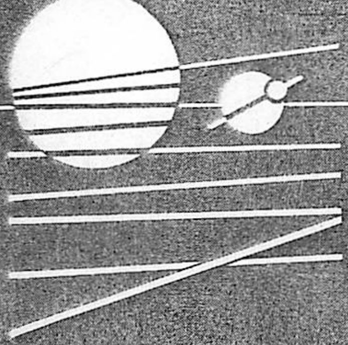
Elizabeth P. Turtle
Lunar and Planetary Lab
University of Arizona
Tucson, AZ 85721



Lunar and Planetary Laboratory
Department of Planetary Sciences

Zib

PTYS 594a

Planetary Geology Field Practicum

Southern California
September 30-October 3 1994

The University of Arizona
Tucson, Arizona

17856

PTYS 594a
Planetary Geology Field Trip

Southern California/
Beach Processes

Sept. 30- Oct. 3, 1994

Table of Contents

Potentially Useless Information.

②

PTYS 594a,

PLANETARY FIELD GEOLOGY PRACTICUM

Itinerary, Beach Processes Field Trip 30 September-3 October 1994

H. J. Melosh, 353 Space Sciences, 621-2806

We will assemble at 7:30 am on Friday, 30 September from the LPL loading dock off Warren St. in five 8-passanger Suburban vans. Try to be at LPL by 7:30 am to get the vans loaded. Please be sure that you have had breakfast beforehand, have ice for the coolers, etc. before we are scheduled to leave: Breakfast and ice runs just before departure have caused long delays in the past!

Our approximate itinerary, as worked out at the last class meeting is:

Friday, 30 September:

8:00 am	Distribute handouts, Depart LPL, turn right on Cherry to Speedway, then travel East on Speedway to I-10, proceed North on I-10 to I-8. Turn West on I-8 toward Gila Bend
10:00 am	Stop at rest stop in Sentinel volcanic field. Geology of Sentinel volcanics and Gila river graben by **Wei Dai.**
12:00 noon	Lunch stop near Yuma on I-8.
1:00 pm	Continue West on I-8 to San Diego
4:00 pm	Arrive San Diego, Turn North on I-5, drive to San Onofre Bluff campground. Register at campground, select camping sites.
5:00 pm	Walk on beach to examine wave cut platforms, explained by **Jim Head,** Cristianitos fault, and study beach cusps under direction of **Jeff Johnson.**
6:30 pm	Make camp at the Bluff site. Campfire talk on wave generation by **Vince Converse.**

Saturday, 1 October:

8:00 am	Break Camp, return South on I-5 past San Diego to Silver Strand Beach.
9:30 am	Arrive Silver Strand beach, change into bathing suits, study near-shore currents in the surf zone using dye markers under supervision of **Barbara Cohen** and **Jennifer Grier.** Also observe rip currents under guidance of **Nancy Chabot** and **Greg Hoppa,** physics of breaking waves with **Mark Fischer** and beach profiles with **Janet McLarty** and **Betty Pierazzo.**
12:00 noon	Lunch on Beach
1:00 pm	Continued observation and discussion of heavy mineral laminae by **Mike Nolan** and small scale sedimentary features by **David Wood.**
2:00 pm	Depart Silver Strand Beach and Drive North on I-5 toward Los Angeles.
3:00 pm	Stop at former coastal estuary, discussion of formation of spits, bars, lagoons, estuaries by **Andy Rivkin** and **Zibi Turtle.**
3:30 pm	Leave I-5 at San Clemente, continue North on Rte. 1 toward Long Beach.

5:00 pm	Arrive at Portugese Bend landslide near Palos Verdes Estates. Discussion of history of landslide and mechanics of sliding by **Bob Reid.**
6:00 pm	Return to San Onofre Bluff campground
7:30 pm	Make camp, fireside chat on tides by **Tamara Ruzmaikina.**

Sunday, 2 October:

8:00 am	Break camp, return North on I-5, then take Rte 1 at San Clemente, continue North toward Ventura, change to Rte 101 at Oxnard.
10:00 am	Arrive at Channel Islands visitor center in Ventura. Talk by **Eric Wegryn** on geology of the Channel Islands.
11:00 am	Continue North on Rte 101 to Carpenteria.
12:00 noon	Lunch stop on beach at Carpenteria. Observation and discussion of the fossil brea displayed there by **Will Grundy.**
1:30 pm	Continue North on Rte. 101 to Santa Barbara.
2:00 pm	Exit Cabrillo Blvd and proceed to Santa Barbara City College campus for an overlook of the Santa Barbara harbor, whose development will be explained by **Ellen Howell.**
3:00 pm	Return to Rte. 101 and proceed East towards Los Angeles. Remain on 101 at Oxnard and continue driving on the Ventura plain, over the hills at Thousand Oaks, and into the San Fernando Valley. Geology will be described by **Fatima Ebrahim,** along with a discussion of the origin of the Whittier Narrows gap, where we will exit to the I-10 freeway traveling East. Continue on I-10 to the exit on Rte 243 at Banning. Proceed South on 243 to Idyllwild and the campground in the National Forest.
6:30 pm	Camp at Dark Canyon/Idyllwild campground in the Black Mountain Group Campground, site 1. Campfire talks on Martian shorelines by **Doug Dawson** and on Lake Bonneville shorelines by **Cristine Jennings.**

Monday, 3 October:

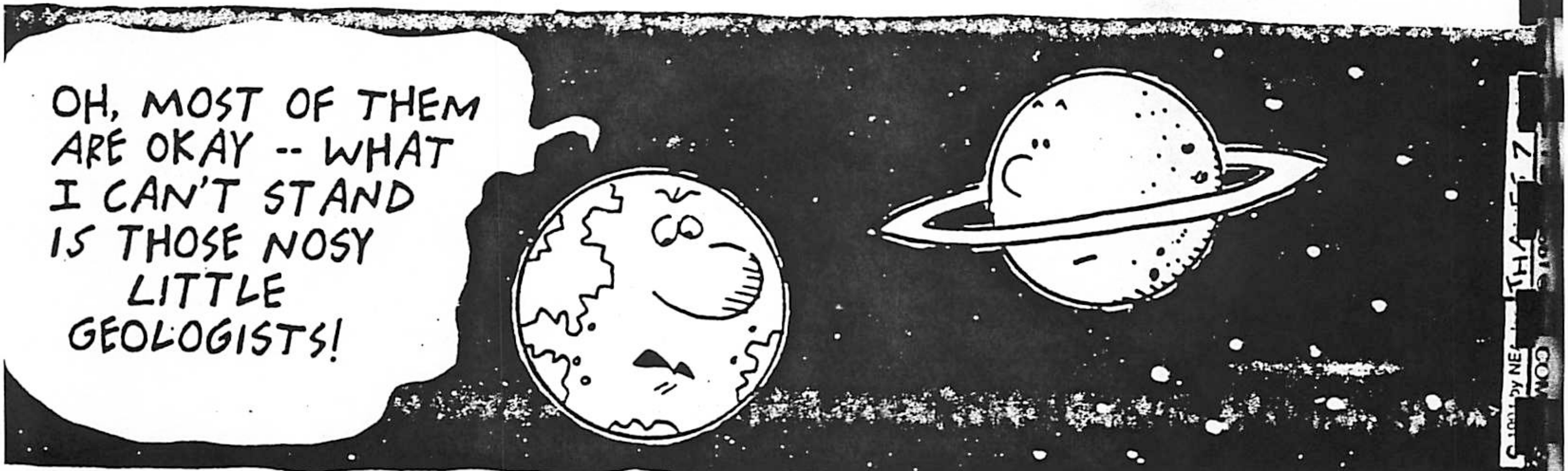
8:00 am	Break camp, return to I-10 via Rte 243, continue East.
9:00 am	Take Indian Avenue exit at Palm Springs, proceed West to power substation, park and leave vehicles to study ventifacts on Garnet Hill.
10:00 am	Continue east on I-10 to Indio. Possible stop at Shields Date farm for refreshment and instruction on date habits. Continue East on I-10 towards Phoenix.
12:00 noon	Lunch stop at I-10 rest area near Blythe
1:00 pm	Continue East on I-10 to Buckeye, turn South on Rte 85 to Gila Bend, then proceed East on I-8 to I-10 at Casa Grande (thus avoiding a drive through Phoenix). Continue South on I-10 to Tucson. Exit Speedway Blvd. and return to the LPL loading dock.
6:00 pm	Arrive Tucson, unpack and clean vans, go home.

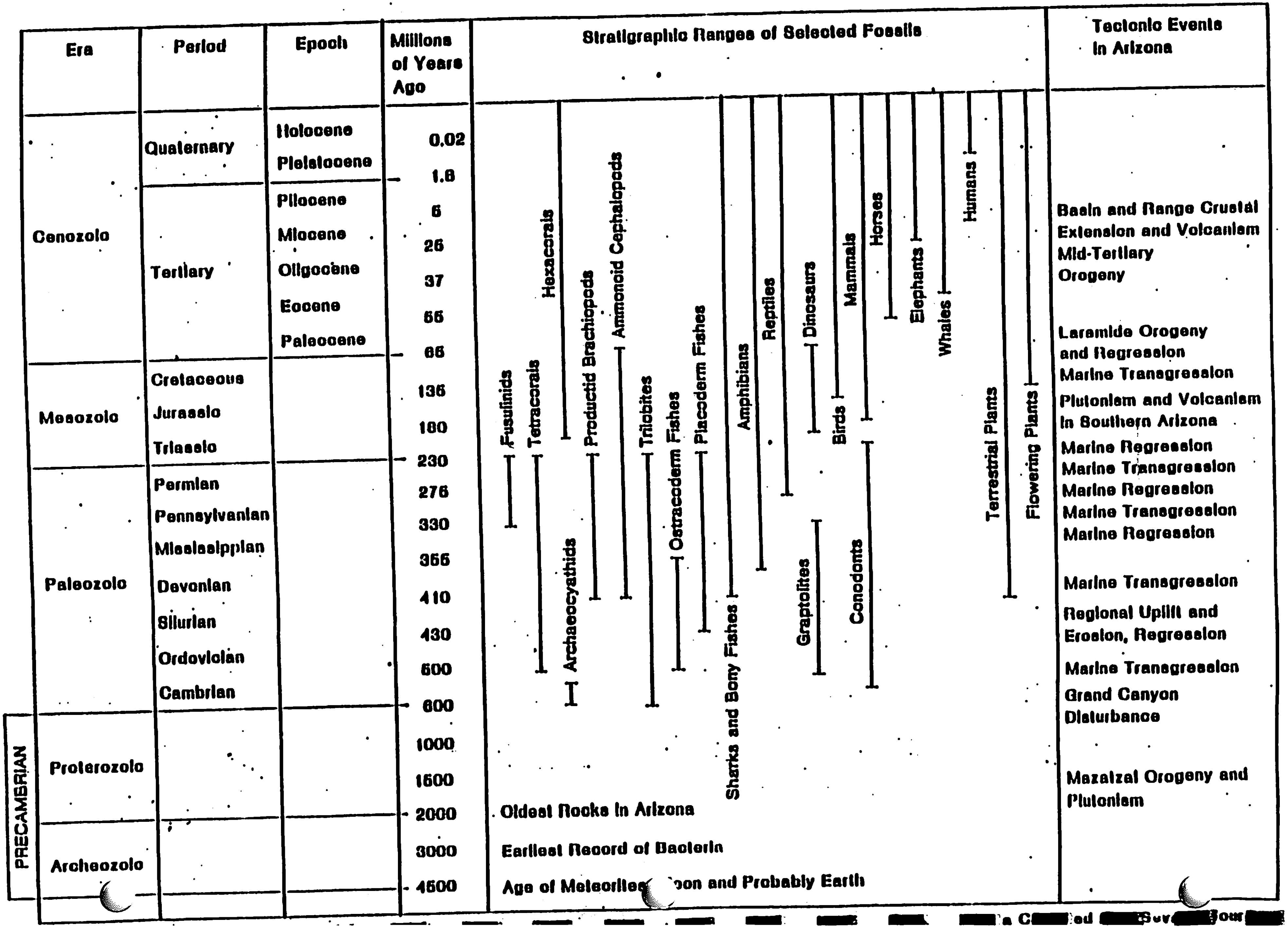
<u>Primary Drivers</u>: Converse, Dawson, Grundy, Nolan and Reid

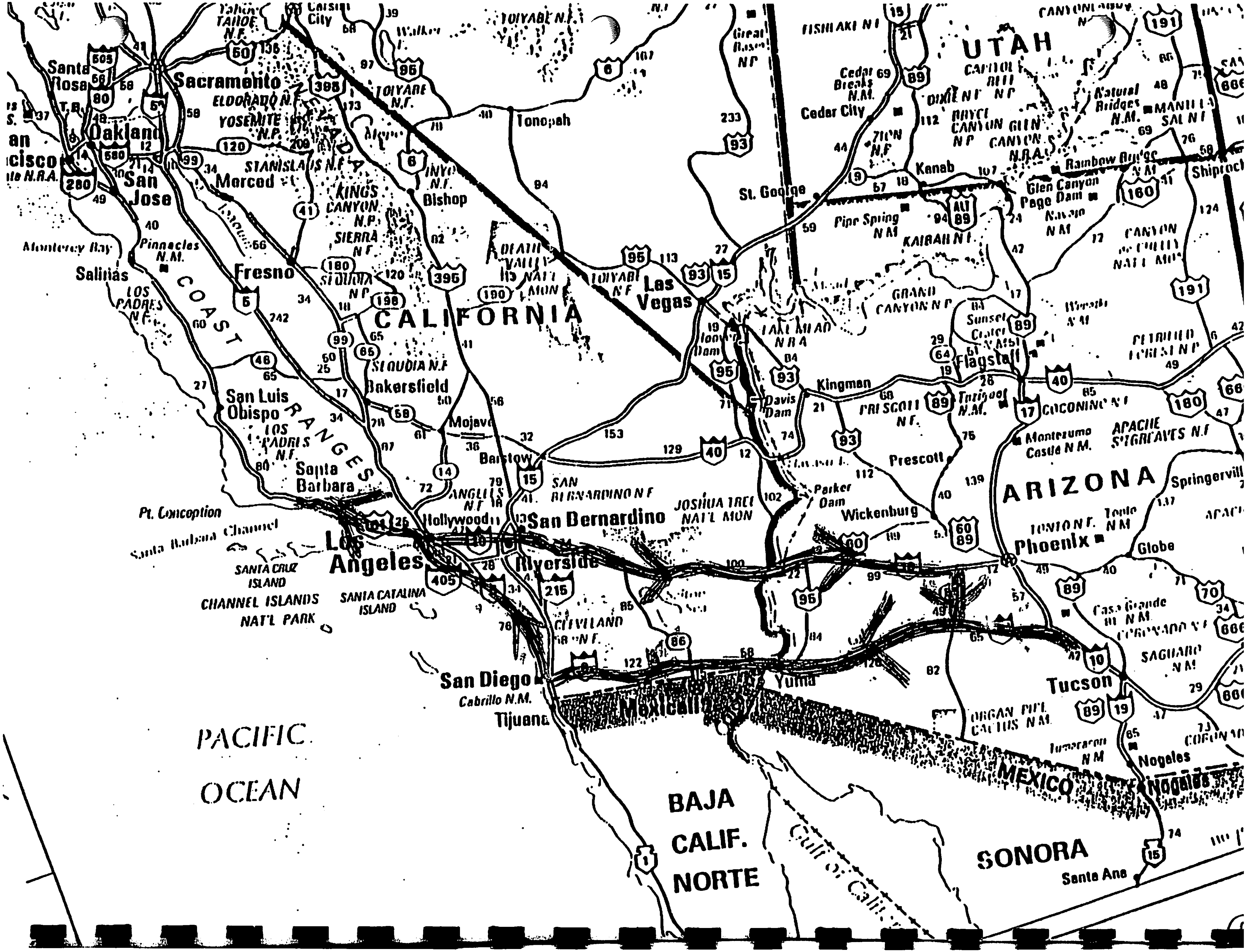
<u>Participants</u>:

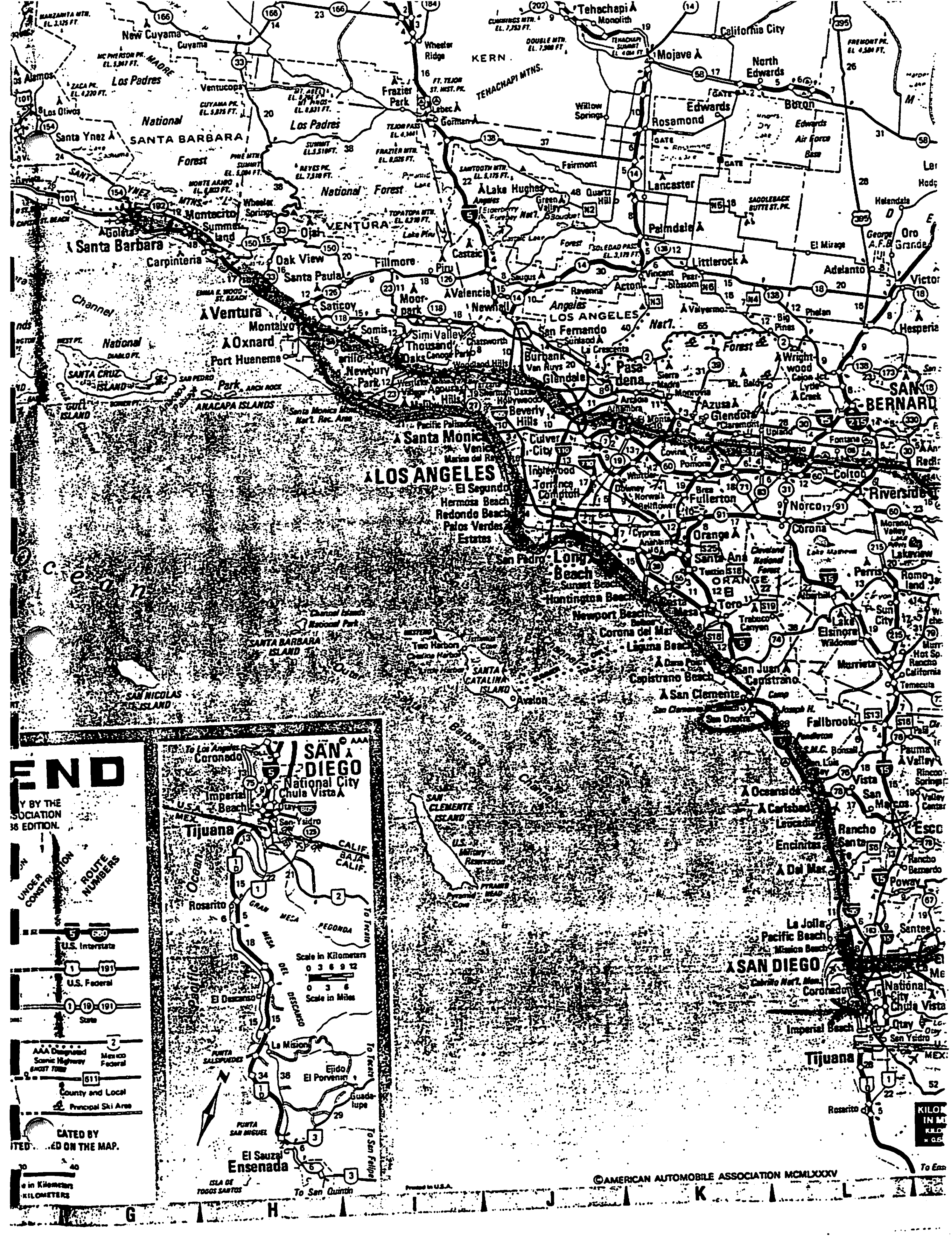
B. Bottke
B. Cohen
W. Dai
D. Durden
M. Fischer
W. Grundy
G. Hoppa
J. Johnson
J. Mclarty
E. Pierazzo
A. Rivkin
E. Turtle
D. Wood

N. Chabot
V. Converse
D. Dawson
E. Ebrahim
J. Grier
J. Head
E. Howell
D. Kring
M. Nolan
B. Reid
T. Ruzmaikina
E. Wegryn
"Virtual Val" Hillgren




Era
Period
Epoch
Millions of Years Ago
Stratigraphic Ranges of Selected Fossils
Tectonic Events in Arizona
Cenozoic
Mesozoic
Paleozoic
PRECAMBRIAN
Proterozoic
Archeozoic
Quaternary
Tertiary
Cretaceous
Jurassic
Triassic
Permian
Pennsylvanian
Mississippian
Devonian
Silurian
Ordovician
Cambrian
Holocene
Pleistocene
Pliocene
Miocene
Oligocene
Eocene
Paleocene
0.02
1.8
5
25
37
55
65
135
180
230
275
330
355
410
430
500
600
1000
1500
2000
3000
4500
Fusulinids
Tetracorals
Hexacorals
Archaeocyathids
Productid Brachiopods
Ammonoid Cephalopods
Trilobites
Ostracoderm Fishes
Placoderm Fishes
Sharks and Bony Fishes
Amphibians
Reptiles
Graptolites
Dinosaurs
Birds
Conodonts
Mammals
Horses
Elephants
Whales
Humans
Terrestrial Plants
Flowering Plants
Oldest Rocks in Arizona
Earliest Record of Bacteria
Age of Meteorites, Moon and Probably Earth
Basin and Range Crustal Extension and Volcanism
Mid-Tertiary Orogeny
Laramide Orogeny and Regression
Marine Transgression
Plutonism and Volcanism in Southern Arizona
Marine Regression
Marine Transgression
Marine Regression
Marine Transgression
Marine Regression
Marine Transgression
Regional Uplift and Erosion, Regression
Marine Transgression
Grand Canyon Disturbance
Mazatzal Orogeny and Plutonism


UTAH
CALIFORNIA
ARIZONA
BAJA CALIF. NORTE
SONORA
MEXICO
PACIFIC OCEAN
COAST RANGES
Santa Rosa
Sacramento
Oakland
San Jose
Monterey Bay
Salinas
Pinnacles N.M.
Merced
Fresno
Carson City
Tahoe N.F.
Eldorado N.F.
Yosemite N.P.
Stanislaus N.F.
Kings Canyon N.P.
Sierra N.F.
Sequoia N.P.
Sequoia N.F.
Inyo N.F.
Bishop
Toiyabe N.F.
Tonopah
Death Valley Nat'l Mon
Las Vegas
San Luis Obispo
Los Padres N.F.
Bakersfield
Mojave
Barstow
Santa Barbara
Pt. Conception
Santa Barbara Channel
Santa Cruz Island
Channel Islands Nat'l Park
Santa Catalina Island
Los Angeles
Hollywood
Angeles N.F.
San Bernardino
San Bernardino N.F.
Riverside
Joshua Tree Nat'l Mon
Cleveland N.F.
San Diego
Cabrillo N.M.
Tijuana
Mexicali
Yuma
Parker Dam
Davis Dam
Hoover Dam
Lake Mead N.R.A.
Great Basin N.P.
St. George
Cedar City
Cedar Breaks N.M.
Zion N.P.
Kanab
Pipe Spring N.M.
Kaibab N.F.
Bryce Canyon N.P.
Capitol Reef N.P.
Dixie N.F.
Fishlake N.F.
Glen Canyon N.R.A.
Page
Glen Canyon Dam
Rainbow Bridge N.M.
Natural Bridges N.M.
Navajo N.M.
Canyon de Chelly Nat'l Mon
Shiprock
Grand Canyon N.P.
Kingman
Prescott N.F.
Prescott
Wickenburg
Flagstaff
Sunset Crater N.M.
Wupatki N.M.
Walnut Canyon N.M.
Coconino N.F.
Montezuma Castle N.M.
Petrified Forest N.P.
Apache Sitgreaves N.F.
Springerville
Tonto N.F.
Tonto N.M.
Phoenix
Globe
Casa Grande Ruins N.M.
Coronado N.F.
Saguaro N.M.
Tucson
Organ Pipe Cactus N.M.
Tumacacori N.M.
Nogales
Santa Ana
Gulf of California



©AMERICAN AUTOMOBILE ASSOCIATION MCMLXXXV

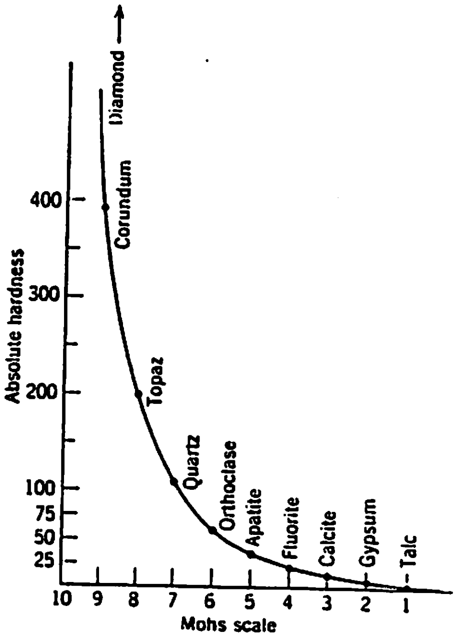
Some Common Minerals and their Physical Properties

Mineral name & composition	Common Color	Luster	Hardness	Cleavage
Quartz SiO_2	clear colorless milky white, pink, etc.	glassy	7	conchoidal fract.
Plagioclase *(feldspar)* $NaAlSi_3O_8$-$CaAl_2Si_2O_8$	white, gray	peary, glassy	6	2 planes at 90°
Orthoclase *(K-feldspar)* $KAlSi_3O_8$	pink, gray, white	glassy, pearly	6	2 planes at 90°
Muscovite *(white mica)* $KAl_3Si_3O_{10}(OH)_2$	clear to silvery-yellow	silky, pearly	2-2.5	1-D in thin sheets
Biotite *(black mica)* $K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$	dark brown to black	silky, pearly	2.5-3	1-D in thin sheets
Hornblende *(amphibole)* $Ca_2Na(Mg,Fe)_4(Al,Fe)$ $(Al,Si)_8O_{22}(OH)_2$	dark green to black	glassy	5-6	2 planes at 60°
Augite *(pyroxene)* $Ca(Mg,Fe,Al)(Si,Al)_2O_6$	dark green to black	glassy	5-6	2 planes at 90°
Olivine $(Mg,Fe)_2SiO_4$	green to brown	glassy	6.5-7	conchoidal fract.
Calcite $CaCO_3$	colorless to white	glassy, earthy	3	three directions
Pyrite FeS_2	brassy yellow	metallic	6-6.5	none

Moh's Hardness Scale (decreasing hardness):

10	Diamond
9	Corundum
8	Topaz
7	Quartz
6	Orthoclase feldspar
5	Apatite
4	Fluorite
3	Calcite
2	Gypsum
1	Talc

the hardness of the fingernail is a little over 2, a copper coin about 3, the steel of a pocket knife a little over 5, window glass 5½, and the steel of a file 6½.



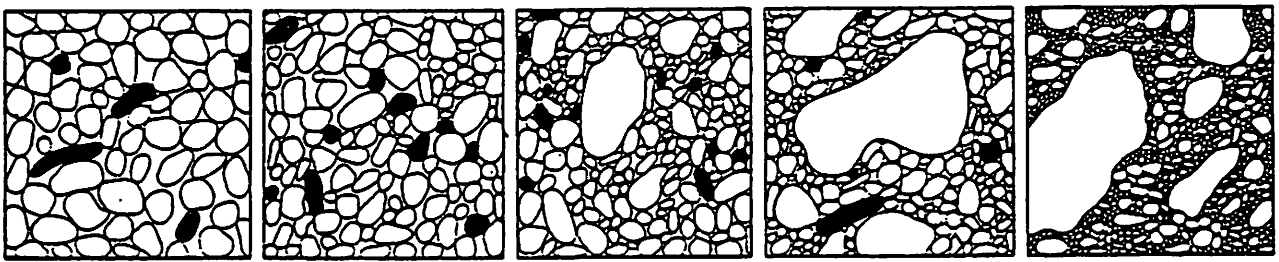
Comparison of Mohs relative hardness scale and ab-

TERMS AND SIZES FOR CLASTIC SEDIMENTS AND CLASTIC SEDIMENTARY ROCK TYPES*

	Name	Millimeters	Micrometers	Φ
GRAVEL		4,096		−12
	Boulder			
		256		−8
	Cobble			
		64		−6
	Pebble			
		4		−2
	Granule			
		2		−1
SAND	Very coarse sand			
		1		0
	Coarse sand			
		0.5	500	1
	Medium sand			
		0.25	250	2
	Fine sand			
		0.125	125	3
	Very fine sand			
		0.062	62	4
MUD	Coarse silt			
		0.031	31	5
	Medium silt			
		0.016	16	6
	Fine silt			
		0.008	8	7
	Very fine silt			
		0.004	4	8
	Clay			

*After J. A. Udden (1898) and C. K. Wentworth (1924). The Φ scale, devised by W. C. Krumbein (1934), is based on a logarithmic transformation, $\Phi = -\log_2 S$, where S is grainsize in millimeters. The Φ scale is commonly used in sedimentological studies because it is more convenient in presenting data than if values are given in millimeters.

Degrees of sorting in sandstones and conglomerates. (From R. R. Compton, 1962, *Manual of Field Geology*, John Wiley & Sons.).



Very well sorted Well sorted Moderately sorted Poorly sorted Very poorly sorted

⑩

Algodones Dune Chain, Imperial County, California

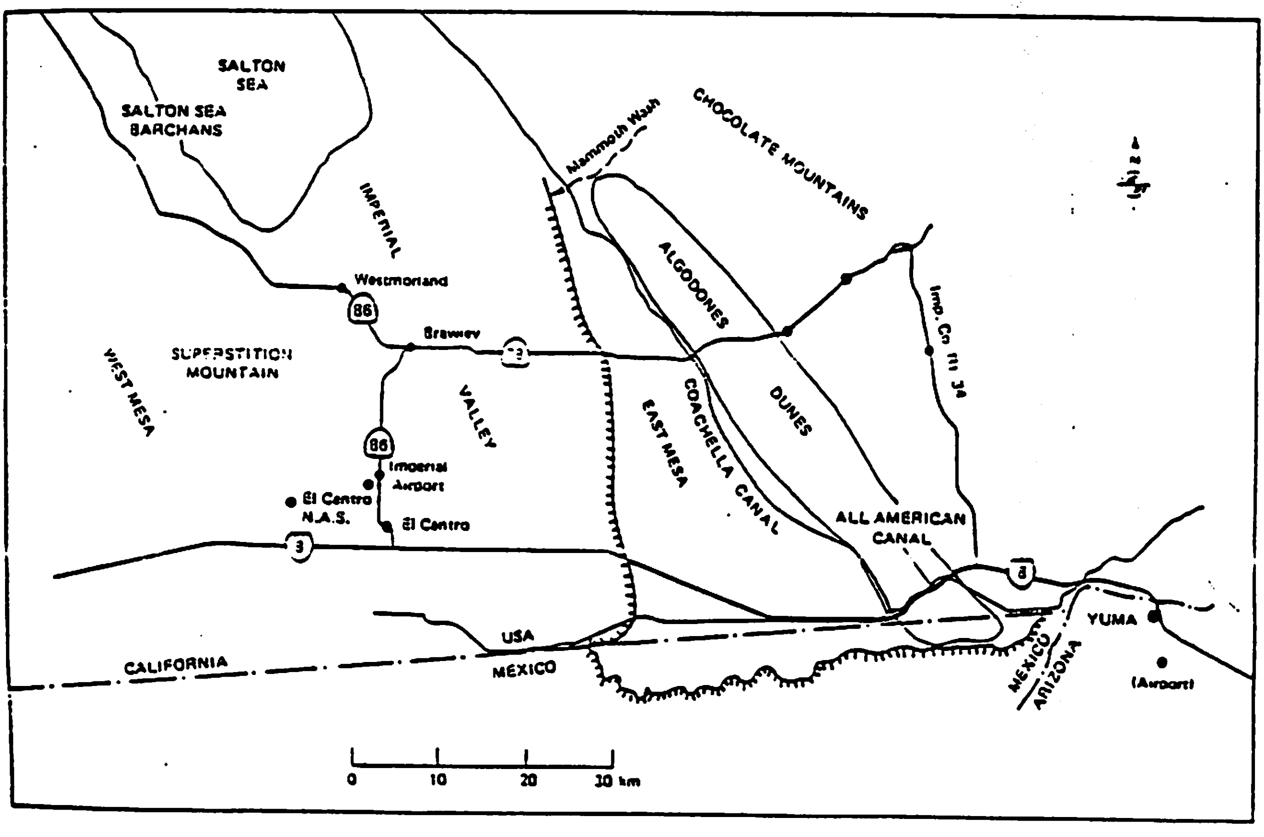
reprint courtesy of J im Head

The Algodones Dune chain represents one of the largest (and most accessible) fields of unstabilized dunes in the United States. It is of particular interest to planetologists because the various aeolian landforms may provide analogs for Martian landforms. Breed (1977) has compared the Algodones dune chain with the Hellaspontus dune field on Mars.

Description: The dunes overlie Cenozoic lacustrian and deltaic deposits, forming a NW-SE trending chain ~70km long and 1-8km wide (widening toward the south). The chain extends from Mammoth wash in the north to the Colorado flood plain just south of the border (see figure). The chain consists primarily of complex, coalesced domal dunes 30-90m tall which are commonly joined into dumbbell-like forms by NE-trending saddles 300-1200m long. South of the All-American canal, the dunes break up into sets of barchanoid forms about a kilometer across. The intradune hollows are floored by lag gravel. Individual barchans are observed to migrate roughly 10-20m a year. Along the SW margin of the field are longitudinal dunes paralleling the chain. These are typically 5-25m high. Dunes on East Mesa (west of the chain) and along the NW margin are stabilized by vegetation. In addition, there are many small scale features present. These include small sand ripples, large granule ripples, and bush-anchored sand streamers.

Winds: The wind regime of the dune chain is poorly characterized because 1) there are no weather stations within the field and 2) the records at the nearest stations (Imperial and El Centro to the west, Yuma to the east) show different wind directions. Winds are strongest in the spring, weakest in the fall.

Origin: The proximity of ancient Lake Chuilla shore lines to the dune field led some workers to conclude that these beach sands are what form the dune chain, whose ultimate sources are the alluvial fans of local mountain ranges. (The SW margin of the chain lies along the 37,000 year old lake stand. More recently, the shoreline ran along the present day margin of East Mesa.) However, van de Kamp (1973) showed that the dune sands resemble Colorado River sand and are dissimilar to local alluvial fan material and the ancient beach sands. Therefore, it is thought the dune field consists of Colorado River deltaic sand. The same source is cited for the Pinacate-area dune field.



Index map of dune areas in the Imperial Valley, California.

Spheroidal Weathering

reprint courtesy of Valerie Hillgren

Kinds of rocks that spheroidally weather:
1. have no layering
2. are homogeneous
3. have lots of feldspar
   (usually granite-like rocks)

Q: Why is feldspar so important?
A: It's strong <u>but</u> weathers easily:
feldspar + rainwater –>
clay + water with stuff dissolved in it

Finally, need a set of *joints*-- three sets of mutually perpendicular fractures.

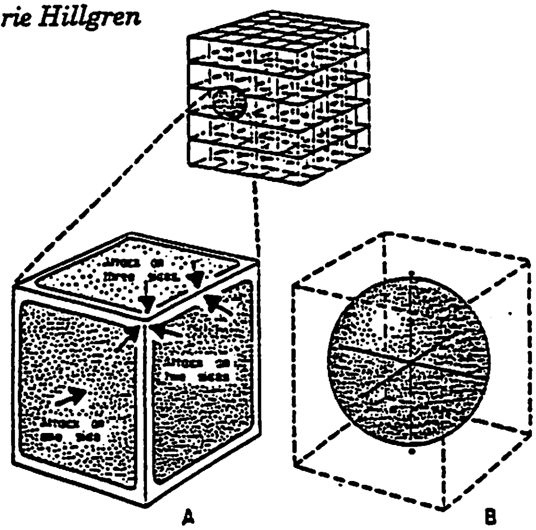


Fig. 17.6 Geometry of spheroidal weathering.

Climate helps formation of spheroidal boulders. In wet climates, weathering occurs too quickly and nice soils form allowing pesky plants and trees to obscure the boulders.

12

Gila River Graben and Sentinel Volcanic Field to Yuma

Wei Dai

Ptys 594a,Fall 1994

Around 10 to 6 million years ago, most of the separate basins, each with its own drainage system, became so full of debris from the mountains that streams could flow from basin to basin. Most southern Arizona streams joined together as tributaries of the **Gila River**, which dicovered a ready-made pathway across the state. From time to time, volcanic outpourings dammed streams and temporarily isolated new lakes. Quite recently, less than 5 million years ago, the Colorado River became the master stream of this desert region, with the Gila flowing into it near Yuma.

As through drainage was established, downcutting by rivers and streams increased, the Gila and its tributaries began to erode through the looser fill of the moutain basins. Within the last 2 million years, alternating rainy and dry cycles, which may have been in step with glacial and interglacial climates farther north, caused development of complicated arrays of terraces along the upper Gila River and its tributaries, and along the Colorado River father west.

In general, the overall grain or fabric of the land in the region near Vekol Wash at milepost 151 is NW-SE–sharply defined, ridge like mountain ranges paralleling long, open valleys. Near Gila Bend we find evidence of a change of scene. For most of its journey from Phoenix to the Colorado River, the Gila River flows along a northeast-southwest trough that seems boldly to ignore the "lay of the land". Seismic studies, which analyze hidden subsurface features by bouncing man-made shock waves off underground reflective layers, show a **Graben** 100 miles long and 10 miles wide, a down dropped trough edged on each side by nearly vertical faults. The lava flows of the Gila Bend Mountains deflected the Gila River from this southwestward route, so that it bends south around both lava flows and Precambrian rock, then northwest to rejoin its former channel.

Northwest of Gila Bend, the Gila River bends northward through a narrow channel between the Painted Rocks and Gila Bend Mountains and into the graben, the Gila Trough. The almost horizontal floor of Gila Bend plain is now heavily cultivated. The main crops are cotton and cattle feed. Ranges surrounding the plain are almost all volcanic. Lava flows make up all but the eastern most part of the Gila Bend Mountains.

Sentinel Volcanic Field is in one of the youngest displays of volcanism in Arizona, individual flows are thin,the basalt lava was fluid and erupted quietly, spreading in sheets and shallow lava ponds. Because of the ease with which it flowed and the apparent low gas content of the lava, there is little buildup around the volcanic vents and they are hard to identify. All these flows are less than 2 million yrs old, having erupted early in Pleistocene time. The original surface of the uppermost flow has had time to weather and break up, leaving scattered blocks of basalt strewn about on the surface.

Sentinel lavas lie over Gila River Sediments-fine, well sorted sand and silt-suggesting that the river , after being deflected southward around the Gila Bend Mountains, for some time flowed south of its present course. The Sentinel lava flows may have been the deciding factor in its return to the Gila Trough.

