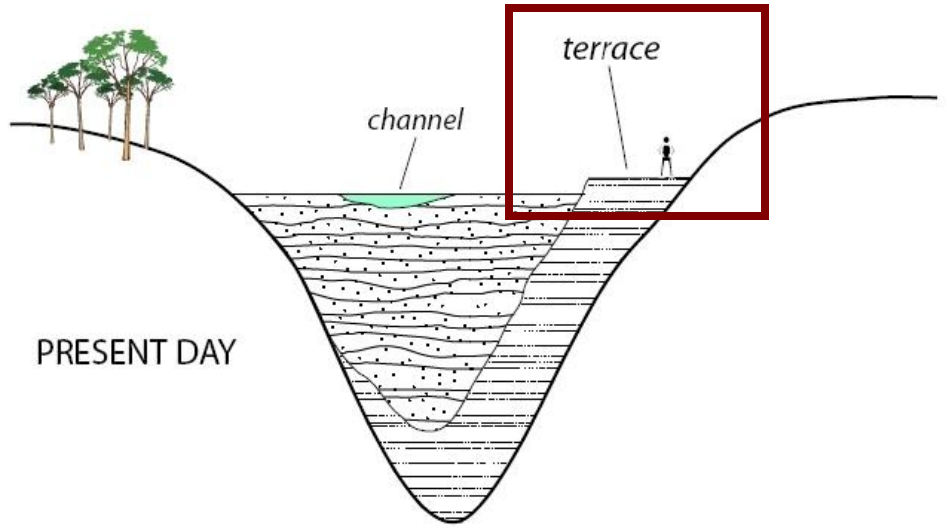
(This is what San Diego County's coastal lagoons looked like before they filled up with sediment.)

Marine terraces = where sea level used to be

6. Sea rises again, but not as high as before; ocean water floods the valley.



7. Valley fills up with sediment; tidal channels again connect stream to ocean.

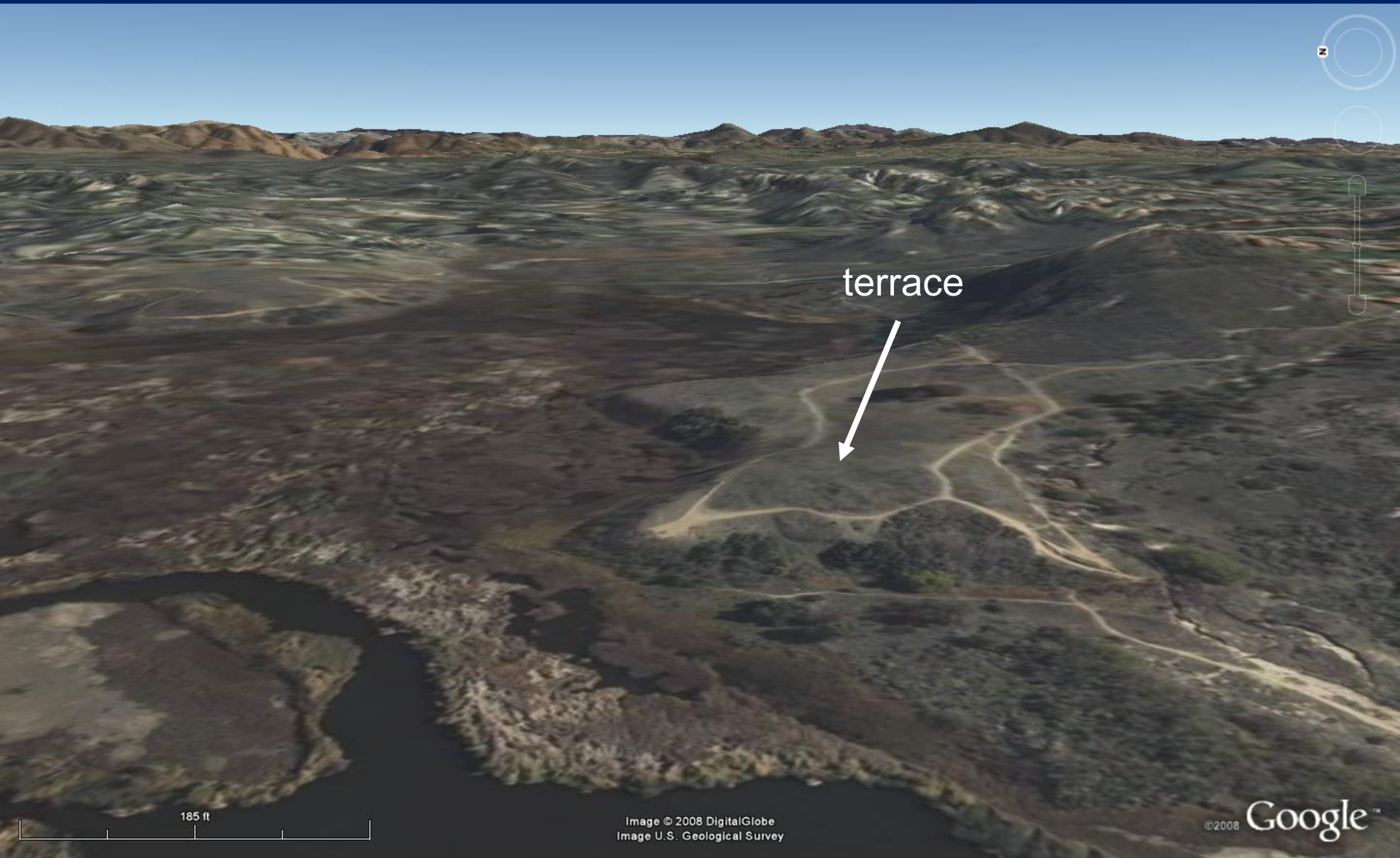


Marine terraces = where sea level used to be

Marine terrace in Penasquitos Marsh

Marine terraces = where sea level used to be

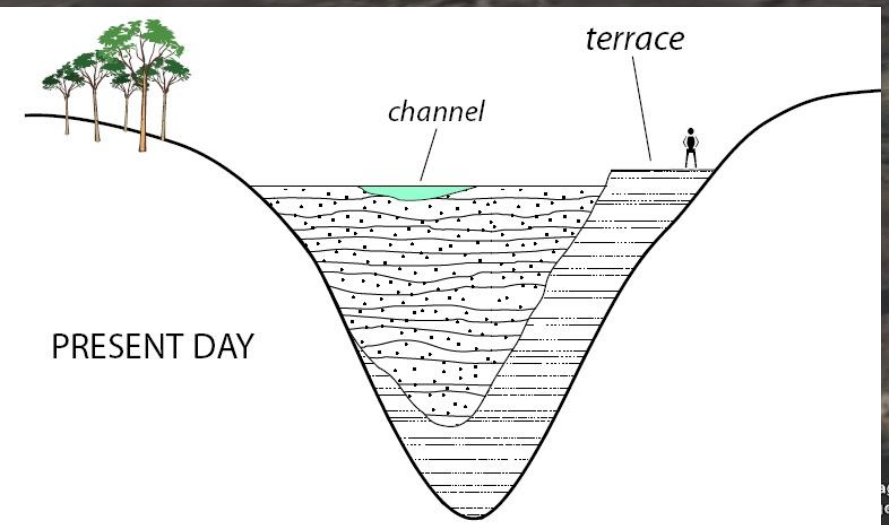
Marine terrace in San Elijo Lagoon



Marine terraces = where sea level used to be

Marine terrace in San Elijo Lagoon

terrace



San Elijo Lagoon

Marine terrace in San Elijo Lagoon

terrace

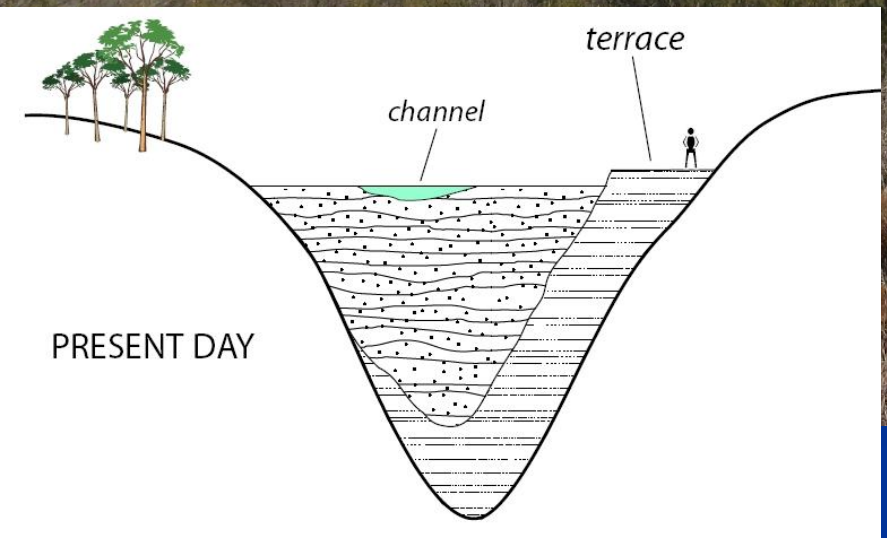
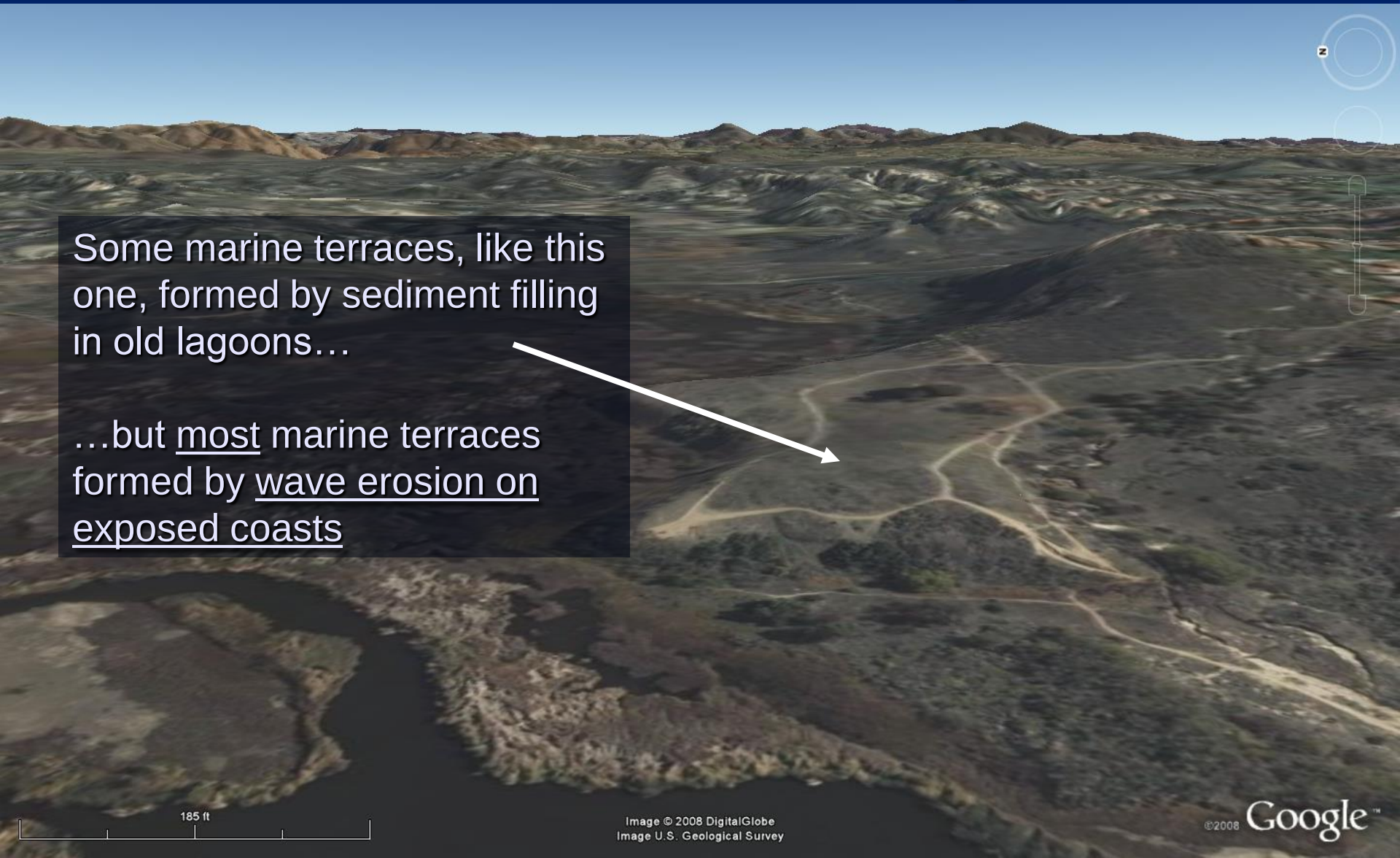


