

Topic 12: Mass Movements in SoCal

test #4 will include HW2 questions
(see geowiki under 'tests' tab)

10/25 – this Sunday
geowiki link to virtual beachwalk
(homework B) will open
due: 11/9 (no late submissions!)

Sinkholes – Sudden Subsidence (Topic 11)

- collapse in karst (limestone) regions
- carbonate dissolves in water
 - underground caves
 - **SINKHOLES**

NATURAL CAUSES:
subsurface weathering
drought

"in 2015, USGS estimated damage from natural sinkholes to be \$300+M/year" (Wikipedia)

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.
sinkhole in Winter Park, FL; 5/10/81



Source: Abbott "Natural Disasters"

Karst in Minerve, France



Source: Wikimedia

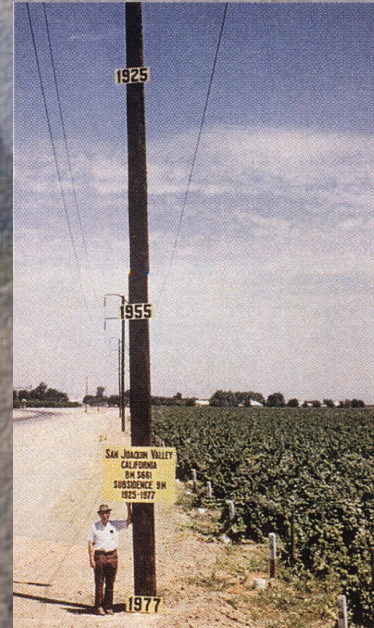
Anthropogenic Subsidence and Sinkholes (T 11)

slow subsidence

excess groundwater withdrawal
oil withdrawal

sudden sinkholes

excess irrigation
failing pipes
leaking pools
-> subsurface weathering
-> collapse



Anthropogenic Subsidence (Topic 11) - Slow

San Joaquin Valley (in Central Valley)
➤ drop of groundwater by 1970: 120 m
➤ subsidence of ground: 8.5 m

excess withdrawal for
➤ farming
➤ city

no recovery if
aquifer collapses



Source: USGS/Wikipedia

Las Vegas
since 1935, subsidence
by several m

Anthropogenic Sinkholes - Mining

excess withdrawal: Coal Mining, CO

Fig. 34. Aerial view of subsidence pits above an abandoned underground coal mine in the Powder River Basin of Colorado. Collapse is occurring above "rooms" in the mine where coal was removed. Areas that have not collapsed are above the pillars of coal the miners left to provide support. Note the dirt road for scale.



source: Holzer "Living with Unstable Ground"

Sinkholes – Bangkok 2025

9/24/25

7:14 am: local 30m across, then grew

- near a hospital & police station
- closed indefinitely

cause:

- * “undetermined”
- * construction of underground subway tunnel and station underway
- * area known for soft soil and subject to subsidence
- * ongoing heavy monsoon rain
- * “leaky water main may have contributed”

*BTW – unrelated but just in:
drill for second Gotthard tunnel, CH got stuck*



source: wikipedia

Sinkholes – San Diego

Point Loma, San Diego; 19 Oct 2005



Genessee Ave near UCSD
06 Oct 2011



2023: Gilman Dr
massive repair
residents relocation
2024: homes still
uninhabitable

- failing underground water infrastructure
- U.S.: 10-30% water unaccounted for (with 30% in cities)
- who pays for repairs?