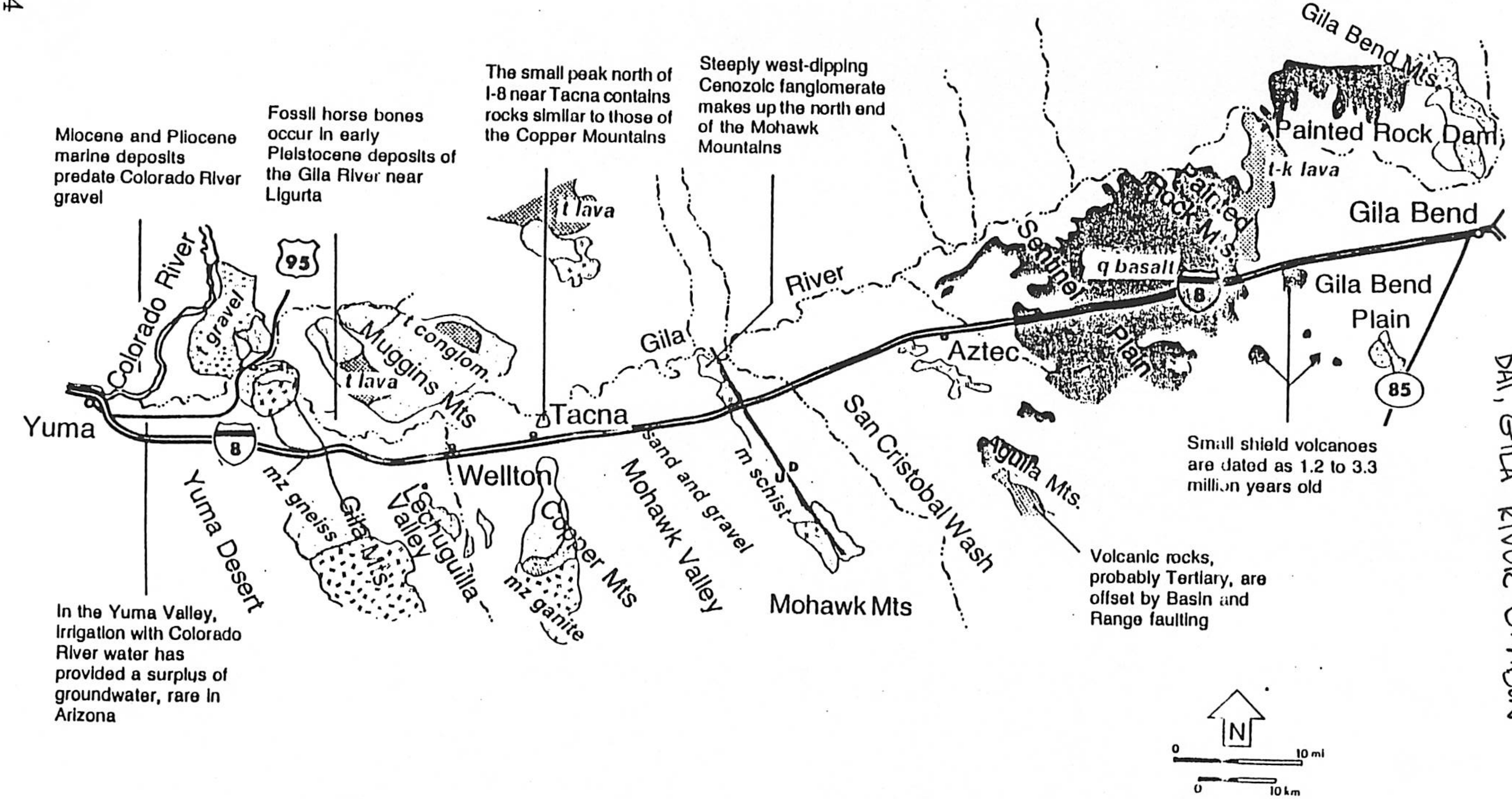
References:

Halka Chronic, 1983, Chapter 2. *Roadside Geology of Arizona.*

(14)

DAI, GILA RIVER GRABEN

I-8
Gila Bend to Yuma



Small shield volcanoes are dated as 1.2 to 3.3 million years old

Volcanic rocks, probably Tertiary, are offset by Basin and Range faulting

Steeply west-dipping Cenozoic fanglomerate makes up the north end of the Mohawk Mountains

The small peak north of I-8 near Tacna contains rocks similar to those of the Copper Mountains

Fossil horse bones occur in early Pleistocene deposits of the Gila River near Ligurta

Miocene and Pliocene marine deposits predate Colorado River gravel

In the Yuma Valley, irrigation with Colorado River water has provided a surplus of groundwater, rare in Arizona

MARINE TERRACES IN COASTAL SOUTHERN CALIFORNIA

conducted by James Head (West)

A marine terrace is a planar erosion surface cut into a shoreline by wave action and subsequently left stranded above the surf line by a combination of tectonic uplift and lowering of sea level. A terrace evidences a time of stability of sea level relative to the shoreline. Since the changes in sea level due to glaciation (eustatic sea level) are the same worldwide, that component can be filtered out of the terrace record leaving only tectonic uplift. Uplift preserves terraces that otherwise would be drowned. In stable regions, the first terrace marks the 120ka sea level highstand, while in active regions an earlier (~80ka) highstand is first. **N.B. You don't have to** be John Lewis to play fast and loose with your uplift rates. In many cases, workers assume that uplift has remained constant over timescales much longer than it has proved possible to measure.

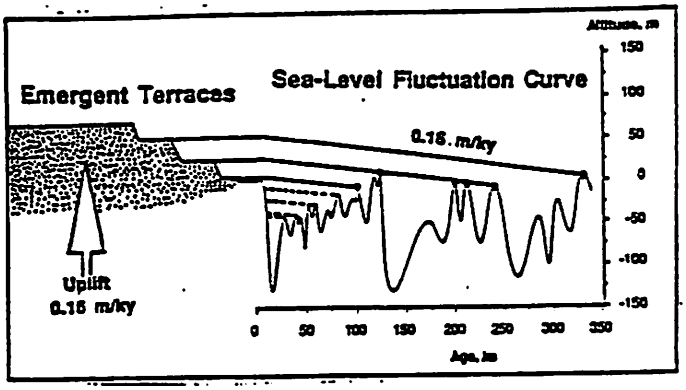


Figure 1

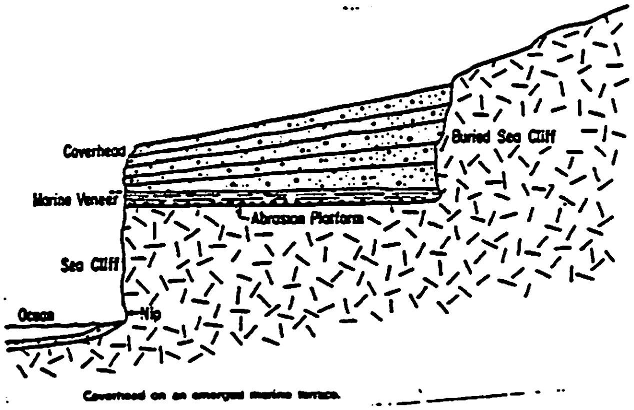


Figure 2

MORPHOLOGY

For much of our *yatra* along coastal Southern California we will be traveling on terraces. For obvious engineering reasons, that's where the roads are. The broad flat (average slope~0.6 degrees) terrace is typically bound by degraded seacliffs which delineate the paleo-shoreline. Older terraces have suffered more degradation and might only appear as notched ridge crests. Where the morphology is poor, one can use the presence of beach gravels and appropiate fossils as corroborating evidence. Altitudinal spacings of flights of terraces can be correlated with other, better preserved terraces as well.

GEOCHRONOLOGY

Various geochronometers can provide a wealth of information about terrace ages, sea level history, marine paleotemperatures, and late Quaternary tectonics. Typical dating tools include

A) U-Th-Pa (U-series) dating of corals. This method reliable only in providing minimum ages. It also requires that enough material has survived. This is a problem along the Pacific coast.

B) Thermoluminescence. Insolation "zeroes out" light sensitive TL sites before burial. These are replaced by ionizing radiation from ambient U, Th, and K at a roughly constant rate over the ~Ma timescale for TL dating. Precision is roughly 20-35%.

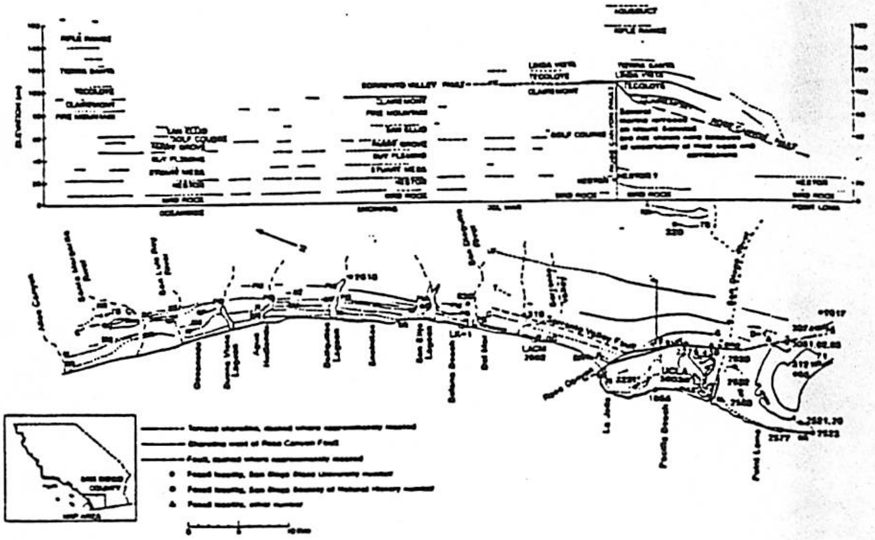
C) Carbon-14. Utility limited to about 40ka (note timescale on Figure 1)

D) Oxygen isotopes in fossils. Function of isotopic composition and temperature of sea water at time of shell precipitation. Calibrated from dated terraces in Barbados, New Guinea, and California (future field trips?). Useful for correlating terraces.

E) Aminostratigraphy. Living organisms produce left-handed amino acids (L) which convert (in a process called racemization) to their right-handed (D) enantiomorphs. Larger D/L implies older fossils. The enantiomeric ratio also depends on temperature history, genus, and a variety of diagenetic processes (it gets complicated quickly). Again, primarily useful for correlating terraces (figure 6).

The last two methods probably will not be useful on Mars.

J. PHILIP KERN AND THOMAS K. ROCKWELL



—Map and profile showing terrace shorelines, major faults, and fossil localities, San Diego to Camp Pendleton. UCLA—University of California, Los Angeles; LACM—Los Angeles County Museum; LK-1—Wehmiller sample.

Figure 3

SAN DIEGO-OCEANSIDE

Figure 3 shows 16 mapped terraces between San Diego and Oceanside. The Shoreline has been modified by uplift and the Rose Canyon Fault system. Platform widths range from meters to >2km, with a strong correlation between terrace width and erodibility of the rock. Beach ridges are present. Elevation and ages gives a regional uplift rate of ~0.13m/ka and an oldest terrace age ~1.3Ma. Note that the bending of paleo-shorelines (Tecolote and Clairmont terraces) indicate the presence of islands, shallows, or promontories. Terrace displacement indicates the Rose Canyon fault has been active ~1Ma.

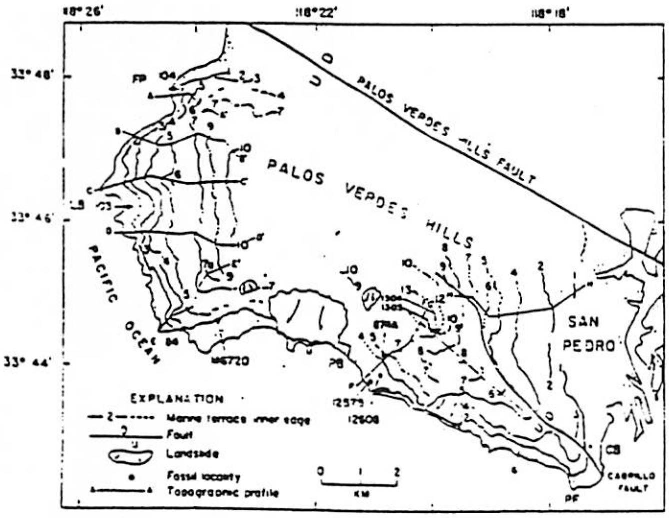


Figure4

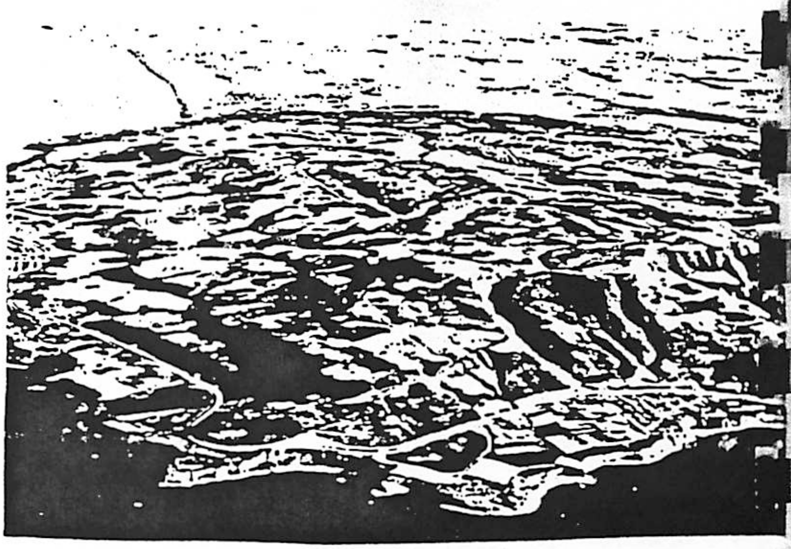


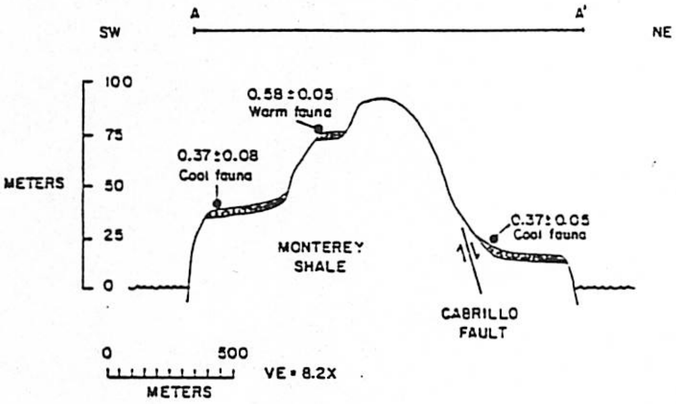
Figure 5

PALOS VERDES-SAN PEDRO

Figure 4 shows 13 mapped terraces ascending to ~400 meters. Figure 5 is an airphoto of much the same area. Note the stairstep appearence of the terraces. Ages and elevations give uplift rates of 0.38-0.72m/ka and resolve a 0.20m/ka verticle slip along the Cabrillo fault--a rate about half that derived from offshore Holocene deposits. Figure 6 shows how correlations are used to resolve the fault motion from the regional uplift. These elevations and uplift rates are rather modest. New Zealand terraces have been described at altitudes of over a mile, with implied uplift rates of ~6 m/ka. These results have been corroborated by fission track techniques.

MARS (not *this* trip, the *next* one)

Figure 7 is an airphoto of terraces that represents what Mars Pathfinder might see. The original resolution was ~meters but after a few photocopies we're down to ~10 meters. This implies that a meter resolution system on Pathfinder should detect and identify terraces (distinguish from landslide slump blocks, etc.). However, the great age of possible Martian terraces (billions vs. millions of years) makes me suspect that old sea cliffs might be obliterated. Therefore good topographic data (10 meter vertical resolution) might be a better tool.



—Geologic cross section across Point Fermin (location shown in Fig.4) showing terraces, the Cabrillo fault, thermal aspects of terrace faunas, and alle/Ile ratios in *Tegula*.

Figure 6

Figure 7

REFERENCES

Fletcher,III and Wehmiller (1992) Quaternary Coasts of the United States:Marine and Lacustrian Systems. Project 274 Quaternary Coastal Evolution. Society for Sedimentary Geology.

Oakeshott (1971) California's Changing Landscape. McGraw-Hill Inc.

Sharp (1978) Coastal Southern California. K/H Publishing Co.

see also

Bull and Cooper (1986) Uplifted Marine Terraces Along the Alpine Fault, New Zealand, *Science*, 234 1225-1228.

with response by Ward *Science* 240 803-805.

and just for giggles

Prior (1991) Landforms of Iowa, University of Iowa Press.

(18)

BEACH CUSPS

Jeff Johnson, PTYS 594A, Fall 1994

➊ Definition: Uniformly spaced, arcuate scallops in sediment that form at the shoreward edge of the episodically exposed portion of a beach known as the swash zone (Werner and Fink, 1993).

➋ Features:

➢ Form over period of hours to days on oceanic and lacustrine beaches in any type of beach sediment (boulders/cobbles to fine sands), and can be centimeter to meter-scale in size and spacing.

➢ Require near-normal incident waves of small amplitude, but with long crests lengths and "regular" (non-storm waves).

➢ Development favored on steep beach faces under surging, non-breaking wave conditions.

➢ Spacing of cusps depends on wave heights and swash distance (distance from wave break to highest point of swash).

➢ Offshore bays and deltas correspond to onshore ridges and cusps, respectively.

➢ Ridges (horns) of cusps show coarser sediments than embayments between ridges. Ridges are thus sites of accretion while bays are more erosional. Swash runup is deflected by the ridges into the bays and flows seaward as runout.

➌ Models of formation mechanisms:

➔ **Standing wave model (Komar, Guza):** Combination of *edge waves* and normal incident incoming waves produces sinusoidal variations in swash front, leading to development of cusps and ridges onshore.

➢ *Edge waves:* Generally standing waves with crests normal to the shoreline and wavelengths parallel to the shoreline; they are opposite in orientation to the

JOHNSON, BEACH CUSPS

incoming waves. Edge wave oscillations best observed as a "run-up" on the sloping beach face. Their height is greatest at the shore and decreases rapidly (within one wavelength) from the shore. Where edge waves are in phase with normal waves, the swash reaches highest on beach face; where out of phase, swash is lowest. Predicts that cusp spacing is equal to:

$$\lambda = (\sin\beta/\pi)gT^2$$

where T is the incidence wave period, g is gravitational acceleration (REM: for Mars, g is 3.7 m/s^2), and β is the slope of the beach.

Problem: Edge waves are have not been observed unambiguously with beach cusp formation.

➔ **Self-organization model (Werner):** Incipient topographic depressions in beach ("bottom morphology") are amplified by attracting and accelerating water flow, enhancing erosion.

Problem: Leads to same predictions for spacing and formation of cusps as edge wave model. But the conditions necessary for self-organized model (coupling between alongshore surface gradients and flow) are incompatible with the those required for the standing wave model (gradients in sea surface arising from wave patterns), at least according to Werner and Fink (1993).

➔ **Experiments in N. Carolina (Werner):** Wakefield (1994) reported on experiments done in N. Carolina, where existing beach cusps were bulldozed and observations were made of the beach morphology and swash flow until the cusps returned, some 12 hours later, which was faster than expected. Also, the spacing of the cusps was irregular, varying up to 30%, which is not predicted by either model. Thus the current results are inconclusive; further experiments were reportedly performed a few weeks ago.

❹ References:

CRC Handbook of Coastal Processes and Erosion, P.D. Komar, editor, CRC Press, Inc., Boca Raton, Florida, 1983.
Guza, R.T., and E.B. Thornton, *J. Geophys. Res.*, 87, 483, 1982.
Komar, P.D., *Beach Proceses and Sedimentation*, Prentice-Hall, 429 pp., 1976
Ritter, D.F., *Process Geomorphology*, Wm. C. Brown Publishers, Dubuque, Iowa, 1986;
Wakefield, J., "Dozer duck dominates the nearshore scene this summer," *Eos Trans.*, Aug. 9, 1994, vol. 75, no. 32, 369-370
Werner, B.T. and Fink,T.M., *Science*, **260**, 968-971, 1993

❺ Best quotes:

Bob Guza (Scripps): "This beach isn't big enough for the both of us."

Bob Holman (OSU): "The work ahead, while necessary and potentially very rewarding, is enough to make any experimentalist shudder."

JOHNSON, BEACH CUSPS

JJ3

KOMAR
1976

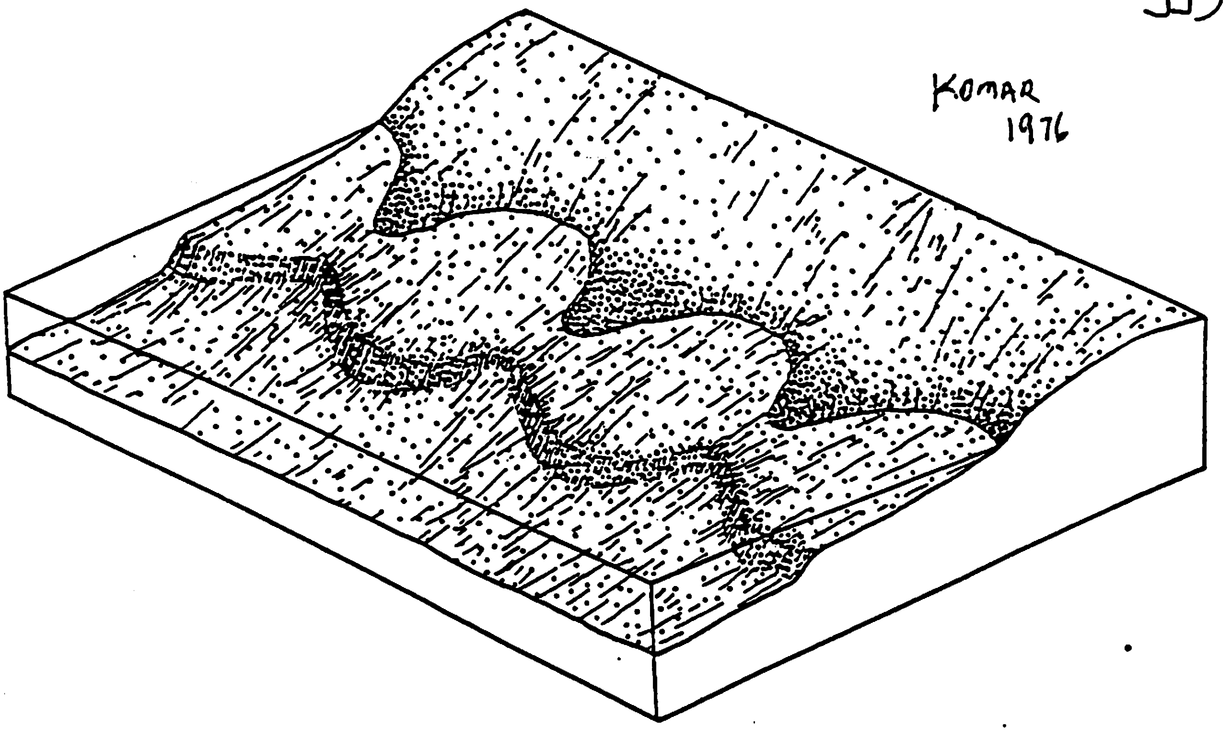


Figure 10-14 Beach cusps and associated underwater "deltas" offshore from the embayments. [*After* Timmermans (1935) and Kuenen (1948)]

WERNER + FINK, 1993

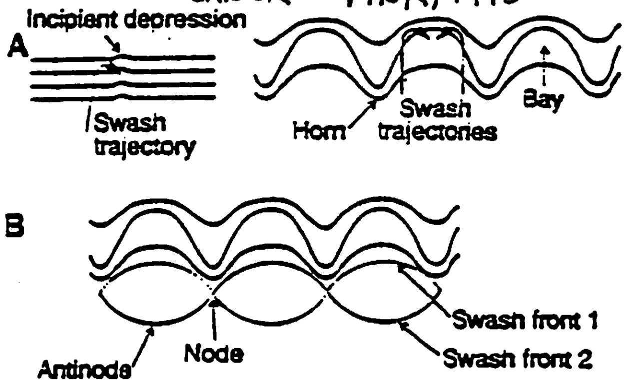


Fig. 1. Self-organization and standing wave models. Seaward is down. Bold lines are beach contours. (**A**) (Left) Deflection of swash flow by incipient topographic depression causing further erosion; (right) swash zone circulation in equilibrium with beach cusps (*6*). (**B**) Alignment of beach cusps and sinusoidal variation in the swash front caused by subharmonic edge waves shown at two consecutive swash cycles as broken and solid lines (*3*). Nodes in the swash excursion align with cusp horns.

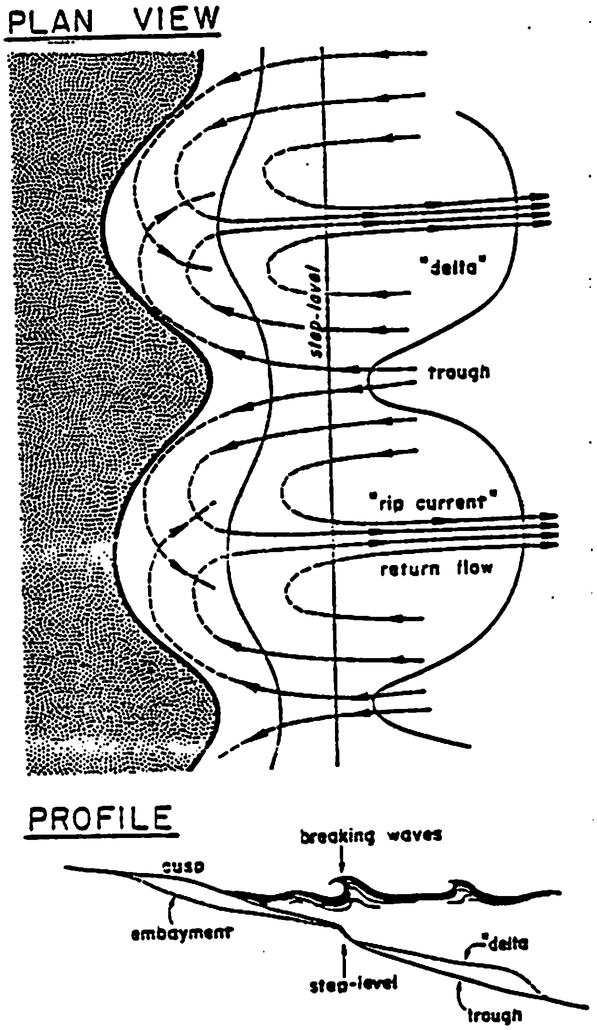


Figure 10-17 Wave swash motions around cusps and within embayments. [*After* Bagnold (1940)] —KOMAR, 1976

KOMAR, 1983

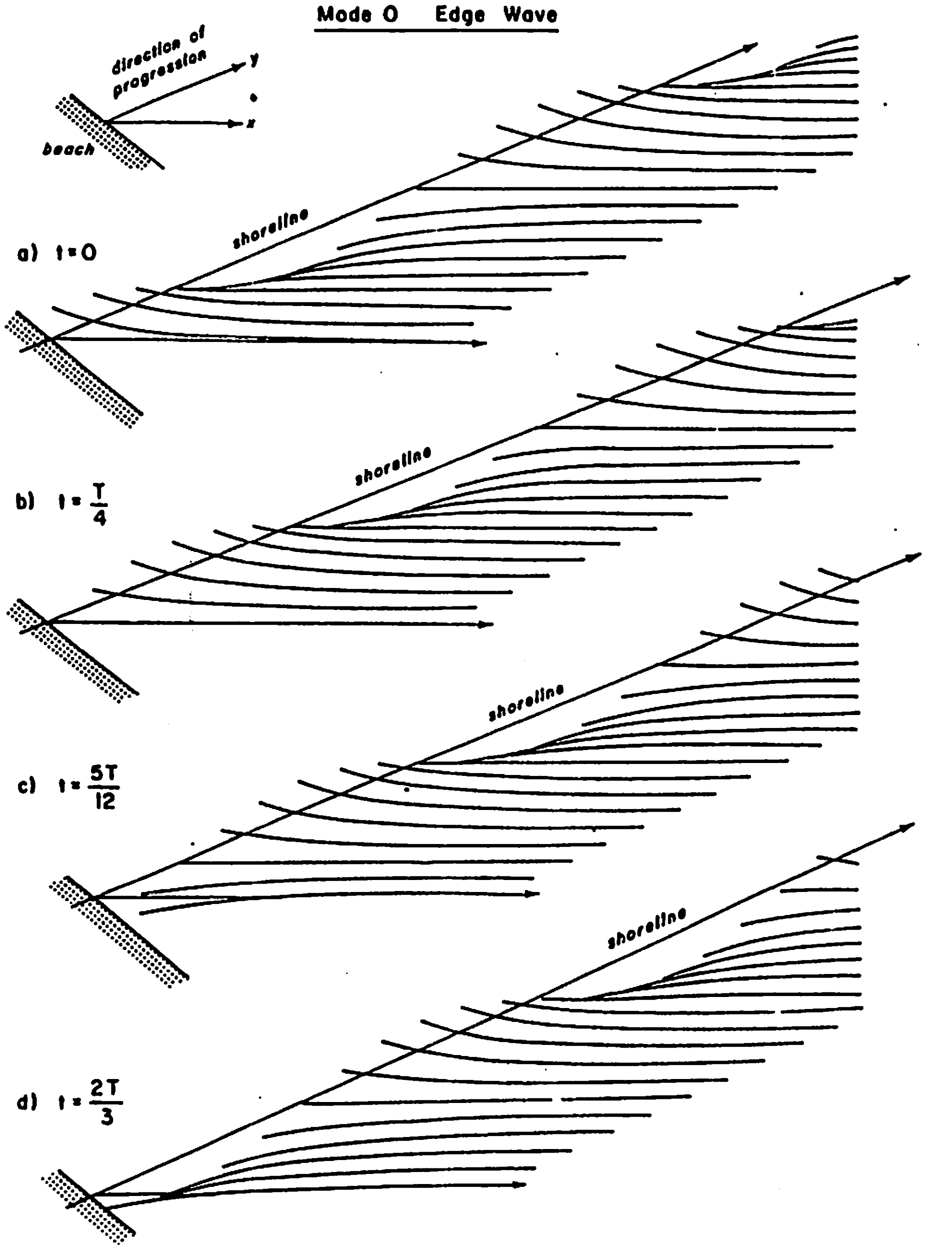
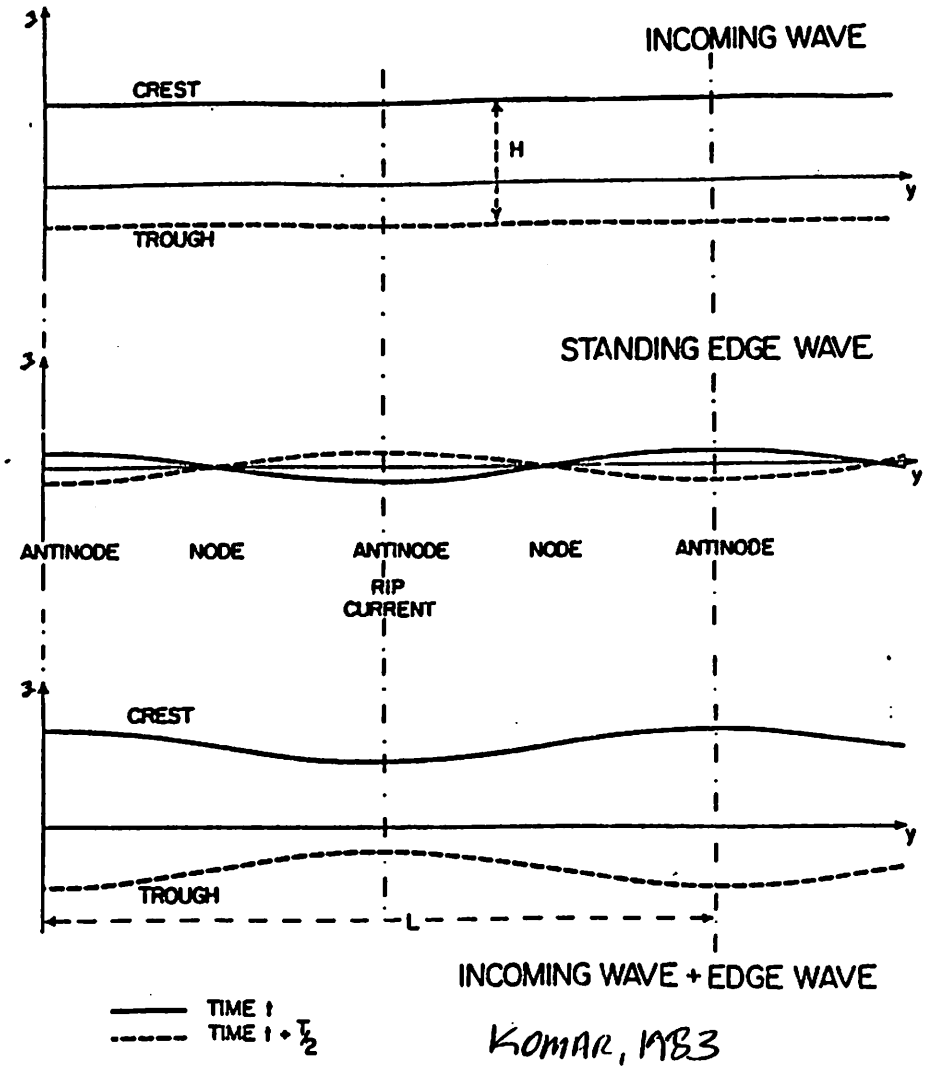


FIGURE 1. A progressive, mode 0, edge wave viewed obliquely from offshore. Seaward is to the right, the shoreline to the left. The shoreline slants away to the upper right. The sinusoidal longshore structure is clearly visible as well as the exponential offshore decay. The time progression of the waves is shown by the four figures, each later in time than the one above it.



KOMAR, 1983

JOHNSON, BEACH CUSPS

II 4 (21)

22

THE PHYSICS OF WAVE BREAKING: A MARGINALLY QUANTITATIVE DISCUSSION

- with your host -

Mark Fischer

"Classical" wave theory:

- Linear solution to ideal fluid equations.
- Assumptions: ρ = constant, **u** & A are small, depth >> A.
- Thus, solution breaks down in shallow water limit.

Complications:

- Seafloor & atmospheric interactions.
- Non-linear instabilities.
- Turbulence.

Surf Parameter:

$$\xi = \frac{s}{[H/\lambda]^{1/2}},$$

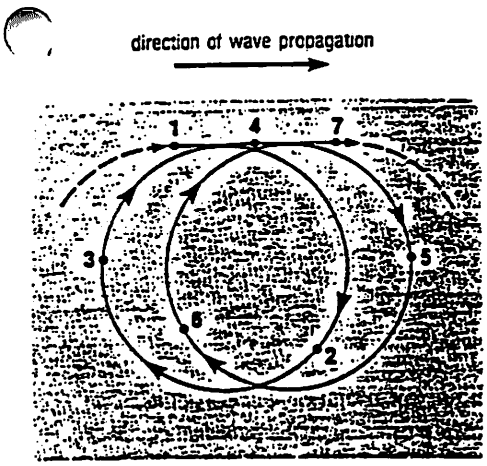
where s = beach slope,
H = wave height,
λ = deep water wavelength.

$\xi = 2.3$ ---> approximate upperbound for breaking.

$\xi < 0.4$ ---> spilling breakers
$0.4 < \xi < 2.0$ ---> plunging breakers
$\xi > 2.0$ ---> collapsing breakers

FISCHER, WAVE BREAKING

(23)



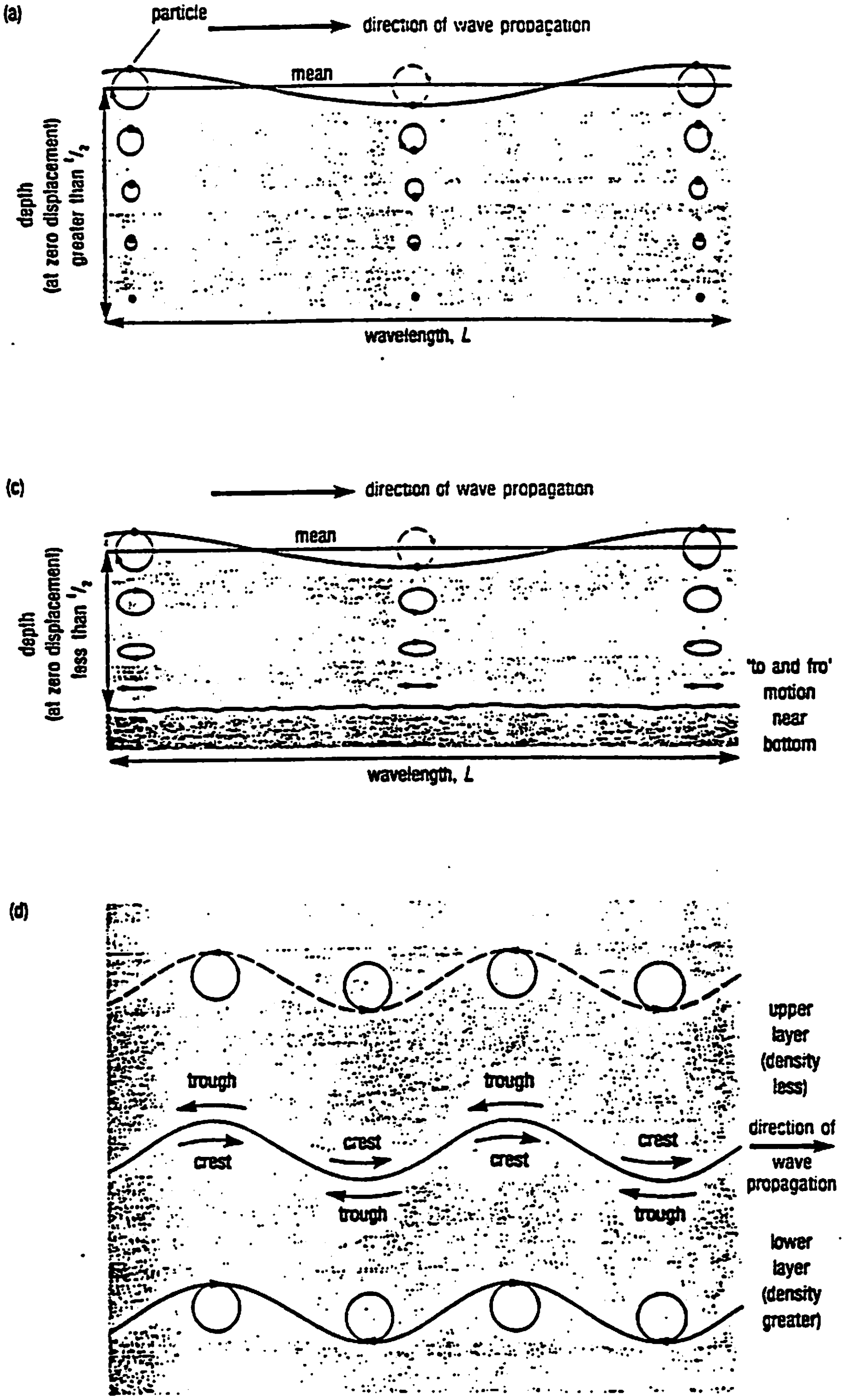


Figure 1.8(a) Particle motion in small deep-water waves, showing exponential decrease of the diameters of the orbital paths with depth.

(b) Particle motion in larger deep-water waves, showing drift.

(c) Particle motion in shallow-water waves, showing progressive flattening of the orbits near the sea-bed.

(d) Particle motions in internal waves. The orbits will only be truly circular if the layers are thick enough (i.e. greater than half the wavelength). The orbital diameters decrease with distance from the interface, as in the case of surface waves.

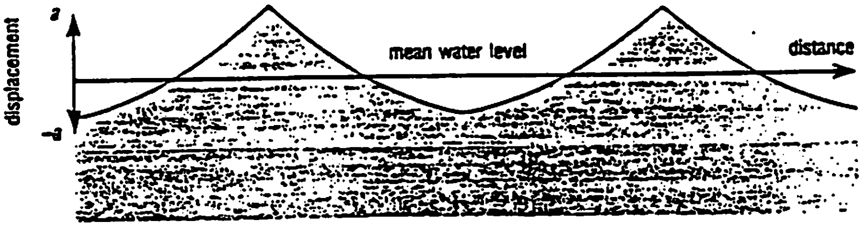


Figure 1.7 Vertical profile of two successive trochoidal waves.