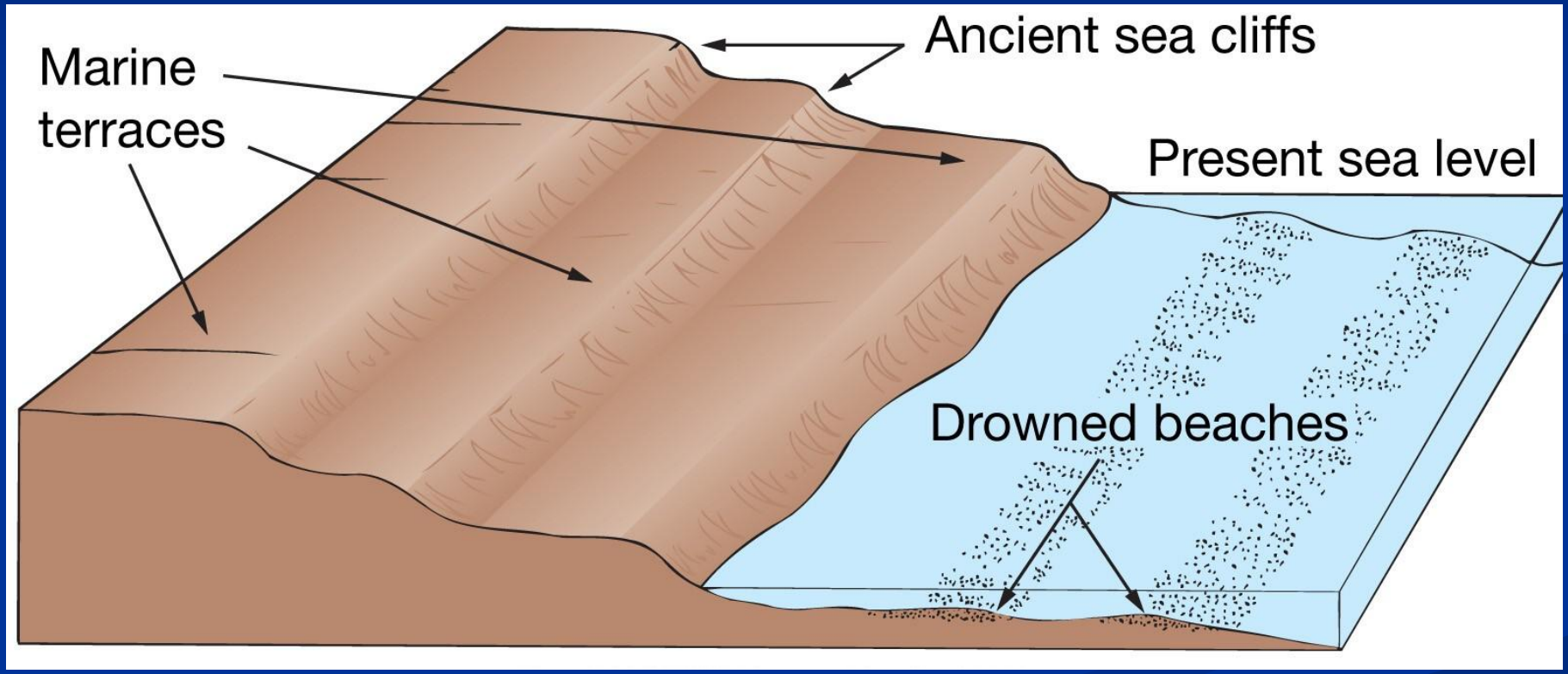
Photo by Chris Metzler

Marine terraces = where sea level used to be

Marine terrace in San Elijo Lagoon

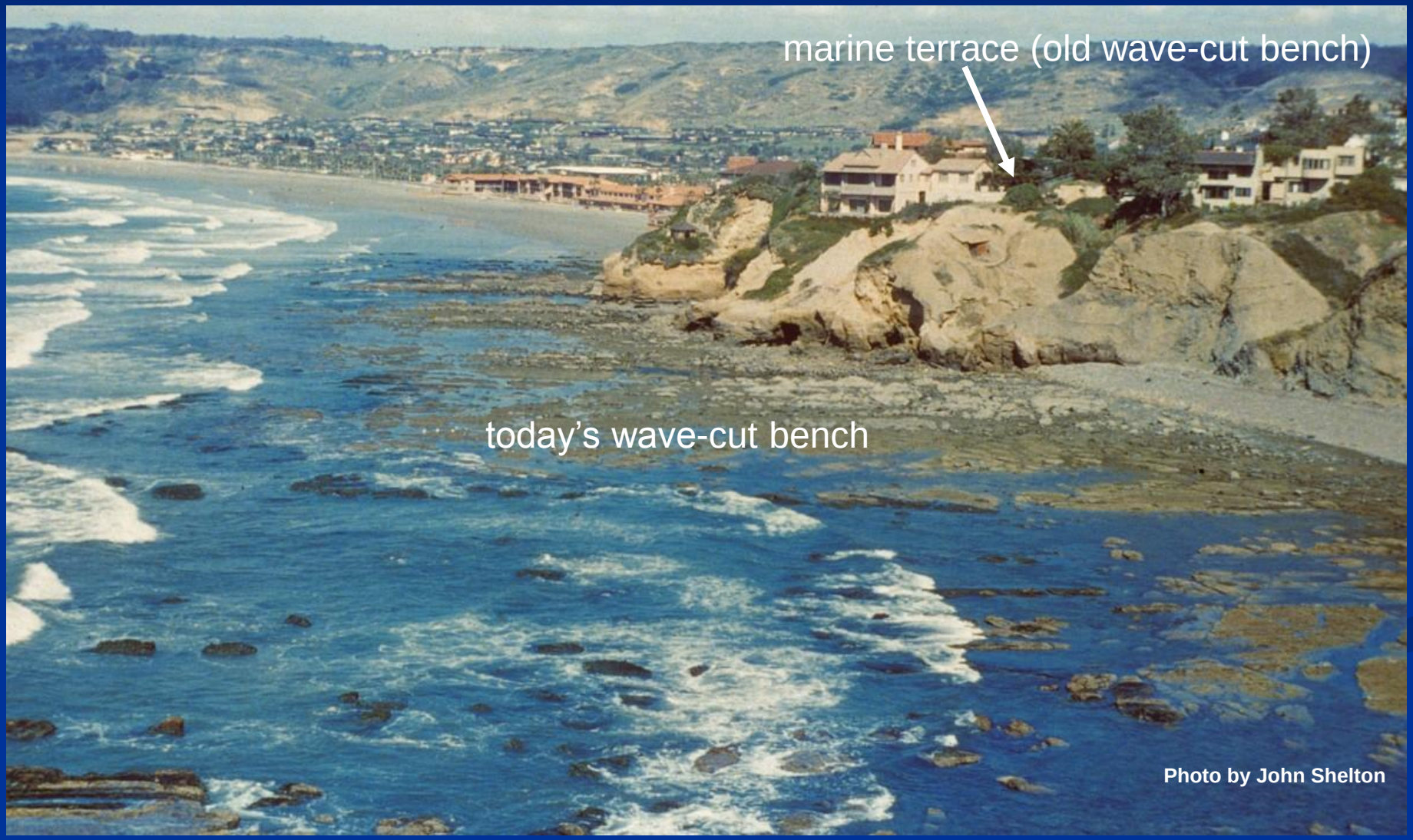


Wave-eroded marine terraces: the most common geologic feature of the San Diego coastline

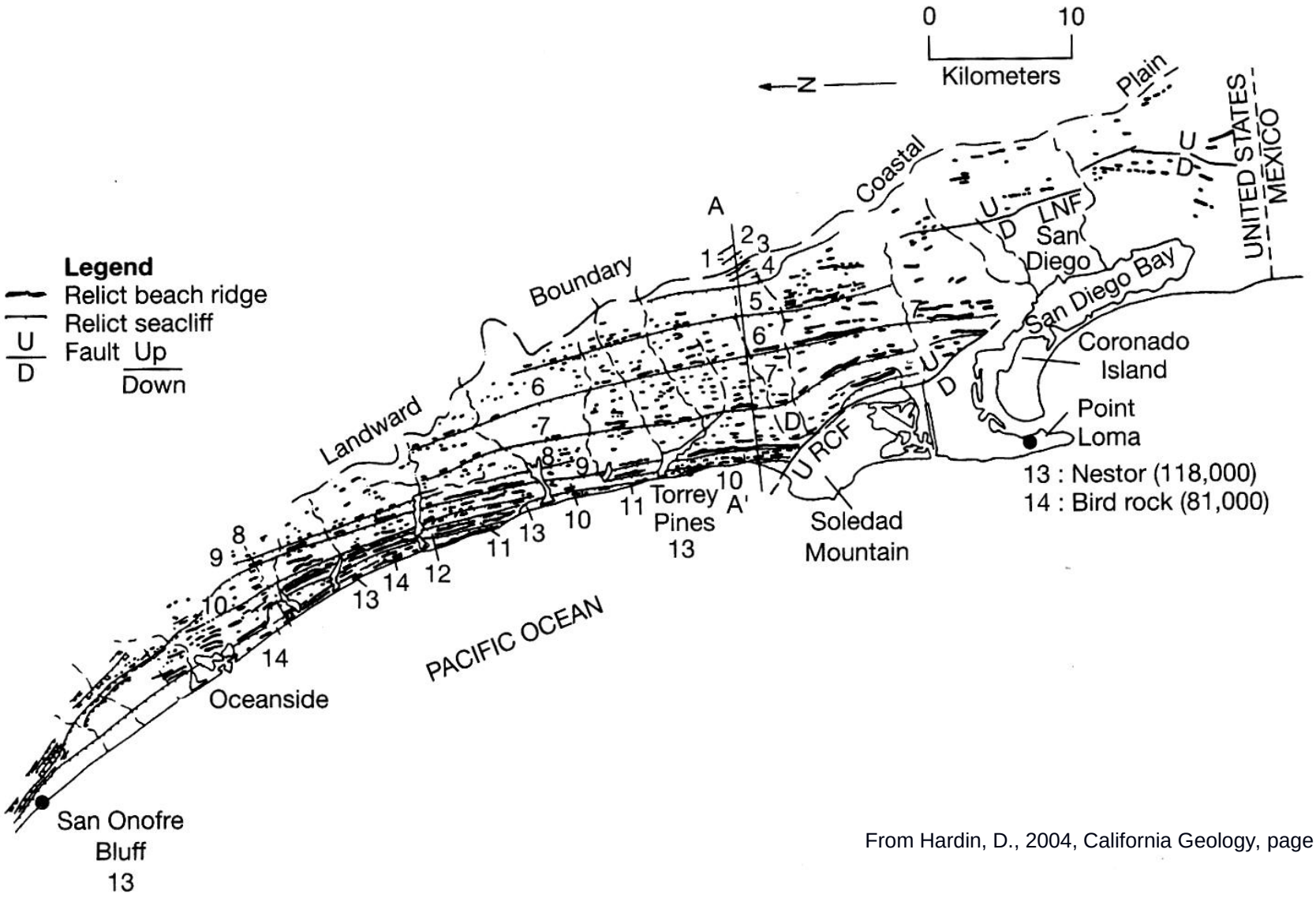


Pearson / Prentice Hall

Wave-eroded marine terraces: the most common geologic feature of the San Diego coastline



Wave-eroded marine terraces: the most common geologic feature of the San Diego coastline