Oceanside; 16 Oct 2014



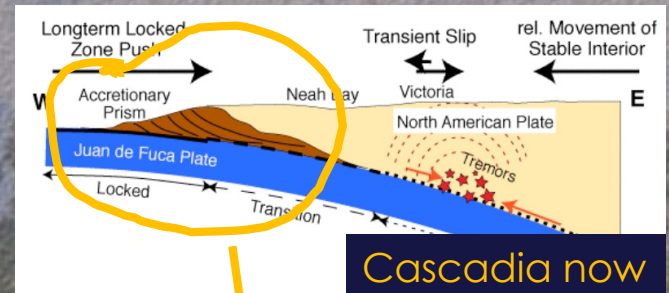
I-8; 20-ft deep; 14 Sep 2017



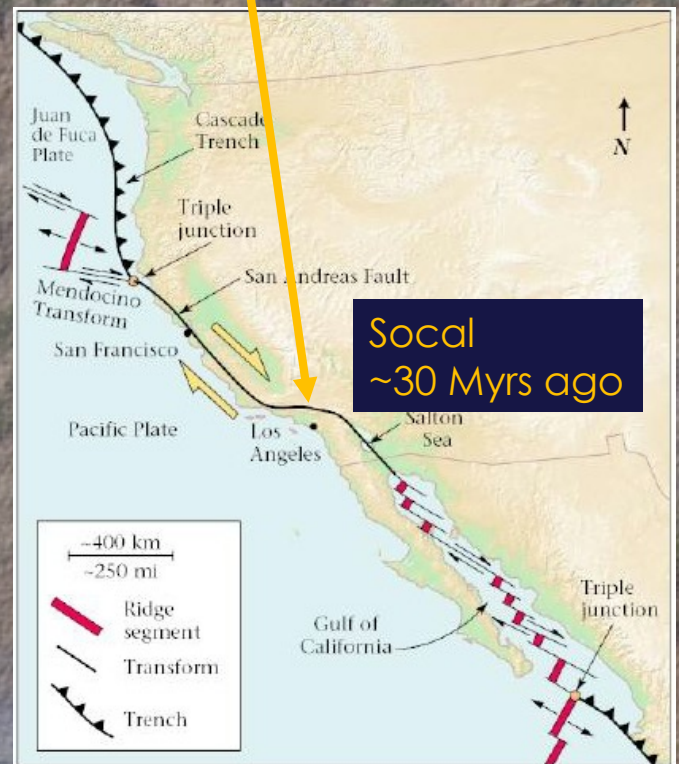
Southern California and Tectonics

active plate boundary for > 50 Mio yrs

- weak substrate (**accretionary prism**)
- compression across SAF and uplift
- faulting during past 15 Mio yrs
- zones of weakness, steep cliffs



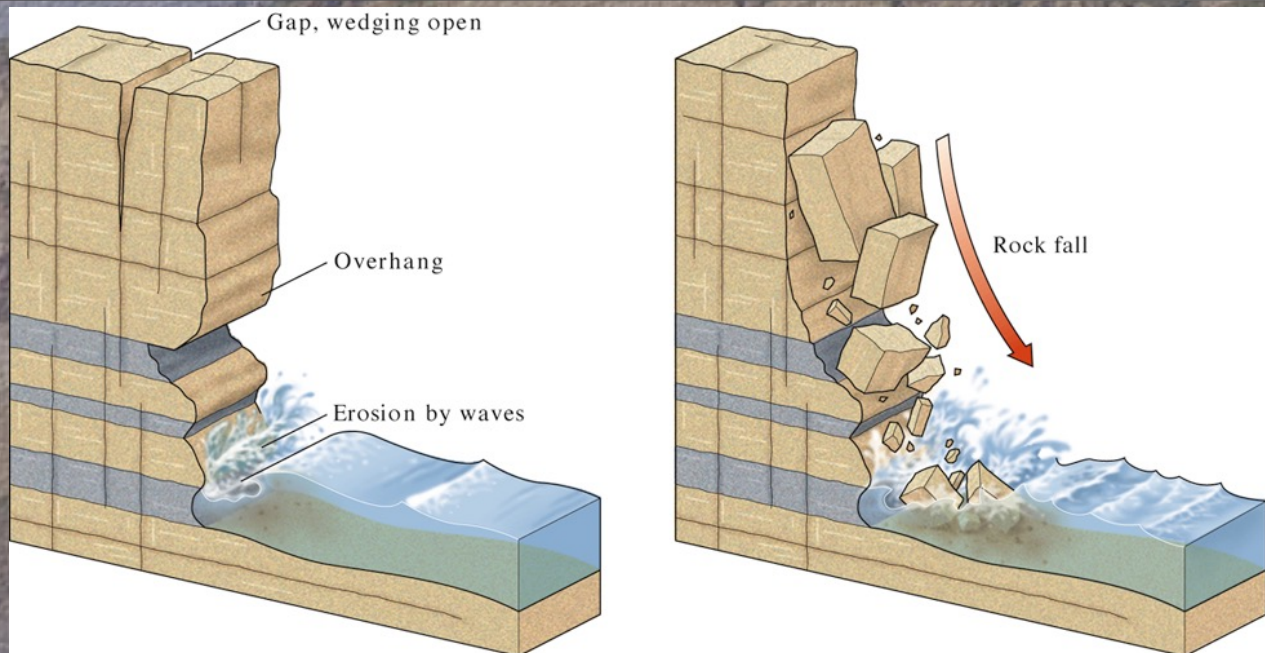
- ✧ uplift -> relief/topography
- ✧ faulting -> weakened crust
- ✧ ancient volcanism -> weak layers
- ✧ weathering, erosion
- ✧ earthquakes -> landslides