(24) FISCHER, WAVE BREAKING

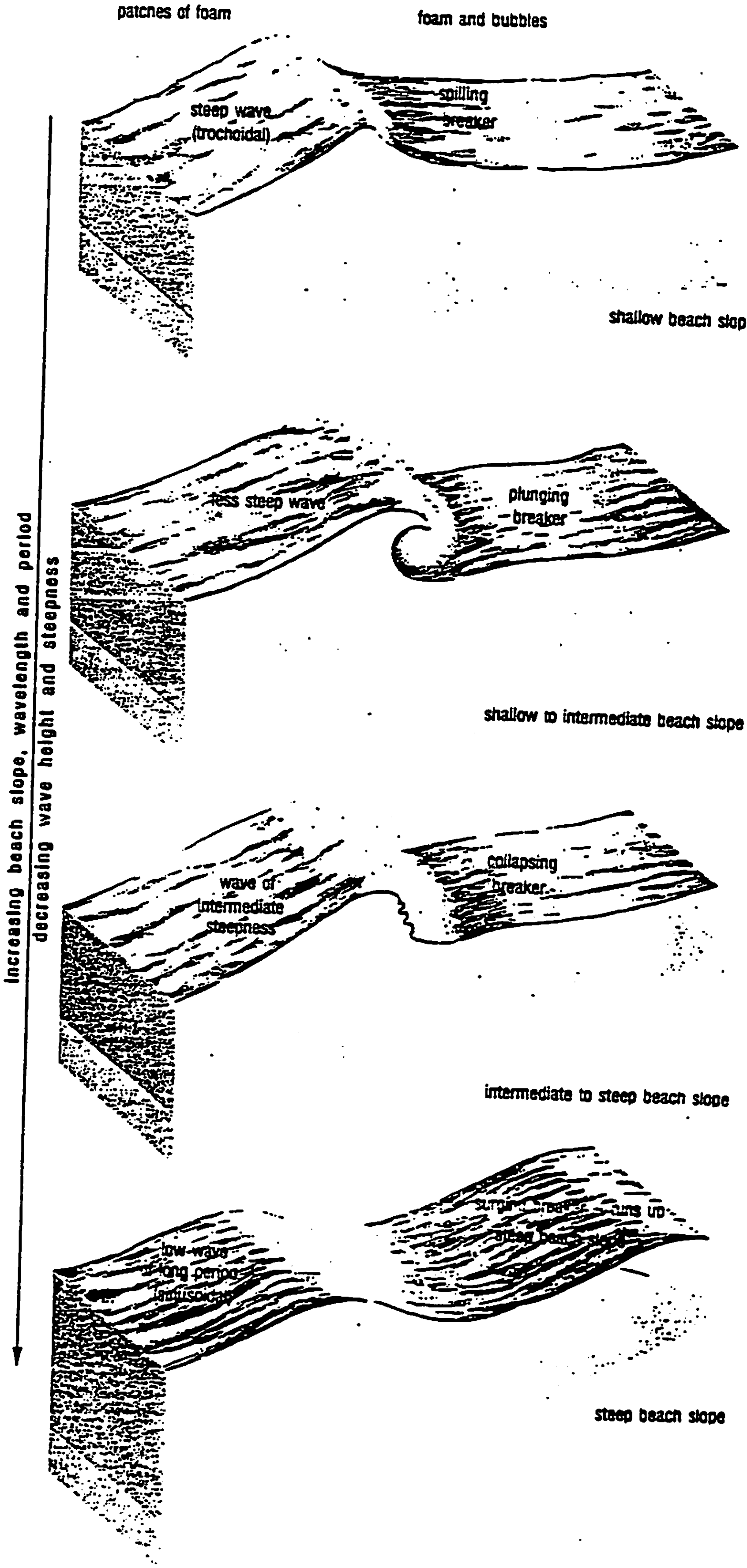


Figure 1.16 Four types of breaker and their relationships to beach slope, wave period, length, height and steepness.

FISCHER, WAVE BREAKING

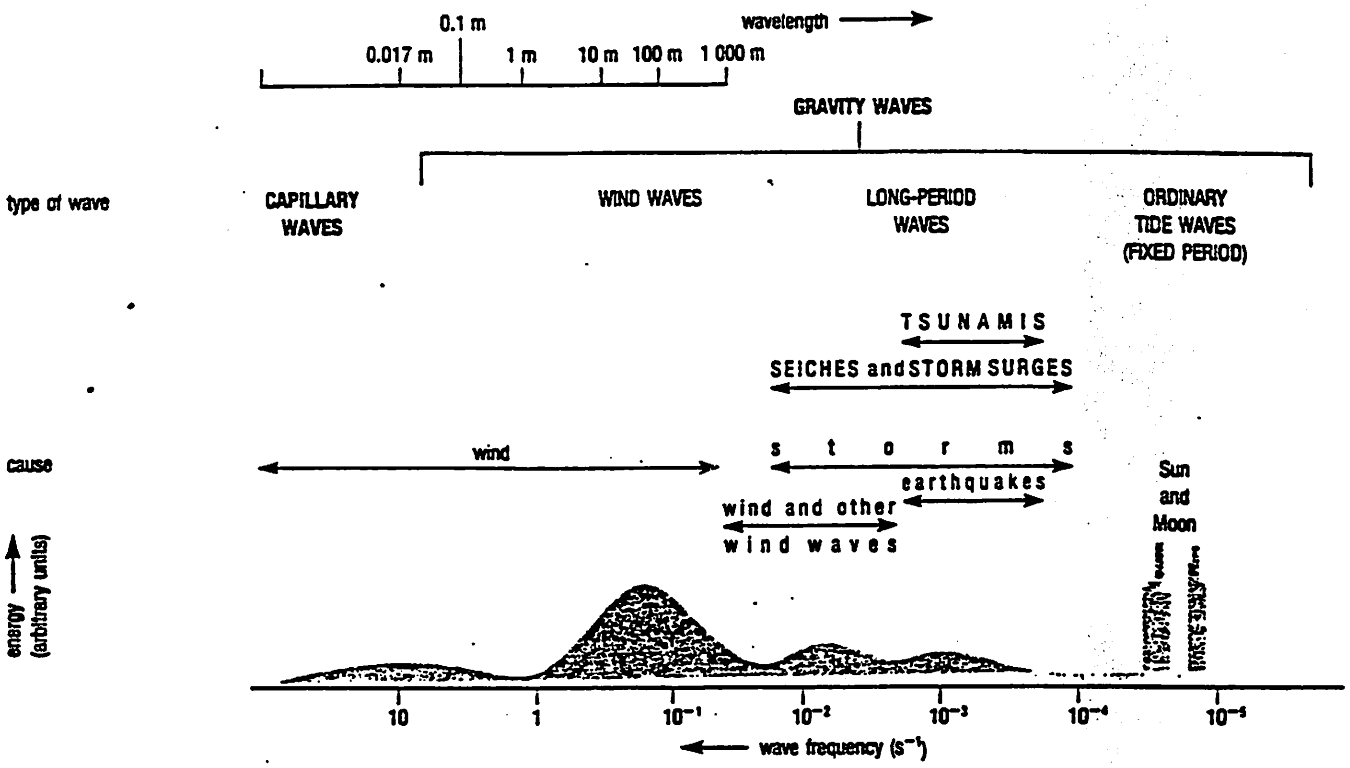


Figure 1.2 Types of surface waves, showing the relationships between wavelength, wave frequency, the nature of the displacing forces, and the relative amounts of energy in each type of wave. Unfamiliar terms will be explained later.

Movement of Grains by a Current in a Benthic Environment: Theoretical, Semi-Empirical, and Experimental Predictions.

a treatise by Jennifer A. Grier

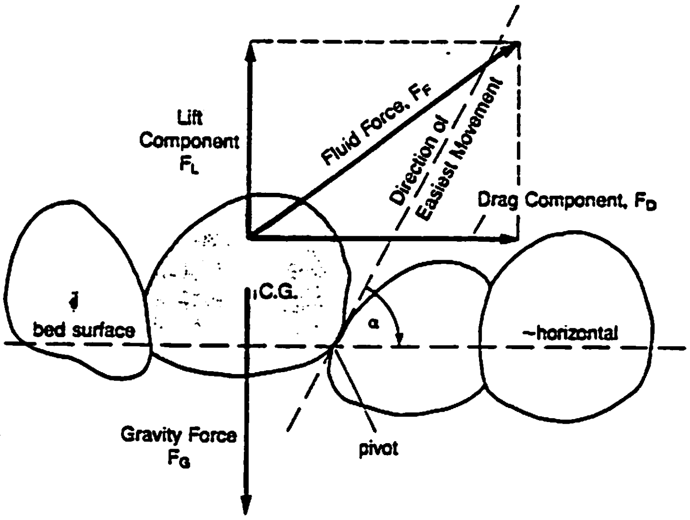


Fig. 1: Forces acting during fluid flow on a grain resting on a bed of similar grains.

The total fluid force (F_F, drag force and lift force) must be large enough to overcome gravity and frictional forces for grain movement to occur.

For the benthic case, the critical conditions for particle entrainment are determined experimentally.

In 1936, Shields (*not* of date farm fame) was able to obtain the threshold of grain motion from the following semi-empirical expression:

$$\frac{\rho_s q_s}{\rho S q} = \frac{10\ \tau_0 - \tau_{ocr}}{(\rho_s - \rho)\, g D}$$

q_s = sediment discharge per unit width
q = water discharge per unit width
ρ_s = sediment density
ρ = water density
S = axial gradient of channel
D = diameter of grain
$\tau_0 = \rho g h S$
h = water height

where sediment transport rate is proportional to the flow shear stress that is excess of the critical shear stress τ_{ocr}.

He obtained the following curve where dimensionless shear stress and grain Reynolds number are represented:

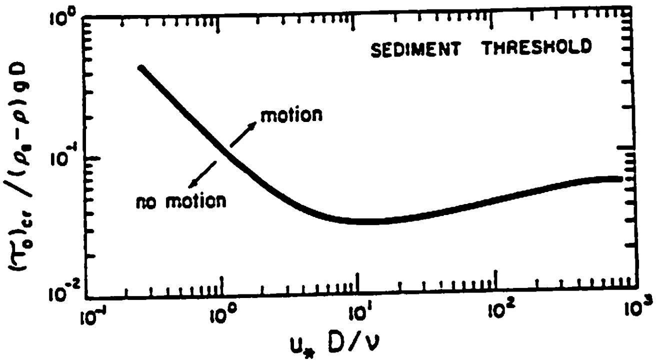
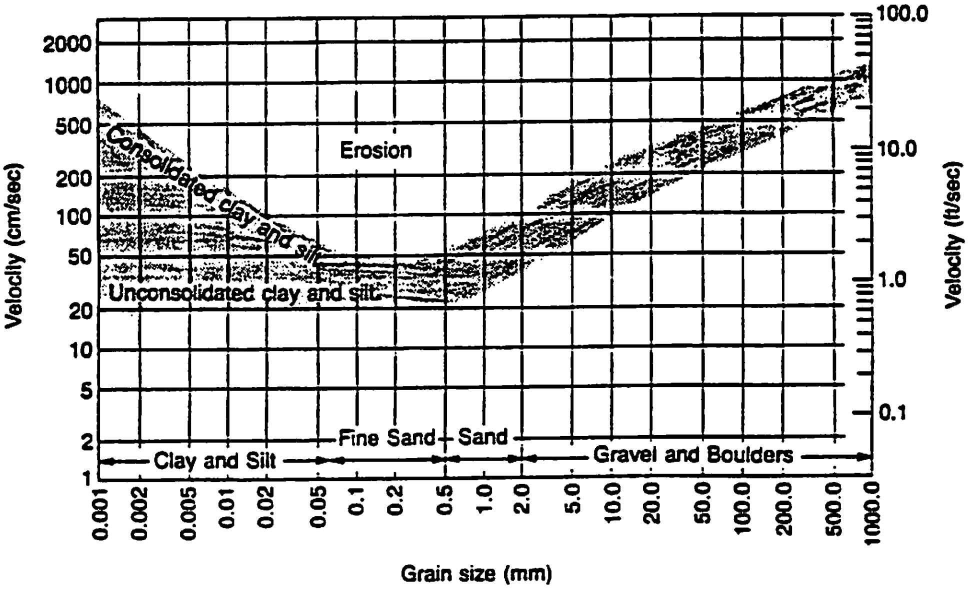


Fig. 2: Shields curve–the critical stress for the threshold of sediment motion for grains of diameter D.

The Shields curve is widely applicable to benthic transport situations but is difficult to interpret. More easily interpreted, but more limited, is the Hjulstrom diagram. This illustrates a direct relationship between current velocity and grain size.



Hjulstrôm's diagram, as modified by Sundborg, showing the critical current velocity required to move quartz grains on a plane bed at a water depth of 1 m. The shaded area indicates the scatter of experimental data, and the increased width of this area in the finer grain sizes shows the effect of sediment cohesion and consolidation on the critical velocity required for sediment entrainment.

assisted and typed by: Babs

Fig. 1. The Grunion, *Leuresthes tenuis*. Male, length 5¾ inches, taken April 16, 1919, at Long Beach, California.

Reprinted from *Fish Bull. No. 3*:2-29 (1919)

THE SPAWNING OF THE GRUNION.

(*Leuresthes tenuis.*)*

By Will F. Thompson, assisted by Julia Bell Thompson.

On moonlit nights during the high tides of March, April, May and June, a small smelt comes in on the long sandy beaches of California. It comes in with the sweep of the water up the beach as the waves break, and lies for a moment glittering in the faint light, then squirms and flops back into the wash of the next wave. Along the whole magnificent sweep of broad sandy shore at Long Beach, crowds of people gather to pick up these fish, by the light of the moon, and of bonfires, and of flash-lights. Some content themselves with picking up the stranded fish; others utilize wire screens, or even portions of beach seines, catching the smelt as they venture inshore. The fish they obtain are less than the length of one's hand, slender, with a broad lateral stripe, and very plainly of the smelt family. At Long Beach no name other than "grunion" is ever heard, although one gleans from scientific works such names as "silver-sides" and "little-smelt." Those who gather this "grunion" know that it comes in to spawn its eggs, but of the marvelous story that lies ready to discovery, they know not a whit. The crowds of bathers who follow in their footsteps on succeeding days, little think that four inches below their feet is unfolding one of the really remarkable stories in the annals of natural history.

Surely the grunion has a purpose in thus venturing out of its native element, to lay its eggs in the sand. In some way the act must serve the species, must aid it in its survival. It must escape its enemies, or obtain favorable conditions for development. Other smelts lay their eggs very differently, attached to the rocks or the bottom of the ocean by slender stalks or filaments. Many species migrate into brackish or even fresh water to spawn, while other genera or species are entirely confined to fresh water. Even in species apparently closely related, the spawning habits have become diverse, perhaps under the pressure of the struggle for survival. Fish, smelts and others, lay their eggs in every conceivable marine locality where suitable conditions may be obtained, but it remains for the "grunion" to utilize what is practically dry land.

For that is actually what it is doing when it ventures inshore as far as the high tides will carry it. The eggs are laid in the sand as far down as the fish is able to bury them, and far above the level of the average tide. The way in which it does this, the history of the eggs in the sand, and the story of their escape are interest-compelling.

The Spawning Run.

The grunion comes the second, third, and fourth nights after the full of the moon, according to popular tradition; therefore but once a month and shortly after the highest tides which accompany the full moon. The tides are then highest at about nine o'clock (ten o'clock according to summer time). Shortly before the tide is farthest in, the grunion may be taken with a beach seine placed athwart the wash of the waves. At the same time, occasional fish may be picked up on the beach as they are left exposed at the highest point reached by the waves. Very shortly after the time of the highest tide, and when the moon is well up above the horizon the real run commences, and for an hour or more fish may be found in numbers, especially where there is a light run-off or curve in the beach which produces a swirl in the wash of the waves. Occasionally thousands of fish are within sight at one time. The run diminishes gradually, and finally stops. Our first observations on this run were in April of 1919, on the fifteenth when the moon was full. The first fish were taken on the sixteenth and the last on the night of the eighteenth, thus confirming in a measure the popular belief of the crowds who gather expectantly at the proper time, as given by Mr. J. B. Joplin of Santa Ana, who says, "Three months during the year, usually March, April, and May, on the second, third, and fourth nights after the full moon, at full tide, great schools of them come out in the breakers • • •."

The schools of fish which come in seem to work back and forth on the edge of the beach, and they may be taken some time before they commence to run up the beach. By the use of a short piece of seine, with cork line at the top and lead line below, numbers of fish were taken before high tide time. When the waves washed up the beach the net was lifted, but when the water returned in a torrent the net was dropped and held firmly against the bottom so as to make a manner of bag into which the smelt were carried. Two men captured by this method a bucketful of fish in an hour's work. It seemed possible to do as well by picking up the fish on the beach, but so many people were doing this as to render it very difficult.

---

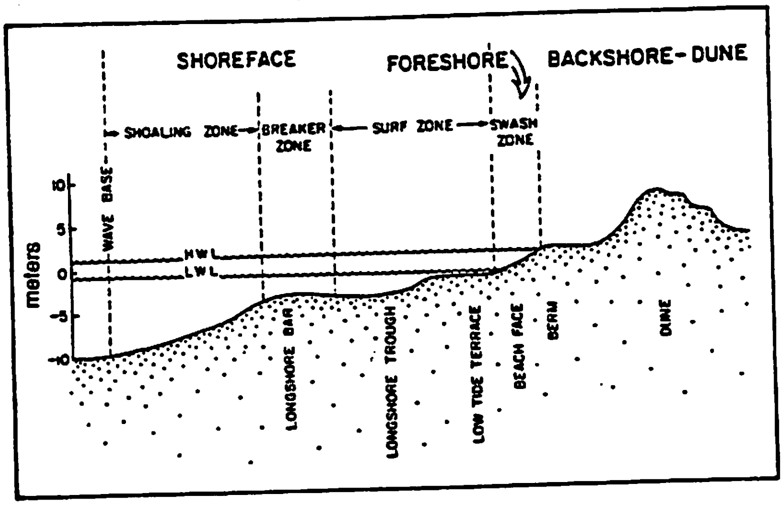
*However, we also observed a spawning run in June, the fourth during the season.

Longshore Currents and Grain Transfer:
Creating a River of Sand

Produced and Directed by Barbara Cohen and Jennifer Grier

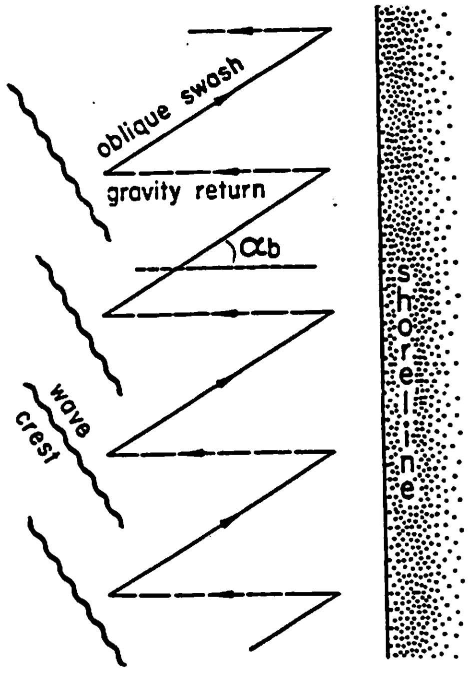
Some potentially useless information:

fig. 1



__Shoaling Zone:__ initial shallowing of the shore, where wavelength and wave velocity decrease, and wave height increases.
__Breaker Zone:__ where waves steepen to the point where orbital velocity exceeds wave velocity and the wave breaks.
__Surf Zone:__ breaking waves generate turbulence that throws sediment into suspension and creates a bore wave that transports this sediment landward in this zone. The width of this zone is governed by the beach slope: the steeper the beach face, the narrower the surf zone.
__Swash Zone:__ a rapid, very shallow swash moves up the beach, followed almost immediately by a backwash flow down the beach. Sand here moves in a zigzag motion:

fig. 2

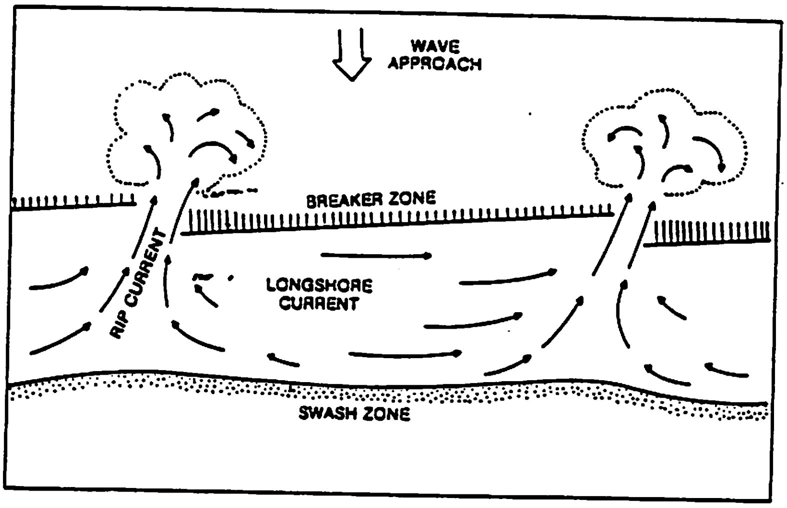


The zigzag motion of the sediment along a steep beach face under the wave swash. The incoming wave swash drives the sand up the beach at an oblique angle and the return gravity flow washes it back to its original level.

Cohen & Grier Longshore Currents: *Creating a River of Sand*

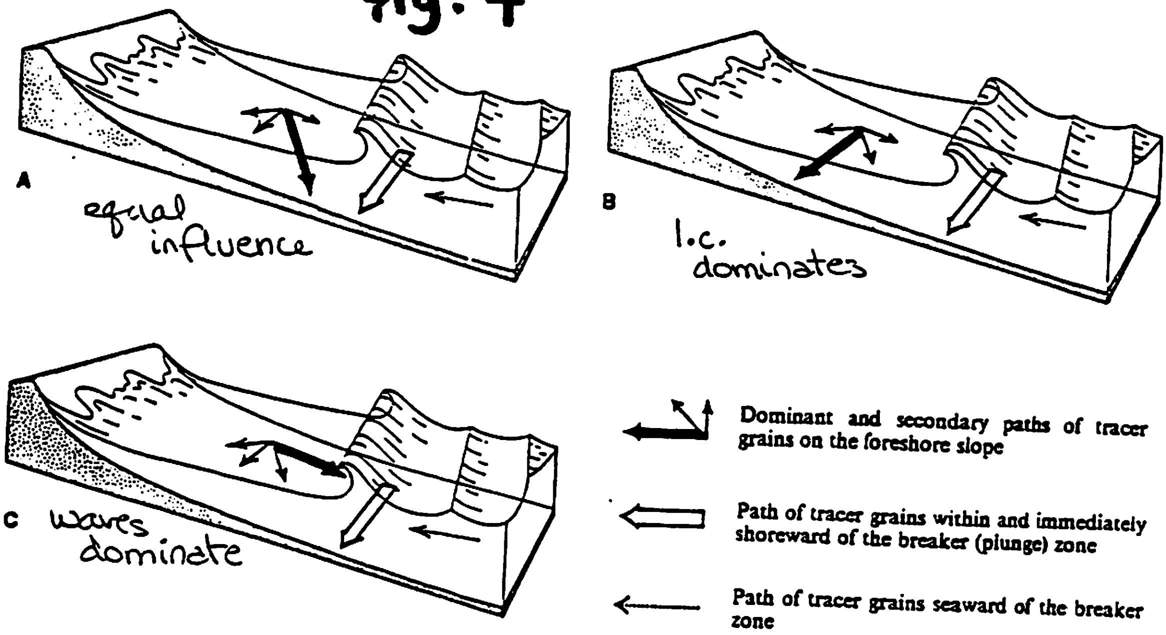
As breakers and winds pile water up against the beach, they not only create bidirectional translation waves that move back and forth in the swash zone, but they also create two types of unidirectional currents. ***Longshore currents*** are generated when waves that approach the shore at an angle break, and a portion of the translation wave is deflected laterally parallel to the shore. These currents move parallel to shore following longshore troughs (the ridge-and-runnel system) in the lower surf zone. As incoming waves pile up water and block its return seaward, the longshore currents carry water to a break between sand bar, where it flows outward in a ***rip current*** (see also Chabot and Hoppa, this book).

fig. 3



Both wave action and longshore currents move sand along beaches. The direction of net sand transport in the longshore current is, obviously, parallel to the beach in the direction of current flow. This takes place in the surf zone runnels. In the swash zone, however, motion is more complex, and depends on the relative intensities of wave motion vs. longshore currents.

fig. 4

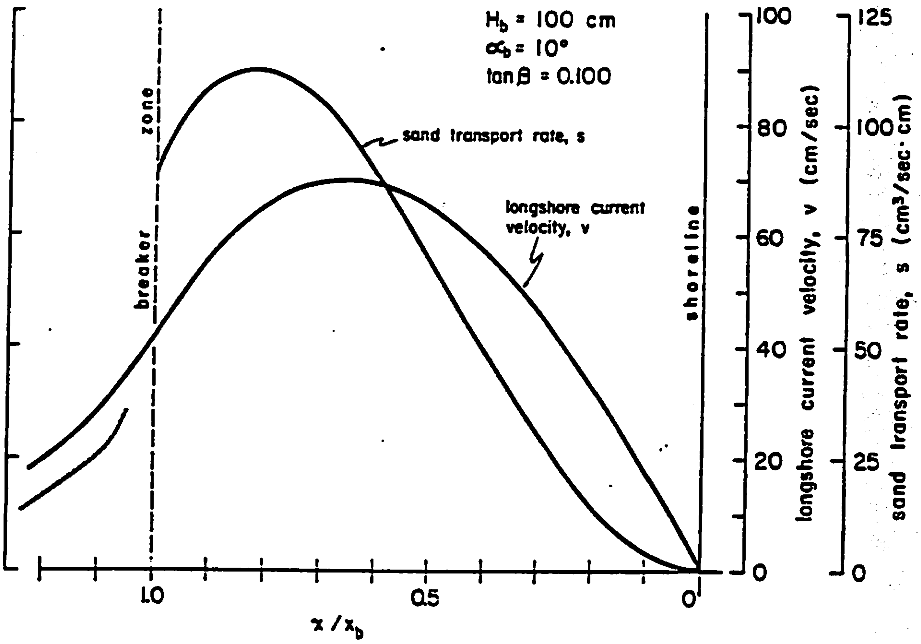


Transport of sand on beaches by longshore currents under different surf conditions. A. Sediment movement under surf conditions where the longshore current and the wave motion exert an equal influence. B. Sediment grain motion under conditions of a high-velocity longshore current (velocity >60 cm/sec). C. Sediment grain motion where the longshore current velocity is <30 cm/sec. and the onshore-offshore motion of waves controls the sediment grain transport.

The wave effect includes, but is not limited to, the velocity of the waves. Longshore current velocity is related to the incoming wave height and the approach angle. There is no accepted all-inclusive theory, though, that allows prediction of current velocity. Empirical relations try to fit observed data using variables such as distance from shore to breaking point, water depth, cross-sectional area of the breaking wave, friction factors, energy considerations, and various fudge factors.

The wave effects and longshore currents work together in transporting sand down a beach to create coastline structures like spits. The sand transport rate can be related to the longshore current rate in this fascinating diagram:

fig. 5



The distribution of the longshore sand transport across the width of the nearshore obtained by having the local transport proportional to the product of the bottom stress exerted by the waves and the local value of the longshore current velocity.

References:

Fisher & Dolan, ed. Beach Processes and Coastal Hydrodynamics. 1977

Boggs. Principles of Sedimentology and Stratigraphy. 1984

Komar. Beach Processes and Sedimentation. 1976

Stanley & Swift, ed. Marine Sediment Transport and Environmental Management. 1976

Let's Dye Together: *an experiment in nearshore transport*

The two modes of transport in the nearshore environment, zigzag motion in the swash zone and channel transport in the longshore current, will be investigated at Silver Strand Beach. This beach was featured in the classic "The Beach: A River of Sand" for its stunning ability to set up extensive longshore currents (largely because it has no major headlands or promontories to bend waves or block transfer, and there are no nearby submarine canyons to suck sand seaward).

First, grain motion in the swash zone will be observed. For detailed study, the available sand is used because it is the correct grain size for transport under the particular beach conditions. However, dying beach sand *in situ* and rereleasing it is a complicated and messy process. Here, we'll use the colored gravel more commonly seen in smaller marine environments (i.e. fishtanks). Because this is not the optimal grain size for the beach, its motion in the swash zone could turn out to be completely random, but we'll try it anyway. By watching the gravel in the swash zone, we'll see the zigzag motion and the direction of net transport will give a sense of the relative strengths of the waves and longshore currents (see fig. 4).

Second, the actual longshore current velocity will be measured. Dye tracers are used in fluid flow experiments like stream gauging to determine not only velocity, but also discharge rates and volumes. We will use the nontoxic fluorescent dye Rhodamine-WT to visually watch the longshore flow and determine its velocity until the dye dissipates. Note that the dye is nontoxic and when extensively mixed, is completely harmless. However, beware of the concentrated dye as it may permanently stain. The longshore current is set up in the breaker zone, and the distance to this zone is determined by the wave energy and amplitude. We may be able to see the dye while standing on shore. However, this distance may be substantially offshore (especially if there are storms over the sea) and we will probably need to wade a fair distance out into the ocean. Beware of rip currents!! Be sure to swim PARALLEL to shore if caught in one, for these are usually rather narrow zones.

Silver Strand Beach: A River of Sand?

convenient tear-out data sheet

Name ____

1) While Jen and Barb attempt to understand dye procedures, you (yes, YOU) can get a feel for the relative importance of the longshore current vs. the influence of waves (refer back to fig. 4). Get a group of 3-4 of your closest friends together and grab some colored fishbowl gravel. Put some in the swash zone and watch the net motion of the grains. Try placing the grains at different distances from the shore and see how this affects the motion. Record your observations here:

Did the net motion appear to be downshore or out to sea? ____________________

2) Get Wet and Dye: If this works, we'll obtain a longshore current velocity using the complex equation distance / time = velocity (ooh, ahh). Spread out down the beach in pairs or threes. While one person wades out to the surf zone and yells when they see the dye, another will stand on shore and record the distance and time.

Distance from injection point: ______________________________________

Time of arrival: ________________

comments :

3) Poll Question: what is your favorite color?

Left Blank

RIP CURRENTS

Nancy Chabot and Greg Hoppa

As waves break upon a coastline, long shore currents develop that eventually turn back towards the sea, forming a rip current. These rip currents are narrow near the coast, but once past the breakers, they disperse to form a rip head. Rip currents serve as a means to balance the water transported to the beach by the breakers.

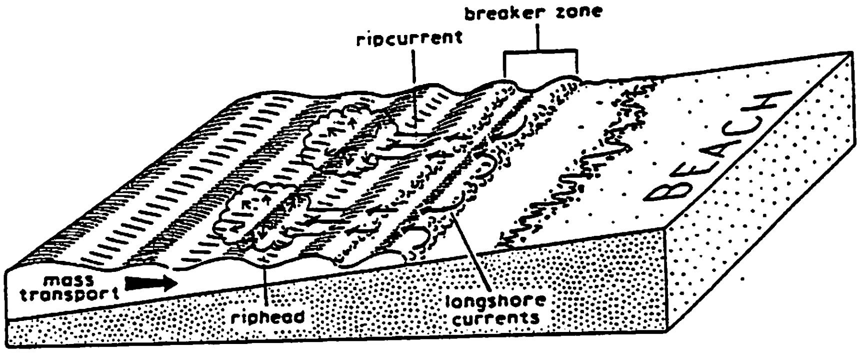


Figure 1: General location and behavior of the rip current and rip head; Pethick, p.38.

The outgoing rip currents pass through the breaker zone through the troughs formed by edge waves. Edge waves are stationary waves which are perpendicular to the incoming waves but with the same period, thus causing regular wave height variations. Typically rip currents move at a speed of 1 to 2 m/s. Waves with a large amount of incident energy produce a few concentrated rip currents, while less energetic waves form a larger number of weaker rip current systems. When waves approach the beach at an angle, the resulting rip currents are deflected at a diagonal instead of returning straight back to the ocean.

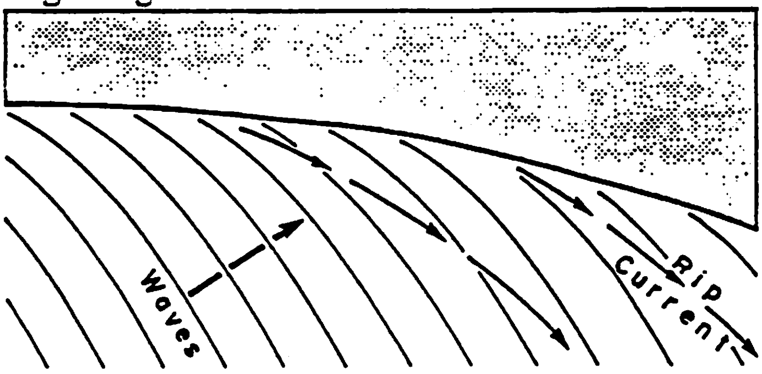


Figure 2: The resulting rip current from angled incident waves; Bird, p.18.

While rip currents provide a means to return water to the ocean, they can also effect beach formations. Rip currents may cut channels in the sea floor as they pass through the breakers. These channels can have a spacing ranging from 15 to 1500 meters. During high tide these channels are submerged, at mid tide the rip currents reach their maximum velocity, and during low tide the channels are exposed. Similarly, these currents can cut through off shore bars. Once these channels through the bars are established they are maintained by the rip currents, regardless of the location of the edge waves. Finally rip currents can form giant cusps, also known as sand waves or transverse bars. Once these cusps are formed they are stable due to the balance between the rip current and the long shore current that develops.

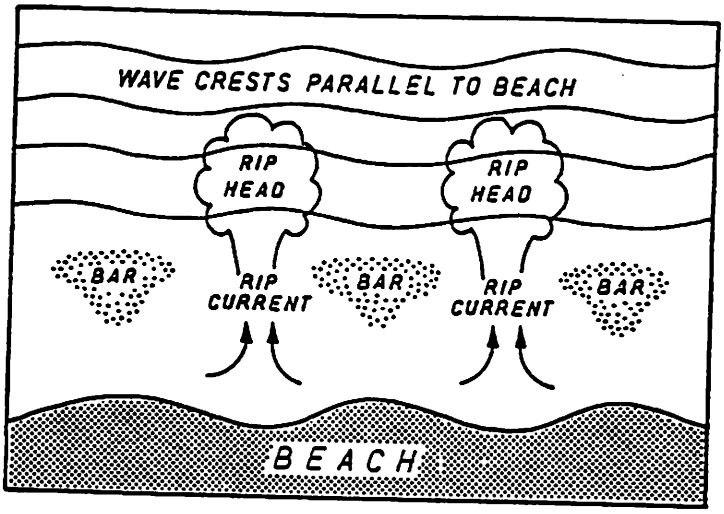


Figure 3: The interaction of a rip current system with an off shore bar; Pethick, p.115.

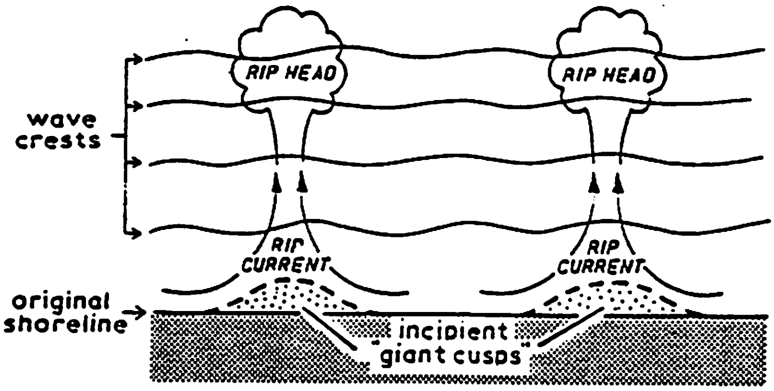


Figure 4: The formation of giant cusps due to rip currents; Pethick, p.116.

CHABOT & HOPPA, RIP CURRENTS

Rip currents can be extremely dangerous for an unexperienced swimmer. Many lifeguards along California beaches mark the daily location of the rip currents to warn swimmers. Since rip currents are narrow, a swimmer should swim parallel to the shore if they are ever caught by one. However, many experienced surfers use rip currents to pass quickly through the breakers.

REFERENCES

Bird, Eric C. F., Coasts, Basil Blackwell Inc., New York, NY, 1984, p.16-19, 138-139, 146-147.

Fox, William T., At the Sea's Edge, Prentice-Hall, Englewwod Cliffs, NJ, 1983, p.142-143.

Hansom, J. D., Coasts, Cambridge University Press, Cambridge, England, 1988, p.24-25.

Pethick, John, An Introduction to Coastal Geomorphology, E. Arnold, Baltimore, MD, 1984, p.38-39, 114-116.

Beach Profiles

Betty Pierazzo and Janet McLarty

Beaches are accumulations of unconsolidated sediment (sand, shingle, cobbles, and so forth) extending shoreward from the mean low-tide line to some physiographic change such as a sea cliff or dune field, or to the point where permanent vegetation is established. Under this definition, a beach does not include any portion that is permanently under water. However, it is in this underwater portion near the beach that the important processes of beach formation occur. So, in this report we extend the term "beach" to include the underwater zone where sediment transport by surface waves is important, i.e. up to depths varying from 10 to 20 meters (this is closer to the definition of "littoral" than beach). Under this assumption, fig. 1 reports the general terminology used to describe the beach profile.

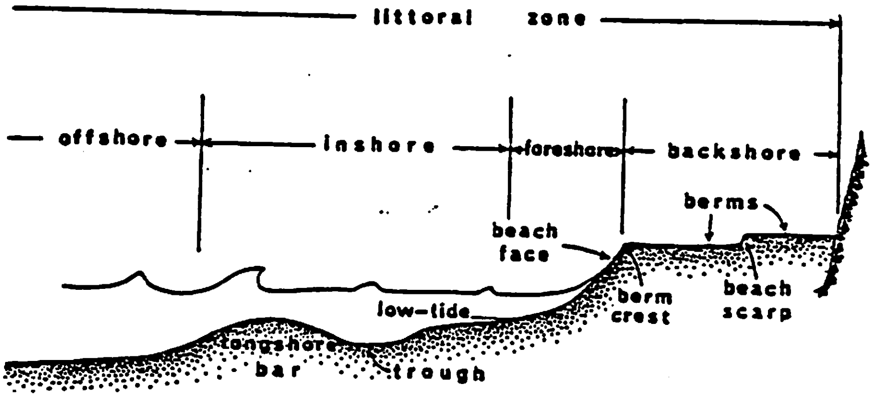


Figure 1

Glossary

Backshore: The zone of the beach profile extending landward from the sloping foreshore to the point of development of vegetation or change in physiography (sea cliff, dune field, and so on).

Beach face: The sloping section of the beach profile below the berm which is normally exposed to the action of the wave swash.

Beach scarp: An almost vertical escarpment notched into the beach profile by wave erosion. Its height is commonly less than a meter, although higher examples are found.

Berm (beach berm): A nearly horizontal portion of the beach or backshore formed by the deposition of sediment by the receding waves. Some beaches have more than one berm, while others have none.

Berm crest (berm edge): The seaward limit of a berm.

Foreshore: The sloping portion of the beach profile lying between a berm crest (or in the absence of a berm crest, the upper limit of wave swash at high tide) and the low-water mark of the backrush of the wave swash at low tide. This term is often nearly synonymous with the beach face but is commonly more inclusive, containing also some of the flat portion of the beach profile below the beach face.

Inshore: The zone of the beach profile extending seaward from the foreshore to just beyond the breaker zone.

Littoral: The area across the beach and into the water to a depth at which the sediment is less actively transported by surface waves.

Longshore bar: A ridge of sand running roughly parallel to the shoreline. It may become exposed at low tide. At times there may be a series of such ridges parallel to one another but at different water depths.

Longshore trough: An elongated depression extending parallel to the shoreline and any longshore bars that are present. There may be a series at different water depths.

Offshore: The comparatively flat portion of the beach profile extending seaward from beyond the breaker zone (the inshore) to the edge of the continental shelf. This term is also used to refer to the water and waves seaward of the nearshore zone.

Shore: The strip of ground bordering any body of water, whether the ground is rock or loose sediment. If it is unconsolidated sediment, then *shore* becomes synonymous with *beach* used in its restricted sense.

Shoreline: The line of demarcation between the water and the exposed beach.

Profile Changes

The first thing that must be remarked about the beach profile is its dynamic personality. While an equilibrium beach profile may be achieved in a laboratory tank where a constant wave input is maintained, on natural beaches the changing waves give rise to an ever-varying equilibrium which the beach profile attempts to achieve but seldom does.

The profile, or cross-section, of a beach at any given time is determined by several factors. The most important are: *weather*, *tides* and *winds*.

Weather: The weather situation, i.e. the occurrence of storms, is probably the most important factor in characterizing the beach profile. It has been seen that the shift of sand can be correlated with wave activity. During storm conditions (large wave activity), sand is shifted offshore from the berm to the bars, while during smaller swell wave conditions the reverse is true, and sand is shifted back onshore to the berm. The terminology *summer* and *winter profile* is a consequence of the fact that such shifts in the profile were first observed off the west coast of the United States, where storm waves are typical of the winter and longer-period swell waves typical of the summer. A more convenient terminology is *storm profile* instead of winter profile, and *swell profile* instead of summer profile.