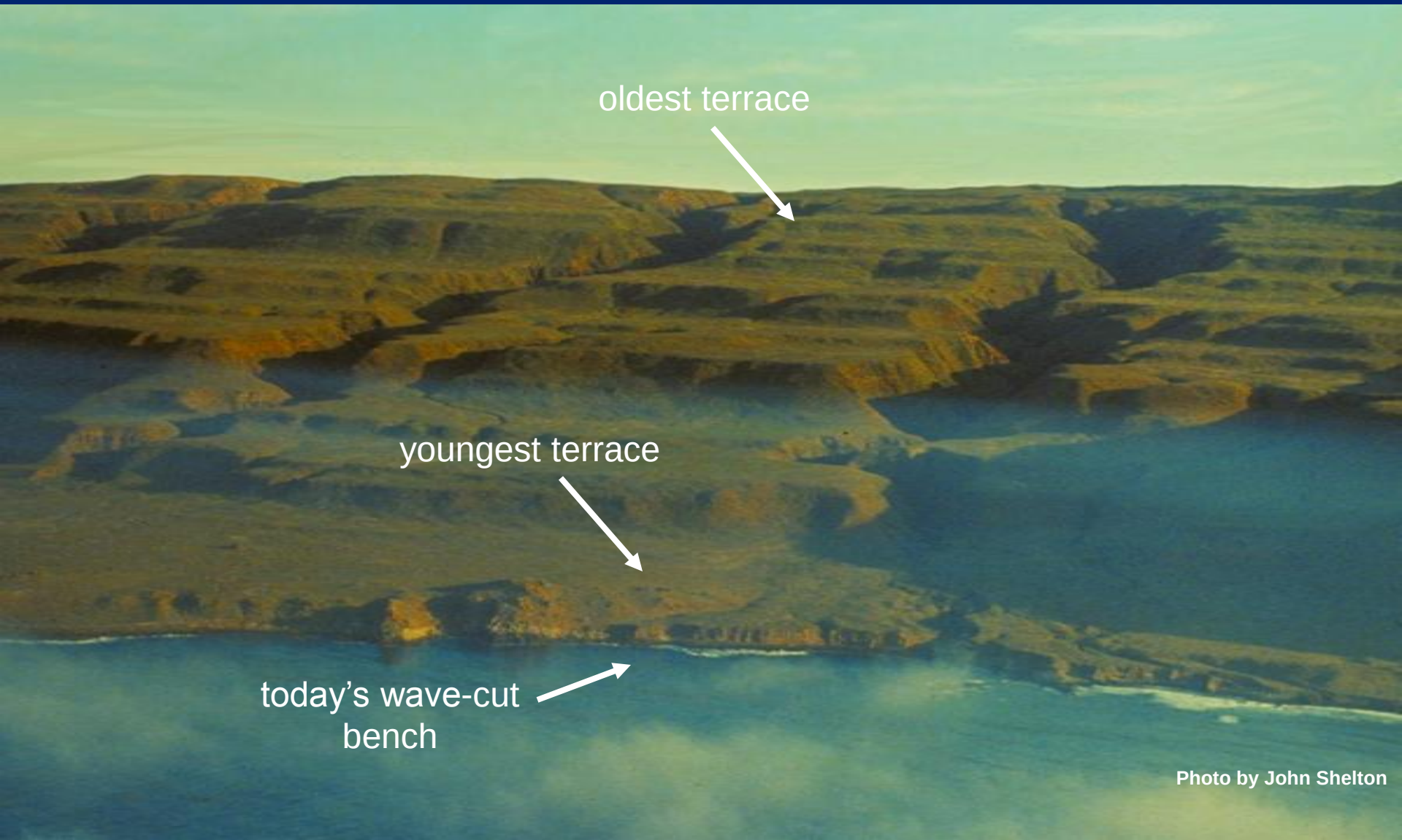


From Hardin, D., 2004, California Geology, page 418

Wave-eroded marine terraces: San Clemente Island

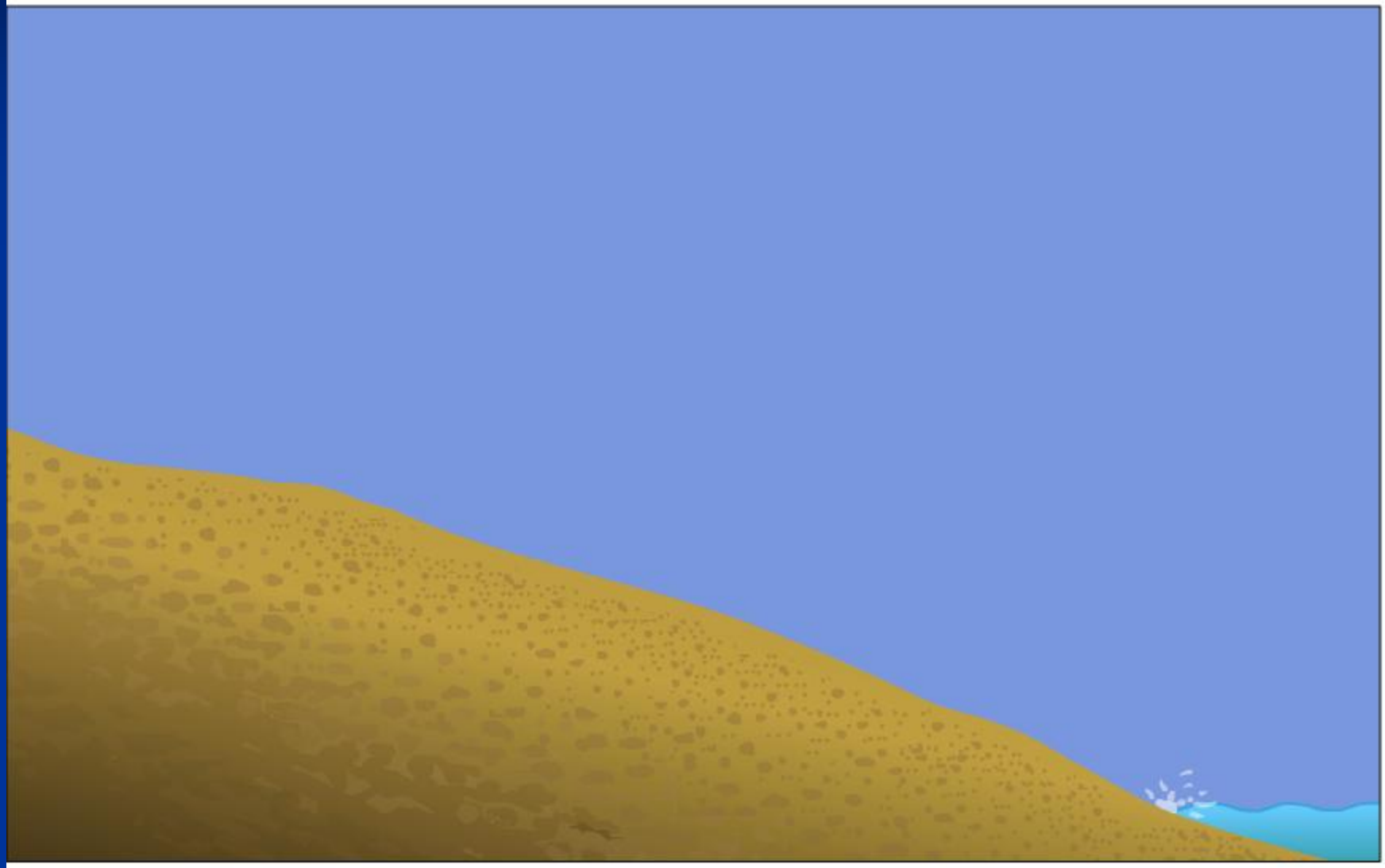
Photo by John Shelton

Wave-eroded marine terraces: San Clemente Island

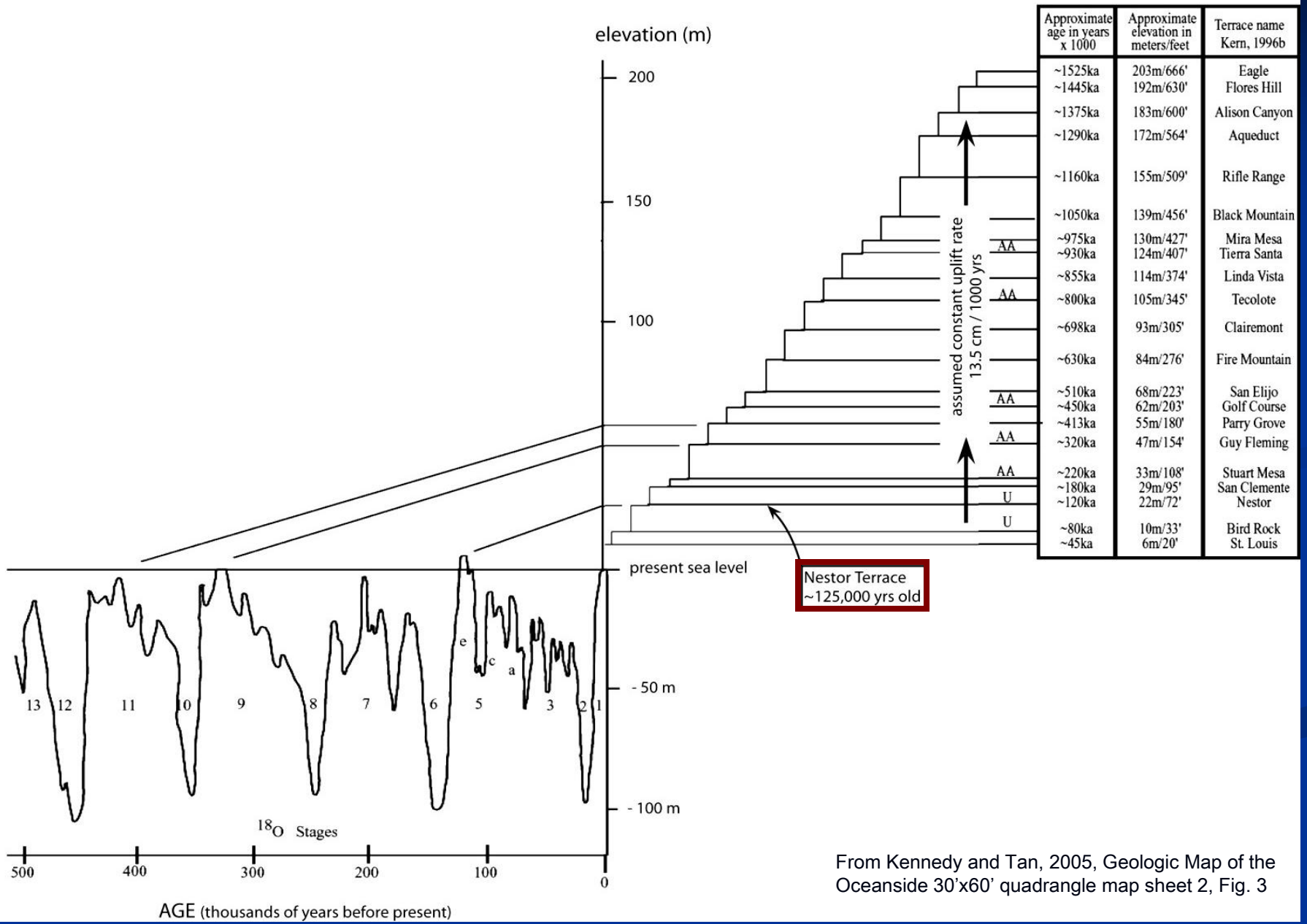


Sea level, land uplift, & marine terrace formation

Animation by Tanya Atwater



Sea level, land uplift, & marine terrace formation



Approximate age in years x 1000	Approximate elevation in meters/feet	Terrace name Kern, 1996b
~1525ka	203m/666'	Eagle
~1445ka	192m/630'	Flores Hill
~1375ka	183m/600'	Alison Canyon
~1290ka	172m/564'	Aqueduct
~1160ka	155m/509'	Rifle Range
~1050ka	139m/456'	Black Mountain
~975ka	130m/427'	Mira Mesa
AA ~930ka	124m/407'	Tierra Santa
~855ka	114m/374'	Linda Vista
AA ~800ka	105m/345'	Tecolote
~698ka	93m/305'	Clairemont
~630ka	84m/276'	Fire Mountain
~510ka	68m/223'	San Elijo
AA ~450ka	62m/203'	Golf Course
~413ka	55m/180'	Parry Grove
AA ~320ka	47m/154'	Guy Fleming
~220ka	33m/108'	Stuart Mesa
AA ~180ka	29m/95'	San Clemente
U ~120ka	22m/72'	Nestor
U ~80ka	10m/33'	Bird Rock
~45ka	6m/20'	St. Louis

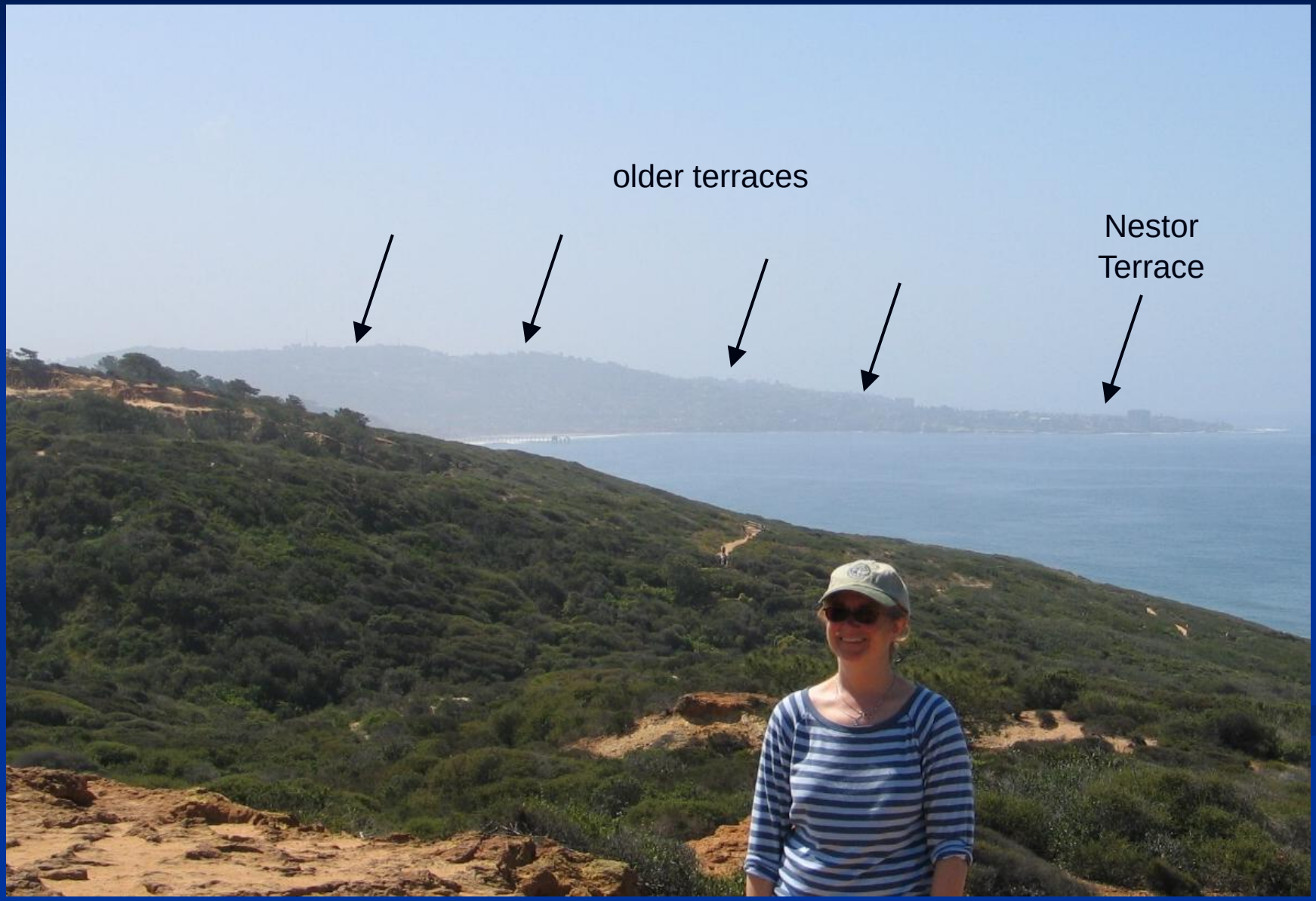
From Kennedy and Tan, 2005, Geologic Map of the Oceanside 30'x60' quadrangle map sheet 2, Fig. 3