Coastal Southern California and Weathering

- chemical and physical weathering
- tides, wave attack -> **undercuts**

weathered sandstone -> clay; reduces friction in glide horizon
weathering can also happen far inland! -> larger area involved



source: Marshak "Earth, Portrait of a Planet"

Palos Verdes Peninsula



- development on unstable ground
- planting of non-native vegetation
- irrigation on unstable cliffs
- ignorance/disregard of imminent risks
- leaky pools

<http://maps.google.com>

highest coastal retreat in SoCal

Palos Verdes Peninsula - Portuguese Bend

HW4



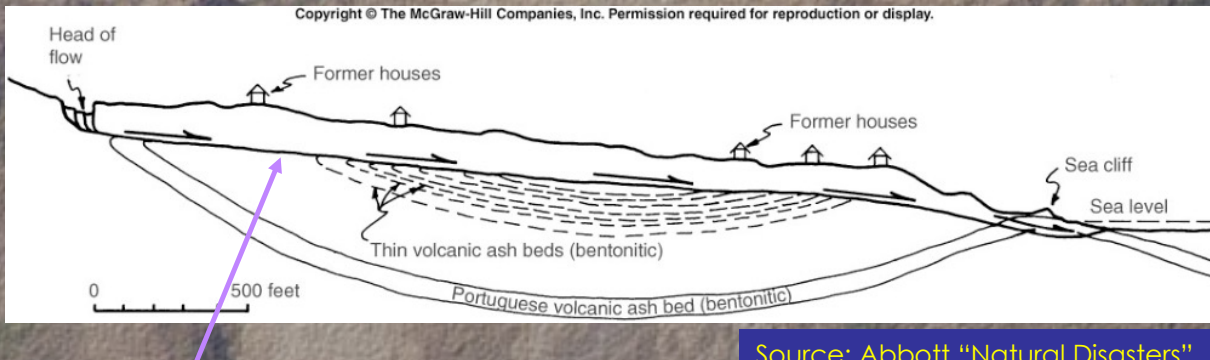
Portuguese Bend, Palos Verdes

permeable

impermeable

1) setting stage geology:

- ancient earthflow
- seaward dipping volcanic tuff
- sitting on shale/volcanic ash



Source: Abbott "Natural Disasters"

ok, as long as groundwater
below glide horizon and no other
water trickles from surface

Portuguese Bend, Palos Verdes

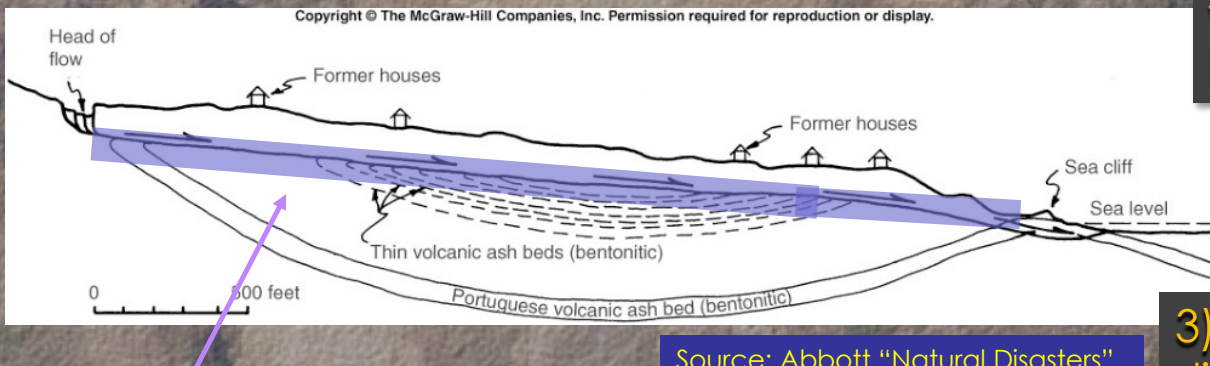
permeable

impermeable

1) setting stage geology:

- ancient earthflow
- seaward dipping volcanic tuff
- sitting on shale/volcanic ash

2) action:
water ->
weathering to
bentonite clay



Source: Abbott "Natural Disasters"

water getting into glide horizon
lowers friction/resistance force

3) consequence:
sliding mass

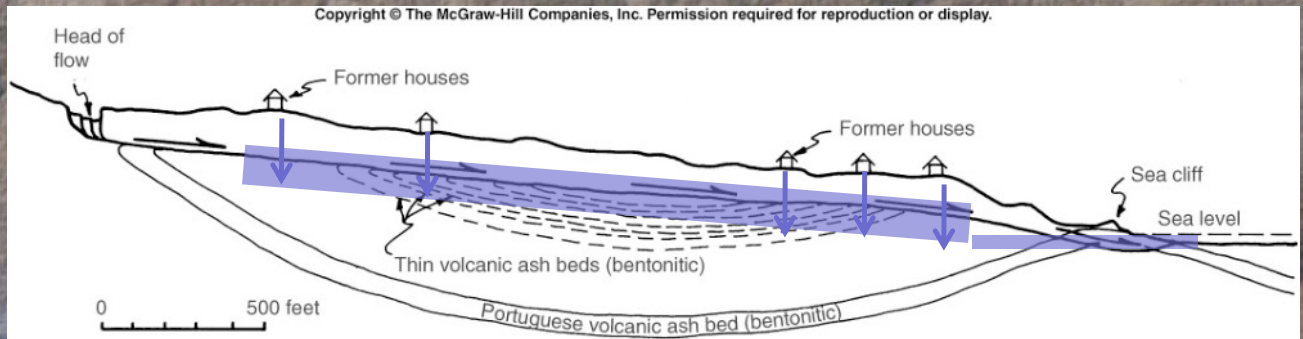
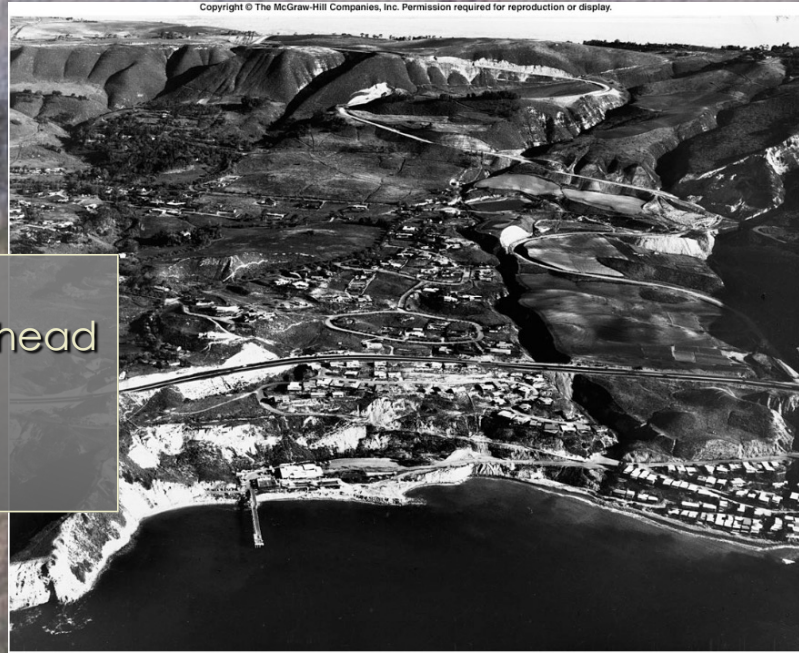
Portuguese Bend, Palos Verdes, 1950s

1956-1985:

- moved down 200 m
- 0.3-2.5 cm/day
- destroyed 150 homes

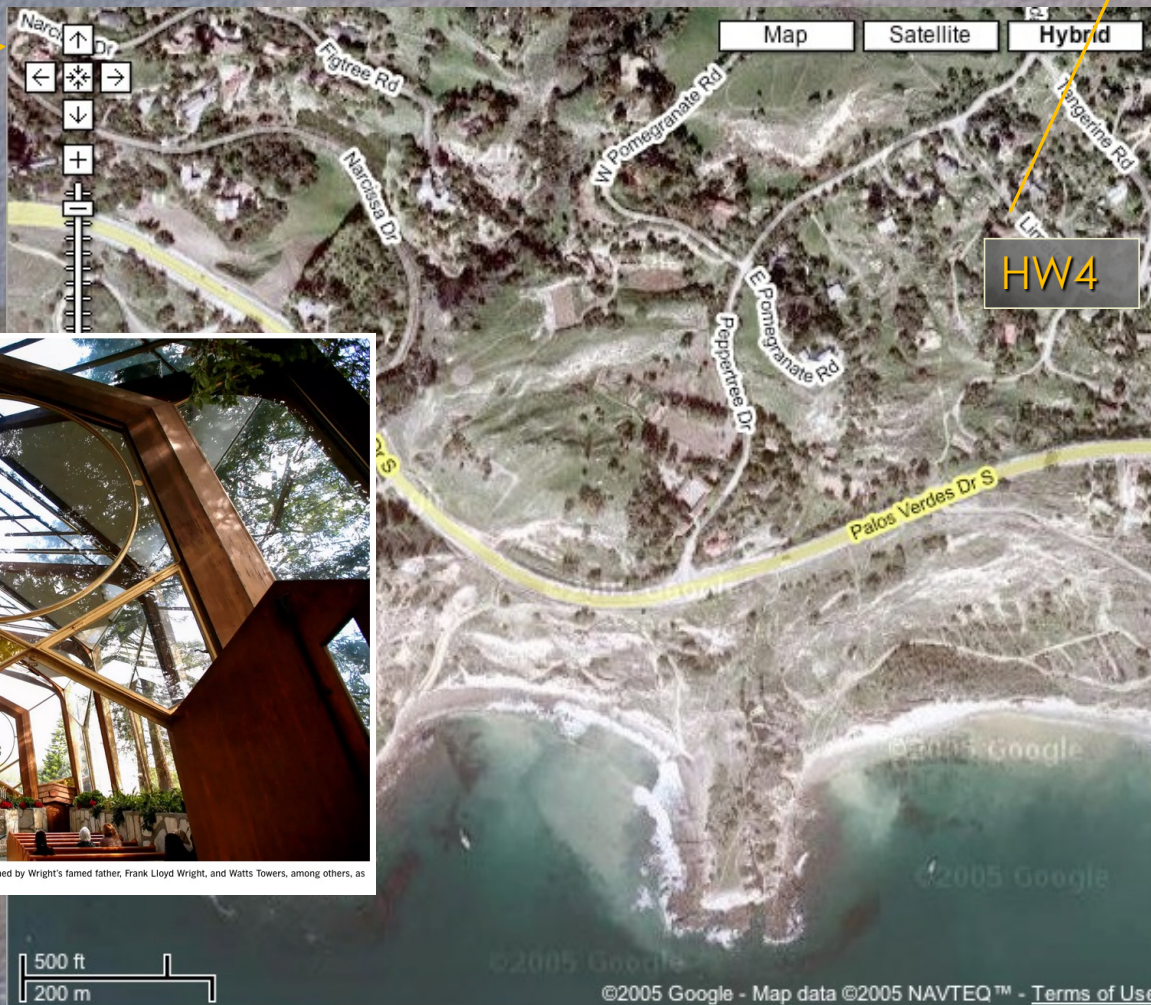
human activity:

- 1950s county deposited 23m of fill at head
- development with NO sewer system
septic tanks instead
- water got into glide horizon



Palos Verdes Peninsula - Portuguese Bend

Wayfarers Chapel
popular wedding place
2023: historic landmark
2024: closed – shifting soil



Wayfarers Chapel, designed by Lloyd Wright, will join the Eames House, Hollyhock House, designed by Wright's famed father, Frank Lloyd Wright, and Watts Towers, among others, as a National Historic Landmark in Los Angeles. (Genaro Molina / Los Angeles Times)

Source: LA Times

LOSSAN – San Clemente Section

train track right
on beach

San Diego –
San Luis Obispo

- one of nations busiest
- San-LA 8M people/yr
- \$1B in goods/yr
- \$12M repairs

Google Earth

SIC 1985

lat 33.403609° lon -117.605397° elev 21 ft eye alt 420 ft

LOSSAN – San Clemente 2023

new slump: Casa Romantica

After landslide, an Orange County beach town finds itself between a bluff and a hard place

rail closure!