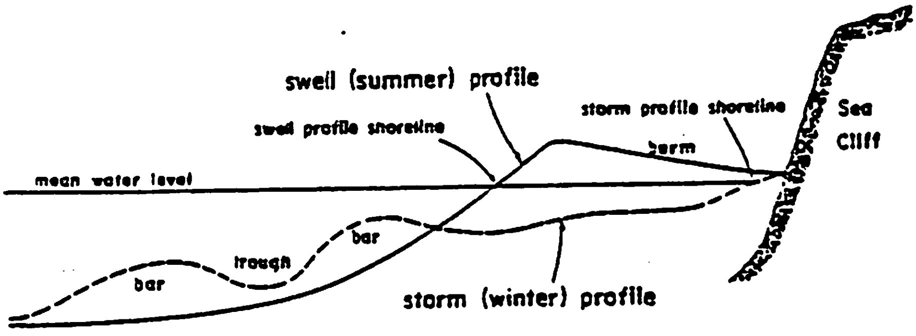


Fig 2 The storm beach profile with bars versus the profile with a pronounced berm that occurs under swell wave conditions.

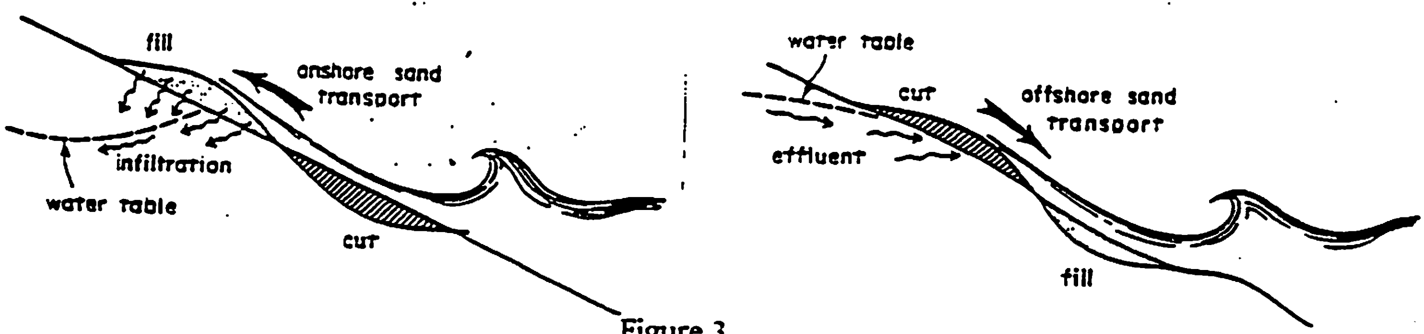
The main distinction between the *storm* and the *swell profiles* (see fig. 2), is an overall smaller profile slope in the storm profile. The *swell profile* is characterized by a wide berm and a smooth offshore profile with no bars except perhaps in relatively deep water.
In contrast, the *storm profile* has almost no berm, the sand having shifted offshore to form a series of bars parallel to the shoreline.

The onshore-offshore shift of sand associated with profile changes from storm to swell conditions is generally correlated with the wave steepness H_∞/L_∞ (the ratio of the deep-water wave height H_∞ to the deep-water wave length L_∞), where $L_\infty=(g/2\pi)T^2$. Storm waves have high steepness values, because of both their greater heights and shorter periods, while long swell waves have low steepness values. Several authors have discussed the value of the "critical steepness" governing the switch from swell (summer) profiles (for smaller values of steepness) to storm (winter) profiles (for bigger values of steepness), without reaching an agreement. The main problem is that the understanding of the critical wave steepness is still incomplete. Dependencies on wave height and sediment grain size, as well as on the wave period and time of wave travel between the break point and the limit of swash, have been found by several authors. Various experiments clearly demonstrate that an increase in the wave height during storm conditions leads to the storm profile with an offshore shift of sand. The dependence on the wave period is however less clear.

In addition to onshore-offshore shifts of sand, longshore sand movements may also affect the beach profiles. Within pocket beaches, a shift in the wave direction will reorient the shoreline such that it retreats in the updrift side and advances in the downdrift side of the pocket. This is what happens at Boomer Beach, La Jolla, where within 24 hours after a change in wave direction the sand shifts to the opposite end of the pocket, up to a 3 m. thickness of sand disappearing from the updrift end.

Tides: Hourly changes resulting from the rising and falling water level of the tides and longer-term effects due to the differences in the range of spring (new and full Moon) and neap (1st and 3rd quarter) tides can appear on beach profiles. This effect is much smaller than the wave effect; however, on southern California beaches. The beach surface a few meters above the mean tide level reaches its minimum elevation a few days after spring tide and its maximum elevation following the neap tide.

Daily tidal cycles coupled to the water table produce some changes in the profile, too. During a flood, tide water from the wave swash is lost by percolation into the beach and the backwash is weaker than the shoreward swash. Just the opposite is true during the ebb tide, since water is added to the backwash (see fig. 3).



(a) Flood Tide

(b) Ebb Tide

Figure 3
Water table effects on the cut an fill of the beach profile during flood and ebb tides

Winds: Onshore winds cause a landward movement of the surface waters which must be compensated by a seaward current at depth. The reverse is true with offshore winds, the near-bottom currents being onshore. These currents will be a factor in the onshore-offshore transport of sediments and therefore have a bearing on the response of the beach profile. It is however quite difficult to separate the importance of any wind-induced currents from the effects that winds have on the waves, and therefore indirectly on the beaches. For example, with strong onshore winds steep waves may be locally generated which have a destructive influence on the beach profile in addition to the reaction of the beach to the wind-induced current that also tend to cut back the beach.

References

Bird, E. C. F. 1969. *An Introduction to Systematic Geomorphology volume four COASTS*. The M.I.T. Press, Cambridge, Massachusetts.

Komar, Paul D. 1976. *Beach Processes and Sedimentation*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Small Sedimentary Structures

David A. Wood, Jr.

Swash Marks:

As wave swashes move up the beach, sand and debris are caught by the surface tension of the water. When a swash reaches its greatest advance, the sand and debris are deposited in the shape of the leading edge of the wave. The deposits are ~1-2 mm high.

Swash marks are wavy and generally irregularly shaped. Two reasons for this are:

(1) Beach topography and the local wave height are variable. These affect the run-up distance of the swash. Over horizontal scales as small as ~1 dm, the maximum greatest advance can vary dramatically;

and, (2) Succeeding swashes obliterate portions of existing swash marks.

Swash marks form only on the upper part of the beach (above the water table). Below the water table level, the water does not pick up sand and debris as easily. Water percolating out of the beach face tends to wash away any existing marks.

V-swash marks are formed when a pebble (or other obstruction) deflects the backwash flow of the swash. Also called "current marks", these structures are created when the backwash excavates material surrounding the obstruction and deposits it further downslope.

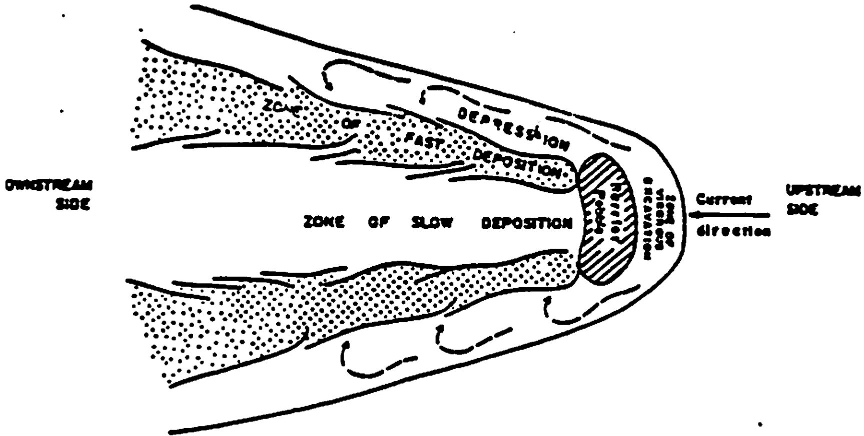
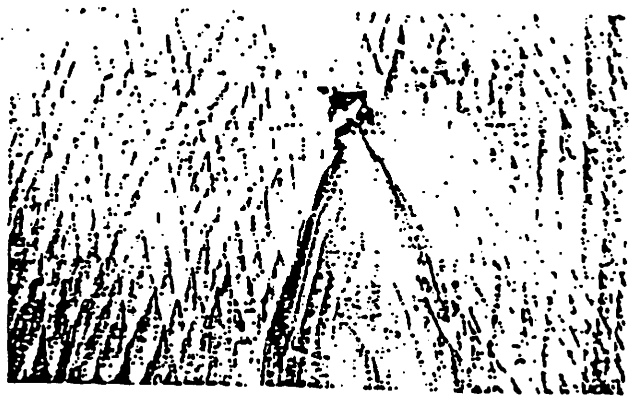


Figure 13-10 Zones of deposition (dotted) and erosion around a pebble caused by sheet flow, whether in a stream or in a backwash, producing a V-swash mark. [*From* Sengupta (1966)]



WOOD, STRUCTURES

Rhomboid Marks: (also called rhomboid ripple marks or rill marks)

Rhomboid marks range in size from 1 to 46 cm in length with the most common ones ranging from 3.75-13 cm long. The ratio of the long diagonal to the short diagonal varies from 2:1 to 5:1. The long diagonal is always found to be in the flow direction. Hoyt and Henry (1963) also found a direct correlation between the length to width ratio and the beach face slope.

Rhomboid marks are formed in the wave backwash. They occur on coarse-sand beaches but are most visible on finer-grained beaches. The backwask selectively sorts finer-grained, dark, heavy materials from lighter quartz grains. The lighter grains are thrown forward while the heavier minerals fill the hollows between these "tongues" of quartz. The separation of the light material from the dark material produces a distinctive color pattern.

There is no agreement on the mechanism for generating rhomboid. What seems to be required is a mechanism for deflecting the sheet flow from its natural course. The rhomboidal pattern is strongly reminiscent of interference patterns in waves.

One useful geologic application of rhomboid marks is to determine the slopes of ancient beach faces. By studying the geometries of the marks, geologists can learn something about the wave properties along ancient shorelines.

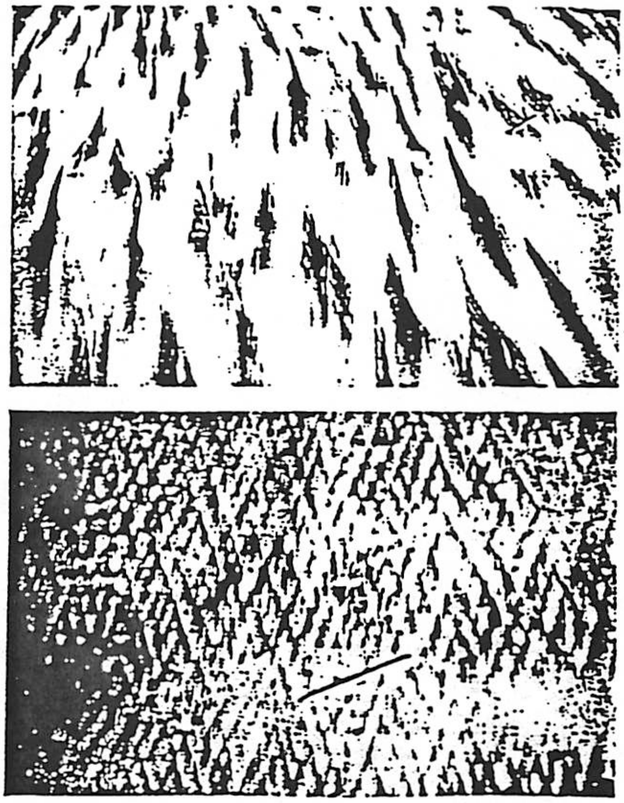


Figure 13-11 Examples of rhomboid marks.

WOOD, STRUCTURES

Ripples:

Backwash ripples are formed as a swash of water retreats from the beach. Their heights are generally very low; so the ripple index (ratio of length to height) range between 30-100. This is much larger than for other water-formed ripples.

Backwash ripples generally migrate downslope and are assymetrical. Their leading edges may be bisected by small rilles and may exhibit small-scale rhomboid marks. Concentrations of heavy, dark minerals behind a leading edge of quartz grains give the ripples a banded appearance.

Current ripples and oscillatory ripples tend to act at right angles to each other and they are known as "ladder-back ripples." Oscillatory ripples are produced by waves so their crests act parallel to the shoreline. Current ripples are generated by longshore currents and indicate flow in the longshore direction. In general, combinations of these ripples are produced and depending on the relative strengths of the waves and longshore currents, one or the other can dominate the ladderback pattern.

Oscillatory ripple marks found offshore of the breaker zone are sometimes found in assymetrical patterns. While it is not clear what these ripples are, Komar (1976) suggests they are an intermediate case of the current versus oscillatory ripples.

Figure 13-12 Low-amplitude backwash ripples, exposed at low tide on the beach face. Ocean is to left.

5-4 (48 m)

8-33 (98 m)

Figure 13-19 Ripple marks observed in bottom photographs in a transit across the Oregon continental shelf. Station numbers and water depths are given for each photo. [*From* Komar, Neudeck, and Kulm (1972)]

WOOD, STRUCTURES

Rill marks:

Rill marks are generally formed by water percolating and seeping from the beach face. The water can accumulate into small "capillary-like" structures called rills. As more water enters a rill, it grows. Smaller rills combine to form large rills.

Large rills look like small-scale braided streams. The "dendrite-like" features at the ends of a rill are drainage channels which always point in the downhill direction (usually seaward). Because rills resemble plant stems, early geologists mistook them for such.

Laminations:

Laminations are alternating layers of quartz and darker minerals that appear in a cross-section of the beach and sand deposits. Each lamination consists of coarse quartz near the top and finer material at the base. This gives the cross-section a banded appearance. Over time, the fine-grained material falls to the bottom layer and displaces the quartz to the top.

Cross-laminations are the result of migrating sedimentary structures. Instead of having vertical layers, the layers are bent; occasionally crossing one another.

Sand Domes:

When large waves hit part of a beach that was originally dry, the water seeps into the sand and pockets of air get trapped. The air tries to force its way through the wet sand layer which causes the layer to become bowed over the air pocket. The bowing of the wet sand layer gives the domed shaped appearance to the sand.

References:

Hoyt, J. H. and Henry, V. J. (1963), Rhomboid Ripple Mark, Indicator of Current Direction and Environment, *J. Sediment. Petrol.*, 33, 604-608

Komar, Paul D. (1976), Beach Processes and Sedimentation, Prentice Hall, Inc., Englewood Cliffs, New Jersey

WOOD, STRUCTURES

Figure 13-13 Rill marks.

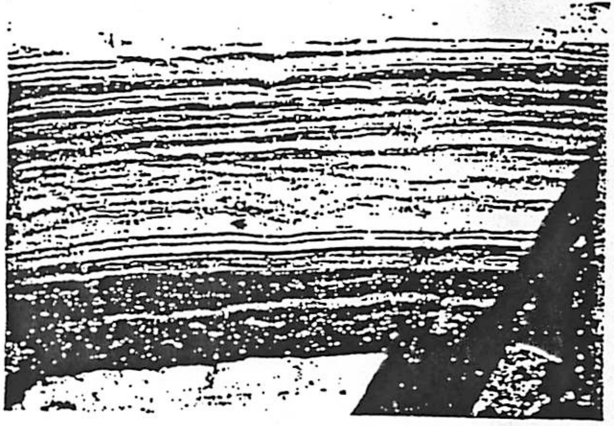


Figure 13-14 Laminations and heavy mineral concentrate shown in a trench cut into beach face. Shovel at right for scale.

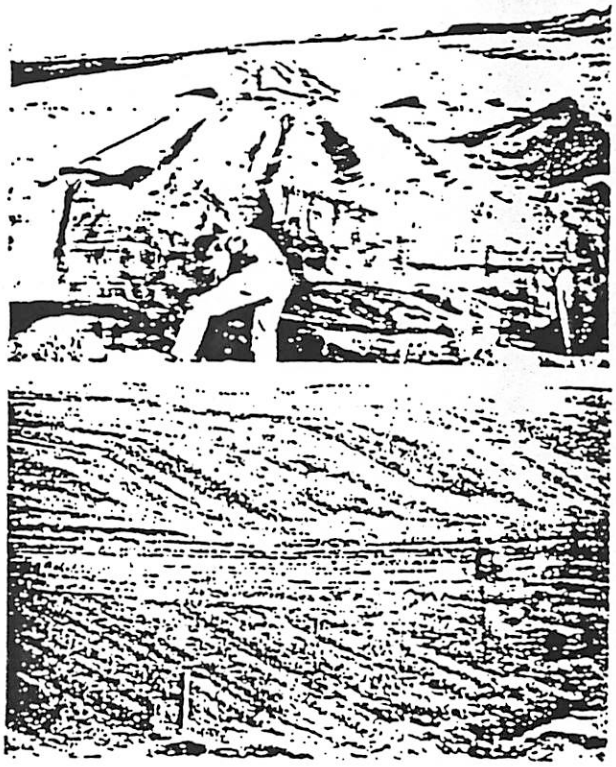


Figure 13-16 Internal cross-stratification, dipping shoreward, produced by the landward migration of a bar. [*From* Hayes (1972)]

Nolan, Heavy Mineral Laminae

(47)

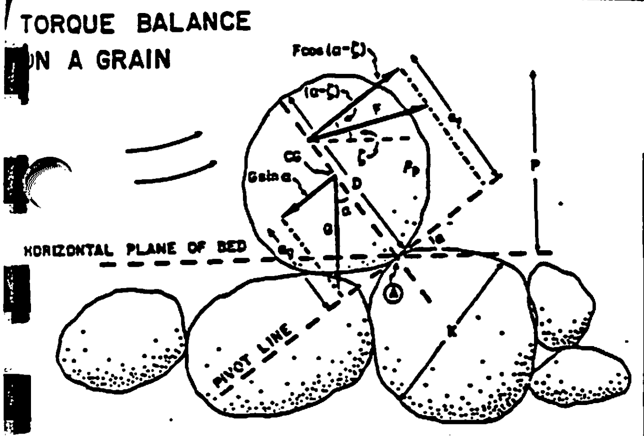


Figure 3 Definition diagram for calculating the initiation of grain motion on a horizontal bed. A subspherical grain of diameter D and density ρ_p, protruding above the bed a distance P, must pivot about point A on a downflow grain of diameter K. A fluid force vector F, representing both drag and lift forces, acts at a distance a_f away from a pivot line through A and at an angle ζ from the horizontal. A grain weight vector G acts through the grain center of gravity CG at a distance a_g away from the pivot line. At the moment of entrainment, the fluid torque must be greater than the resisting torque.

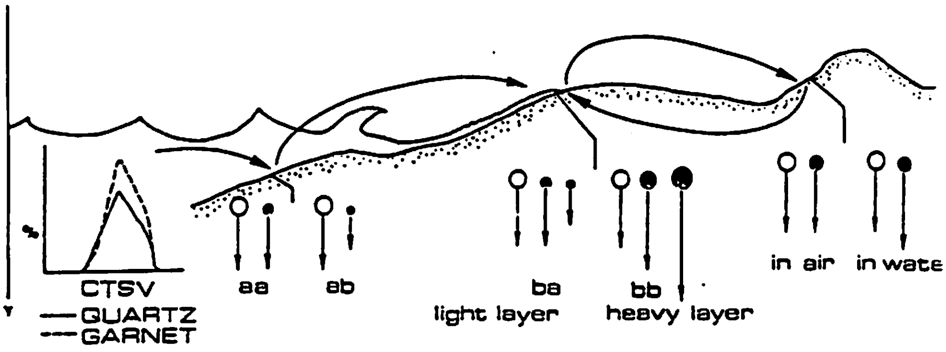


FIG. 14.—Schematic heavy and light mineral size budget for Presque Isle beach.

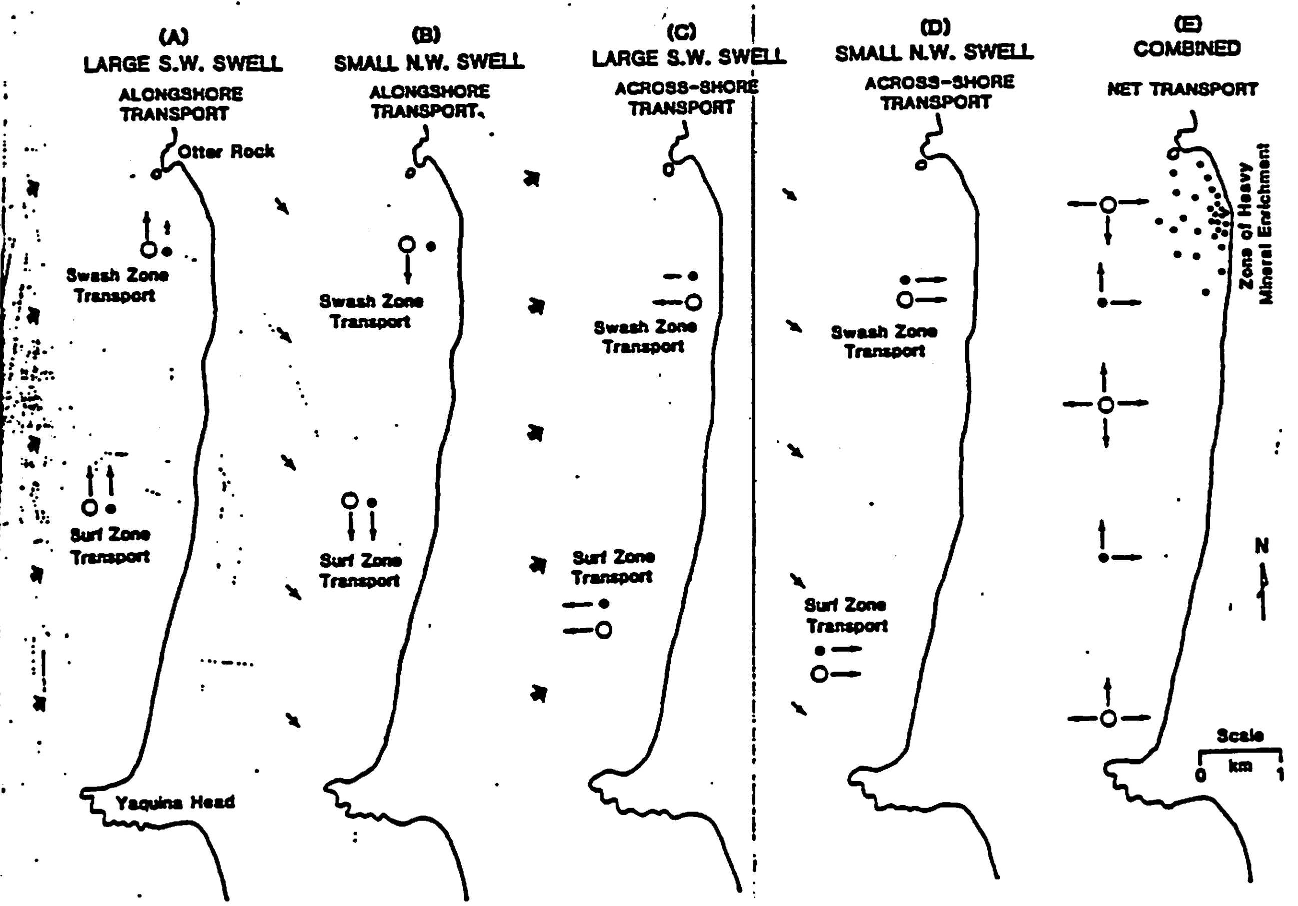


FIG. 8.—General model of heavy mineral enrichment in the nearshore. Seasonally reversing swell conditions serve to drive nearshore sediments to the north and south alternately and to move sediment onshore and offshore. Due to the differential transport rates of light and heavy minerals under conditions of entrainment transport, the heavy minerals are enriched in the backshore of beaches where longshore flow decelerates in the northern portion of littoral cells. Arrows in the figure represent direction and relative transport efficiency of light minerals (open circles) and heavy minerals (black dots) under storm and fair weather conditions.

Spits, Bars, Lagoons, and Estuaries
with your littoral hosts

Andrew S. Rivkin and Elizabeth P. Turtle

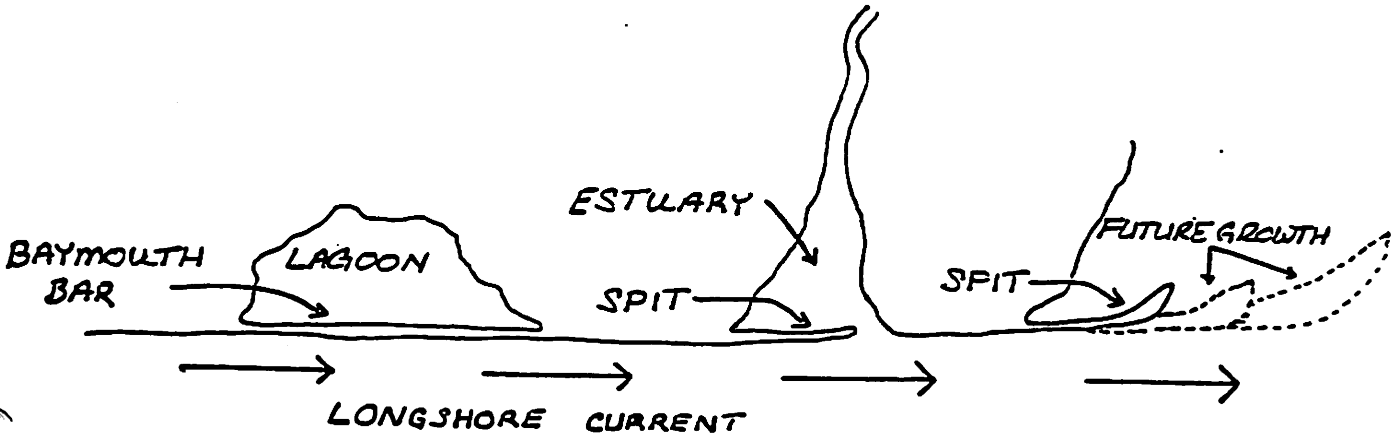
Definitions:

Spit – A narrow ridge of sediment projecting from the shore into open water. Spits are usually created when the littoral current diverges from the shoreline. In the deeper water the shallow current does not create enough movement at the bottom to carry the sediment. The result is that the sediment is deposited at the point of divergence.

Bar – A spit that has grown completely across the mouth of a bay or estuary. Sometimes called a barrier island (not to be confused with the type of barrier islands seen on the East Coast) or a bay-mouth bar (among many other sometimes conflicting definitions).

Lagoon – A bay that has been closed off from the ocean by a bar (among many other sometimes conflicting definitions).

Estuary – A river mouth that is later embayed due to coastal subsidence or to a rise in sea level. Estuaries have a salinity gradient resulting in lots of weird biological stuff we won't be telling you about. The estuaries along the southern California coast are older and have been filled with sediments carried by their rivers.



S, B, L, E

Andy & Zibi 2/6

Cronin, L.E., Editor, Estuarine Research, Academic Press, Inc., New York, 1975.

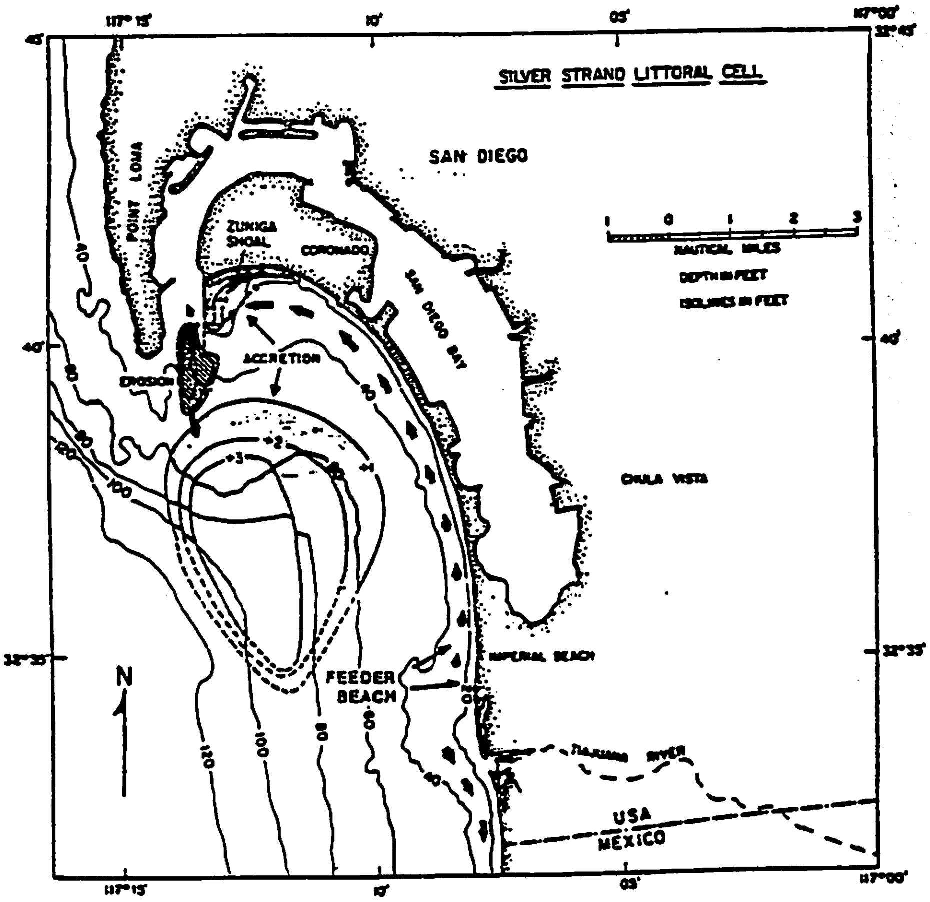
Gilbert, G.K., Lake Bonneville, U.S.G.S. Monograph I, Washington, 1890.

Komar, P.D., Beach Processes and Sedimentation, Prentice-Hall, Inc., New Jersey, 1976.

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

Shepard, F.P., Submarine Geology, Harper and Row, New York, 1963.

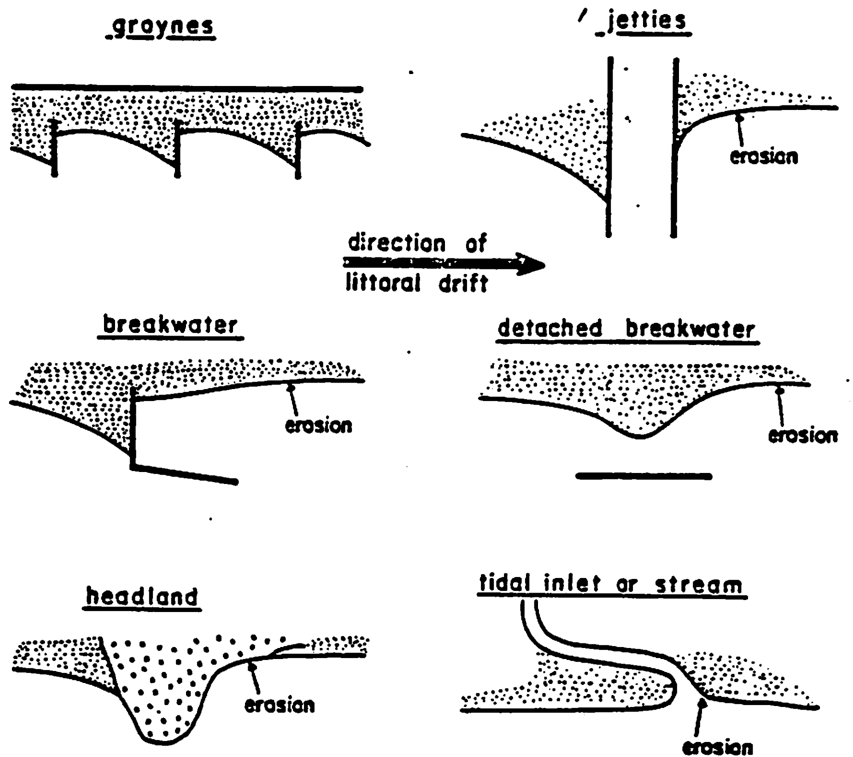
Stanley, D.J. and Swift, D.J.P., Editors, Marine Sediment Transport and Environmental Management, John Wiley and Sons, New York, 1976.



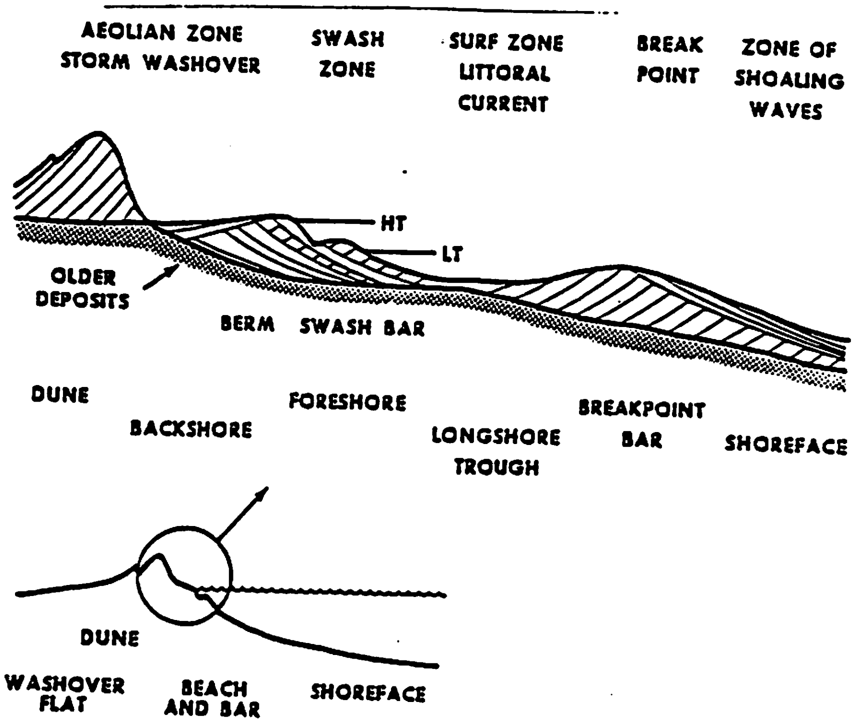
Kuhn and Shepard Figure 98 p. 162

S, P, B, L

Andy + Zibi 3/6



Komar Figure 9-7 p.240



Stanley and Swift. Figure 1 p. 256

S, S, P, B, J

Andy & Zibi 4/6

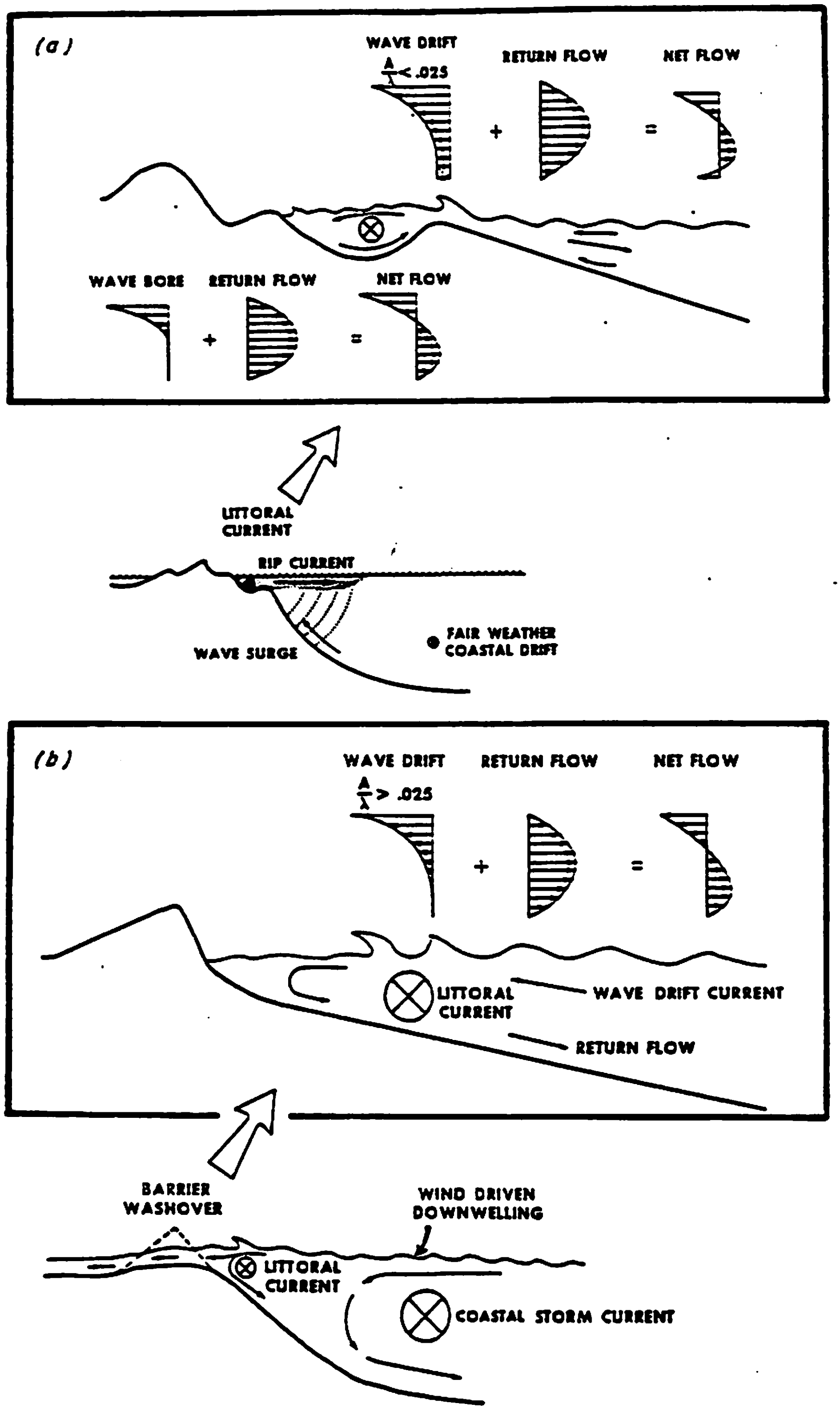


FIGURE 2. *Comparison of* (a) *fair-weather and* (b) *storm hydraulic regimes. Based on Longuet-Higgins* (1953), *Schiffman* (1965), *and Ingle* (1966).

Stanley and Swift p.257

(52)

S, S, S, S, F, S   Andy & Zibi S76

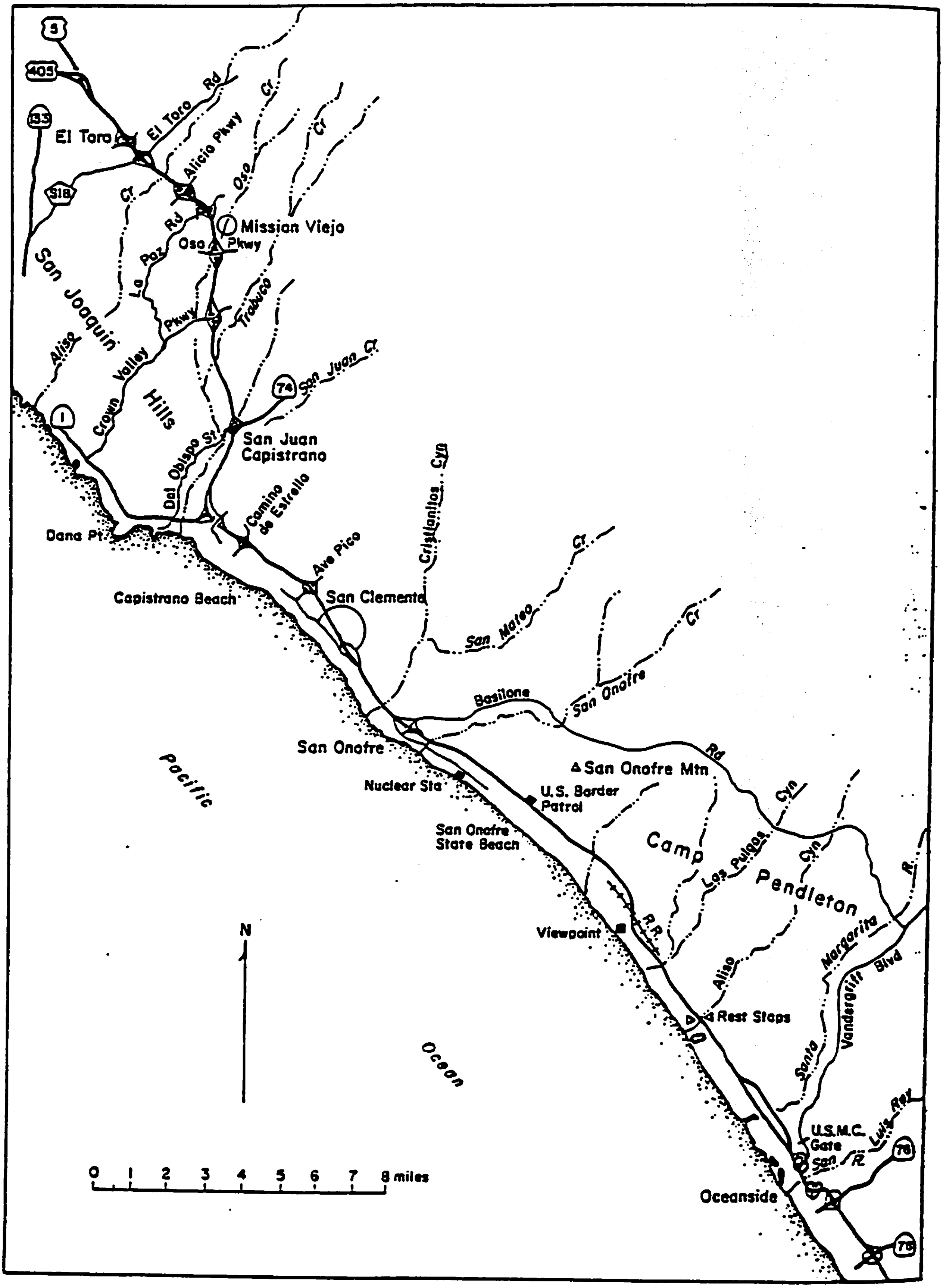


Figure K-1. Segment K, El Toro to Oceanside.