Sea level, land uplift, & marine terrace formation

Downtown La Jolla is built on the Nestor Terrace
(a 125,000-year-old marine terrace)

Photo by Bruce Perry, Department of Geological Sciences, CSU Long Beach

Sea level, land uplift, & marine terrace formation



TOPICS

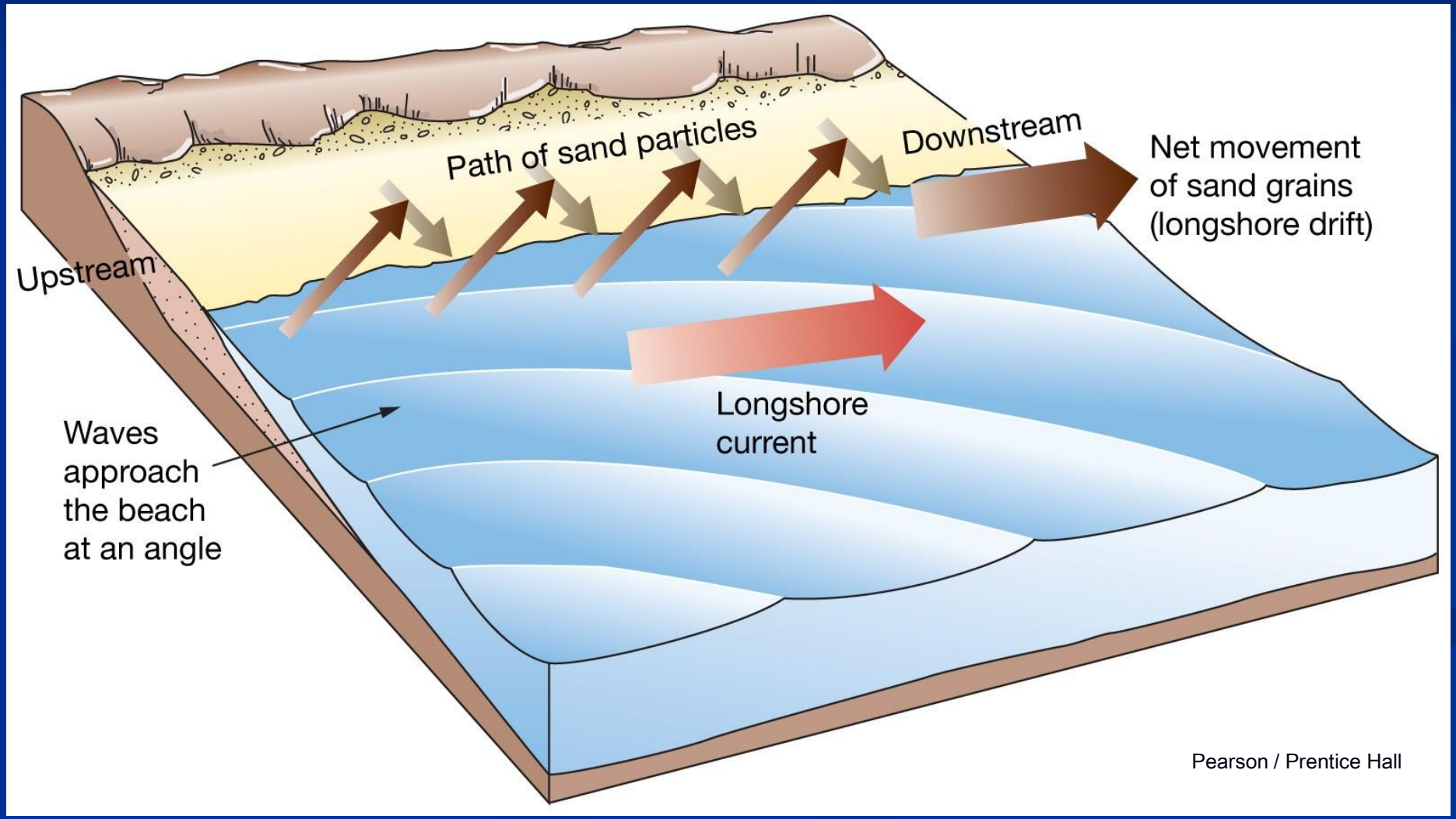
- How our coastal lagoons came to be
  - ice ages & sea level changes
  - formation of lagoons and marine terraces
- Our eroding coasts
  - dwindling sand and rising seas

Shrinking beaches and eroding coasts

View south from Swami's at high tide

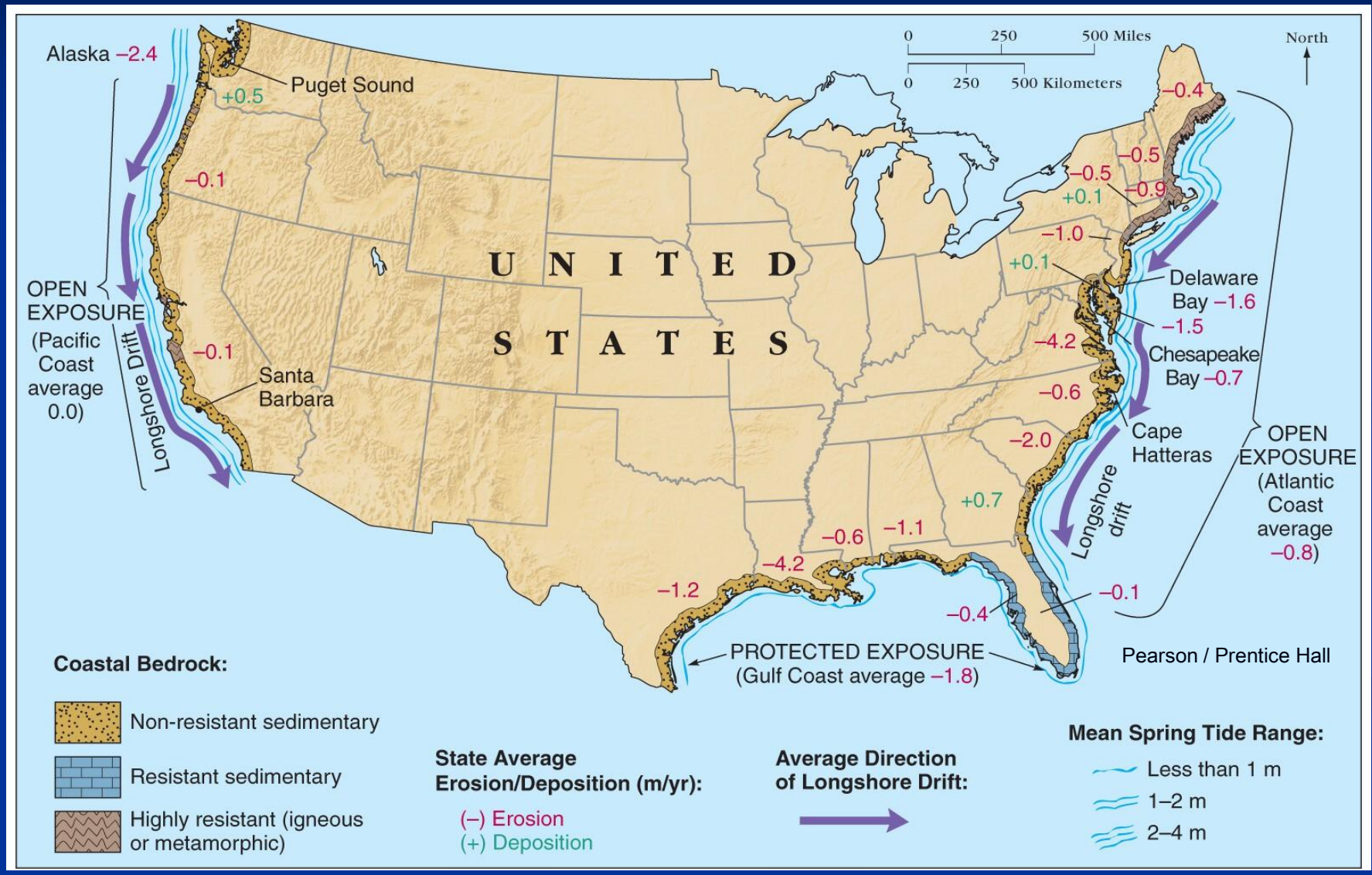
Longshore Drift

Movement of sand along the shore in the direction of the waves.