A Spanish-style white building with red tile roof sits at the edge of a crumbling bluff. (A landslide in April 2023 damaged the historic Casa Romantica Cultural Center and Gardens in San Clemente.)

BY GABRIEL SAN ROMÁN | STAFF WRITER

MAY 16, 2023 5 AM PT

SUBSCRIBERS ARE READING >

CALIFORNIA

FOR SUBSCRIBERS

Dov Charney, Milo Yiannopoulos, Kanye West and the battle over a Silver Lake compound

TRAVEL & EXPERIENCES

FOR SUBSCRIBERS

'I've never seen anything like this': Death Valley gleams with water, wildflowers and color

WORLD & NATION

'The left has really let us down.' Why many American Jews feel abandoned

SCIENCE & MEDICINE

Stanford scientist, after decades of study, concludes: We don't have free will

CLIMATE & ENVIRONMENT

Officials urge California residents to brace for flooding as El Niño looms

ADVERTISEMENT



Source: L.A. Times

LOSSAN – Del Mar

... ongoing cliff collapse
getting ever closer to
train track
repeat \$nM repairs

Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google Earth

1985

lat 32.955996° lon -117.267367° elev 42 ft eye alt 531 ft

San Diego Cliffs

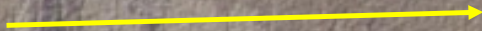
not exactly like Portuguese Bend
BUT

- active EQ faults in S.D. county
- sediments all the way to Tierrasanta/I-15!
- unstable cliffs (shale beneath sandstone)
- Mt. Soledad

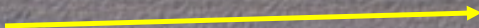
see beach walk!

INTERNAL FAULTS

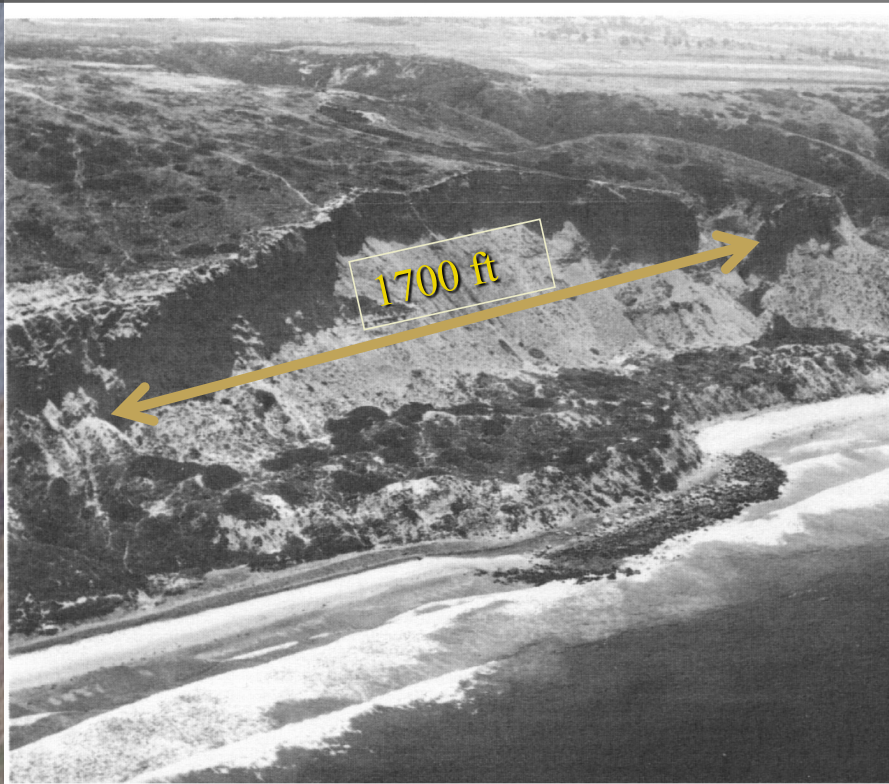
SCRIPPS SANDSTONE



ARDATH SHALE



Torrey Pines Slide 1949



- ancient river fill + uplift -> internal faults
- sparse vegetation (Torrey Pines only deep-rooting native)
- constant cliff erosion from above and below

Mt. Soledad Slump, 3 Oct 2007, a.m.