Sharp, R.P., Coastal Southern California
p. 158

B, P, J, E, L

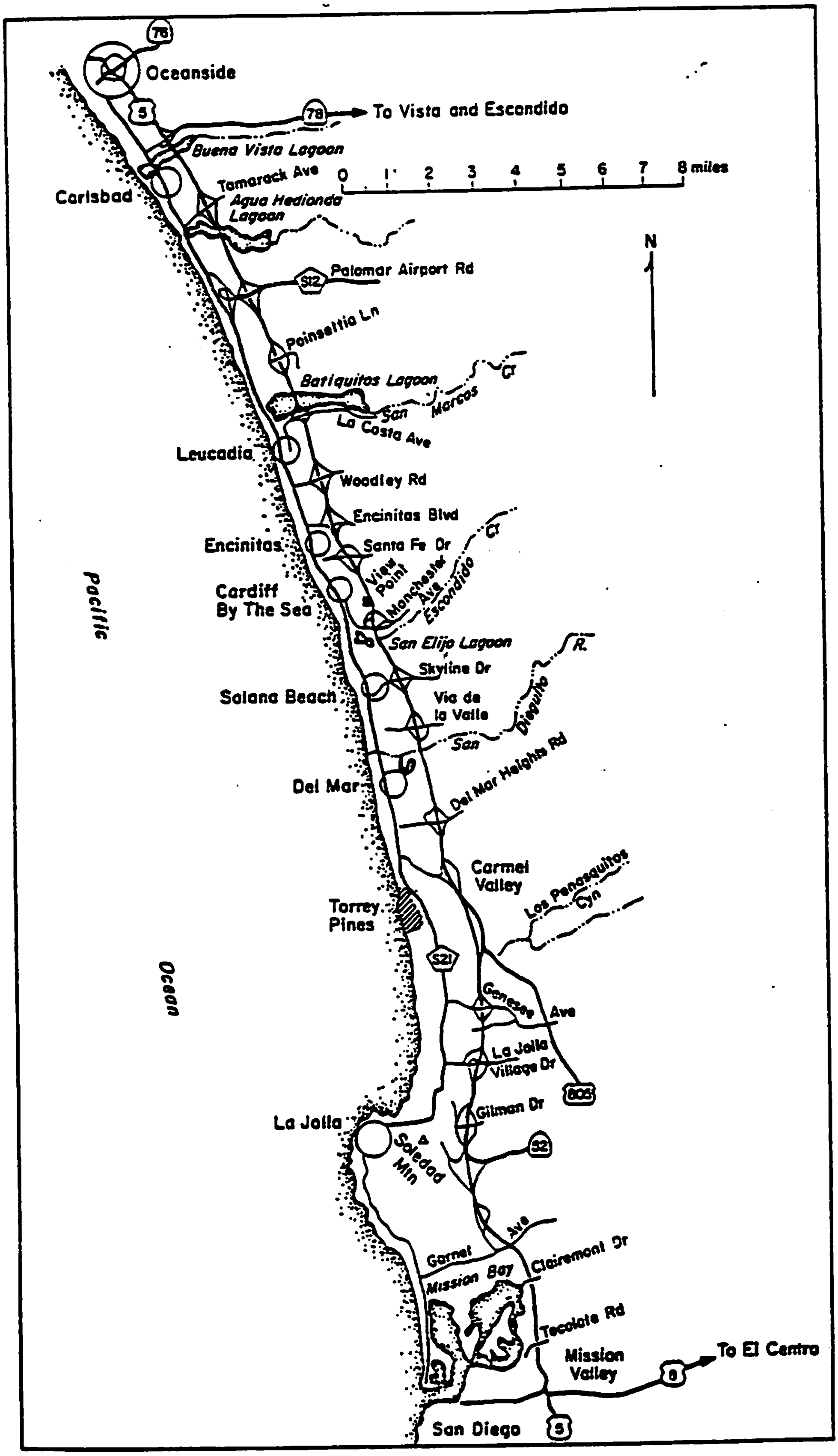


Figure P-1. Segment P, Oceanside to San Diego.

Sharp, p. 213

54

The Portuguese Bend Landslide

Bob Reid
PtyS 594a Fall 1994

The Portuguese Bend Landslide is a reactivated 260 acre section of a stabilized Late Pleistocene landslide. Failure "officially" started on 17 August 1956 resulting in the eventual abandonment and destruction of about 150 homes. Prevailing geologic opinion holds that increased pore pressure from water added to the slide via septic tanks and lawn watering resulted in the failure along the surface of the Altamira Shale member of the Monterey Formation, laid down in the Miocene. However, homeowners successfully sued Los Angeles County for $9.5 million, claiming that road construction cut-and-fill operations destabilized the landslide. Slide rates have ranged from about 10cm/day during the initial failure to as low as 15cm/year in some sections.

Table 4.4 Factors that influence stress and resistance in slope materials.

Factors That Increase Shear Stress

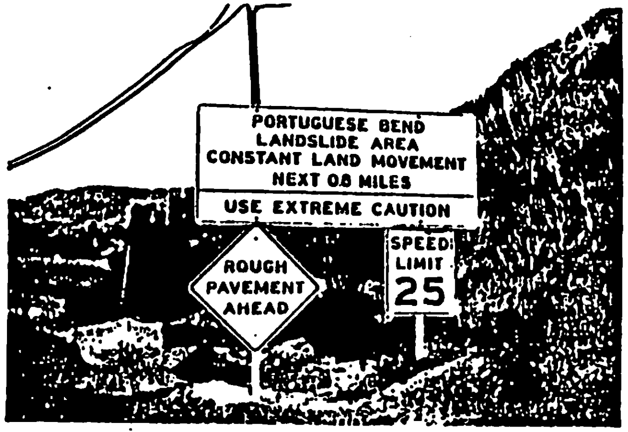
- Removal of lateral support
  - Erosion (rivers, ice, wave)
  - Human activity (quarries, ~~road-cuts~~, etc.)
- Addition of mass
  - Natural (rain, talus, etc.)
  - Human (fills, ore stockpiles, buildings, etc.)
- Earthquakes
- Regional tilting
- Removal of underlying support
  - Natural (undercutting, solution, weathering, etc.)
  - Human activity (mining)
- Lateral pressure
  - Natural (swelling, expansion by freezing, water addition)

Factors That Decrease Shear Strength

- Weathering and other physicochemical reactions
  - Disintegration (lowers cohesion)
  - Hydration (lowers cohesion)
  - Base exchange
  - Solution
  - Drying
- Pore water
  - Buoyancy
  - Capillary tension
- Structural changes
  - Remolding
  - Fracturing

After Varnes 1958 with permission of the Transportation Research Board.

Ritter



Reiter

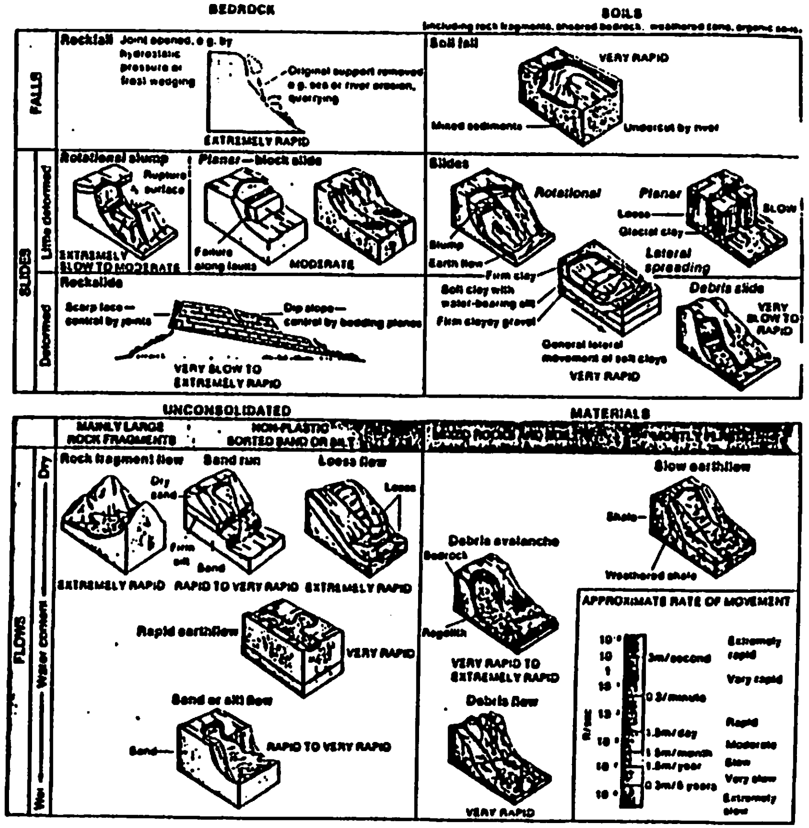
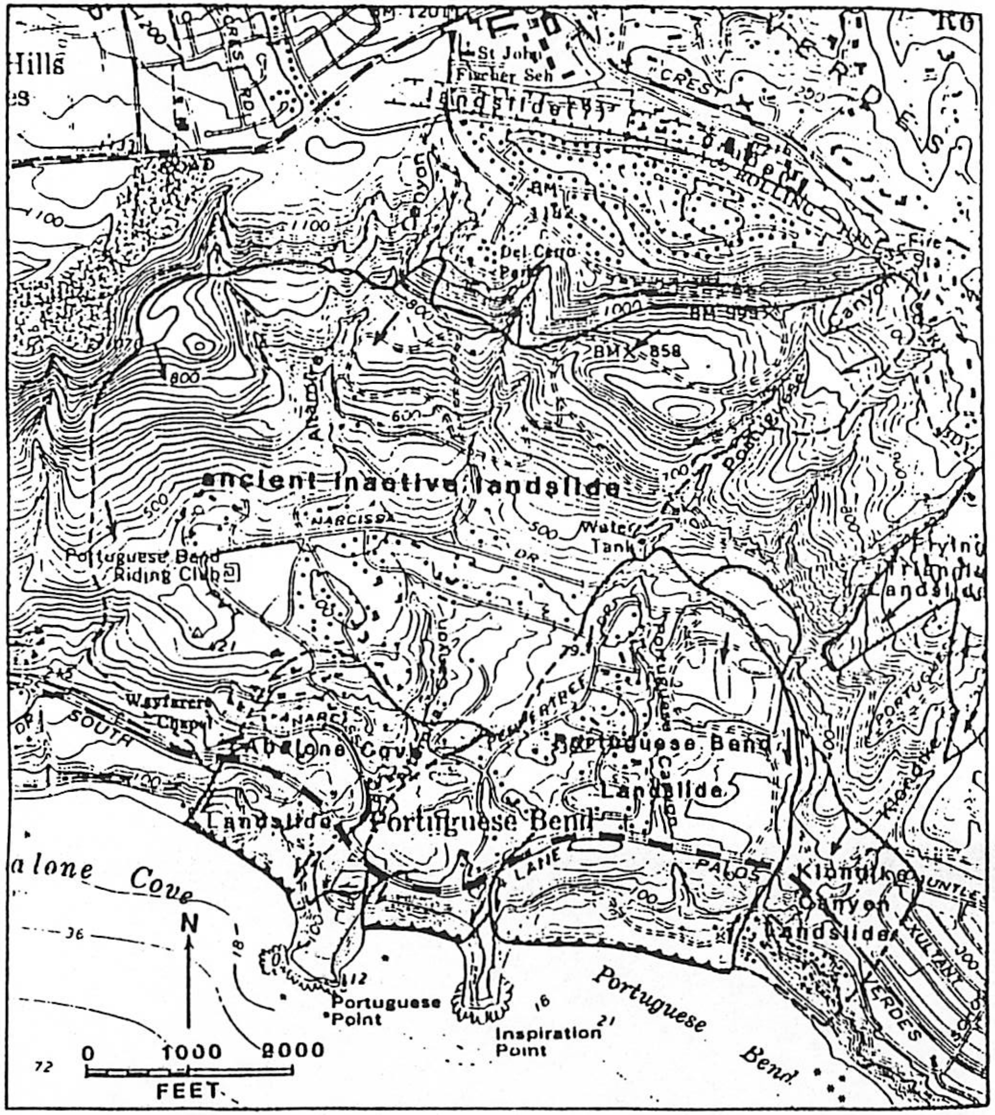


Figure 4.29.

Ritter

Since the sl s active, it's not clear what we're going to see. In other words, featu
on maps will probably have changed to some degree. Some things to look for:

- Extensional microtectonics (normal faults, graben)
- Compressional microtectonics in toe (thrust faults, anticlines)
- Effects on human structures (roads, remains of houses)
- Effect of slide base structure on surface topography



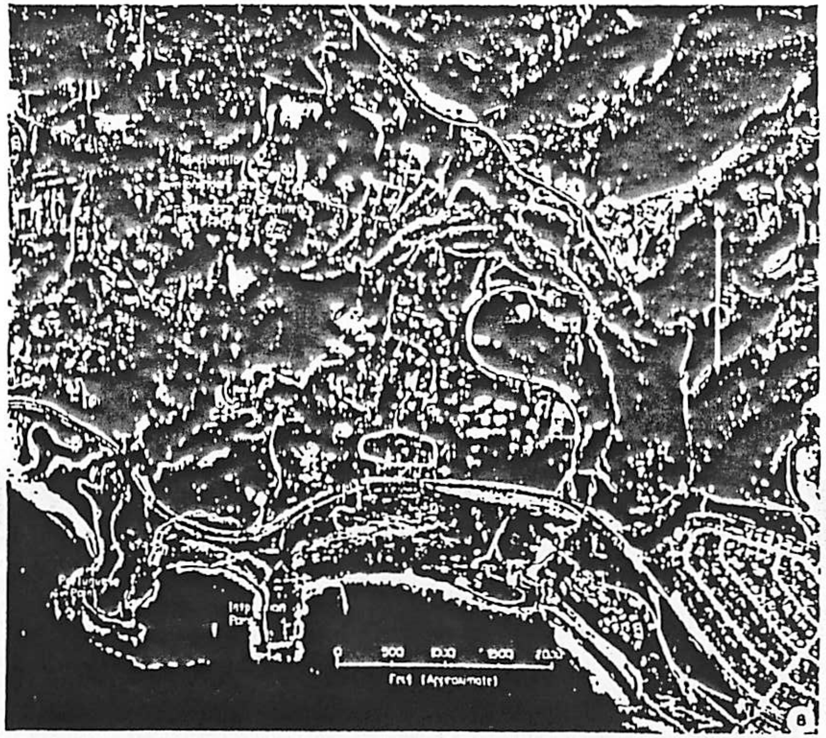
Ehlig

Figure 1. Map showing locations of the Portuguese Bend, Abalone Cove and Flying Triangle landslides and the adjoining ancient inactive landslide. Part of the active Flying Triangle landslide is also shown but it is not connected to the others. Slide movement has greatly modified the topography in the Portuguese Bend landslide from that shown.

Linden

Fig.7. Vertical air photograph of area later affected by Portuguese Bend landslide. This was the view on August 13, 1956, four days before the first indications of active sliding were recorded. Light area near upper right-hand corner of photograph defines cut and fill operations associated with the construction of Crenshaw Boulevard. Note the numerous houses and facilities of the Portuguese Bend Club south of Palos Verdes Drive South. (Photo courtesy of Geotronics, Long Beach, California.)

REID, LANDSLIDES



Linden

Fig.8. Vertical air photograph of active Portuguese Bend landslide and surrounding area. January 18, 1968. Most of the perimeter of the active slide is defined by light-colored irregular scarps. Comparison of this view with Fig.7 reveals that the shoreline along the active slide east of Inspiration Point has been displaced seaward as a result of the slide movement. Note growth of vegetation on Crenshaw Boulevard cuts and fills, and absence of the Portuguese Bend Club and most of the houses south of Palos Verdes Drive South. (Photo courtesy of Voorheis-Trindle and Nelson, Inc., Westminster, California.)

3 (56)

REID, LANDSLIDES

Anderson

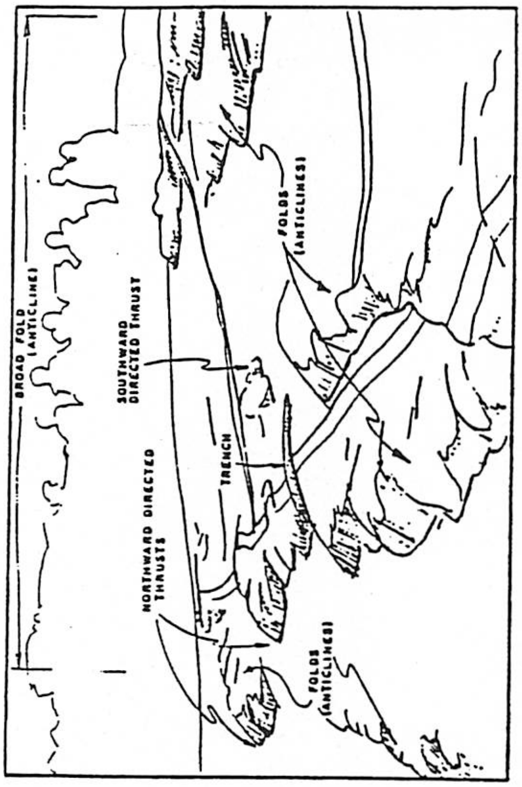


Figure 2 (a & b). Compressional features of the paddle tennis court (spring, 1983); view facing east

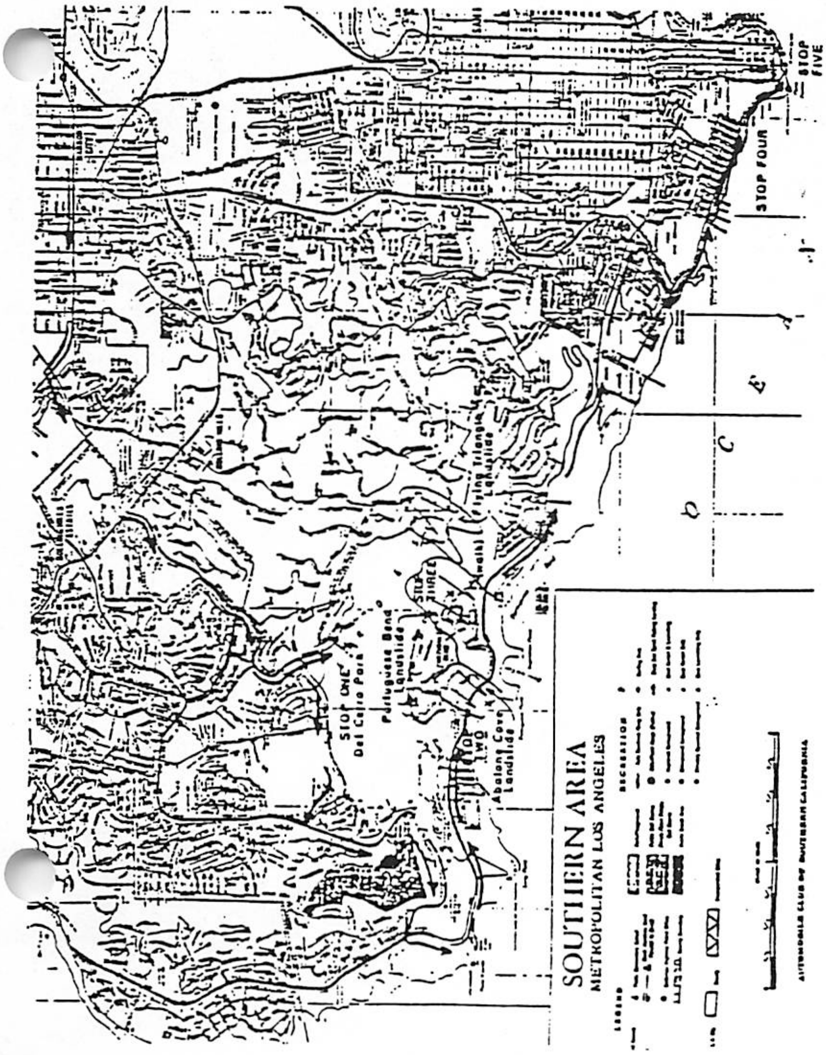


FIGURE 1: Road map and STOP locations, Palos Verdes peninsula.

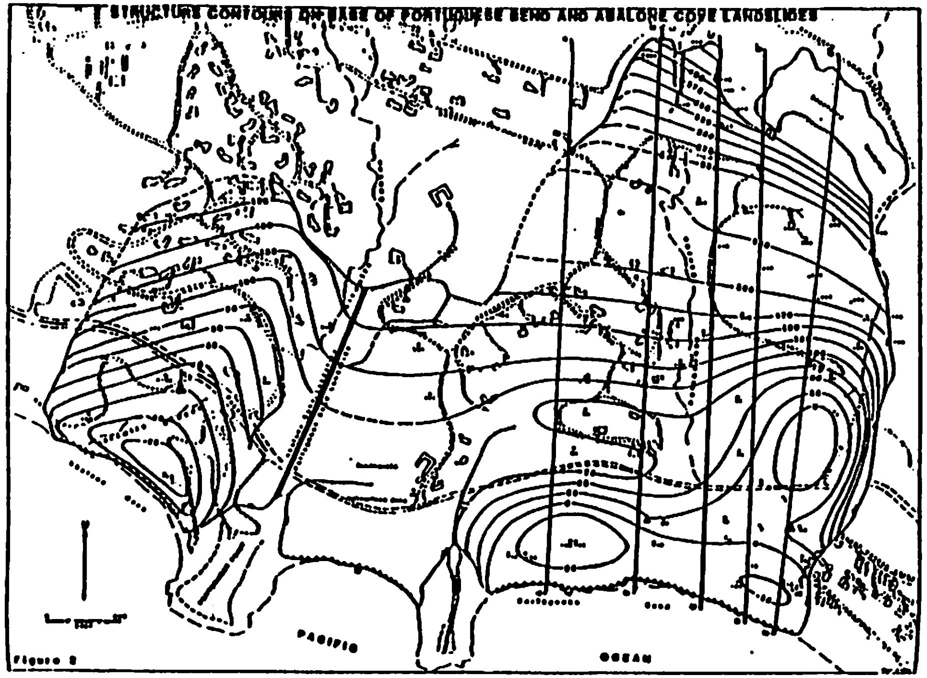
AAPG Field Trip

Generalized Stratigraphic Section of the Palos Verdes Peninsula, Southern California

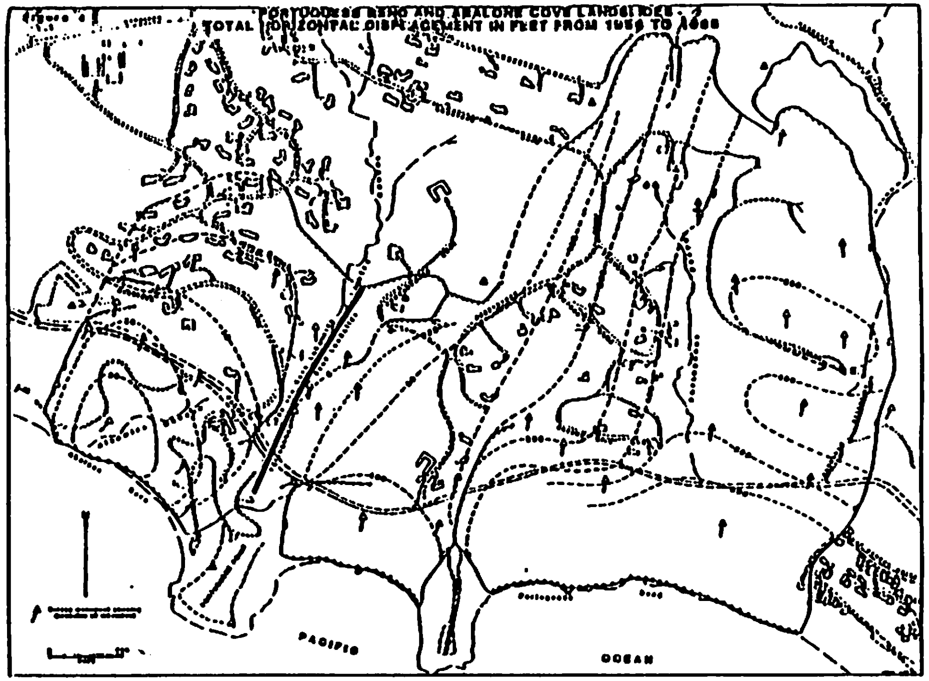
PERIOD	EPOCH		STAGE		FORMATION	MEMBER		GENERALIZED LITHOLOGY
QUATERNARY	PLEISTOCENE	UPPER	HALLIAN		PALOS VERDES SAND			Veneer of marine sand & gravel on youngest marine terrace
		LOWER			SAN PEDRO SAND			Gray to reddish-brown, massive, cross-bedded sand, typically coarse-grained & well sorted
					TIMMS POINT SILT			Yellowish-brown, calcareous siltstone
					LOMITA MARL			Calcareous sand & marl made up of foraminifers, mollusks, echinoids, bryozoa, etc.
TERTIARY	PLIOCENE		REPETTIAN		REPETTO SILTSTONE			Glauconitic, foraminiferal siltstone
	MIOCENE		DELMONTIAN		MONTEREY SHALE	MALAGA MUDSTONE		Black, radiolarian mudstone or siltstone; some layers of dolomite and limestone concretions
			MOHNIAN	UPPER		VALMONTE DIATOMITE		Soft-weathering diatomite, diatomaceous shale & mudstone, some bedded chert & siliceous shale
				LOWER		ALTAMIRA SHALE ("P.V. Stone")	UPPER	Phosphatic & bituminous shale; some beds of dolomite & siliceous shale "Blue schist" sand facies at Point Fermin
			LUISIAN				MIDDLE	Cherty & porcelaneous shale, chert, & limestone Basalt sills/ flows
			RELIZIAN				LOWER	Silty & sandy shale Schist conglomerate Basalt sills/ flows
JURASSIC ?					FRANCISCAN? BASEMENT	CATALINA METAMORPHIC FACIES		Quartz-sericite schist, Quartz-talc schist, "Blue schist" with quartz & glaucophane or crossite

REID, LANDSLIDES

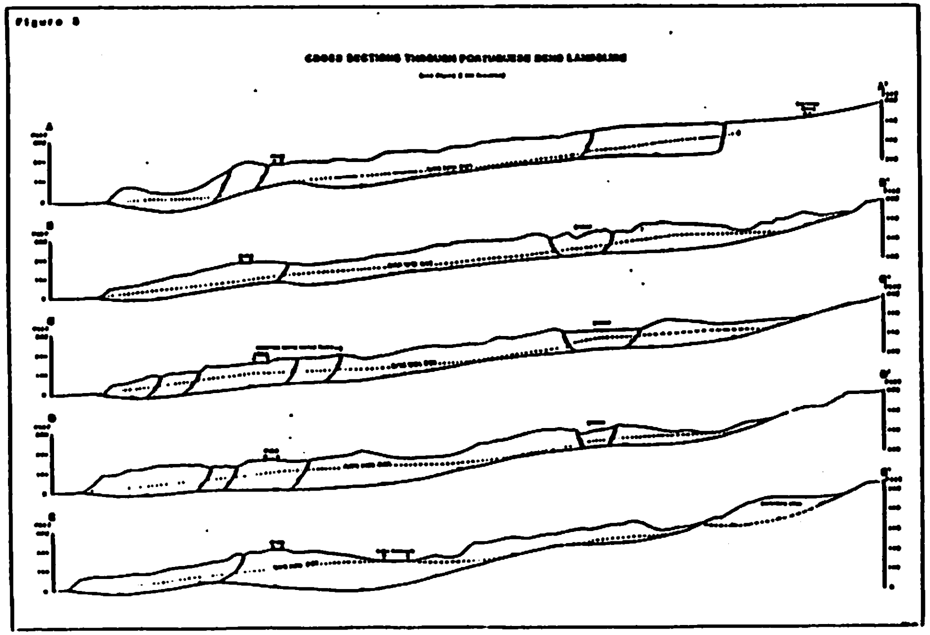
57



Ehlig



Ehlig



Ehlig

References

AAPG Field Trip #2 Road Log (1987) Recent Landslides of the Palos Verdes Peninsula, California, in Geology of the Palos Verdes Peninsula and San Pedro Bay, Fischer, Peter J., ed., 2-37 to 2-38.

Anderson, James L. (1987) Deformation in the Coastal Portion of the Abalone Cove Landslide: A Natural Laboratory for the Study of Tectonics in Miniature, in Geology of the Palos Verdes Peninsula and San Pedro Bay, Fischer, Peter J., ed., 57-62.

Ehlig, Perry L., (1987) The Portuguese Bend Landslide Stabilization Project, in Geology of the Palos Verdes Peninsula and San Pedro Bay, Fischer, Peter J., ed., 2-17 to 2-24.

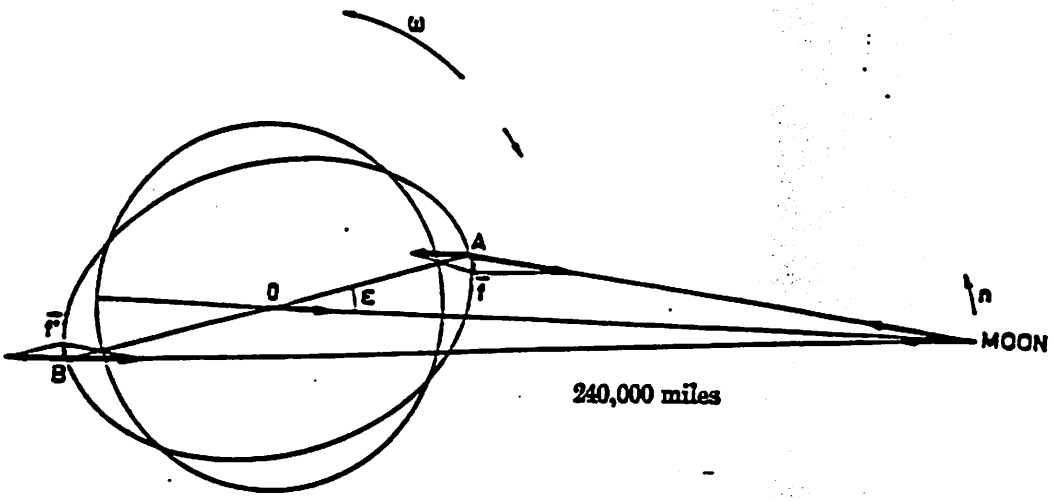
Linden, Karl V. (1989) The Portuguese Bend Landslide, Engineering Geology 27, 301-373.

Reiter, Martin (1984) The Palos Verdes Peninsula, Kendall/Hunt Pub. Co., 61pp.

Ritter, Dale F. (1986) Process Geomorphology, 2nd. ed., Wm. C. Brown Pub., 579pp.

TIDES

by Tamara Ruzmaikina



EARTH AND MOON

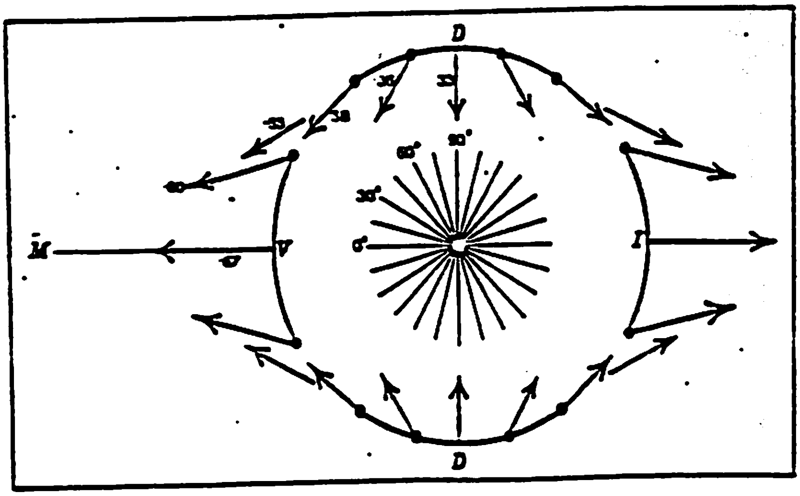
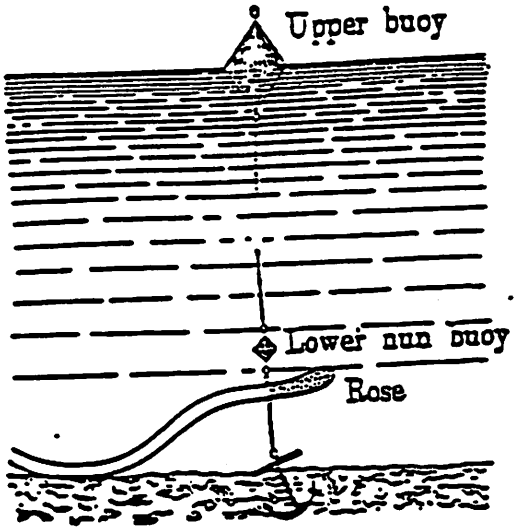


FIG. 1.—TIDE-GENERATING FORCE

RUZMAIKINA: TIDES



Pipe of Tide-Gauge

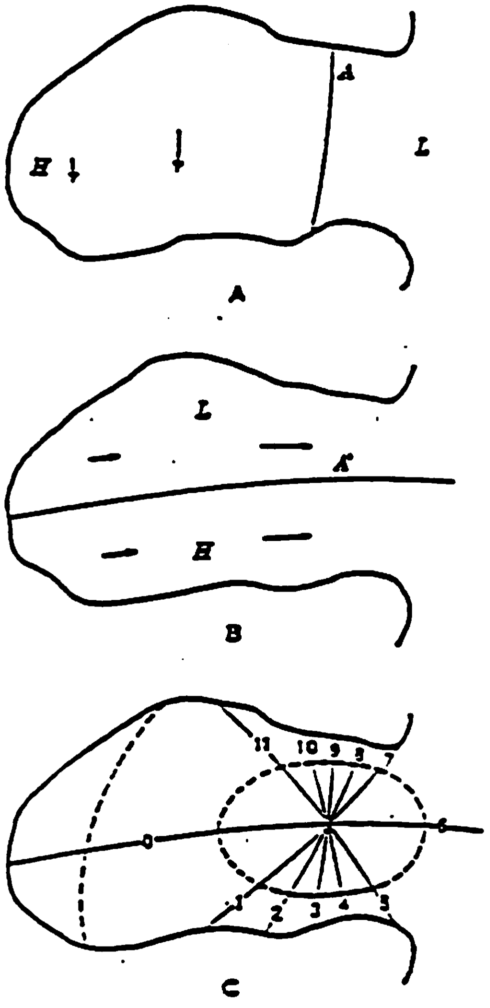


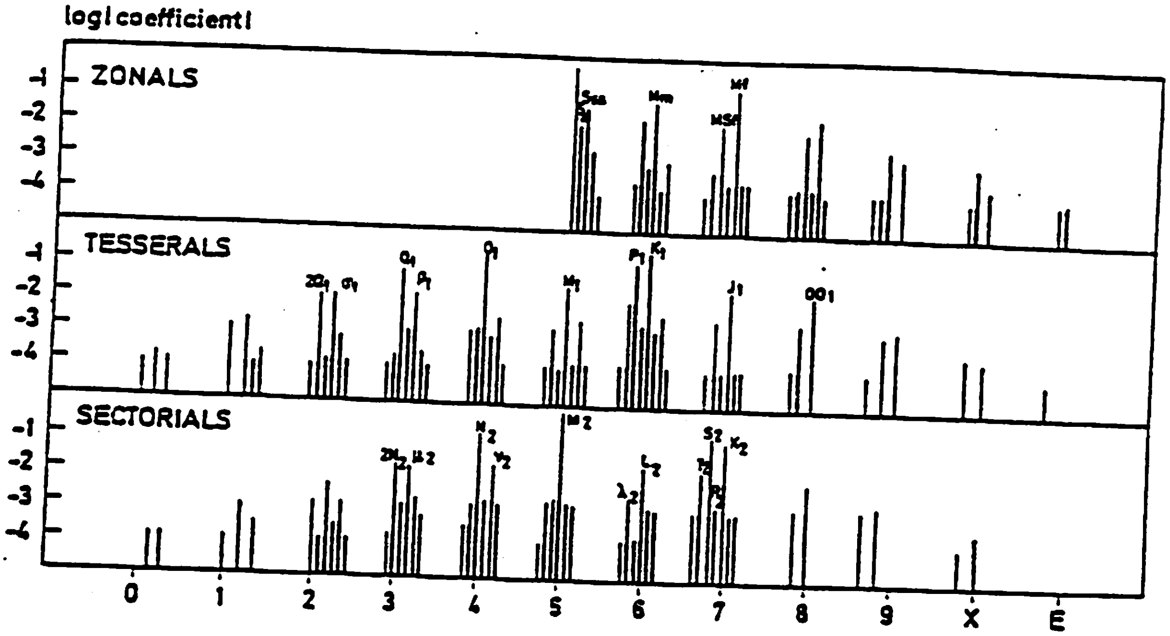
FIG. 2.—MOVEMENT OF THE TIDES IN A GULF. H INDICATES HIGH-WATER LEVEL. L LOW-WATER LEVEL. (SEE TEXT FOR FURTHER EXPLANATION.)

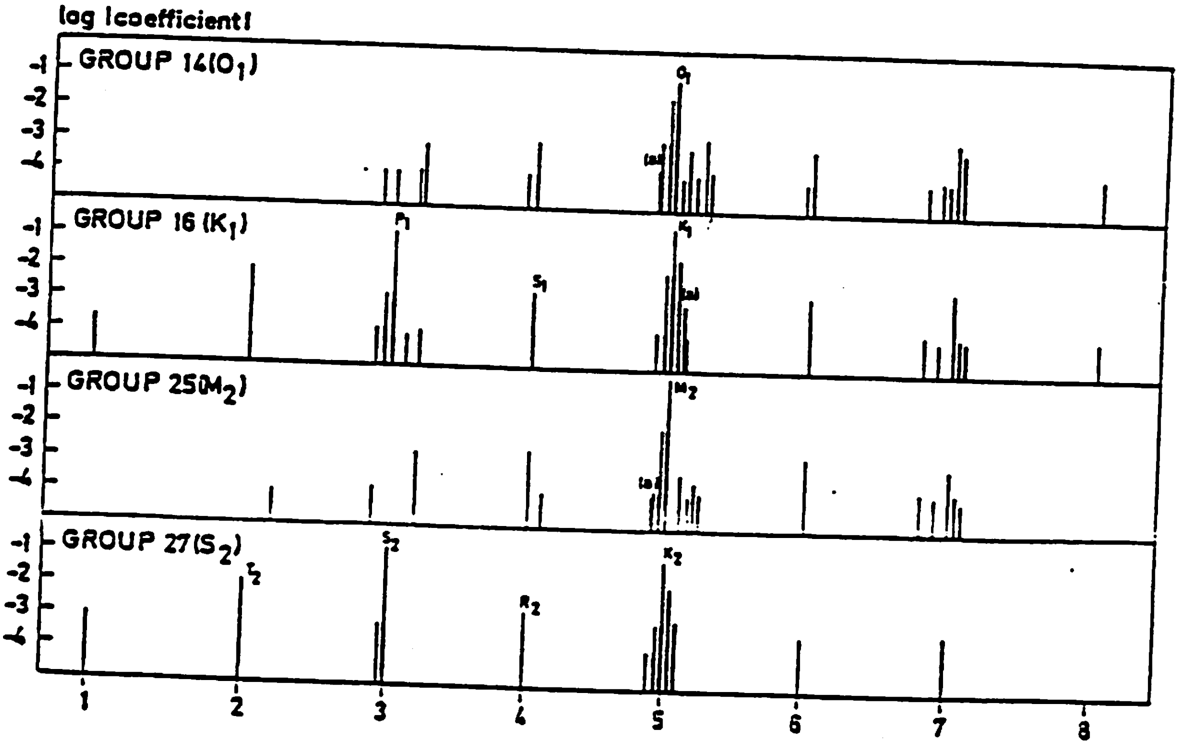
Consider a standing oscillation in a gulf as shown in fig. 2A at the instant of high water at the head of the gulf. The curve *A* has been drawn through all points where the deviation of the water level from its mean is zero at this instant. One quarter period later the water is flowing out of the gulf. At this instant, in the absence of the Coriolis force, the elevation everywhere within the gulf would have its mean value (except for a small frictional effect), and the curve *A* would represent a nodal line. Actually, the elevation will be higher to the right of the outward flowing current, as is shown in fig. 2B, with the curve *A'* lying along points whose elevation is at the mean level. Continuity considerations show that there must have been currents flowing at the instant of high water within the gulf in order to produce the distribution of water level shown in fig. 2B. Possible directions for these currents are shown in fig. 2A.