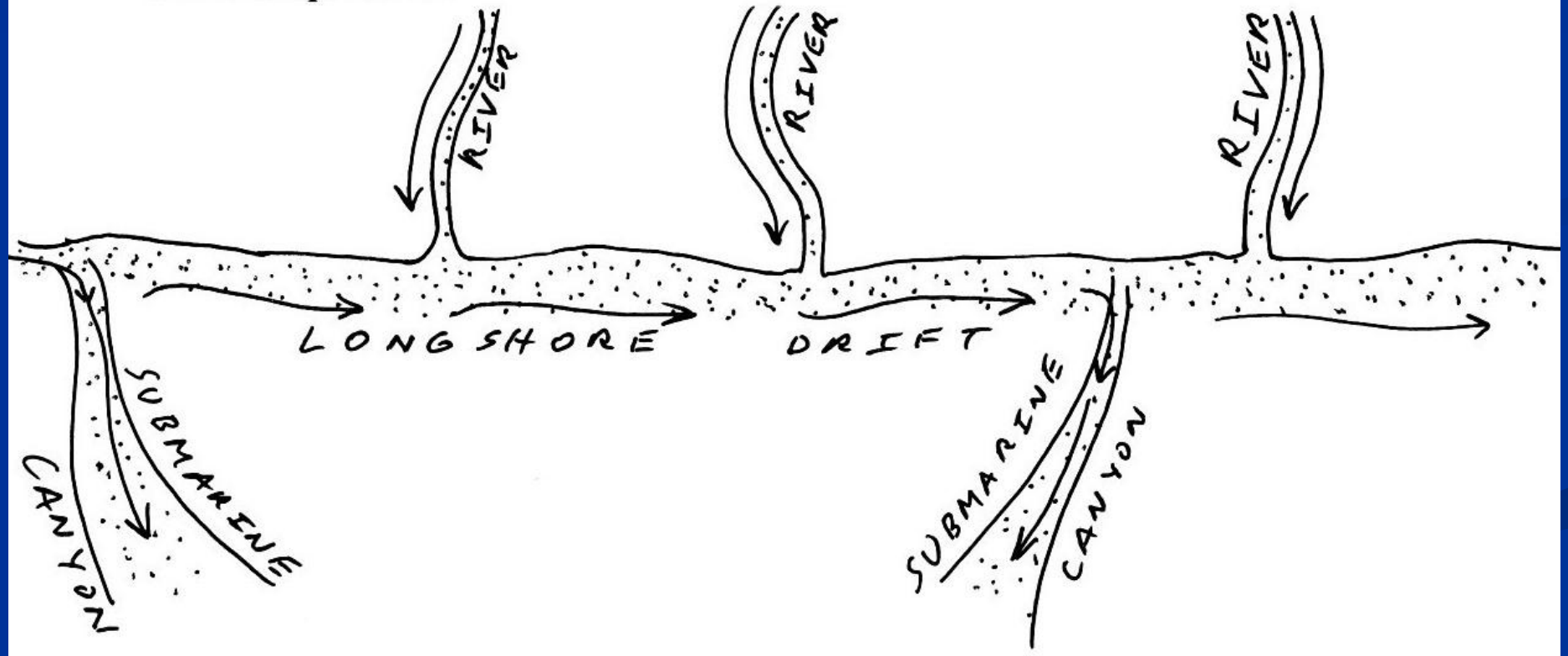
Longshore Drift

Net longshore drift of sand is to the south along both U.S. coasts

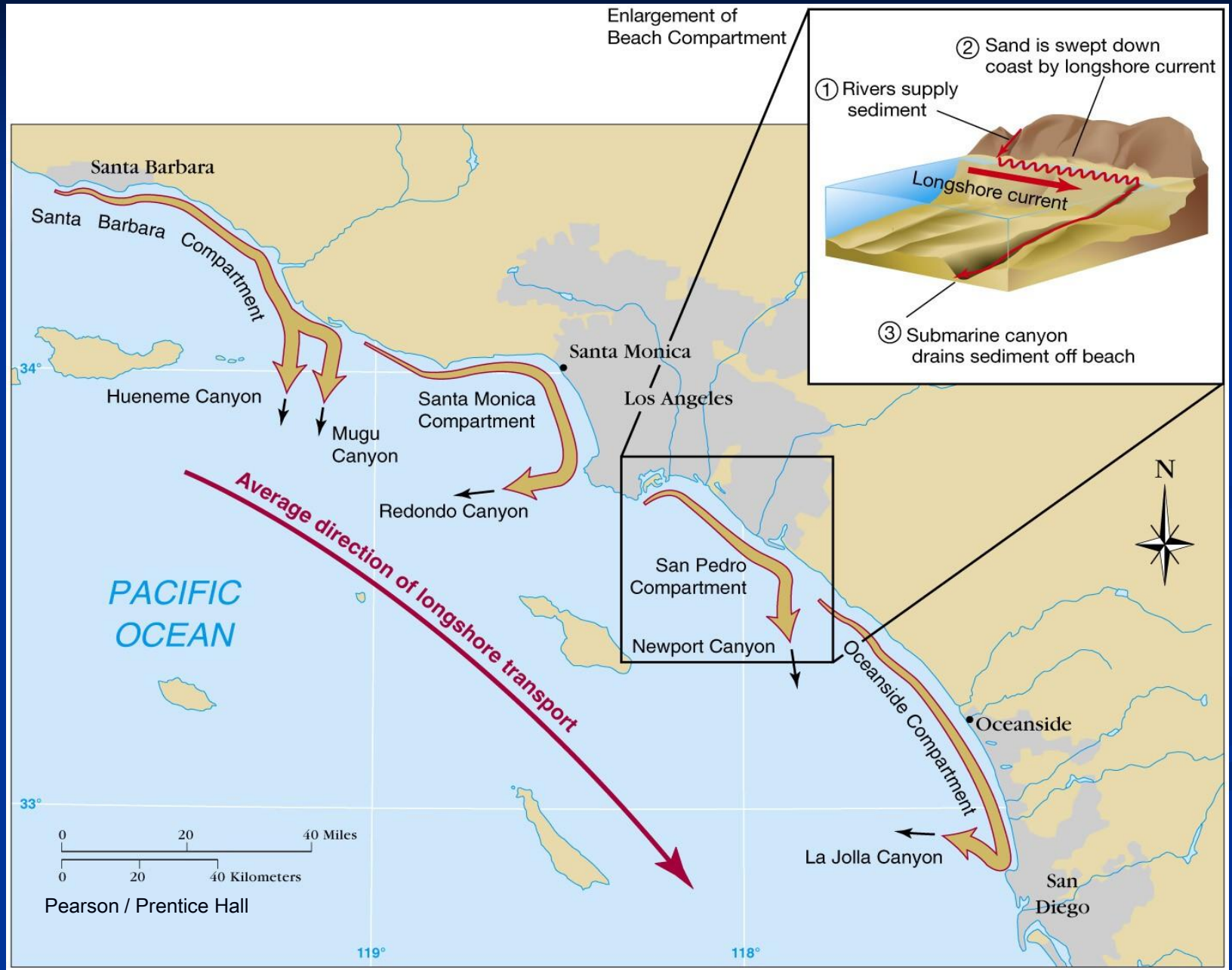


The beach compartment concept:
a "bank account" for beach sand

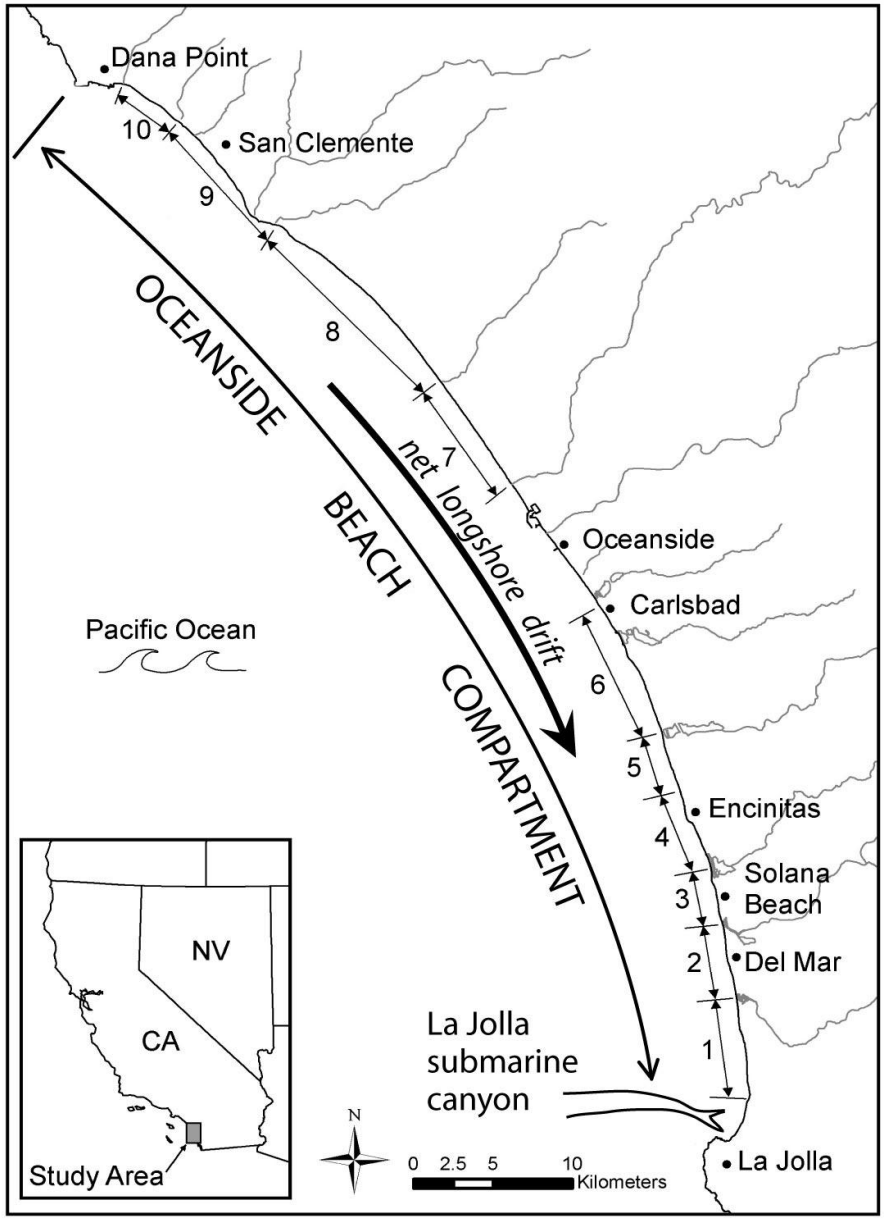
- **Sand is added to beach by *rivers* (~50%), and by *bluff erosion* (~50%)**
- ***Longshore drift* distributes sand along the beach**
- **Sand eventually leaves down *submarine canyons*, which divide the coastline into *beach compartments***



Beach compartments of southern California



Oceanside Beach Compartment

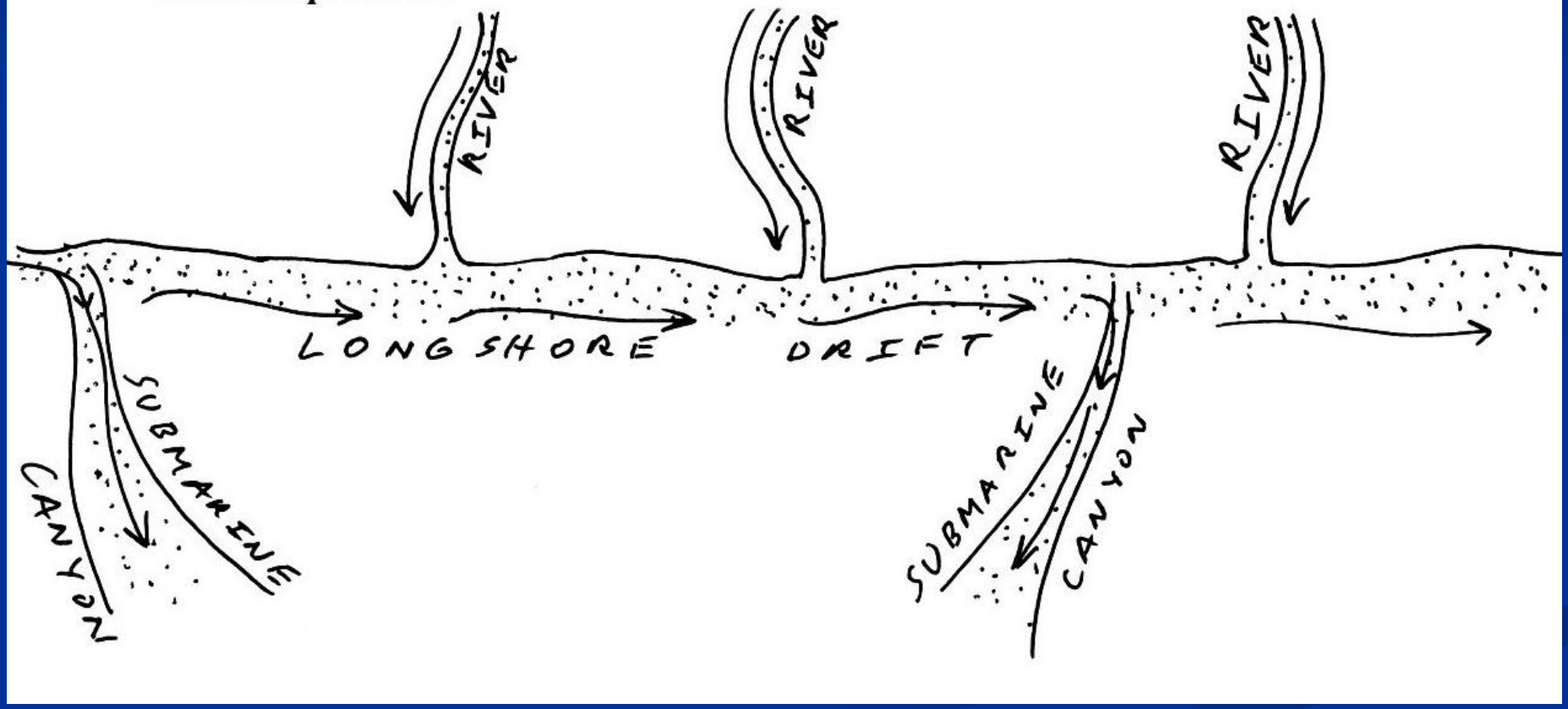


Turbeville, Meldahl and Metzler, 2008, figure 2

La Jolla Canyon: where all of our beach sand is headed!