200 ft of Soledad Mt. Road
2 home destroyed
+ > 7 uninhabitable

residents battled with city
about cracks since July

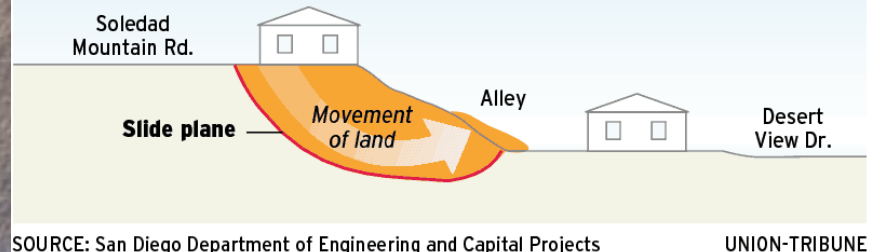


Causes:

- July earthquake cluster?
- vibrations from traffic?
- breaking water main?
- irrigation?

LAND SLIPPING ALONG SOLEDAD MOUNTAIN ROAD

Geologists say the hillside is succumbing to gravity because of a combination of factors, including soil composition, possible effects of a nearby fault and surface impacts of development.



SOURCE: San Diego Department of Engineering and Capital Projects

UNION-TRIBUNE

Mt. Soledad: Recurring Slides

“we mapped a small, uncharted fault 37 ft below the surface. The slides appears to have broken along the same track as the fault”

- at least 3 significant slides 1961-1994
- 1961: 7 homes destroyed



- homeowner policy does not cover landslides
- state law 1998: seller to inform about CURRENT potential hazard; does not have to disclose previous landslides
- Buyer: check city hazard map!