At the intersection of the curves *A* and *A'* there will be no rise and fall of sea level, and such a point is known as an amphidromic point. Let it be assumed that the constituent under consideration correspond to the instant of high water within the gulf as depicted by fig. 2A. Fig. 2C then gives the curves along which high water occurs for each of the 12 constituent hours. Such curves are called cotidal lines. The hypothetical distribution of range of tide is indicated by the dashed curves, called corange lines, each of which connects points having equal range of tide. The amphidromic point, at which the tidal range is zero, lies in the centre of the concentric family of corange lines. The cotidal lines indicate the position of the crest of the tidal wave at any instant, and it is seen that this crest rotates in counterclockwise fashion (in the northern hemisphere) about the amphidromic point. Such amphidromic systems with counterclockwise movement of the tidal crest are characteristic also of the oceans and adjacent (large) bodies of water.

KUZMAKINA: TIDES

Tidal Potential

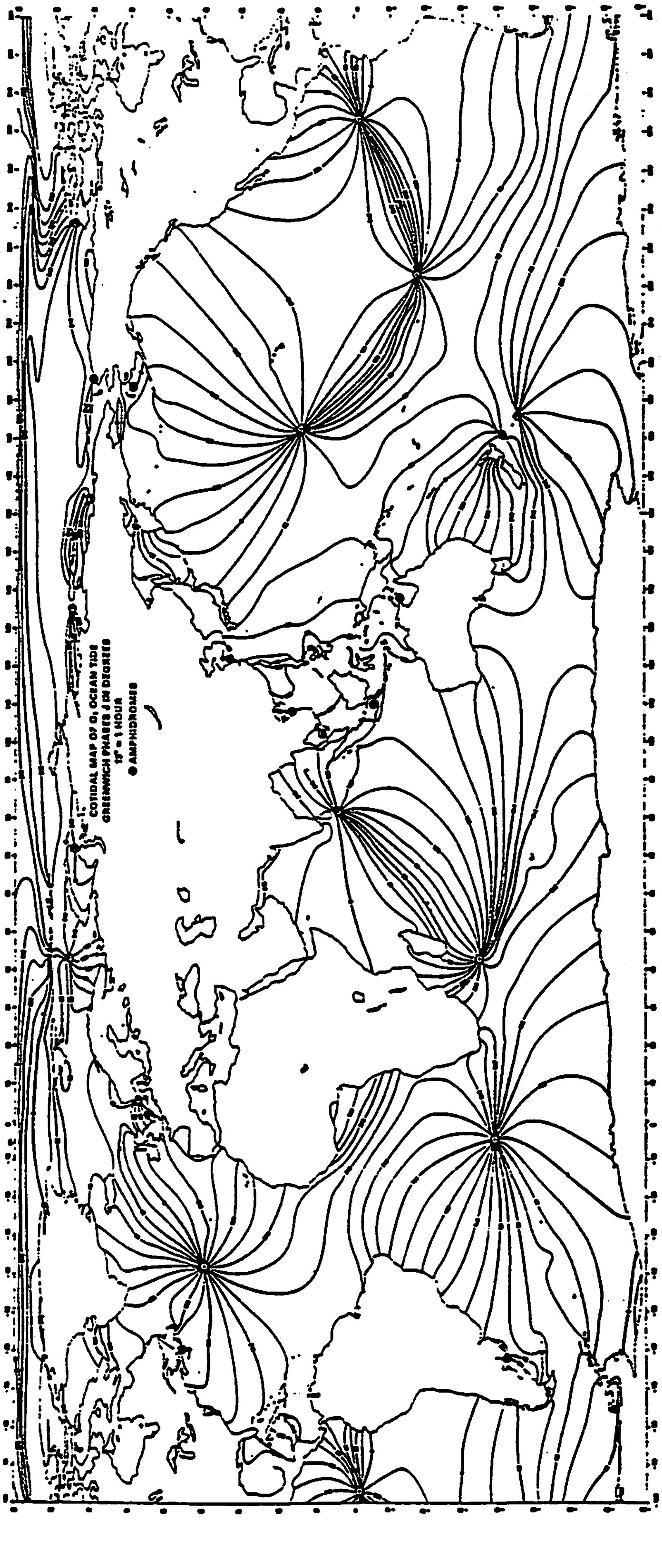




Tidal spectrum

RUZMAIKINA: TIDES

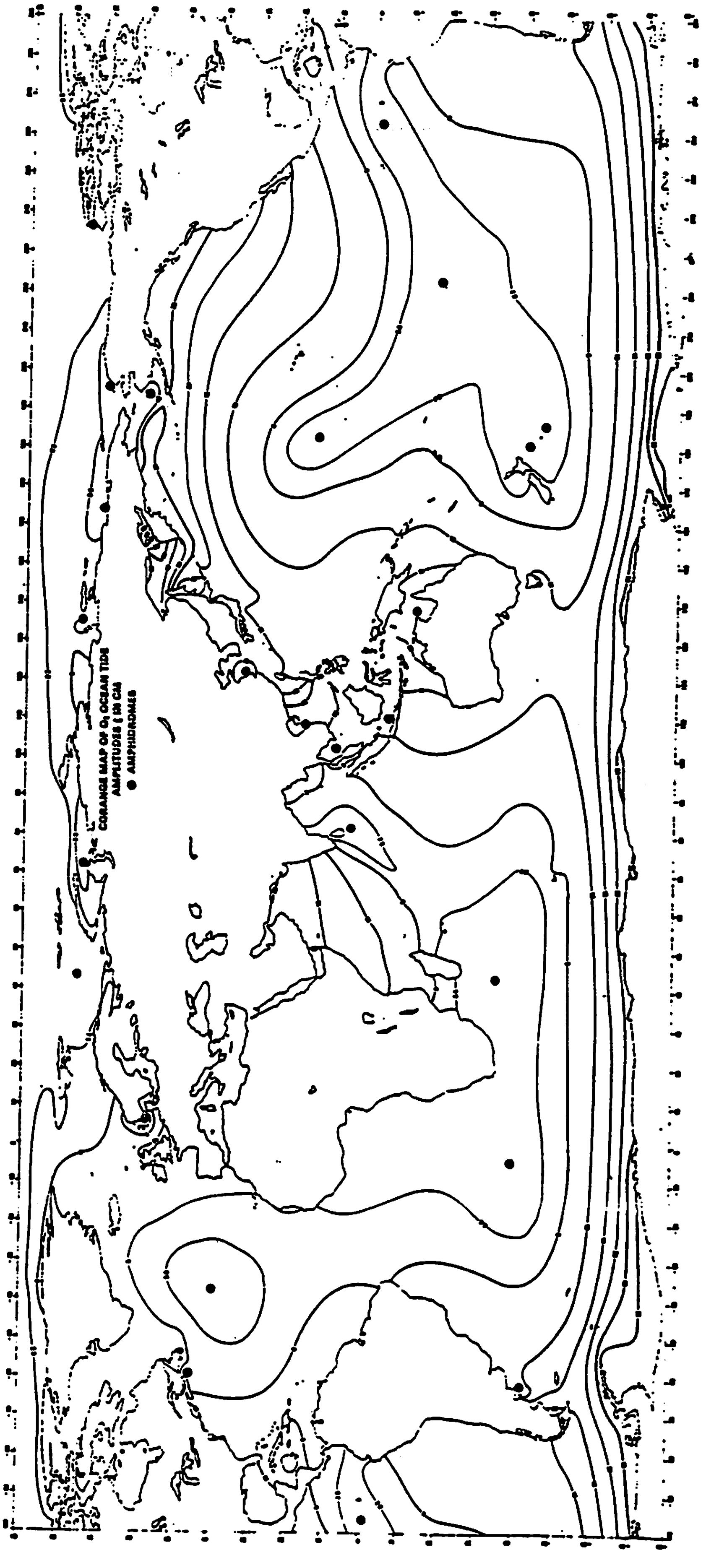
The Tides of the Planet Earth



O_1 cotidal map - cotidal lines in degrees (15° ~ 1 hour).

62

RUZMAIKINA : TIDES

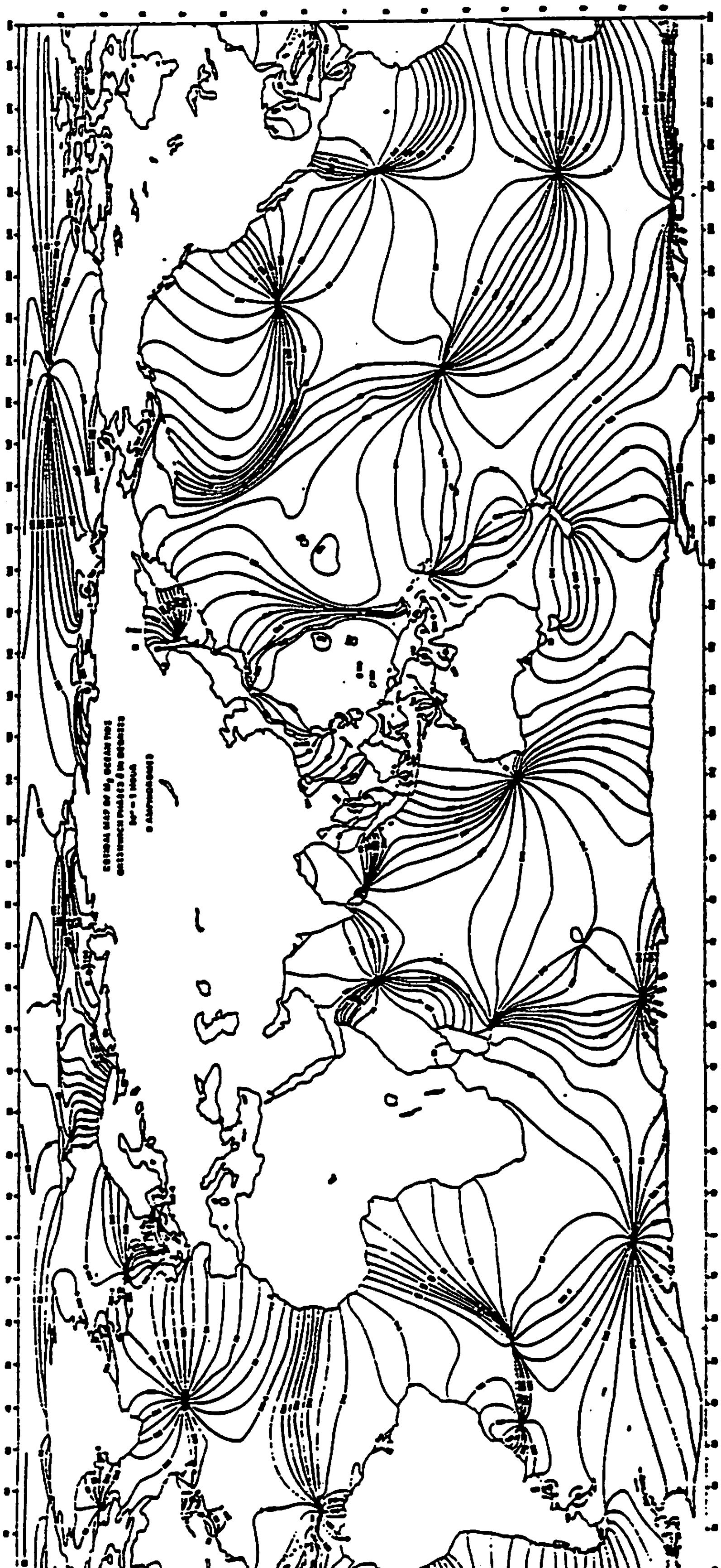


O_1 corange map - amplitudes in cm.

RUZMAIKINA: TIDES

(63)

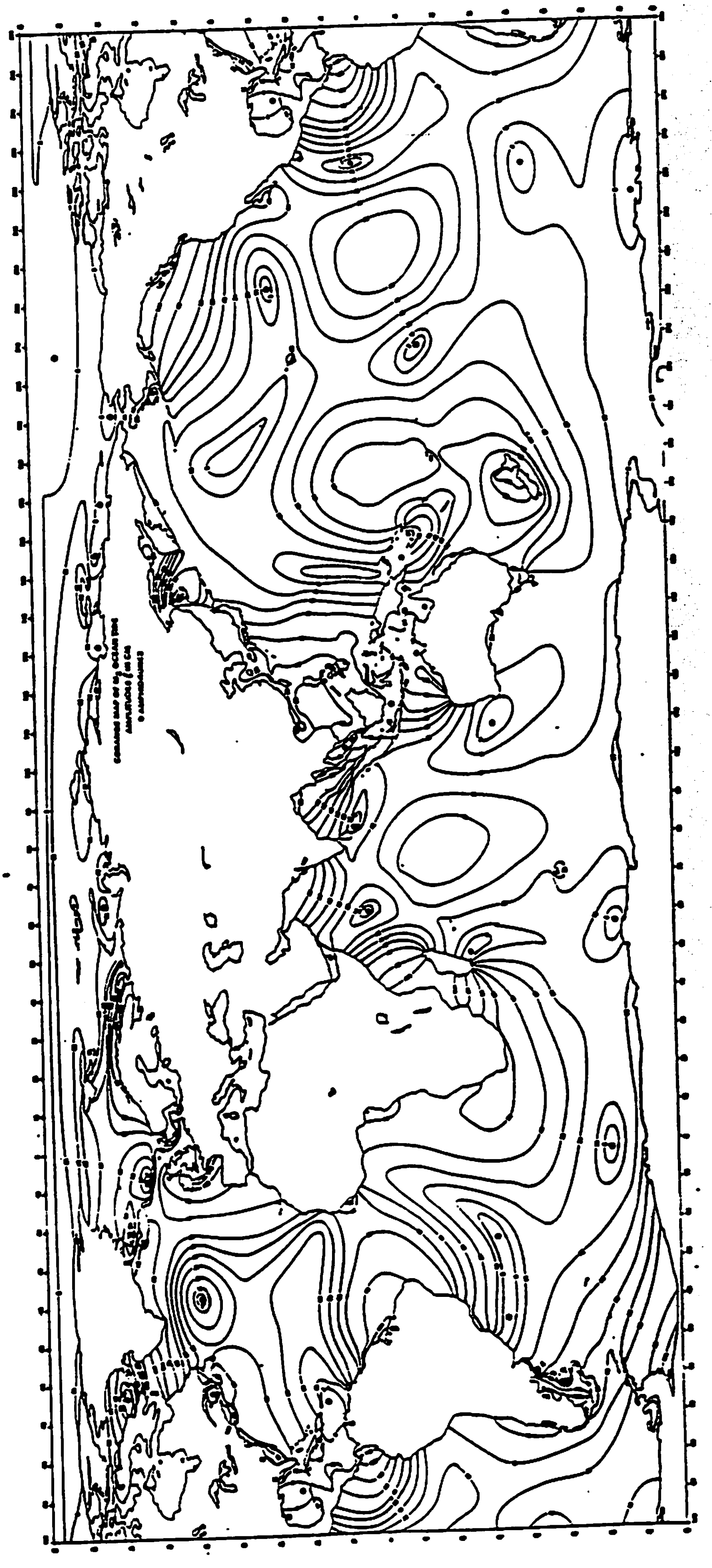
The Tides of the Planet Earth



M_2 cotidal map - Cotidal lines in degrees (30° ~ 1 hour).

64

RUZMAIKINA: TIDES



M_2 corange map - amplitudes in cm.

The Channel Islands

Eric Wegryn

Just off the coast of Southern California, a series of islands stand out majestically from the Pacific. Visible offshore from the city of Ventura, (about 20 kilometers to the southwest) the small island of Anacapa juts up from the sea. Beyond Anacapa, the islands of Santa Cruz, Santa Rosa, and San Miguel follow westward roughly in a line about 100 km long. These four, the northern Channel Islands, are separated from the mainland by the Santa Barbara Channel, from which they draw their name. Further to the southeast lie the islands of Santa Catalina (a popular tourist destination just 40 km southwest of Los Angeles), Santa Barbara, San Nicolas, and San Clemente. The four northern Channel Islands plus Santa Barbara Island were protected by the U.S. Congress in 1980 when they were designated Channel Islands National Park, a unit of the National Park Service.

The Channel Islands exhibit a broad range of topological features. Anacapa, the smallest of the major islands, has the most jagged appearance. Its profile recedes to sea level in two places, dividing the island into three disconnected islets. The most rugged landscape appears on West Anacapa, the largest of the three, while East and Middle Anacapa have lower and mostly flat upper surfaces. The differences in the slopes of the surfaces, in addition to the narrow water passages separating the islets, indicate the presence of faults between the islets.

Santa Cruz is the largest (249 sq.km) and most diverse of the islands. A long central valley running east-west down the center of the island, created by the Santa Cruz Fault, divides the island into two distinct geologic regions.[1] The highest mountain on the islands, Devils Peak (747 m), dominates the northern side of Santa Cruz. The southern side also exhibits high relief terrain, but with the exposed southern coast showing more weathering. Canyons created by water runoff are abundant.

Continuing west, Santa Rosa also shows high relief on its eastern end, with cliffs, mountains, and canyons, but this terrain gradually gives way to rolling hills and grasslands on the western end. The terrain on westernmost San Miguel is nearly flat and mostly barren, weathered by strong winds, terminating with the sandy beach at the western tip of the Channel Islands, Point Bennett.

The origin of the Channel Islands is rooted in plate tectonics. Most of the geology of California is determined by the interaction of two major crustal plates, the Pacific plate and the North American plate. These two plates were once experiencing "Andean" type tectonic motion, with the Pacific plate pushing underneath the North American plate, giving rise to ranges of mountains, including the Sierra Nevadas. Approximately 30 million years ago however, this plate boundary transitioned to a transform margin, whereby the Pacific plate is now sliding northward against the North American plate in a lateral motion, as seen in the San Andreas and its many associated parallel faults.

Early theories of the formation of the northern Channel Islands centered around the idea that they were extensions of the Santa Monica Mountains of the east-west Transverse Ranges.[1] Indeed, they are roughly parallel, and certainly geologically related, containing many of the same rock units. However, the fact that the Santa Barbara Channel is up to 240 meters deep, with significant ocean floor faults, implies that the islands are not simply an extension of the Santa Monica Mountains.

Current theories indicate that the islands were pushed up and torn from the mainland by the lateral motion of the Pacific plate against the North American plate.[2] In addition to uplifting and displacement, this lateral crustal motion would also cause compression, deformation, folding, and rotation of the large mountain blocks which today make up the islands.

As evidence of this theory, the composition of the Channel Islands consists mainly of basaltic material, indicating volcanic origins. In addition however, large amounts of San Onofre Breccia, a sediment characteristic of the Oceanside, CA area over 100 km distant, pervade the islands.[1,2] Other pieces of evidence include the paleomagnetic alignment of Channel Island rocks, which indicate that they have been tectonically rotated by as much as 80° (clockwise, as expected from the lateral motion of the plates) since they were formed.[2] The conclusion then is that the lateral motion of the transform plate margin caused the displacement, uplifting, and rotation of large blocks of material from the mainland to the southeast to create the Channel Islands.

Anacapa may have been formed as a result of this displacement. It consists mostly of basalt, formed from lava welling up through faults approximately 15 million years ago. San Onofre Breccia is the only sedimentary rock found on Anacapa.[2] Just off the eastern tip of Anacapa is Arch Rock, a picturesque flat-topped basalt stack exhibiting yet another interesting material on its upper surface: guano.

Arch Rock is just one example of the wide variety of geologic features seen the Channel Islands. All of the islands exhibit many erosional features around their shorelines, such as wave-cut platforms and marine terraces, high cliffs, and numerous bays and alcoves. These features (as described elsewhere in this report) are created when weaker rock is eroded away by wave action, leaving behind stronger rock. Landslides caused by pounding waves undercutting seacliffs gradually create wave-cut platforms, which may become marine terraces with changes in sea level. (San Miguel is basically a Pleistocene marine terrace, exhibiting beachrock (water-tablerock) and Recent sand.[1]) Wave action is also responsible for the many sea caves around the islands. The largest cave is Painted Cave on Santa Cruz, with a ceiling 40 meters high.

The islands are more exposed to open ocean waves on their southern shores than on their relatively protected northern shores. As a result, the southern shores see more turbulent waters, faster wave erosion, and thus steeper cliffs. Despite the prevalence of steep cliff shorelines, there are beaches around the Channel Islands, each consisting of materials which are most prevalent in that particular area. For example, the beaches on Anacapa contain sand mostly consisting of dark basaltic fragments.[2]

Much of the offshore area surrounding the islands consists of wave-cut platforms and large, shallow submarine terraces. This is evidenced by the many tidepools, rocks (sea stacks), and kelp beds that extend far offshore around the islands.[2]

Information about the geologic history of the islands can also be deduced from the abundant marine and non-marine fossils. The nature of fossils found at a particular site may indicate the conditions to which that site has been subjected. For example, Anacapa consists of volcanic rocks about 15 million years old, but the oldest non-marine fossils on the island are between 4 and 6 million years old. Therefore, Anacapa has only existed above sea level for about the past 5 million years.[2] Fossilized remains indicate that the northern Channel Islands were interconnected during the last (Pleistocene) Ice Age when the sea level was considerably lower, but it is not believed that they were connected to the mainland.

The archaeological record of the Channel Islands also includes evidence of about 6000 years of inhabitation by the Chumash Indians, a group of seafaring Native Americans.

Present day animal life on the islands is just as diverse. The Channel Islands are home to a wide variety of species from sea lions to sea gulls, and are the only domain of the rare island fox. In addition, the protected waters surrounding the islands teem with life, from the smallest tidepool inhabitants, to majestic whales and dolphins. In summary, the Channel Islands are indeed a beautiful exhibit of geological and ecological diversity, certainly deserving of their status as a National Park.

Acknowledgement:
Many thanks to the NPS Park Rangers at Channel Islands National Park for their help in gathering reference material.

References:
1 *Geology of the Northern Channel Islands,* Weaver, Donald W., 1969
2 *Geologic Field Guide to Anacapa Island* (draft), Sadd, James L., 1990

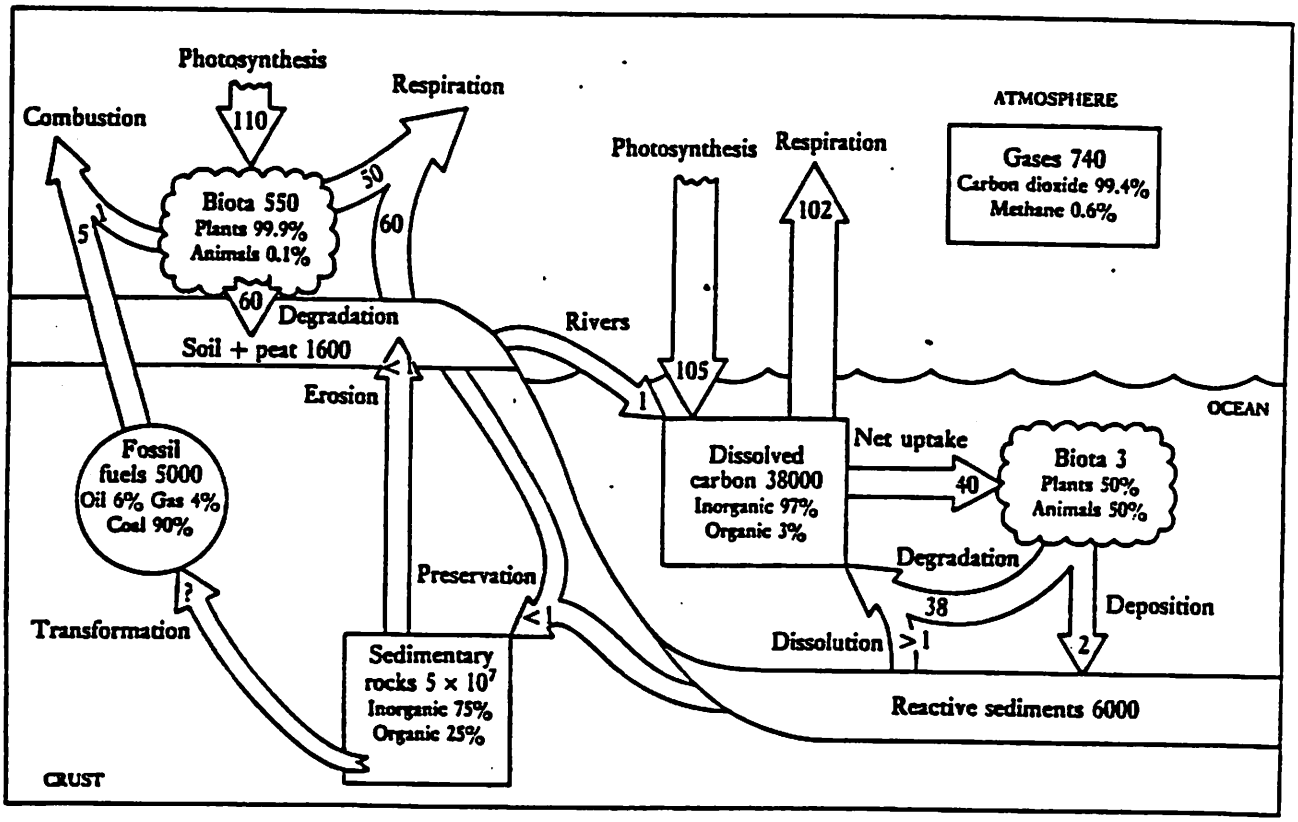
Organic Deposits

– from between the toes of –

Will Grundy

1. WHERE DOES THIS STUFF COME FROM?

On Earth today, it originally comes from biological activity. This diagram shows annual global fluxes and reservoirs of carbon, in units of 10^{15} g (10^9 tons).



From Killops and Killops 1993.

Note that the flux of organic material being preserved as sediment is considerably lower than other fluxes. This is because in almost all environments, any available organic material is consumed by life forms and recycled. Only in unusual environments such as peat bogs and anaerobic underwater basins are organisms unable to efficiently recycle all organic carbon available.

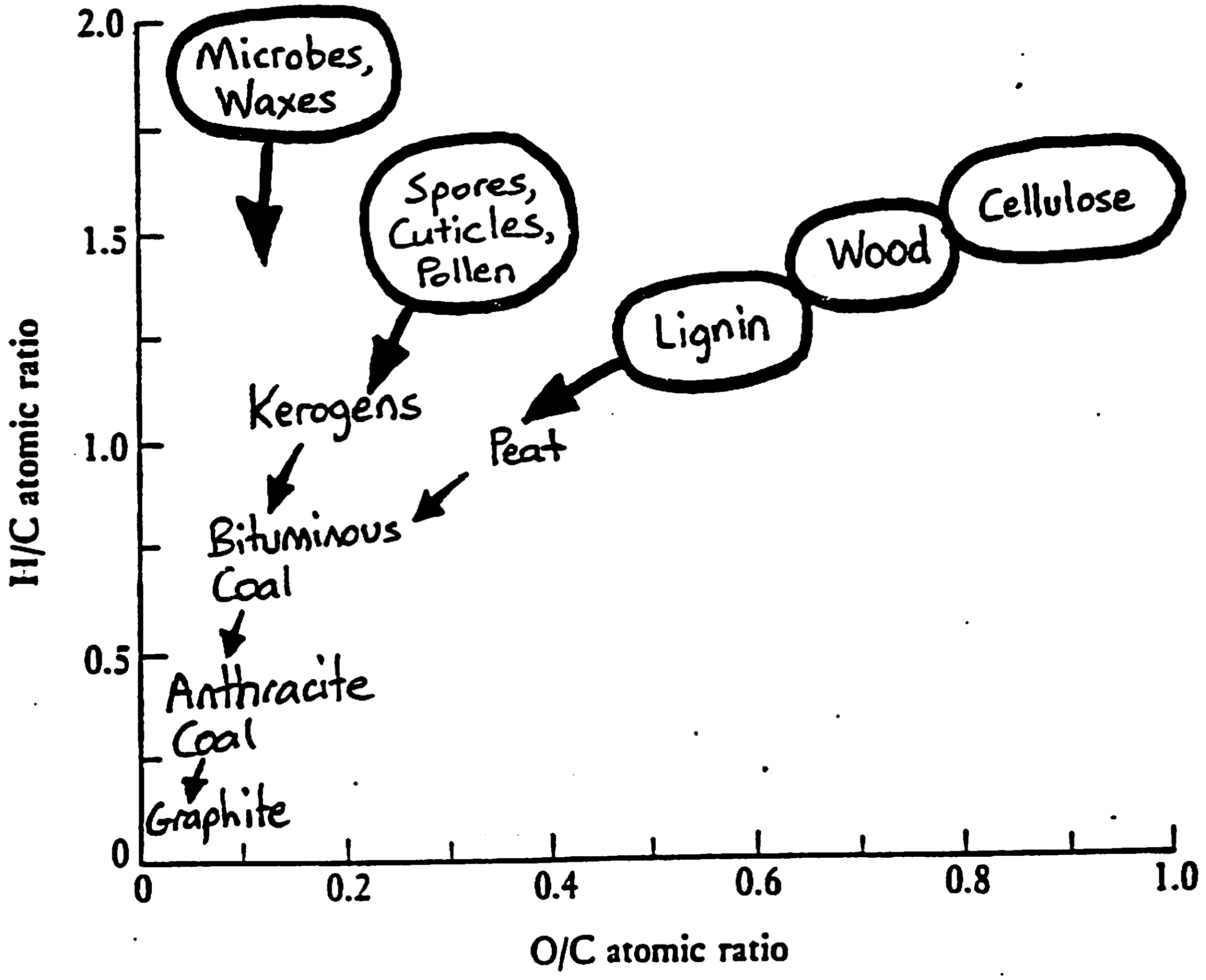
2. CHEMICALLY, WHAT IS IT AND HOW DOES IT FORM?

Start with a minimalist review of CHON chemistry. Don't worry, it's all just nomenclature. Besides, many of these things are good to eat.

- **alkanes** – single bonded C with H tying up loose bonds (saturated).
- **alkenes** – some C double bonded so fewer H (unsaturated).
- **aliphatic hydrocarbons** – alkanes and alkenes
- **aromatic hydrocarbons** – ring of 6 C, alternate single and double bonds (stable).
- **phenols** – aromatic hydrocarbons with an OH functional group.
- **carbohydrates** – having the general formula $C_n(H_2O)_n$.
- **proteins** – polymers of amino acids ($-NH_2$ and $-COOH$ functional groups).
- **lipids** – non water soluble organic compounds including waxes, fats, terpenoids, etc.

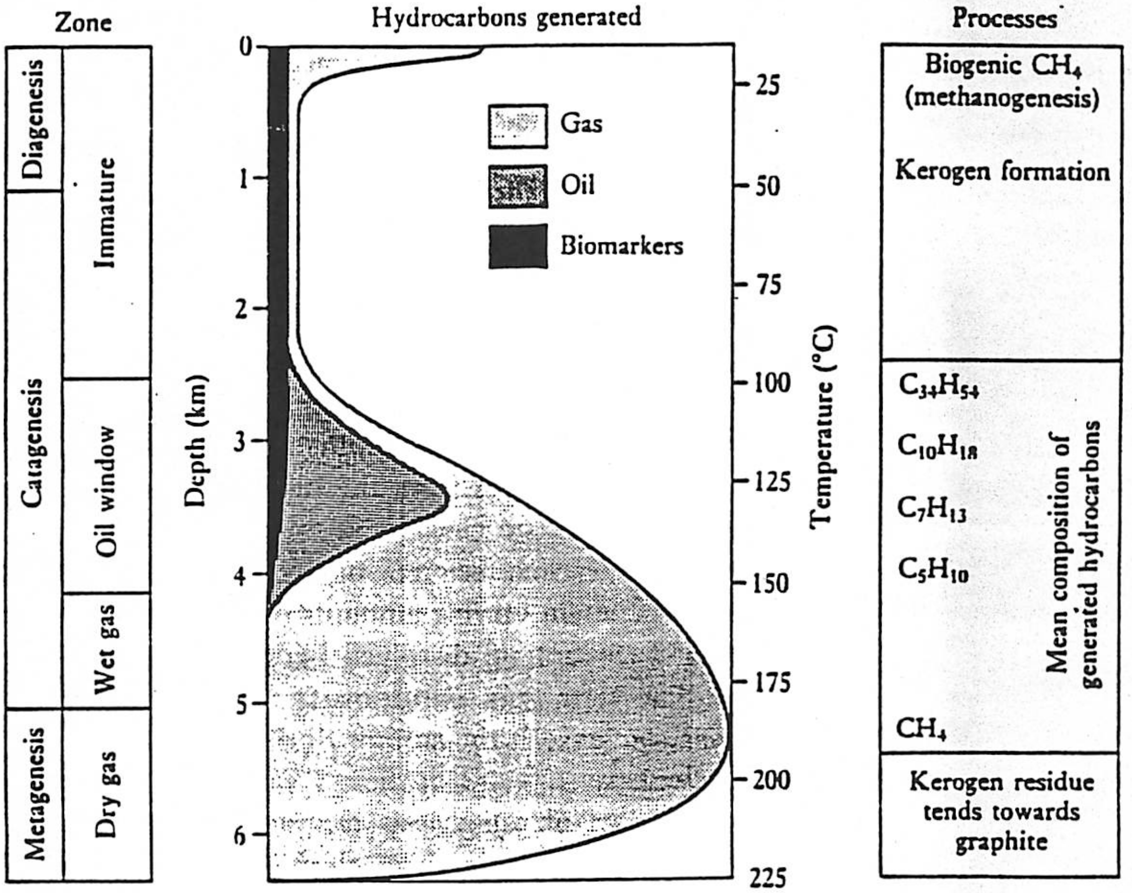
Living (and dead) organisms are made up of these classes of chemicals. Bacteria and lower life forms are generally made of proteins, as well as simpler lipids and carbohydrates, while higher plants have much less lipids and proteins, their structure being mostly made of cellulose (highly polymerized carbohydrates) and lignins (polymerized phenols). Since bacteria generally get the last word in anaerobic and deep underground environments (they thrive on nitrate reduction, sulphate reduction, and methanogenesis), their remains can dominate organic sediments, along with the least digestible parts of higher plants (such as pollen, spores, leaf cuticle bits, and seed coatings).

Even after organic sediments are buried out of reach of bacteria, they continue to evolve chemically. This process is shown in a "Van Krevelen diagram". Heat and pressure cause sediment chemistry to evolve down and to the left from the circled precursors.



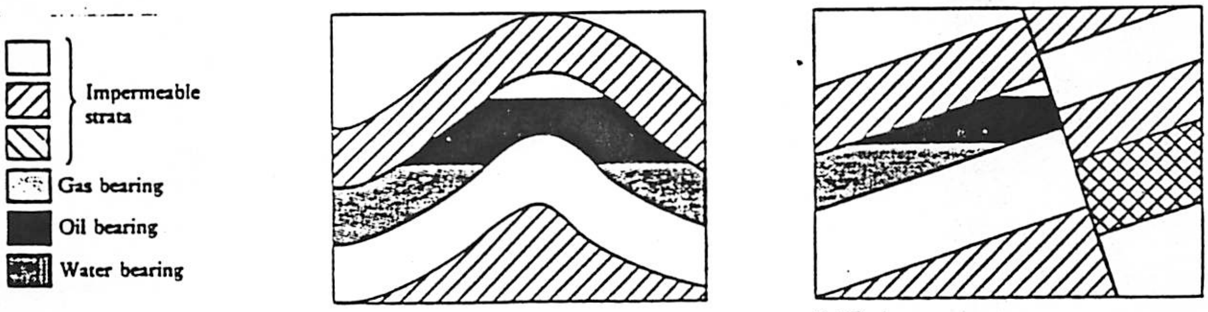
GRUNDY : ORGANIC DEPOSITS

In **diagenesis**, **catagenesis**, and **metagenesis**, functional groups such as –OH, –COOH, and $-NH_2$ are lost, and the residual bonding sites joined up to make a more compact and more highly aromatic structure. Elements lost from the sediment take the form of **petroleum**, which means anything from the heaviest bitumins to methane gas. Water is given off as well. The composition of petroleum given off is strongly dependent on the composition of the precursor material. It also depends on the temperature and pressure, as shown in this figure. The atomic weight composition of crude oil is approximately ~85% C, ~13% H, 0.1–5.5% S, 0.1–4.5% O, and 0.1–1.5% N (Levorsen 1967).



From Killops and Killops 1993.

Sometimes petroleum is able to escape from the stratum where it formed, rising since it is less dense than rocks. If it escapes to the surface, it could reenter the biosphere, burn, or loosing volatiles to the air. form a tar pit or seep. If it rises under a trap of impermeable strata, it can form a reservoir.



(a) Anticlinal trap

(b) Fault trap

GRUNDY : ORGANIC DEPOSITS

3. NATURAL OIL SEEPS AROUND SANTA BARBARA.

Historical evidence:

- **1542** – First European contact with the indigenous Canaleño people. Two Spanish caravels under Juan Rodriguez Cabrillo explored the coast and observed that the Canaleños caulked their boats with tar from local seeps.

- **1776** – Franciscan monk Father Pedro Font wrote: "...much tar which the sea throws up is found on the shores. Little balls of fresh tar are also found. Perhaps there are springs of it which flow out of the sea."

- **1792** – The navigator for Captain Cook's expedition wrote: " The surface of the sea, which was perfectly smooth and tranquil, was covered with a thick, slimy substance, which when separated or disturbed by a little agitation, became very luminous, whilst the light breeze, which came principally from the shore, brought with it a strong smell of tar, or some such resinous substance. The next morning the sea had the appearance of dissolved tar floating on its surface, which covered the sea in all directions within the limits of our view."

- **1860s** – Outcrops of asphault around Carpinteria and More's Landing were being commercially quarried for roofing and paving material for customers as far away as San Francisco. Benjamin Silliman (advocating commercial drilling for oil) proclaimed that the sea "boils like effervescing soda water, with the escaping gas which accompanies the oil, and great globules of pure oil rising with the gas flash out on the surface of the water..."

- **1880s** – Grandiose advertisements in East-coast newspapers claimed the invigorating aroma of the natural oil slick off the Santa Barbara shore "not only made infectious diseases a rarity but also had a salutary effect on almost all chronic illnesses."

Empirical evidence:

We may be able to see an example of a **brea** (Spanish for *tar*) deposit at Carpinteria State Beach Park. The bulk of the tar from the Carpinteria area is no longer there, having been excavated. It once contained a suite of fossils similar to those of the more famous Rancho La Brea tar pits in Los Angeles, including dire wolves, giant cats, camels, horses, bison, plant parts, and some 60 species of birds (they just can't resist oil).

4. CLINKER BEDS AROUND GRIMES CANYON.

A stratum of petroliferous Miocene shale had been burning for centuries before it was extinguished at great expense by the Southern Pacific Railroad. The burning, presumably ignited by lightning, made slopes unstable and was frequently causing stones to fall on their railroad tracks. After burning, the resulting "clinker" beds have been quarried for the unusually colored decorative stone in Grimes Canyon, just east of Santa Paula. The clinkers can also be seen just east of Carpinteria, along the coast. (See Sharp ***Field Guide: Coastal Southern California***. Kendall/Hunt Publishing).