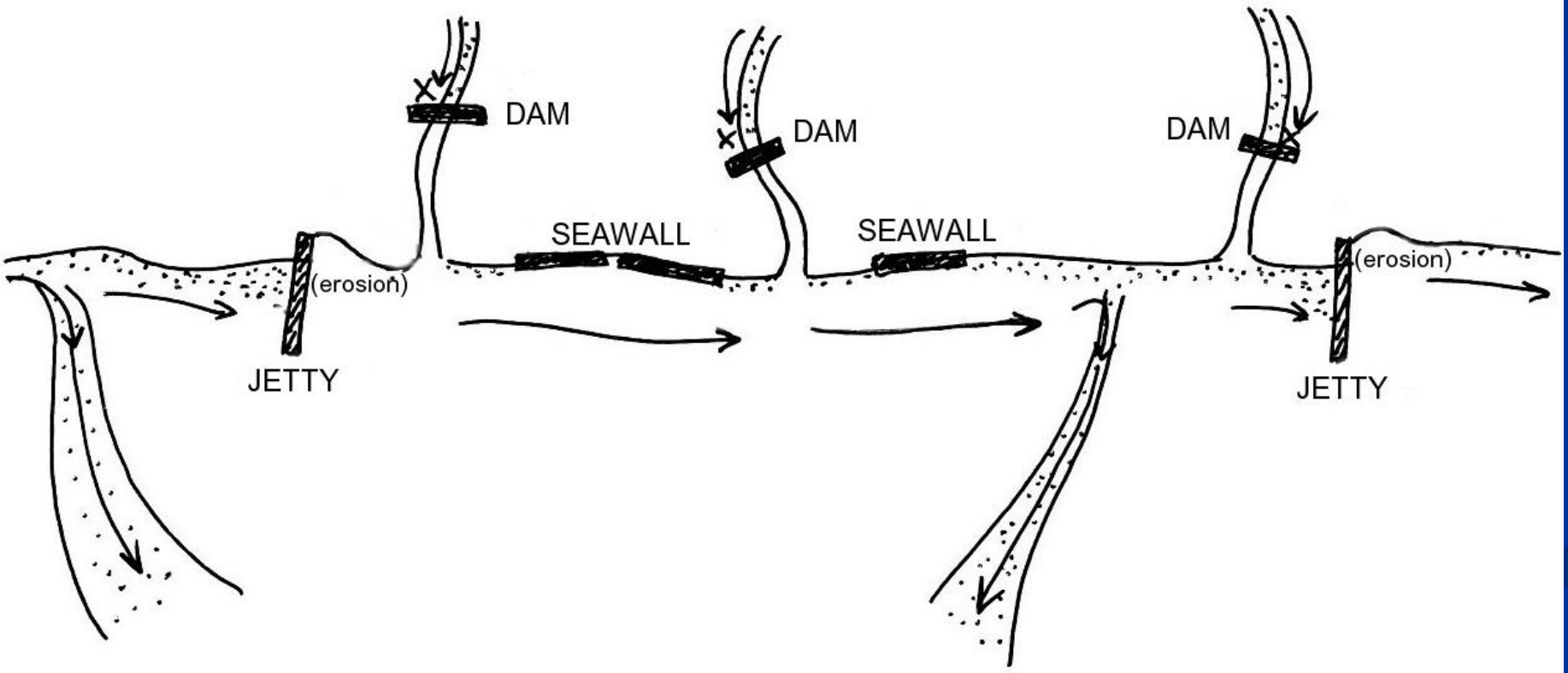
A beach compartment before human alteration...

- **Sand is added to beach by *rivers* (~50%), and by *bluff erosion* (~50%)**
- ***Longshore drift* distributes sand along the beach**
- **Sand eventually leaves down *submarine canyons*, which divide the coastline into *beach compartments***



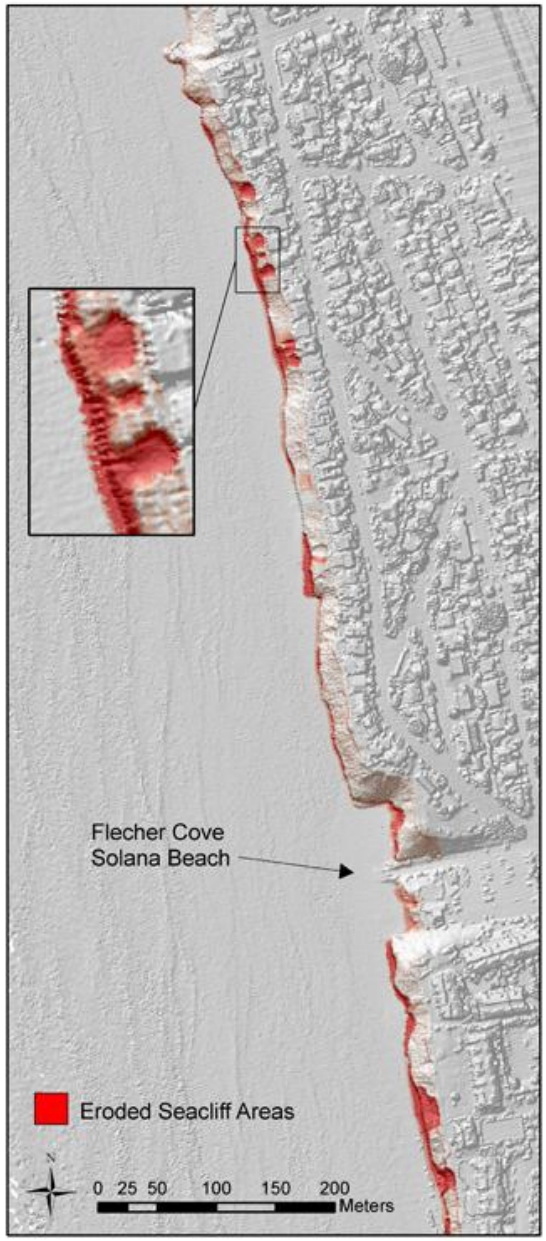
…and after human alteration

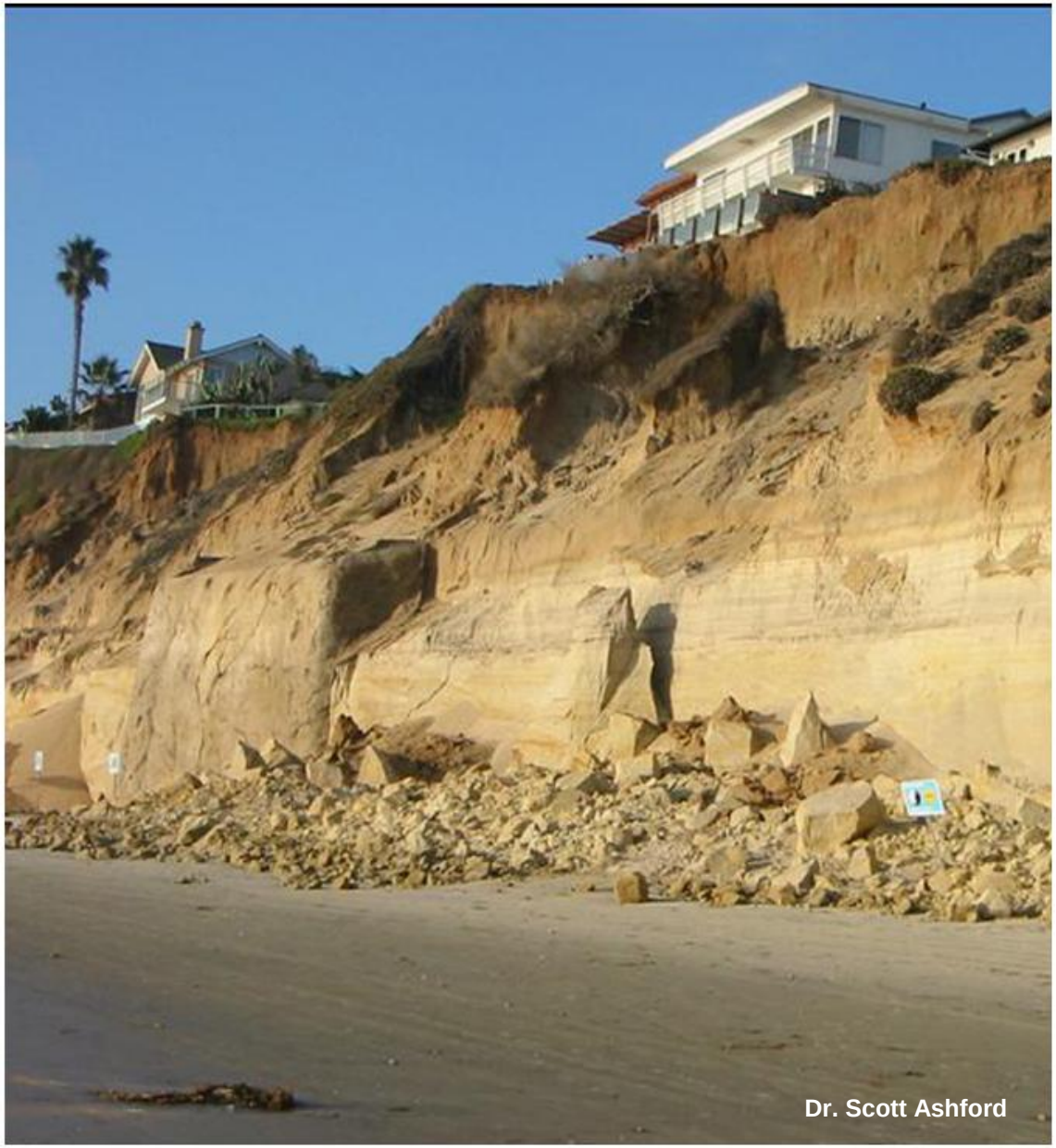
- ***Dams*** **– decrease flow of rivers; trap sand that would otherwise get to the beach**
- ***Jetties & Groins*** **– trap sand on "upstream" side, cause erosion on "downstream" side**
- ***Seawalls*** **– cut off sand that would otherwise come from bluff erosion; cause waves to bounce off with little loss of energy, thus pushing sand off beach**



Net result of human activities = increased beach erosion

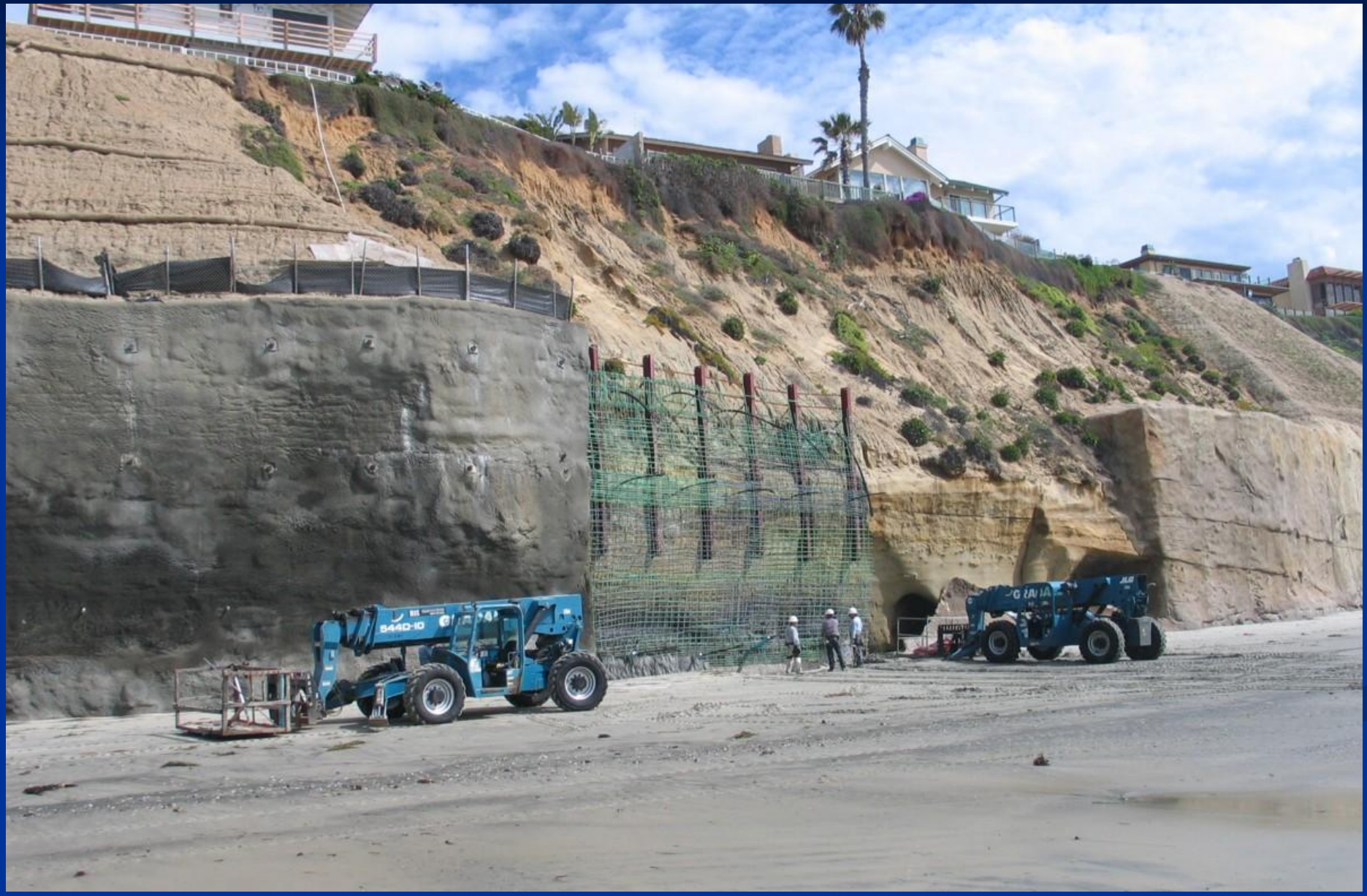
Eroding bluffs make ~50% of our beach sand