RCF

Housing – San Diego vs Tijuana

South Park



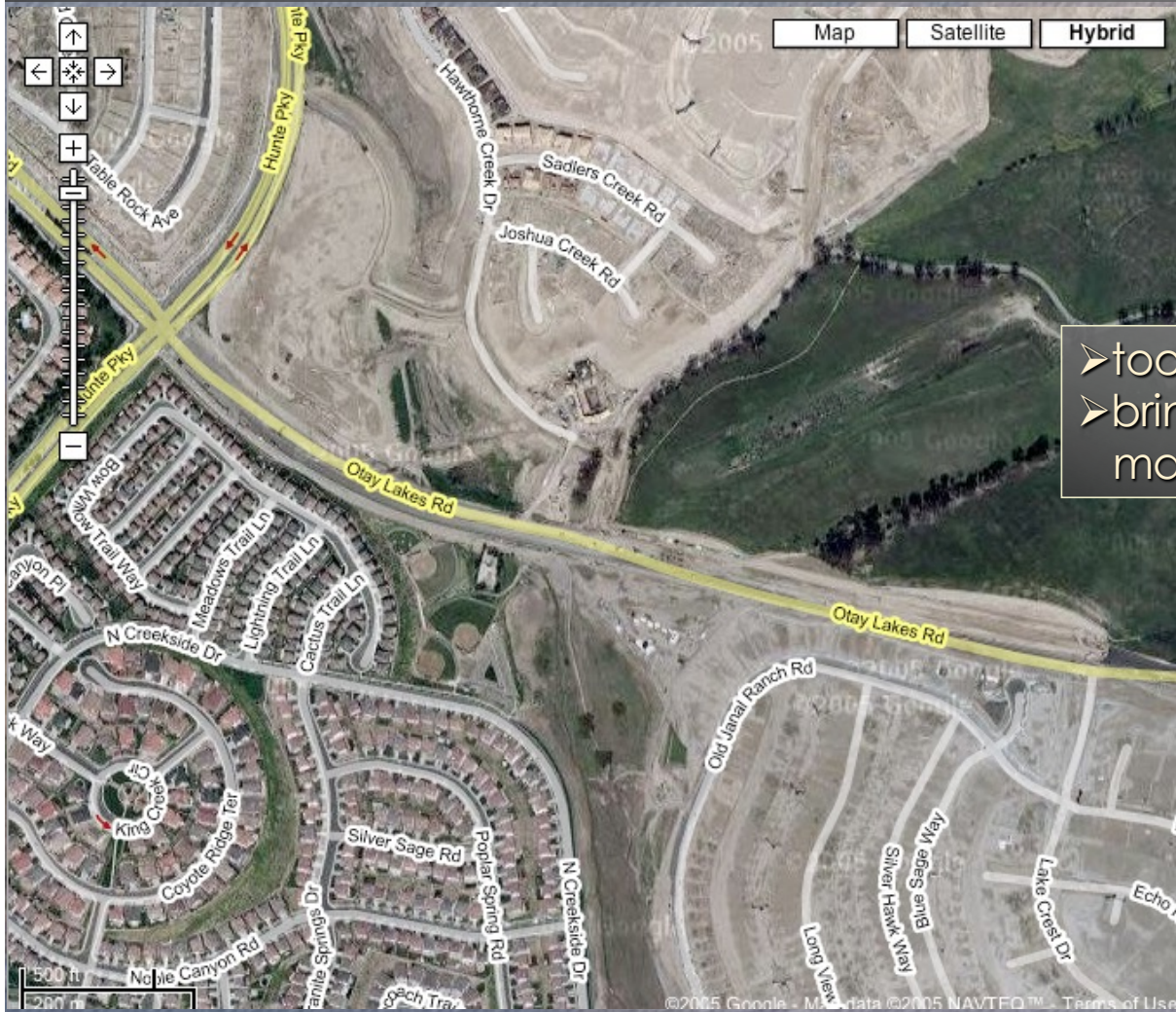
- build on mesas
- hands off canyons

Tijuana



- build everywhere

Housing – San Diego Style



- too many canyons?
- bring in the big machines!

Tijuana Mass Movements

- 1920: landslide closed tunnel in Carrizo Gorge
- 1949: Torrey Pines slump (1 miles long)
- ...
- 1993: flooding in Tijuana triggers international disaster relief
- 1997: remnants of Hurricane Pauline triggers landslide in Tierra Blanca, burying school with 10 children
- Aug 07, 02: Houses of Cerro Maravilla bulldozed by city "unsafe due to landslide threat" (controversial)
- Jan 02, 03: Evacuation of Cumbres del Rubi (23 houses) "overbuilt hillside could collapse after heavy rain"
- Feb ??, 03: small landslide due to inadequate drainage
- Since October 03: mudslides in county after fire
- winter season 04/05: numerous slides and sinkholes
- ...
- 02/02/18: major slide destroyed 70 homes – Lomas del Rubi

Tijuana: 2/2 2018 Lomas Del Rubi



Source: SD Union Tribune, GeoEngineer

70 homes
first signs 1/19/18

SIO15 2025: Topic 12 - Mass Movements in Southern California

Tijuana: 2/2 2018 Lomas Del Rubi



Source: SD Union Tribune, GeoEngineer

70 homes
first signs 1/19/18

SIO15 2025: Topic 12 - Mass Movements in Southern California

Tijuana: 2/2 2018 Lomas Del Rubi



Source: SD Union Tribune, GeoEngineer

70 homes
first signs 1/19/18

SIO15 2025: Topic 12 - Mass Movements in Southern California

Tijuana: 2/2 2018 Lomas Del Rubi



Source: SD Union Tribune, GeoEngineer

70 homes
first signs 1/19/18

SIO15 2025: Topic 12 - Mass Movements in Southern California

Tijuana: 2/2 2018 Lomas Del Rubi

Source: SD Union Tribune, GeoEngineer



development at Valle del Pedregal
destabilized hillside?

need:

- Geologists/geo-engineers
- developers who listen
- Government that cares

What can we do? – Hazard Assessment and Prevention

Assessment

- slope steepness
- strength of substrate
- degree of water saturation
- dip of bedding, joints, foliation relative to slope
- vegetation cover
- climate
- undercutting
- seismicity

Prevention

- re-vegetation
- re-grading
- reducing subsurface water (drainage, irrigation, leaky pools)
- preventing undercutting (off-shore breakwater or pile of riprap)
- constructing safety structures (stabilize slope; retaining walls; spray roadcuts with shotcrete; protect highways with avalanches)