(+2)

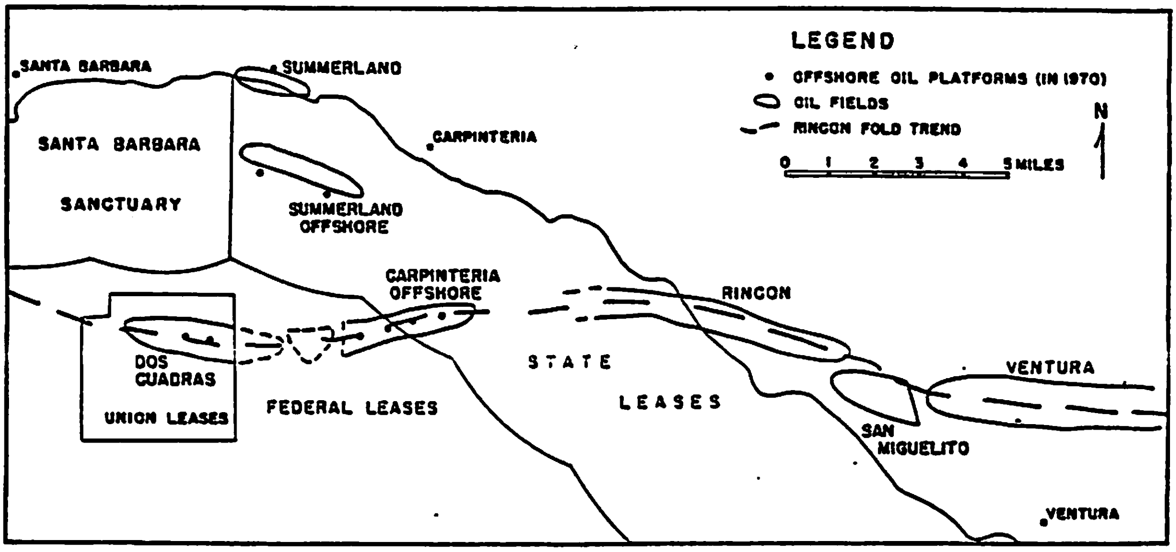
GRUNDY: ORGANIC DEPOSITS

5. OIL EXPLORATION, DRILLING, AND EXTRACTION.

In order to drill to and extract oil from under the sea, the drill bit is encased in a steel pipe, called casing, which is ordinarily cemented to the sea-floor to a depth of at least 300 feet below the sea-floor. The drill string itself is a hollow pipe, and drilling mud is pumped down the center of the drill, returning along the outside, carrying debris removed by the drill bit. This drilling mud serves an additional, crucial purpose – keeping the pressure in the bottom of the bore-hole in hydrostatic equilibrium, so that when oil is struck, it does not explosively decompress through the borehole (a "gusher" or "blowout"). The drill crew must dynamically adjust the density of the drilling mud in order to keep the well in hydrostatic equilibrium.

6. THE SANTA BARBARA BLOWOUT OF 1969.

A blowout occured at Union Oil Co.'s well A-21 in the Dos Cuadras field, January 28, 1969. This accident was followed by a second blowout at the adjacent well A-41, less than a month later. In the Dos Cuadras field, oil lies only 300 feet below the sea floor, so the casings were only cemented to a depth of 240 feet. The cap rock was extremely friable, and after the wells were plugged, the pressure differential was so high that the oil was able to find (or create) other escape routes and continued to pour out of the ocean floor for ~2 months at a rate of something like 20,000 to 200,000 gallons/day. Beaches as far away as San Diego were fouled by oil, and numerous birds were killed, with much press attention. The eventual solution involved pumping 25,000 sacks of cement into shallower holes drilled into the caprock nearby, while simultaneously pumping oil out of the reservoir as fast as possible. (See Steinhart and Steinhart *Blowout: A case study of the Santa Barbara oil spill.* Duxbury Press 1972).



GEOLOGY FROM VENTURA TO LA VIA WHITTIER NARROWS

Fatima Ebrahim

Most of the mountain ranges we will see on this portion of or trip comprise the transverse ranges which stretch from West to East and include the Santa Ynez mountains, the Santa Monica mountains and the San Gabriels.The transverse ranges were formed by intense faulting and folding of extremely complex rock groups very late in geologic time.They consist mostly of igneous and sedimentary rock.(refer to diagram of geologic time) Interestingly enough, anothrite, which is of the same composition as precambrain rocks is found in the San Gabriels.No one can explain why it is seen in such young mountains.

Some Roadside Geology (refer to map)
1)The dry bed of the Santa Clara river is a major source of sand and gravel for Ventura county.The river looks harmless, but in times past it has flooded viciously and occasionally still does.
2)The broad flat Oxnard Plain which opens west from the base of Canejo Grade is a depressed area deeply filled with alluvium from the Santa Clara and other streams.
3)The tanks and pumps at Oxnard oilfield pump oil from beneath buried volcanic rocks like those seen at Canejo Grade.
4)Camarillo Hills are the result of goelogically recent folding and faulting.
5)The Canejo Volcanics are composed of volcanic rocks.
6)Notice that the terrain between Las Virgines Road and Westlake Road on opposite sides of the freeway is strikingly different. To the north the hills are rounded and

(74)

EBRAHIM: VENTURA - LA

low, smooth and grass covered.These are relatively soft fine-grained Miocene sedimentary materials.To the south are volcanics which are higher,rugged,craggy and dark-colored.

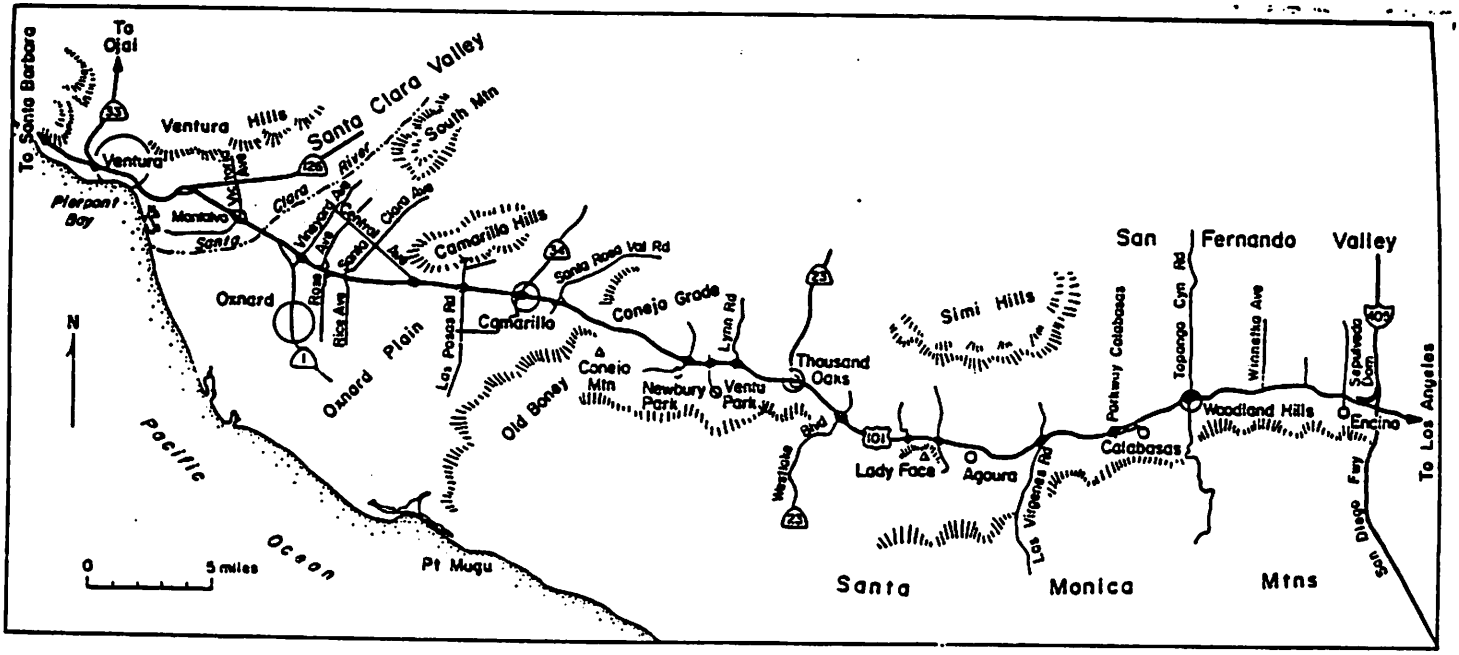
7)The rounded ridges and hillocks on either side west of Topanga Canyon Blvd are composed of shales.

8)The Santa Monica mountains are composed of volcanic and sedimentary rock. The dominant rocks are Cretaceous sandstone and conglomerates .

9)The Santa Susana mountains are composed of relatively fine Miocene and Pliocene marine strata. The reater height of the Santa Susanas is caused by recent tectionic uplift.

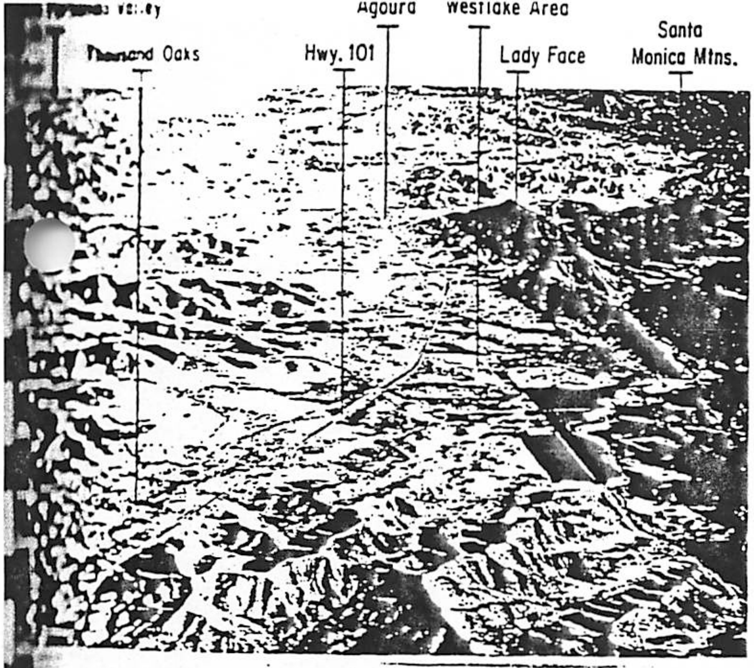
10)The Simi Hills are composed of well-consolidated coarse sandstones that are partly Cretaceous

11)Past the Sepulveda Flood Dam, the San Fernando Valley is a trough filled with about 15,000 feet of sedimentary rocks ,covered with consderable thickness of sand, gravel and soil swept down from bordering mountains largely by tributeries of the LA river.

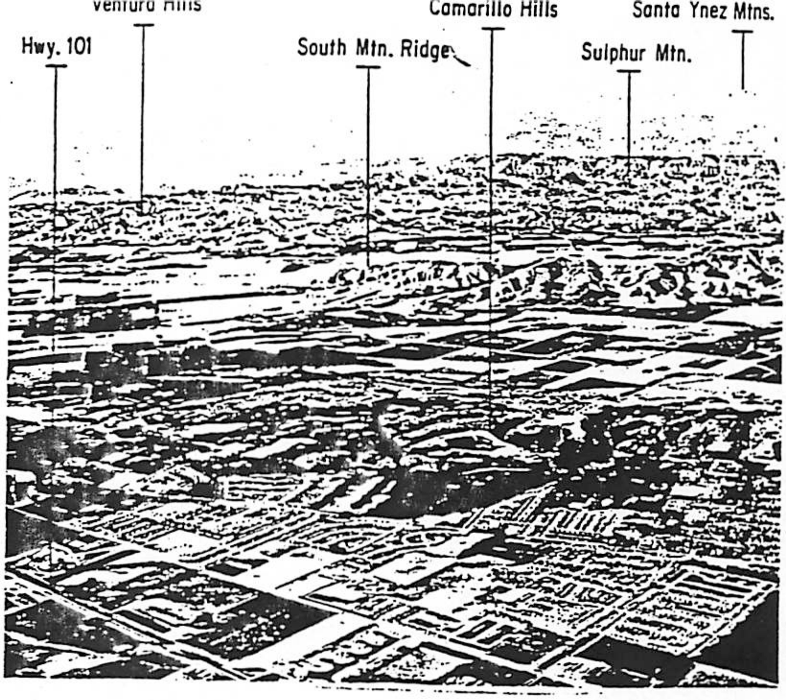


AERIAL PHOTOS

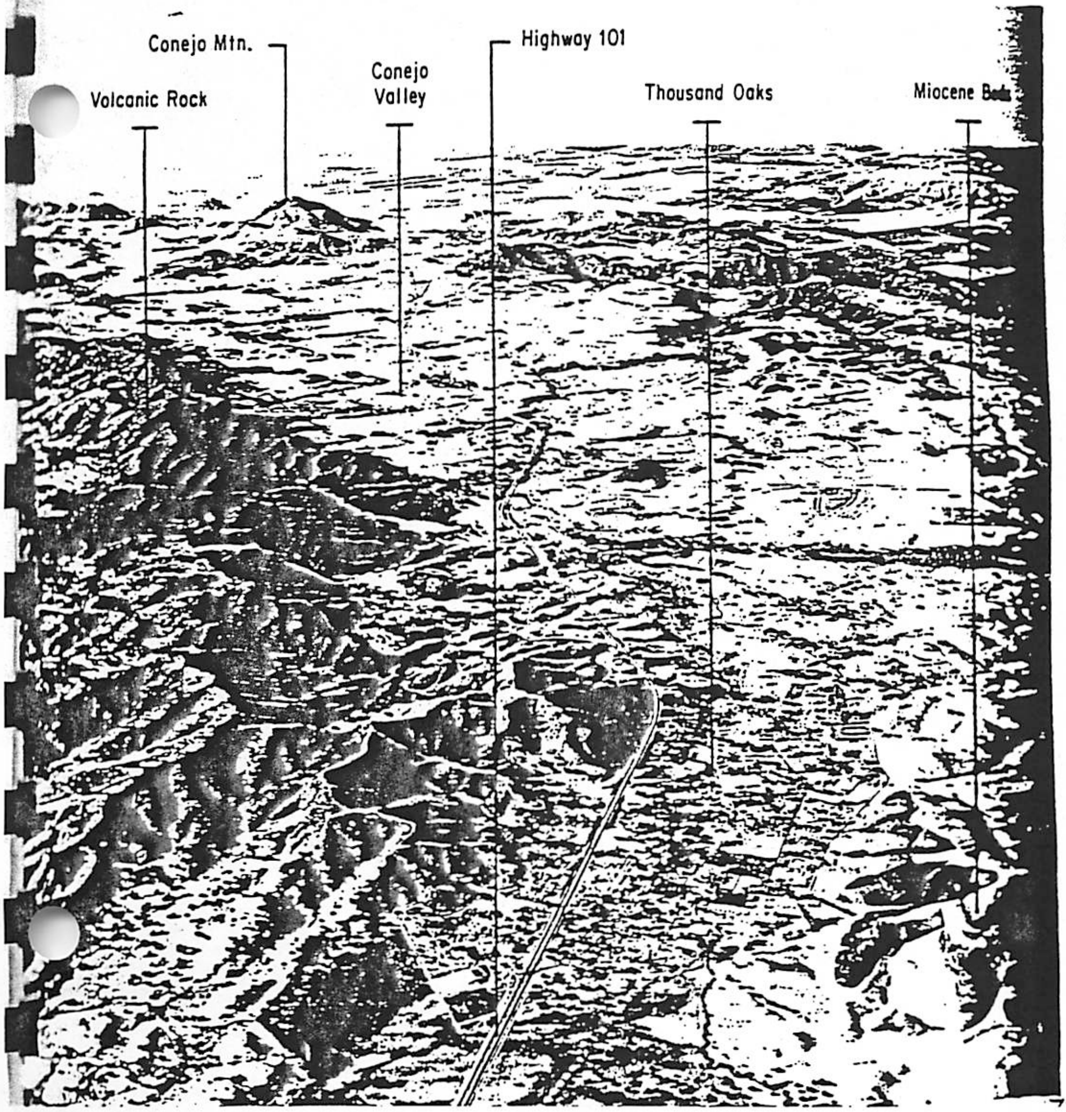
(JUST IN CASE IT'S TOO SMOGGY TO SEE!)



VIEW EAST ALONG HIGHWAY 101 FROM THOUSAND OAKS



VIEW NORTHWESTWARD ACROSS CAMARILLO HILLS AND LOWER SANTA CLARA RIVER VALLEY

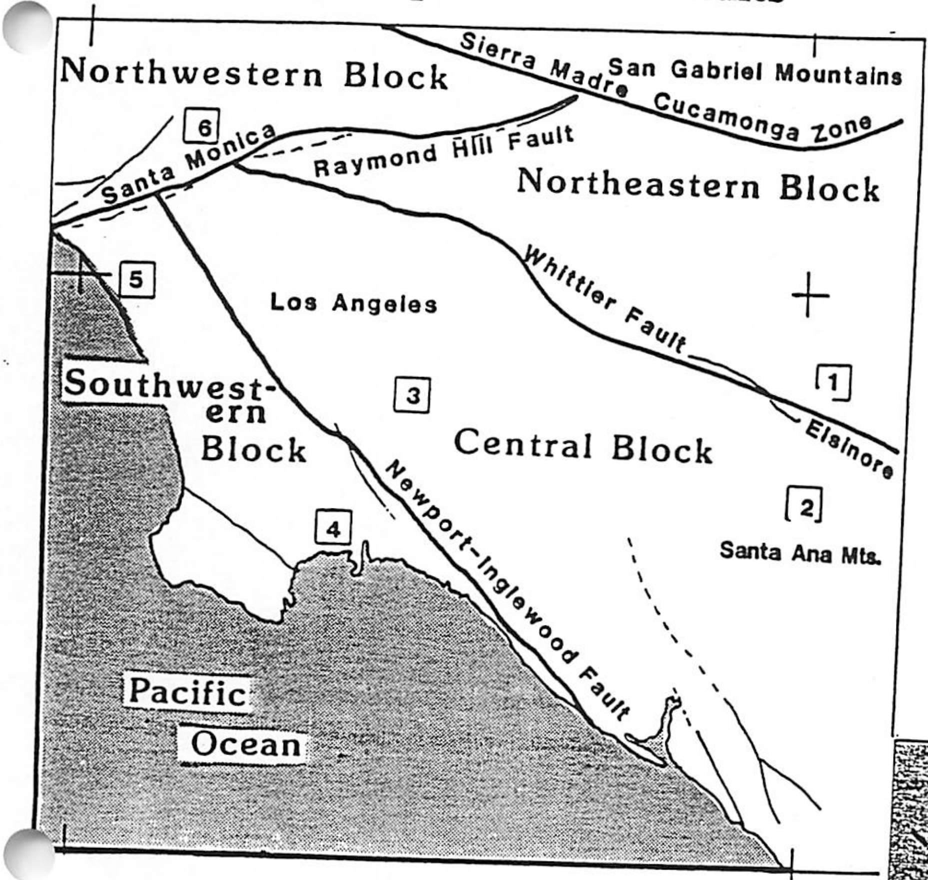


VIEW WEST ALONG HIGHWAY 101 FROM WESTLAKE AREA.

Photos courtesy Fatima.

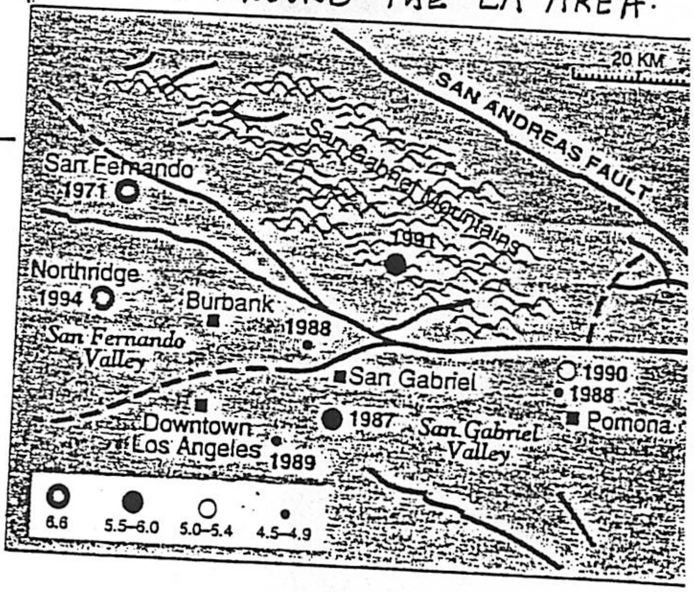
EBRAHIM: VENTURA - LA

Earthquakes and Faults



FAULTS RUNNING THRU LA BASIN

SOME OF THE RECENT EARTHQUAKES IN AND AROUND THE LA AREA.



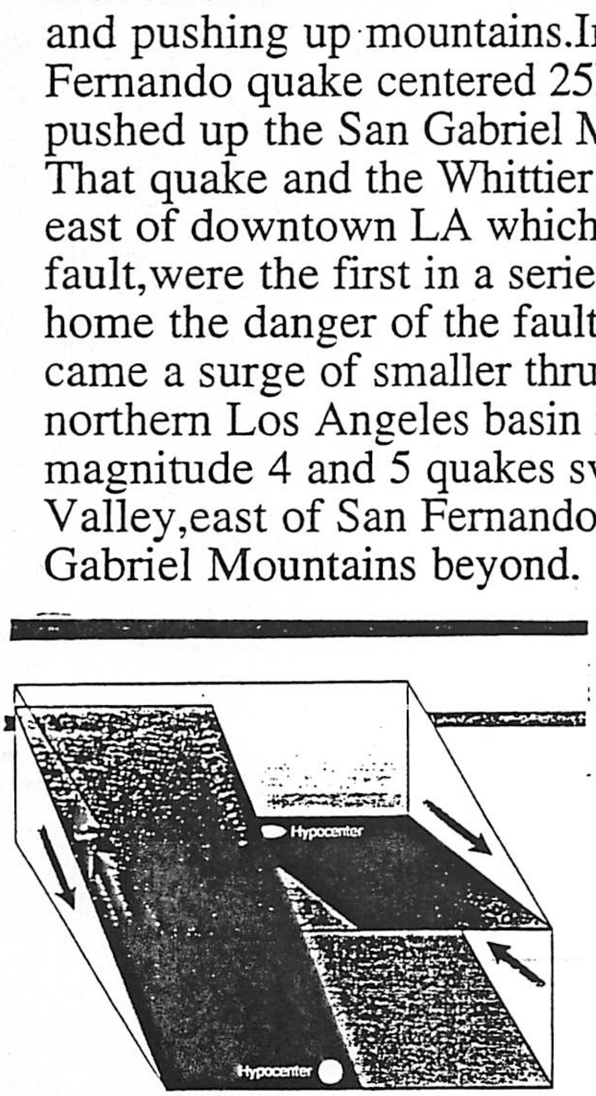
The San Andreas fault where the Pacific Plate slips past theNorth American plate is indirectly responsible for the Northridge Earthquake which ranked 6.6 on the Ritcher scale.If San Andreas cut straight thru California and the two plates ran exactly parallel to each other, no other faults would be neede to take up the motion.

EBRAHIM: VENTURA - LA

Instead of taking a straight shot toward the northwest,San Andreas jogs to the west as it passes LA.Crust sliding northwestward on the west side of the San Andreas encounters this "Big Bend" and is squeezed. As a result the LA region is being shortened by perhaps 10 to 15mm per year from the ocean to San Andreas as the crust is forced around the Big Bend.

The stresses of making the turn around the Big Bend have riddled the LA region with fractures: about 100 major active fractures have been identified so far.Most are the so-called thrust-faults, inclined fractures created by compression. During earthqukes the wedge of crust above the thrust fault shoves abruptly over the lower wedge. The motion shortens the crust and reshapes it,narrowing valleys and pushing up mountains.In 1971 for example, the San Fernando quake centered 25km northeast of Northridge pushed up the San Gabriel Mountains by about 2m.

That quake and the Whittier Narrows quake in 1987 30 km east of downtown LA which also took place on a thrust fault,were the first in a series of warning shots that drove home the danger of the faults beneath Los Angeles.Then came a surge of smaller thrust earthquakes along the northern Los Angeles basin in 1987: a progression of magnitude 4 and 5 quakes swept across the San Gabriel Valley,east of San Fernando valley and into the San Gabriel Mountains beyond.



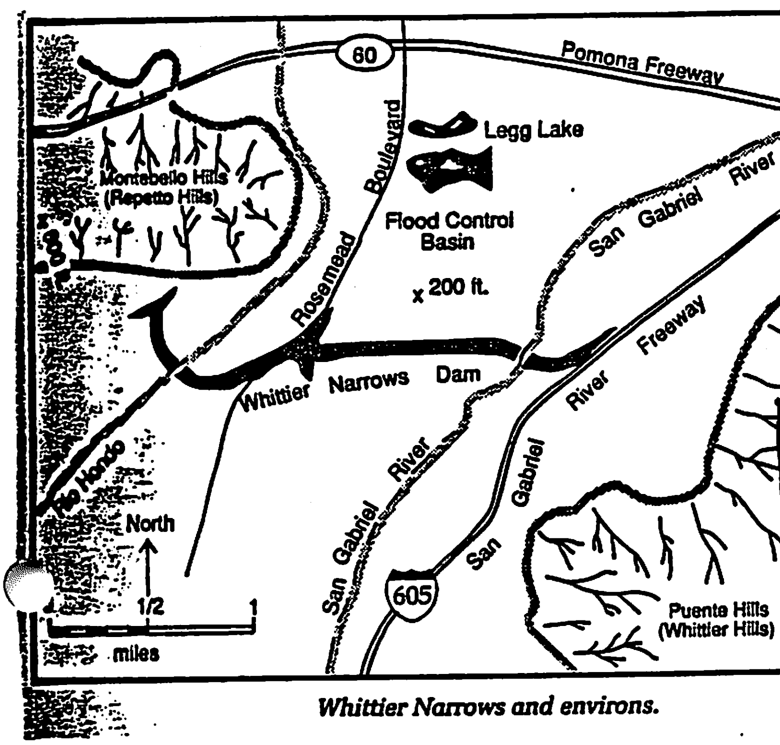
Quite a pair. The thrusting of one crustal wedge over another during the Northridge quake mimics that of the adjacent 1971 San Fernando rupture; the two may be connected.

THE NORTHRIDGE QUAKE CONSISTED OF A 25KM CHUNK OF CRUST BENG SHOVED UPWARD. THE SHAKING WAS STRONG, PARTICULARLY IN THE UPWARD DIRECTION.

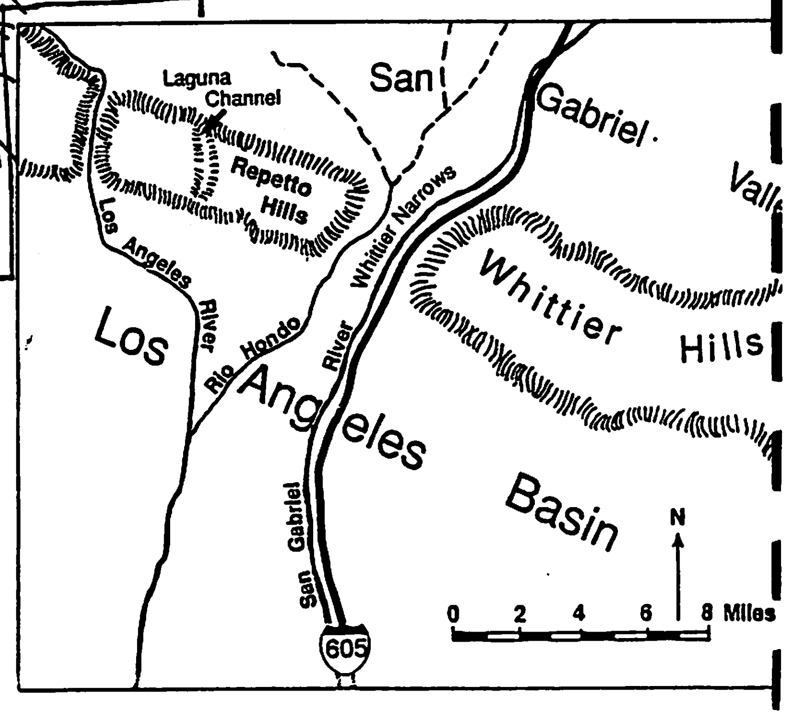
EBRAHIM: VENTURA-LA

Whittier Narrows and the San Gabriel River

The Puente Hills form a formidable barrier the extends east and southeast separating the San Gabriel Valley from the LA basin. Whittier narrows is the only gap in this thousand-foot high hilly barrier.



Whittier Narrows and environs.



Diagramatic representation of Puente Hills uplift separating the L Angeles basin and San Gabriel Valley, and antecedent Whittier Narro

The San Gabriel river cut that gap, two miles wide and 800 feet deep. Whittier Narrows slices the Puente Hills into two parts: the Repetto hills to the west and the Whittier and Chino Hills to the east.

The river was here before the Puente hills arose.That is likely to happen only in regions where the earth's crust is actively deforming.Some of the rocks folded in the Puente Hills are so young that it seems likely the hills are still rising.

Before the Puente Hills rose, the San Gabriel River and several smaller streams flowing south out of the San Gabriel Mountains had established shallow channels across the area. Then a low ridge, the first inkling of the future Puente Hills started to rise. Some of the smallest streams were probably turned aside at once, but the larger, more powerful streams including the San Gabriel River,were able to erode their beds as rapidly as the ridge rose,cutting even deeper channels across the growing barrier.

In due time, one after another of the streams was unable to challenge the rising ridge and was shunted aside.Some of these defeated streams turned east to become tributaries of the San Gabriel River, augmenting its flow and making it more able to erode its channel.Finally only the San Gabriel River survived still breaching the barrier of the Puente Hills.The hills continue to rise and te river continues to cut its way through as it flows south to the ocean.

Valleys that carry streams thru mountain ridges are usually called water gaps.Otherwise they are called wind gaps. Whittier Narrows is a water gap.As the rising ridge raised the abandoned stream valleys it converted the to wind gaps. Four of these wind gaps which indent the crest of the Repetto Hills provide important routes of communication.These are Laguna channel,the route of the Long Beach Freeway,Coyote Pass,traversed by Monterey Pass Road, the channel that Atlantic Blvd follows and an unnamed pass by Garfield Avenue.

8

GEOLOGIC TIME SCALE

NOTE:
C[illegible]t OF EARTH SOLIDIFIED
ABOUT 4,000 MILLION YEARS
AGO

ERAS	PERIODS, EPOCHS	TIME, IN MILLION YEARS	SOME GREAT EVENTS IN CALIFORNIA	LIFE ON THE EARTH
Cenozoic	Quaternary Recent or Holocene	0.01	Continued faulting and mountain building	
	Pleistocene	3		
	Tertiary Pliocene	11	Principal building of Coast and Transverse Ranges	Great land mamm oldest man
	Miocene	25	Local movements in Coast and Transverse Ranges	
	Oligocene	40		First apes
	Eocene	60	Widespread coastal seas	First placental mammals
	Paleocene	70		
Mesozoic	Cretaceous	135	Building of the Sierra Nevada, Klamath, and Peninsular Ranges	Extinction of dinosaurs
	Jurassic	180		
	Triassic	225	Shallow seas	Age of dinosaurs First dinosaurs
Paleozoic	Permian	270	Volcanism and mountain building (extent unknown)	Rise of reptiles
	Pennsylvanian	305		
	Mississippian	350	Probably shallow seas over much of California, Cambrian to Permian	First reptiles First land vertebrates
	Devonian	400		Fishes abundant
	Silurian	440		
	Ordovician	500		
	Cambrian	600		Trilobites domin First abundant fos
Precambrian	Late	1800	Uplift Mountain building in southern California	Organic tubes in marine limeston Oldest fossils
	Early	2700	Oldest rocks and mountains	(algae?) First life (?)

References

1)California's Changing Landscapes.Gordon B. Oakeshott
2)Coastal Southern California .Robert P Sharp
3) Geology Underfoot in Southern California.Robert Sharp
4)How many more after Northridge?.Science Letters.vol 263.28th January 1994.
5)Cenozoic Basin Development of Coastal California. Ingersoll/Ernst,Editors. Rubey Volume 6.

left blank (81-82)

D. Orrison 1

MARTIAN SHORELINES:
the justification for our being here now.
by DOUG DAWSON, granter of all things.

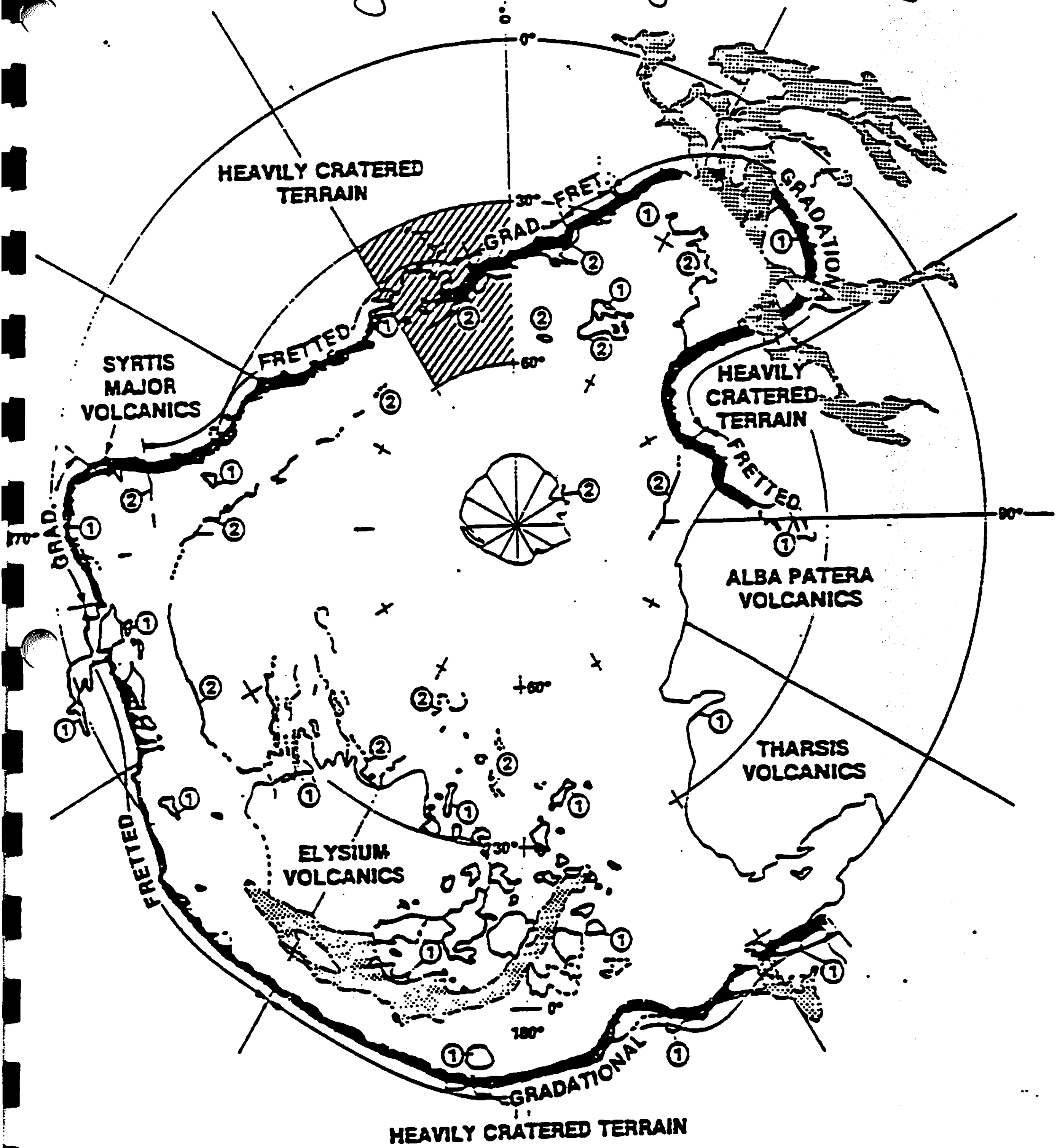
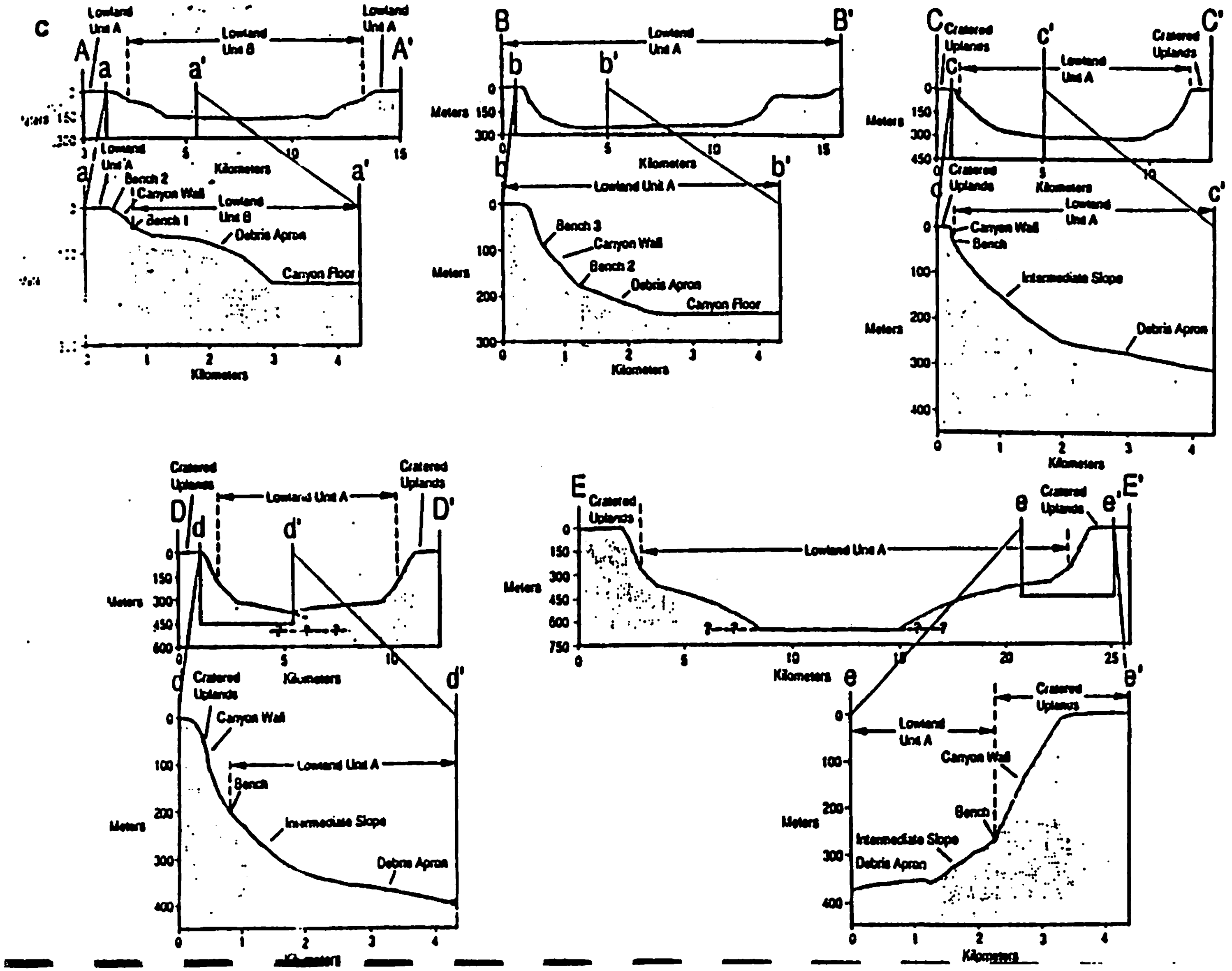


FIG. 1. Polar projection of northern lowland plains of Mars relative to major bounding provinces (adapted from Scott and Tanaka 1986. Greeley and Guest 1987. Tanaka and Scott 1987, and indicated by thin black lines). General location of lowland/upland boundary is indicated by a broad gray line dapted from Scott and Tanaka 1986. Greeley and Guest 1987). The two principal types of lowland/ upland boundary are indicated as either "gradational" or "fretted." Major outflow channels are indicated by stippled areas and by alternate dot–dashed thin black lines. Global distribution of unit boundaries described in the text is indicated by heavy black lines labeled 1 and 2 (dashed where positive identification is limited by available image resolution). Contact No. 1 separates cratered

84

DAWSON: MARS



DAWSON : MARS

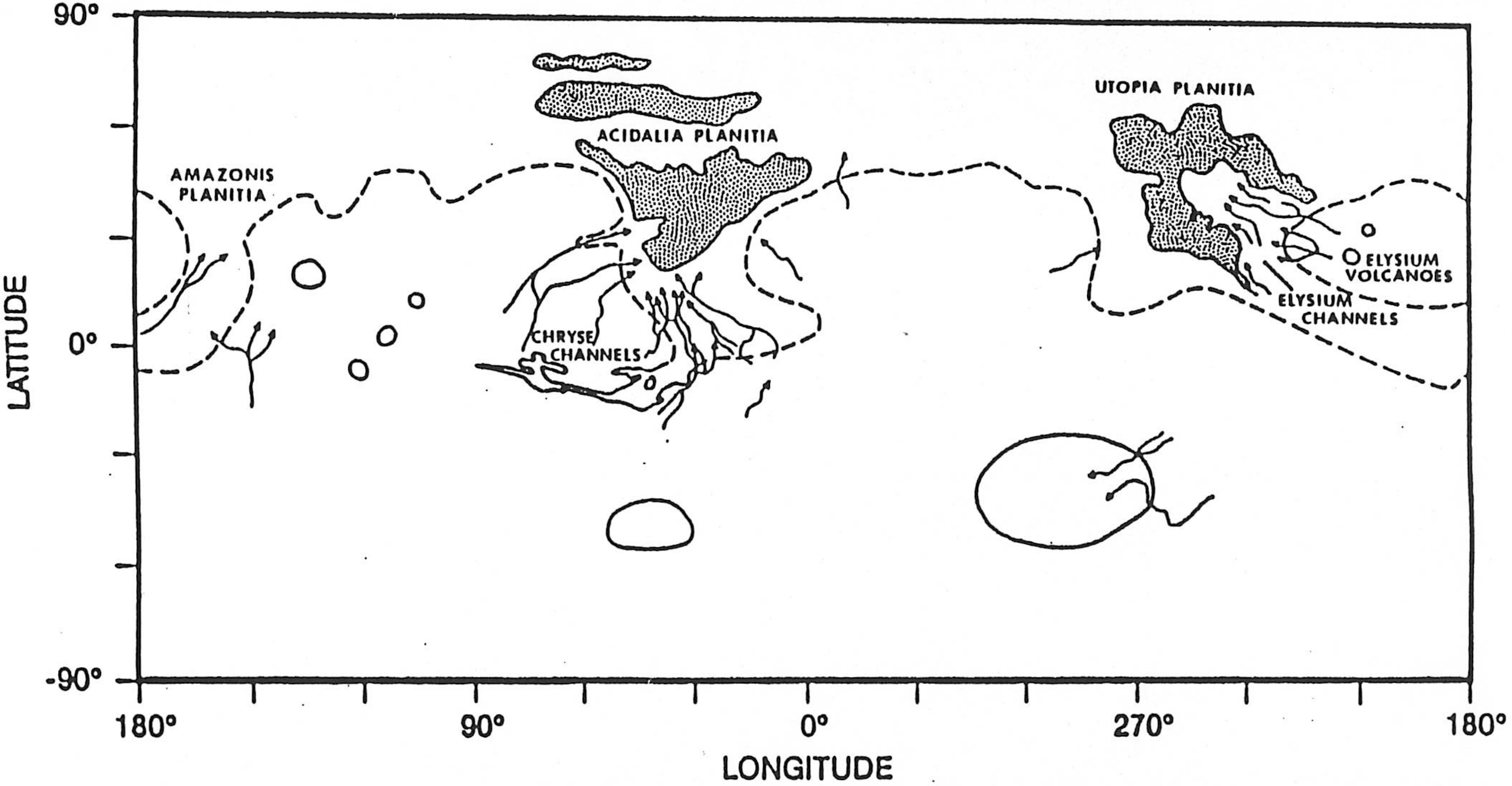


Fig. 3. Map of polygonally fractured terrain (stippled). Northern-highland boundary (dashed line), channels (solid ines with arrows). Note projection of northern plains into southern highlands and their association with channels. Cylindrical projection.