Eroding bluffs make ~50% of our beach sand

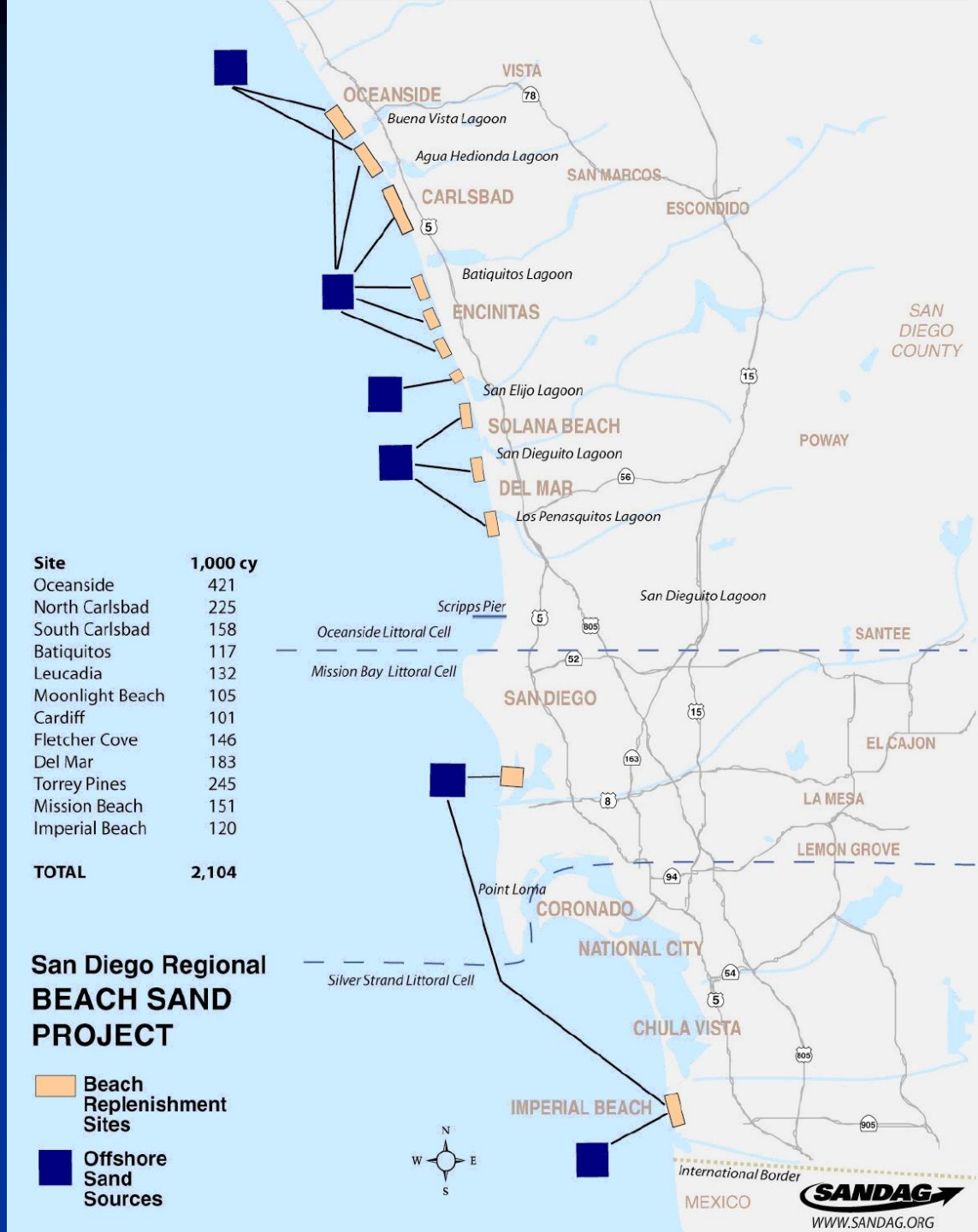
More seawalls = less bluff erosion = smaller beaches



Beach replenishment

The San Diego Regional Beach Sand Project of 2001

- 2.1 million cubic yards of sand (enough to fill one average-size football stadium)
- significant widening of local beaches lasted from one to five years

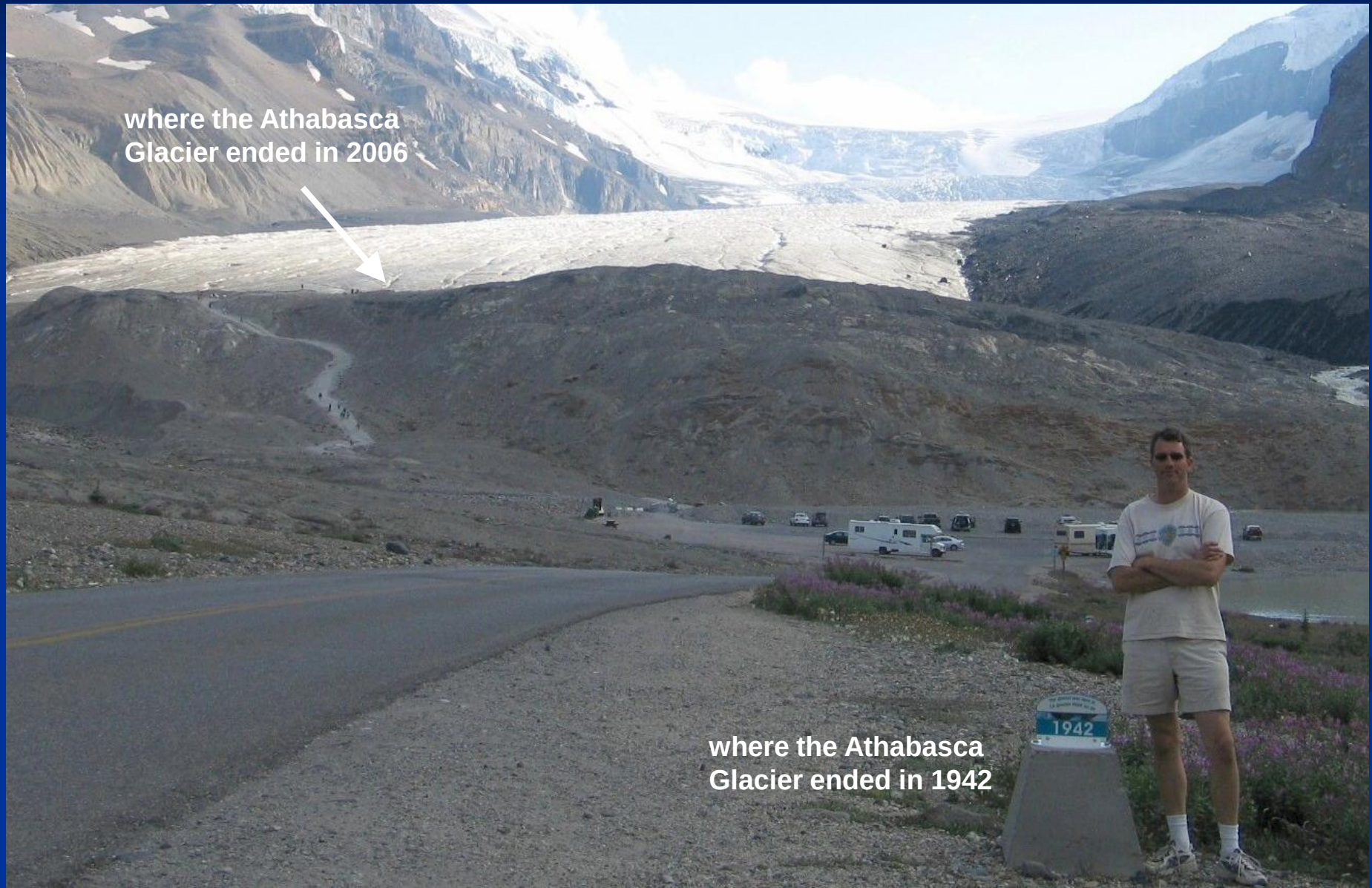


San Elijo Lagoon – what does the future hold?

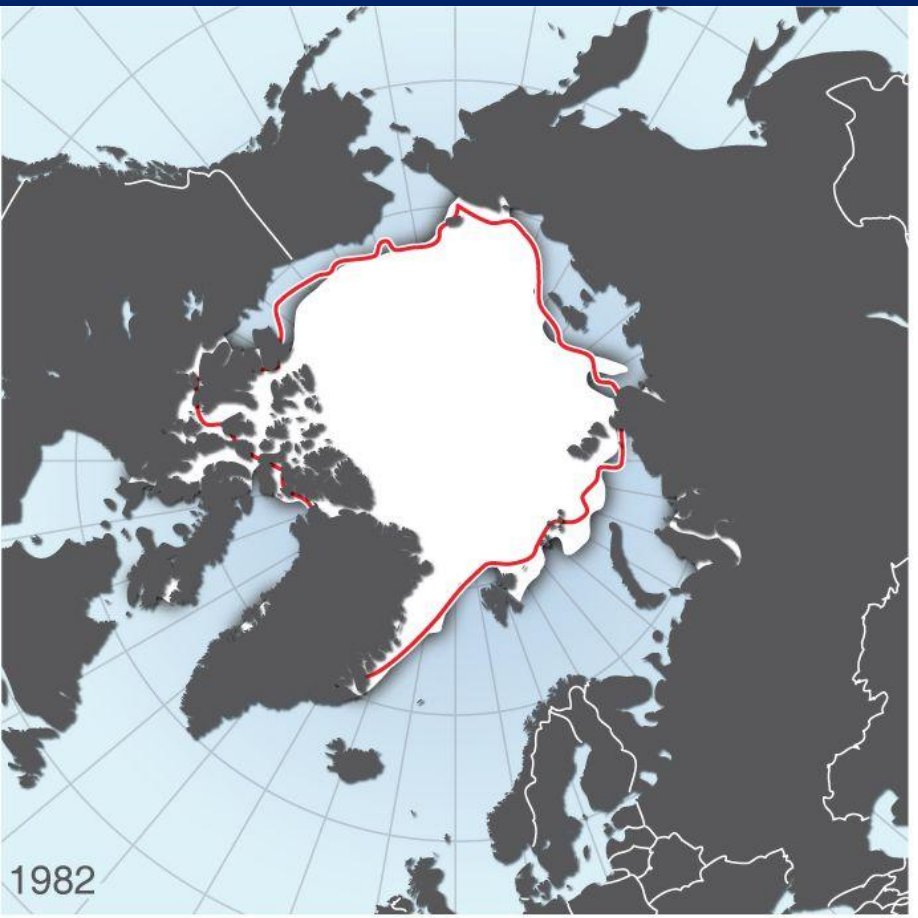
Photo by Bruce Perry, Department of Geological Sciences, CSU Long Beach

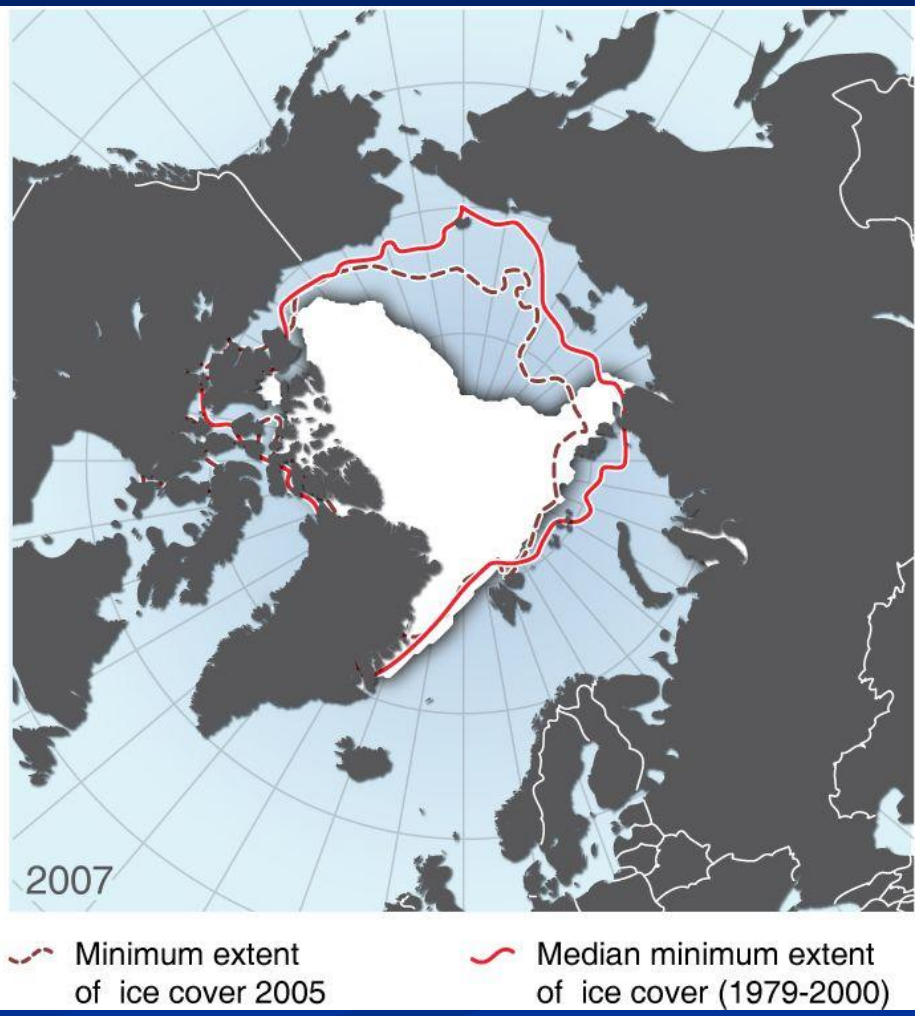
San Elijo Lagoon – what does the future hold?