86

DAWSON : MARS

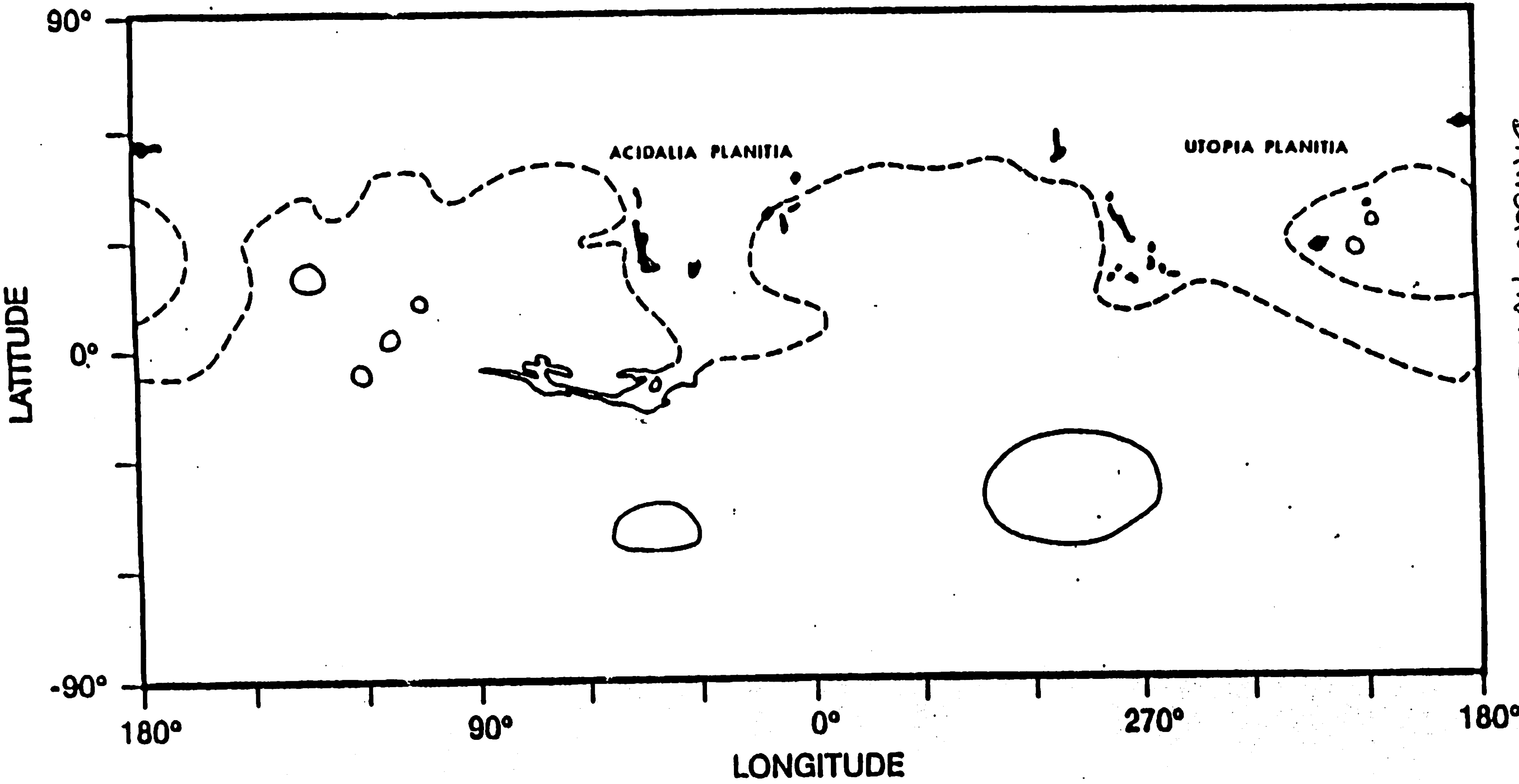


Fig. 5. Location of sinuous ridges (solid black). Many ridges occur in subtle linear depressions and are found near or in front of the northern highland boundary (dashed line). Cylindrical projection.

Titan: Another Planetary Connection for Shoreline and Beach Processes?

Or: Surf Titan   Or: How to Disseminate Potentially Dangerous Propaganda in Your Spare Time

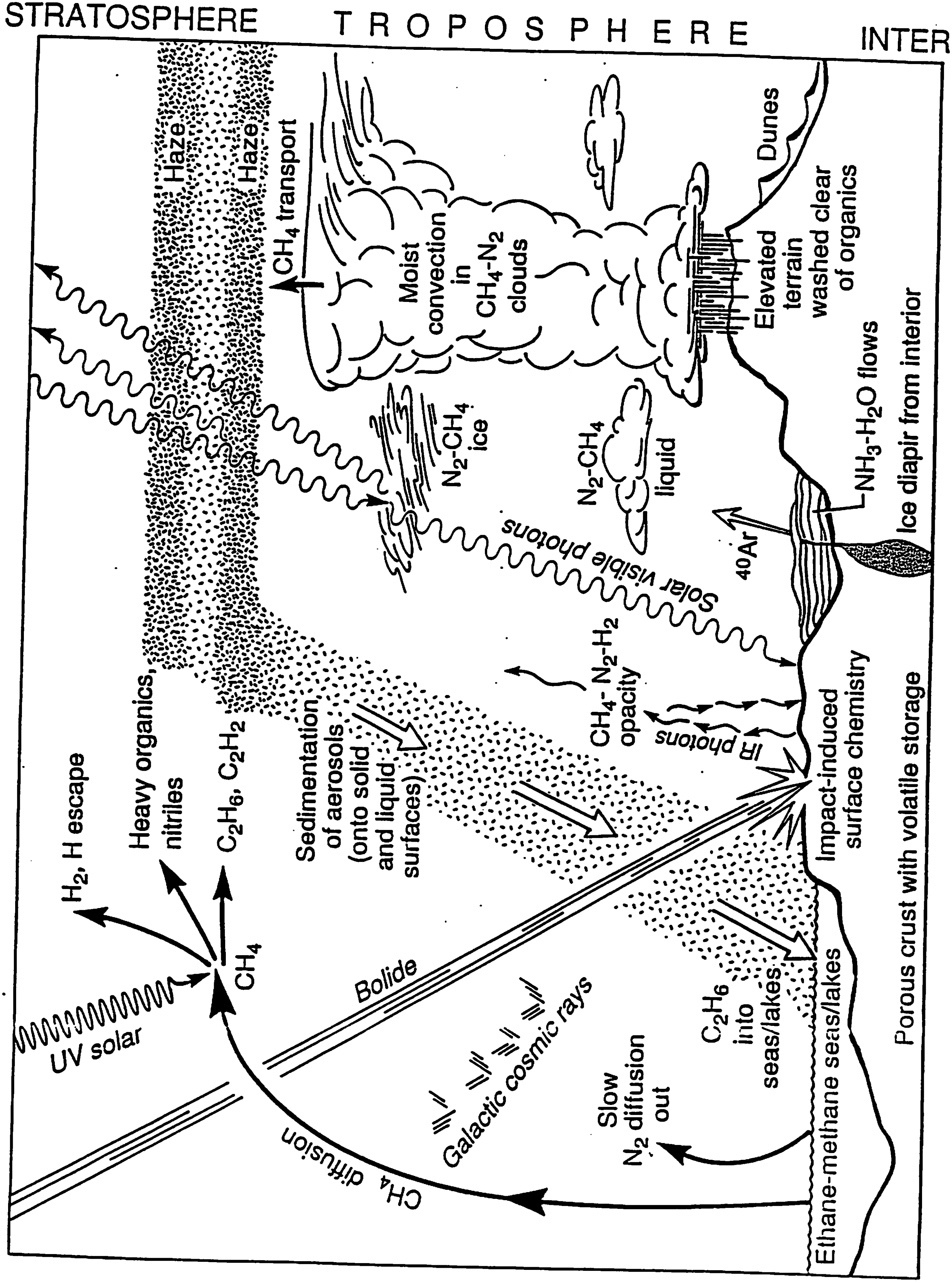
By: Jennifer Grier

The planet Mars is clearly a venue which makes the study of shoreline processes valid and important to planetary science. But Mars may not be the only body which makes this study applicable; it is speculated that Saturn's moon Titan may possess liquid reservoirs. UV photolysis of methane in Titan's atmosphere could lead to the creation substantial quantities of organics, nitriles and especially ethane. Ethane would be liquid at the surface of Titan, and a substantial methane component (also liquid) would explain why the methane in the atmosphere has not yet been depleted by this process (Lunine, 1993).

Although the notion of *global* oceans is not supported by the bulk of available data about Titan, areas of hydrocarbon liquid might exist on its surface. Even if the postulated "ethane- methane ocean" is in fact stored in a porous crust (Stevenson, 1992), low lying areas could be below the hydrostatic liquid level, leading to closed liquid basins. Additionally, IRIS data on the temperature at low altitudes can be interpreted in terms of a drop of as much as several degrees from equator to pole (Stevenson and Potter, 1986), though this is not the preferred interpretation (Flasar and Conrath, 1991). If this temperature drop is real, then the poles are saturated with respect to nitrogen-methane condensate from the atmosphere, and polar seas may be present. At somewhat lower latitudes, near-saturation may lead to frequent rainfall of methane-nitrogen liquid solutions, leading to river systems which likely are extremely rare at the apparently-undersaturated equator.

If rivers, lakes and other large reservoirs of ethane and methane do exist on Titan, then some or all of the forms and processes that we are studying may also exist. The particulate material available for transport may be the aerosol material created by methane photolysis, or water ice and silicate "bedrock" material broken up by impacts or erosion. Titan may be home to waves, longshore and rip currents in its reservoirs, which may contain hydrocarbon dunes, cusps and bars; or estuaries and carved from water ice or silicates, etc. The figure on the next page is included to illustrate the possible processes that may be working on the surface of Titan, and the place that ethane-methane reservoirs may have in this framework (Lunine).

Flasar, F. M. and B. J. Conrath, The Meteorology of Titan, Proceedings Symposium on Titan, ESA SP-338, 1991.
Lunine, J. I., Does Titan Have an Ocean? A Review of Current Understanding of Titan's Surface, *Rev. of Geophys.*, 31, 2, 133-149, 1993.
Stevenson, D.J. and B. E. Potter, Titan's latitudinal temperature distribution and seasonal cycle, *Geophys. Res. Lett.*, 13, 93-96, 1986.
Stevenson, D. J., Interior of Titan, Proceedings of the Symposium on Titan, ESA SP-338, 215-219, 1992.


STRATOSPHERE
TROPOSPHERE
INTERIOR
Haze
Haze
CH_4 transport
Moist convection in CH_4-N_2 clouds
Dunes
Elevated terrain washed clear of organics
NH_3-H_2O flows
Ice diapir from interior
N_2-CH_4 ice
N_2-CH_4 liquid
Solar visible photons
^{40}Ar
CH_4-N_2-H_2 opacity
IR photons
Impact-induced surface chemistry
Porous crust with volatile storage
H_2, H escape
Heavy organics, nitriles
C_2H_6, C_2H_2
Sedimentation of aerosols (onto solid and liquid surfaces)
CH_4
UV solar
Bolide
Galactic cosmic rays
C_2H_6 into seas/lakes
Slow N_2 diffusion out
CH_4 diffusion
Ethane-methane seas/lakes

LAKE BONNEVILLE SHORELINES
by Cristine Jennings

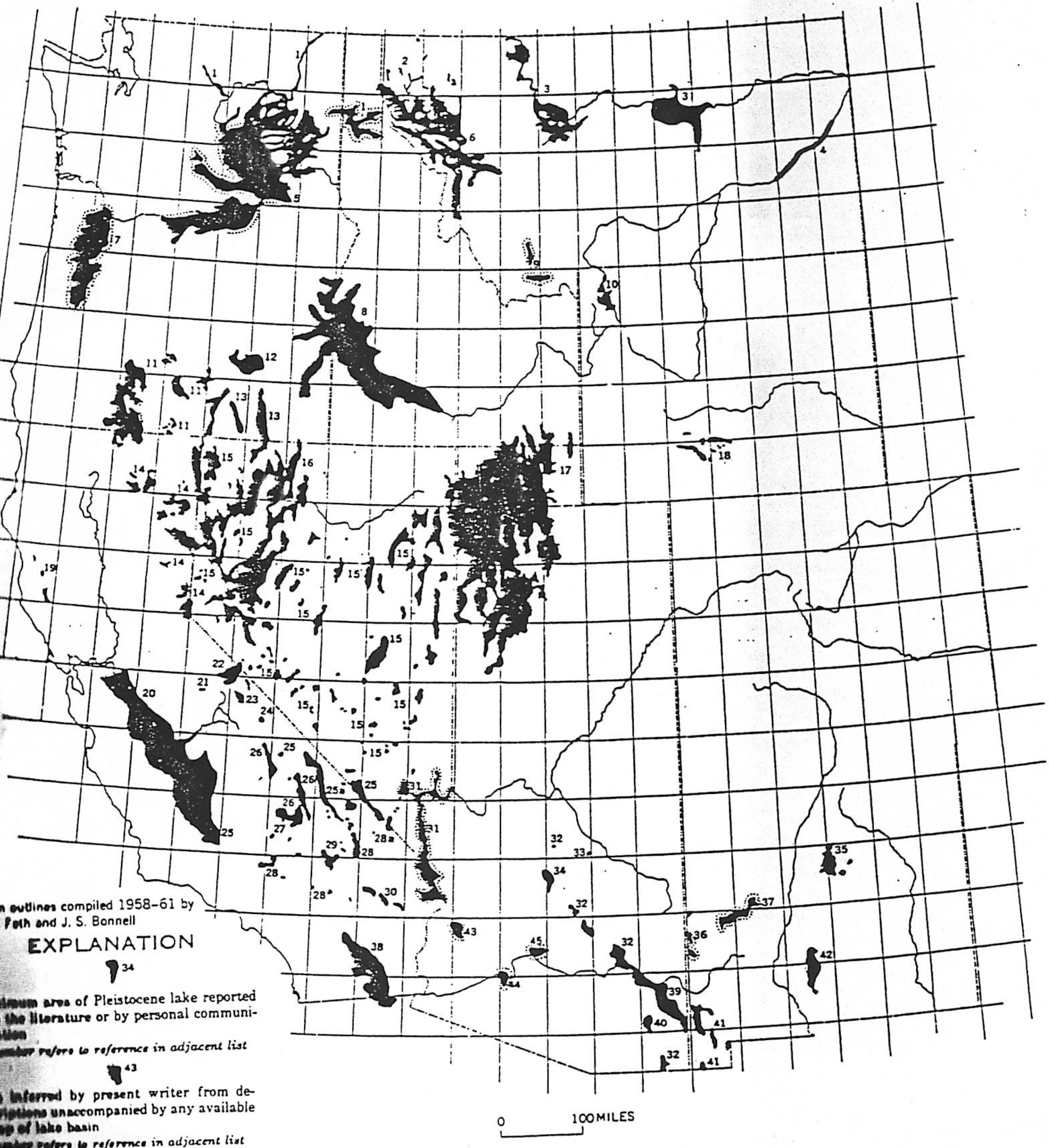


FIG A

LAKE BONNEVILLE : Jennings

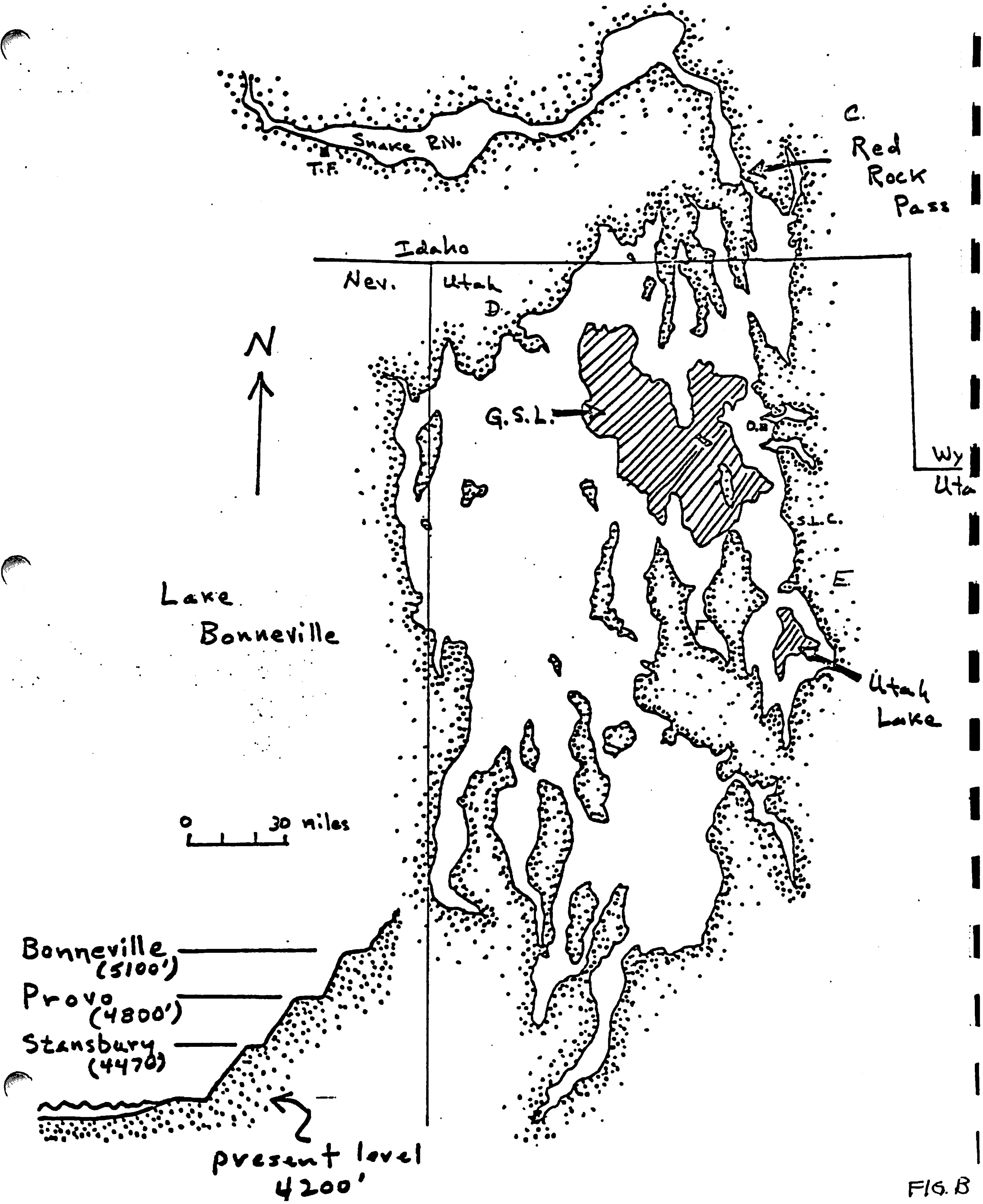
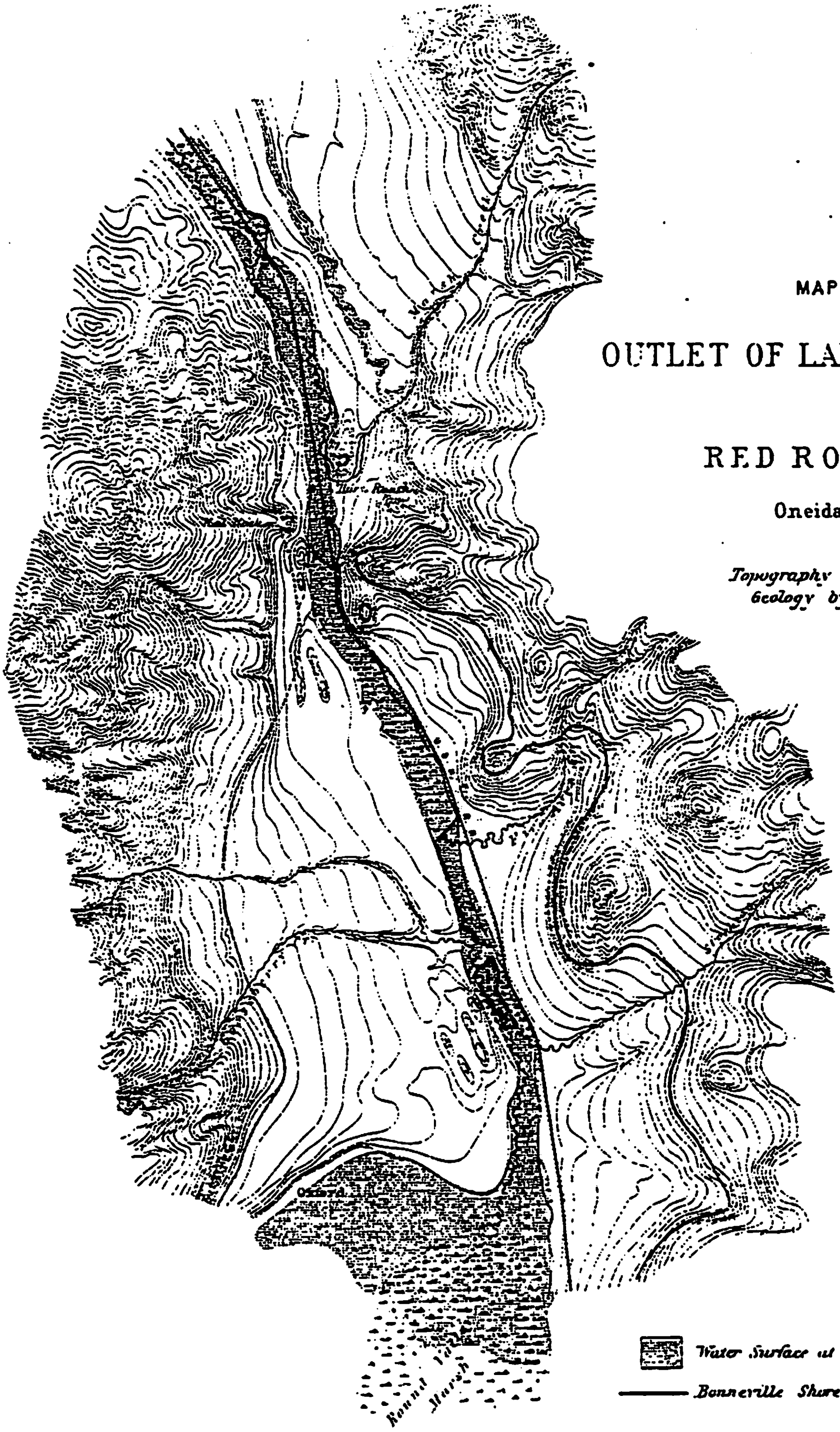


FIG. B

LAKE BONNEVILLE : JENNINGS

91



MAP OF THE

OUTLET OF LAKE BONNEVILLE.

AT

RED ROCK PASS.

Oneida Co. Idaho.

Topography by W. D. Johnson.
Geology by G. K. Gilbert.

SCALE 0 ½ 1 MILE

35½ feet contours.

▨ *Water Surface at the Provo stage.*

——— *Bonneville Shoreline.*

- - - - - - " " *restored.*

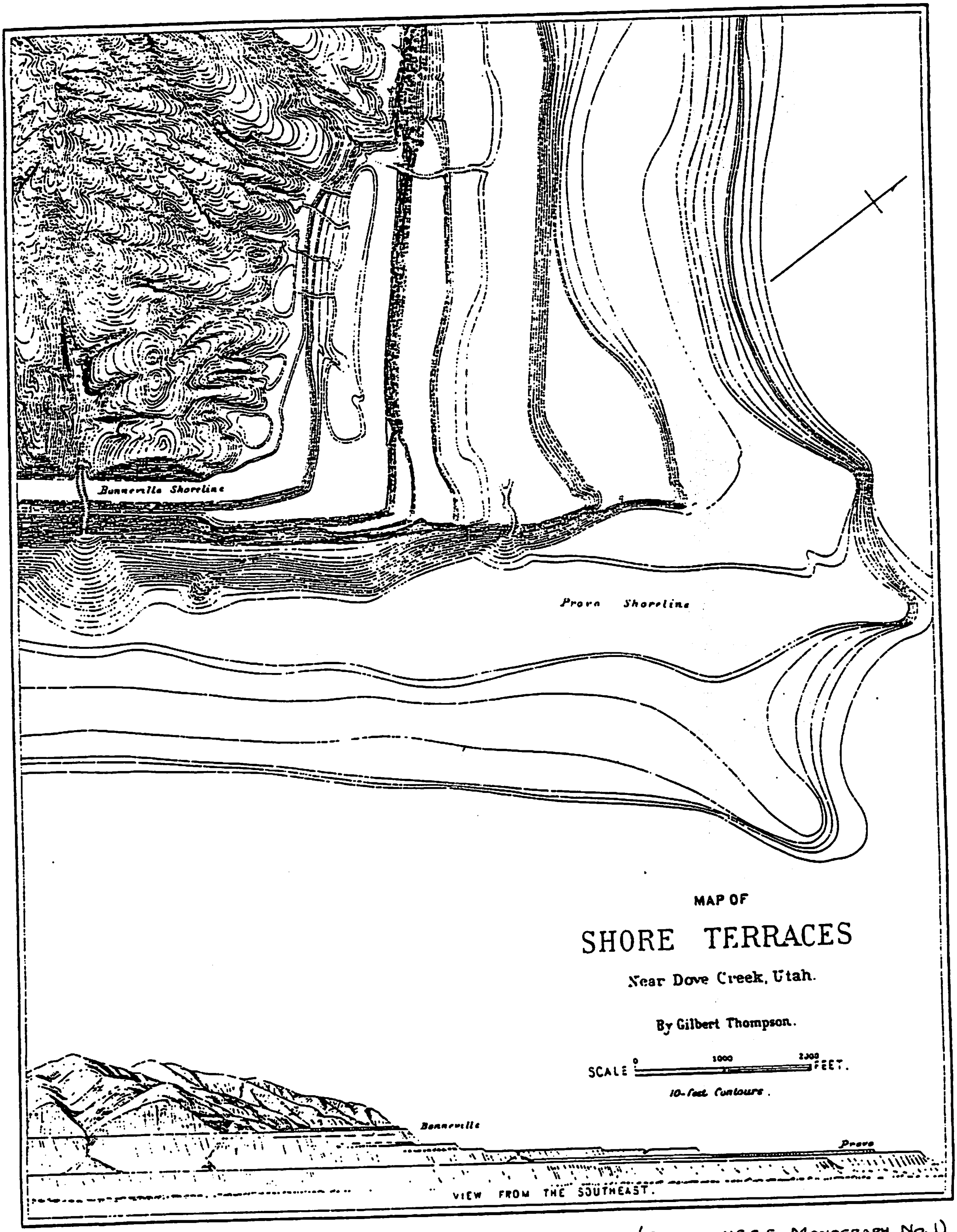
Modern Alluvial Deposits.

Julius Bien & Co. Lith

Drawn by G. Thompson

LAKE BONNEVILLE : JENNINGS

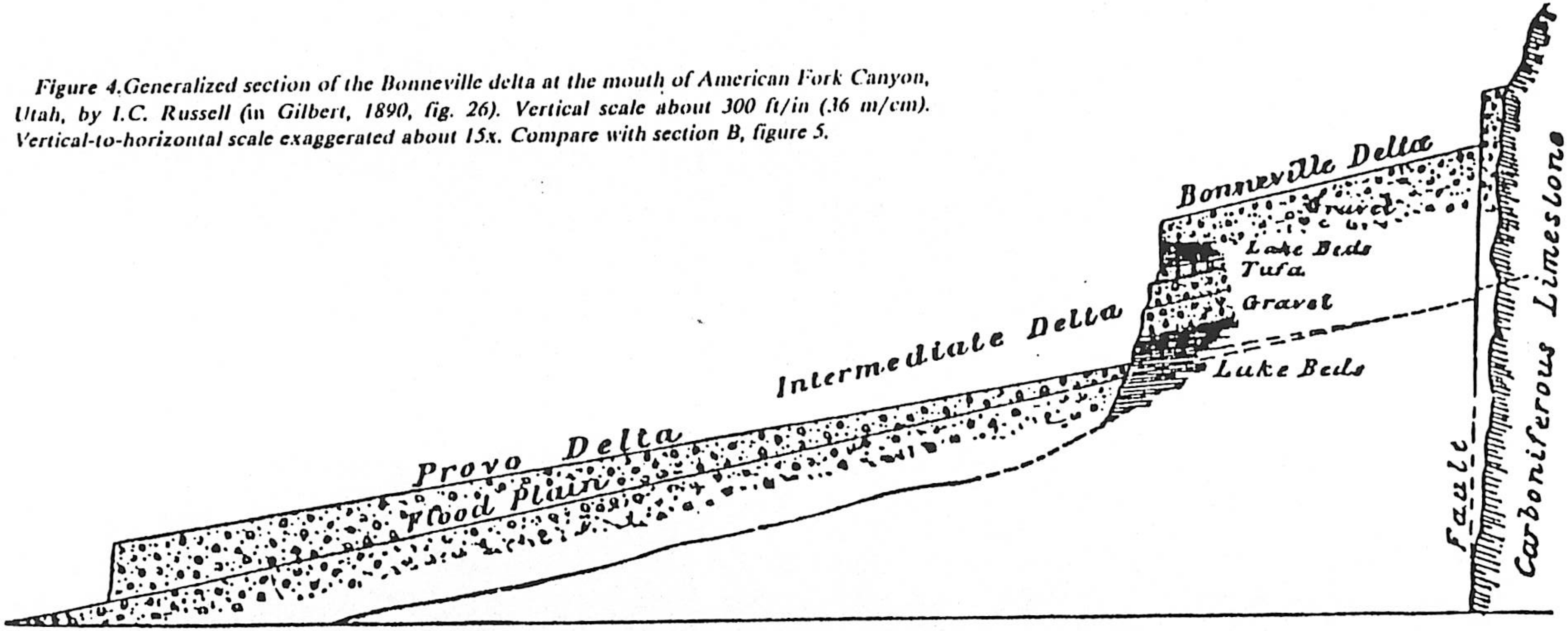
92



MAP AND SKETCH OF LAKE BONNEVILLE SHORELINES (GILBERT, U.S.G.S. MONOGRAPH, NO. 1)

FIG D

Figure 4. Generalized section of the Bonneville delta at the mouth of American Fork Canyon, Utah, by I.C. Russell (in Gilbert, 1890, fig. 26). Vertical scale about 300 ft/in (.36 m/cm). Vertical-to-horizontal scale exaggerated about 15x. Compare with section B, figure 5.



AO.E

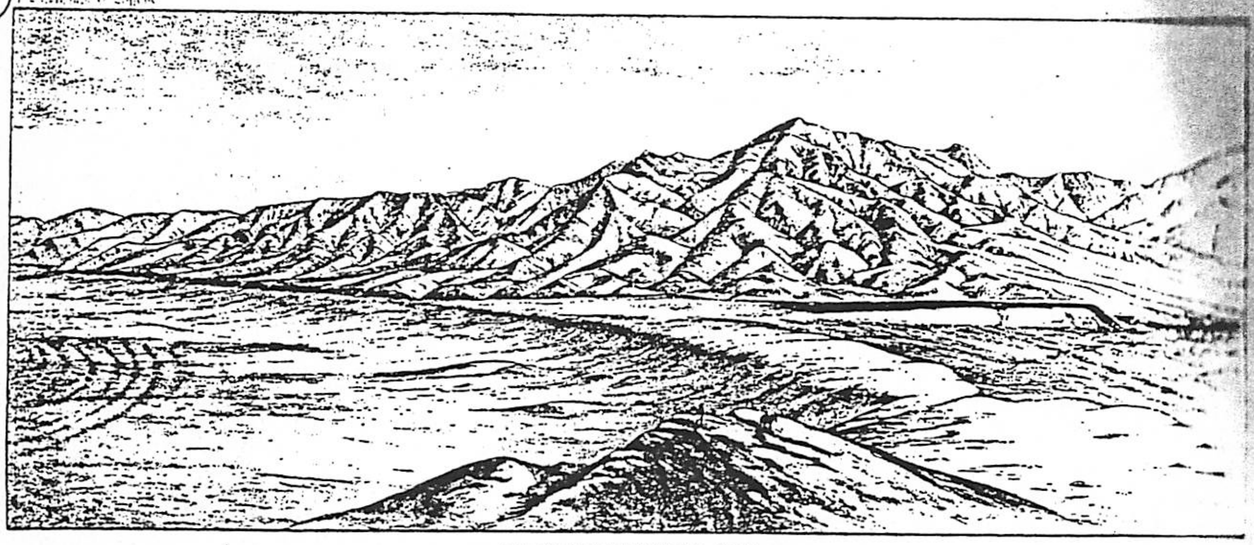


Figure 2. View southeastward from South Mountain, showing The Great Bar at Stockton, Utah (Gilbert, 1890, plate IX).

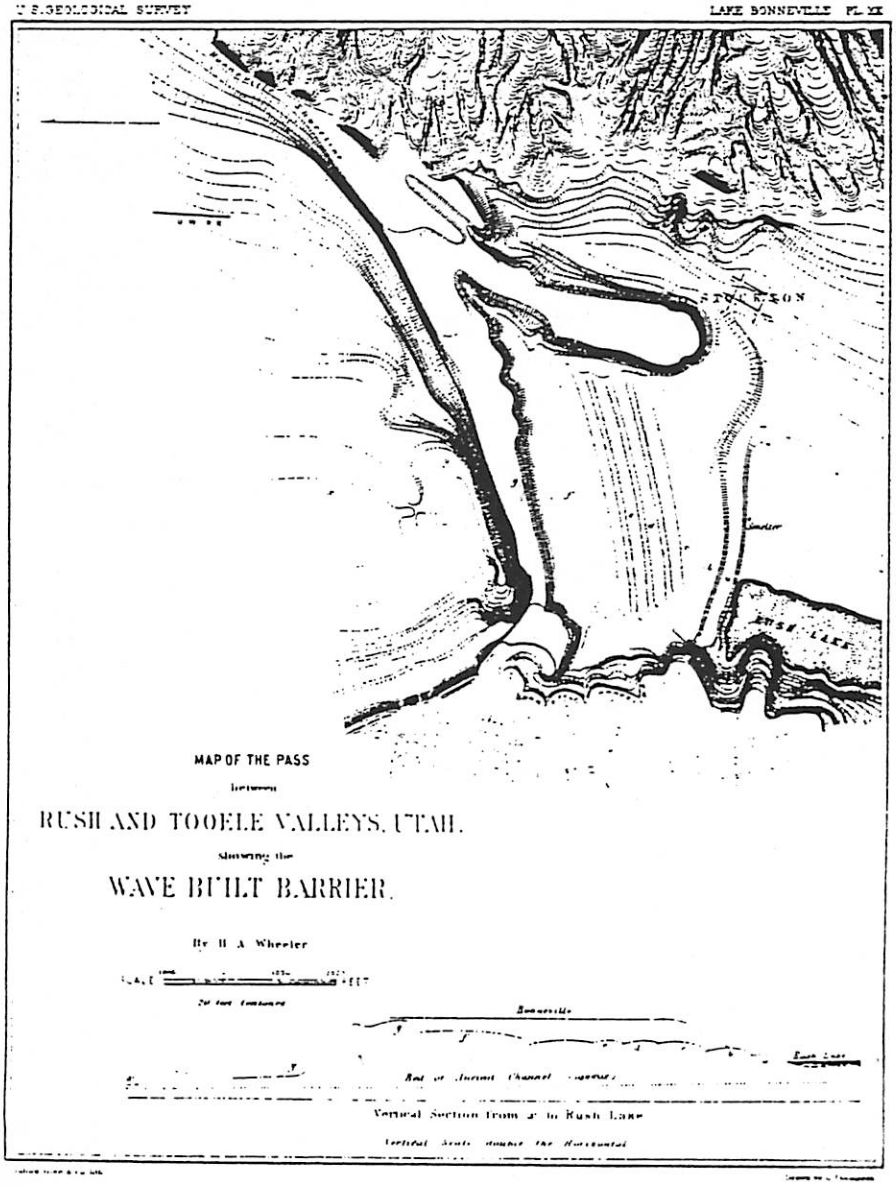


Figure 3. Contour map and vertical section of the Stockton Bar (Gilbert, 1890, plate XX).