San Elijo Lagoon – what does the future hold?



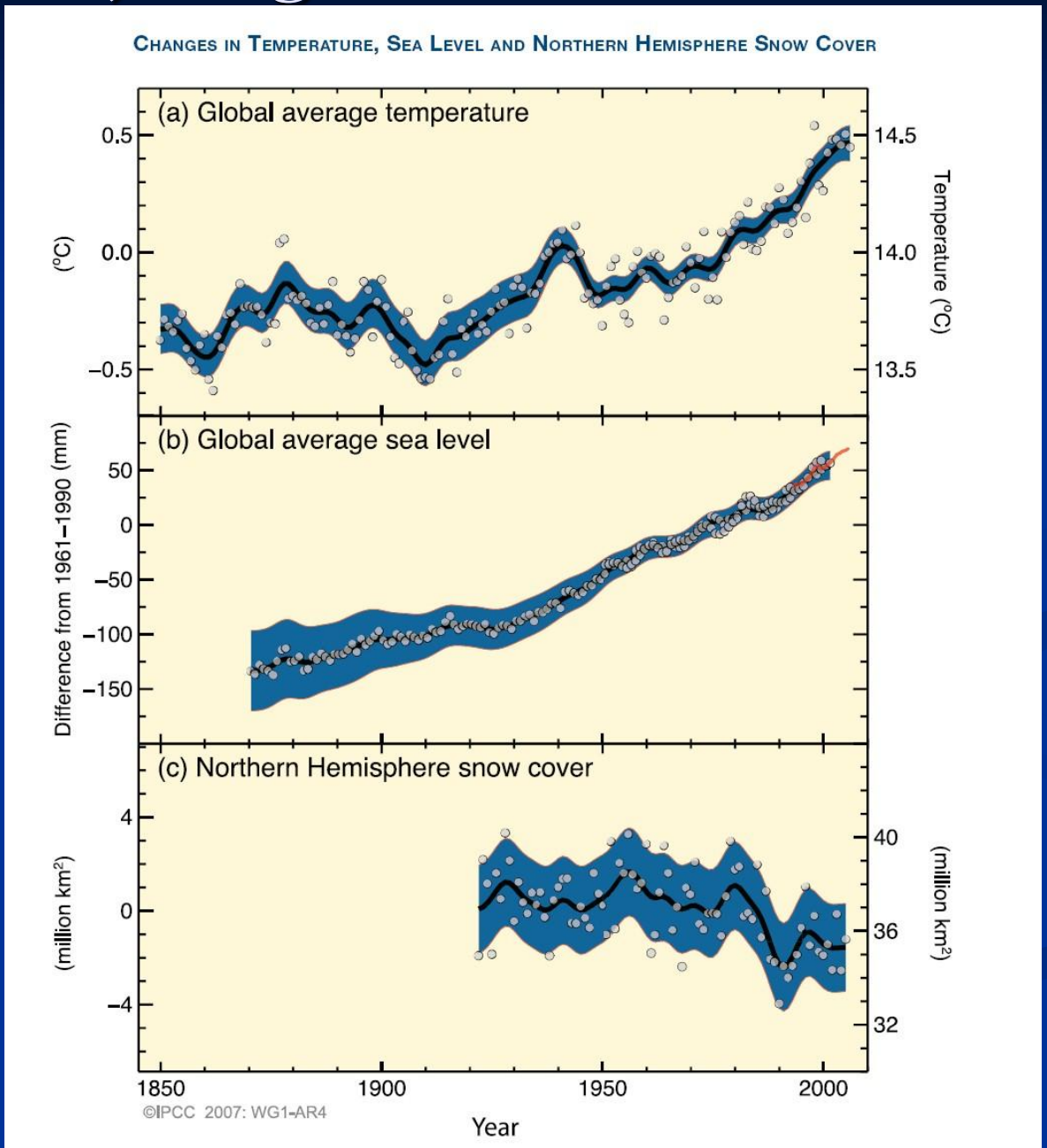
San Elijo Lagoon – what does the future hold?





UNEP/GRID-Arendal Maps and Graphics Library. Retrieved November 4, 2008 from http://maps.grida.no/go/graphic/arctic-sea-ice-minimum-extent-in-september-1982-2005-and-2007

San Elijo Lagoon – what does the future hold?



Contribution of Working Group I to the Fourth Assessment Report: Intergovernmental Panel on Climate Change, 2007, figure SPM.3

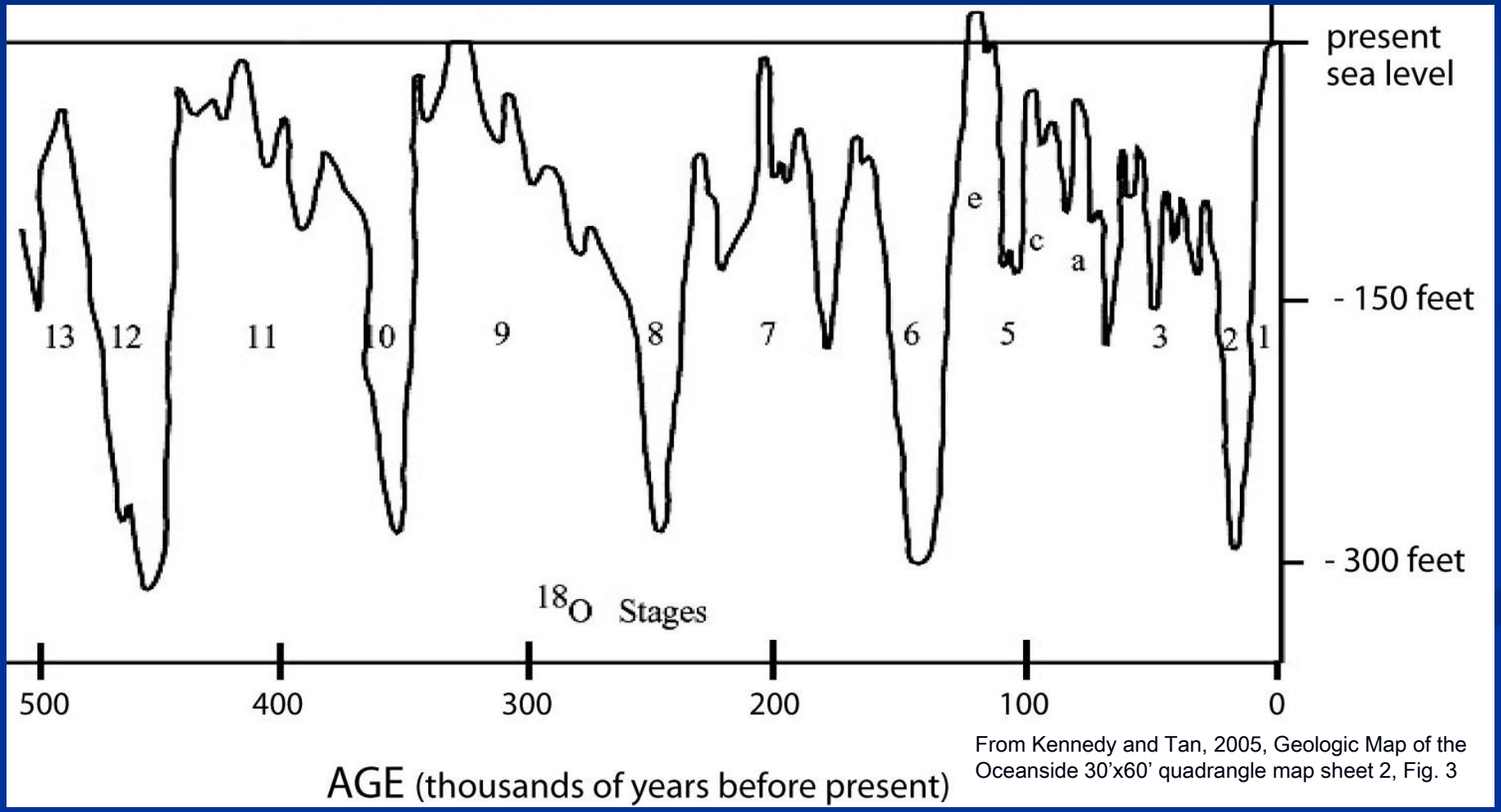
San Elijo Lagoon – what does the future hold?

dwindling beaches + rising seas
= inland retreat of the lagoon

Photo by Bruce Perry, Department of Geological Sciences, CSU Long Beach

Should we worry about the effects of today's rising seas?

YES – for human society's sake.
NO – for lagoon ecosystems. Our coastal lagoons have experienced many rises and falls of sea level in the geologic past, and they've done just fine.



From Kennedy and Tan, 2005, Geologic Map of the Oceanside 30'x60' quadrangle map sheet 2, Fig. 3


WARP
Rising Sea Levels — An Alternative Theory

Sources and recommended reading

Abbott P.L., 1999. The Rise and Fall of San Diego. Sunbelt Publications.

Haas, J. and Driscoll, N., 2005, Sources of Beach Sand in the Oceanside Littoral Cell. Retrieved November 26, 2007, from http://coastalconference.org/h20_2005/pdf/2005/2005_10-27-Thursday/Session6ACoastal_Sediment_Master_Plan/Haas-Sources_of_Beach_Sand_in_the_Oceanside_Littoral_Cell.pdf

Kuhn, G.G., and Shepard, F.P., 1984. Sea Cliffs, Beaches, and Coastal Valleys of San Diego County. Berkeley, University of California Press, 193 p.

Johnson, C.S., 2006, The Making of a Natural Sandy Beach: Have Rivers in Southern California Ever Been an Important Source of Sand? California Sea Grant Research Stories. Retrieved November 30, 2007, from http://www-csgc.ucsd.edu/STORIES/NaturalSandyBeach.html

Johnsson, M. J, 2003. Establishing development setbacks from coastal bluffs. California Coastal Commission Memorandum to Commissioners and Interested Parties. Retrieved November 30, 2007, from http://www.coastal.ca.gov/W-11.5-2mm3.pdf

Kennedy, M.P., and Tan, S.S., 2005, Geologic Map of the Oceanside 30'x60' quadrangle, California (2 sheets: geologic map and correlation and description of map units). California Department of Conservation.

Patsch, K., and Griggs, G., 2006. Littoral Cells, Sand Budgets and Beaches: Understanding California's Shoreline. Institute of Marine Sciences, UC Santa Cruz, and the California Dept of Boating and Waterways. Retrieved November 26, 2007, from http://www.dbw.ca.gov/csmw/PDF/LittoralDrift.pdf

Sources and recommended reading, continued

SANDAG (San Diego Association of Governments), 2007. Feasibility Study: San Diego Regional Beach Sand Replenishment Project. Prepared for the California Dept. of Boating and Waterways, August 2007, by SANDAG and Moffat & Nichol. Retrieved November 25, 2007, from http://www.sandag.org/uploads/publicationid/publicationid_1327_7318.pdf

SANDAG (San Diego Association of Governments), 2003. San Diego Regional Beach Sand Project Fact Sheet. Retrieved November 23, 2007, from http://www.sandag.cog.ca.us/uploads/publicationid/publicationid_340_1057.pdf

Tan S.S. and Kennedy M.L., 1996. Geologic Maps of the Northwest Part of San Diego County, California. California Division of Mines and Geology.

Turbeville, J., Meldahl, K.H., and Metzler, C., 2008. Field Trip #2: Coastal Geology and Erosion Hazards in Northern San Diego County. In: Trujillo, A.P., editor, 2008. Geoscience Investigations in Northern San Diego County and Beyond: Student-Directed Explorations. Field Trip Guidebook: National Association of Geoscience Teachers Far Western Section Conference. March 14-16, 2008, Palomar College, San Marcos California. Available online at: http://www.miracosta.edu/home/kmeldahl/NAGT/FieldTrip2-CoastalErosion.pdf

UCSD (University of California San Diego), 2005. Coastal Bluffs Provide More Sand To California Beaches Than Previously Believed. Press release, October 22, 2005. UCSD Jacobs School of Engineering. Retrieved November 23, 2007, from http://www.jacobsschool.ucsd.edu/news/news_releases/release.sfe?id=485

Young, A.P, and Ashford, S.A., 2006. Application of Airborne LIDAR for Seacliff Volumetric Change and Beach-Sediment Budget Contributions. Journal of Coastal Research, v. 22, no. 2, p. 307-318.