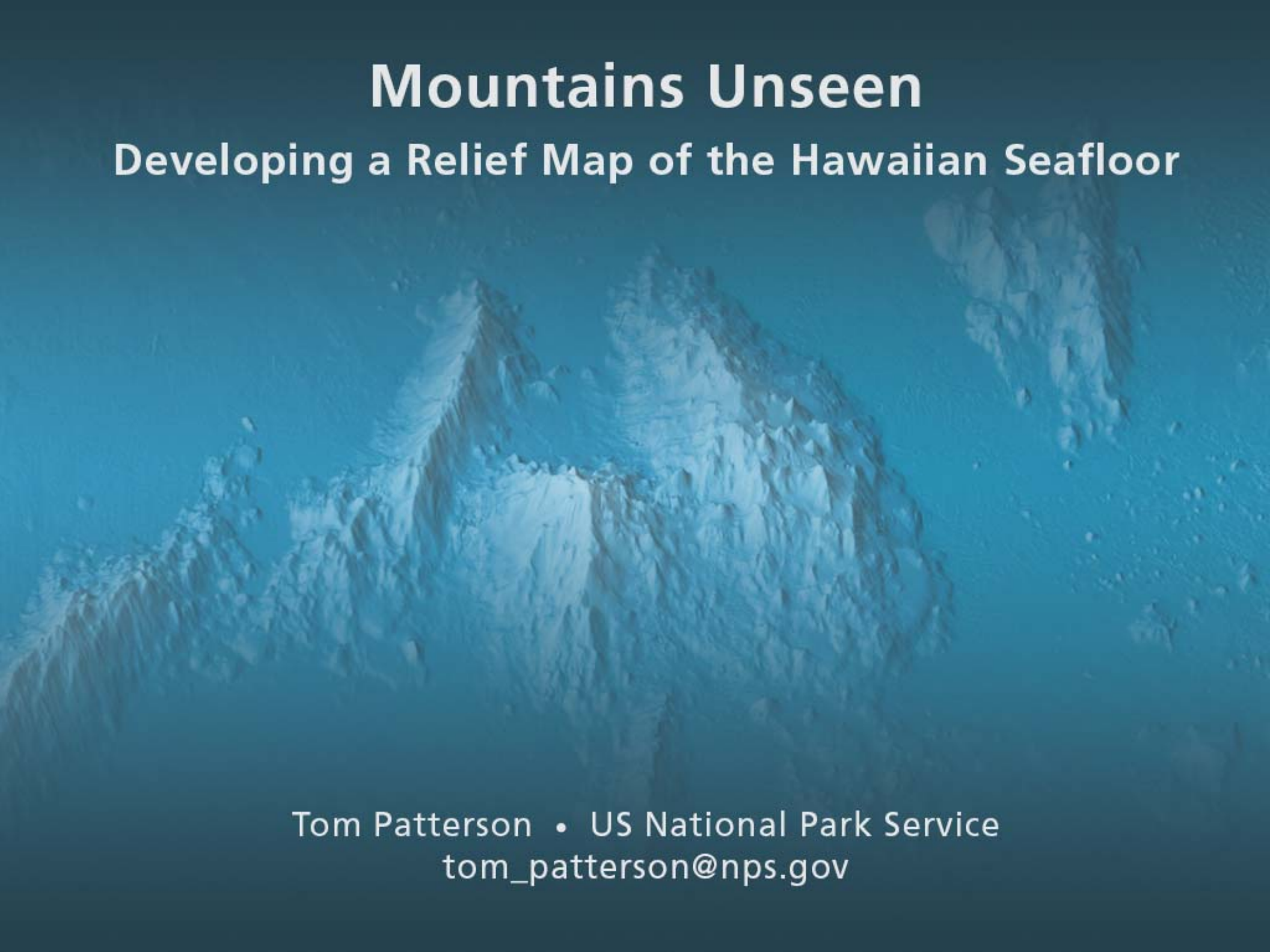
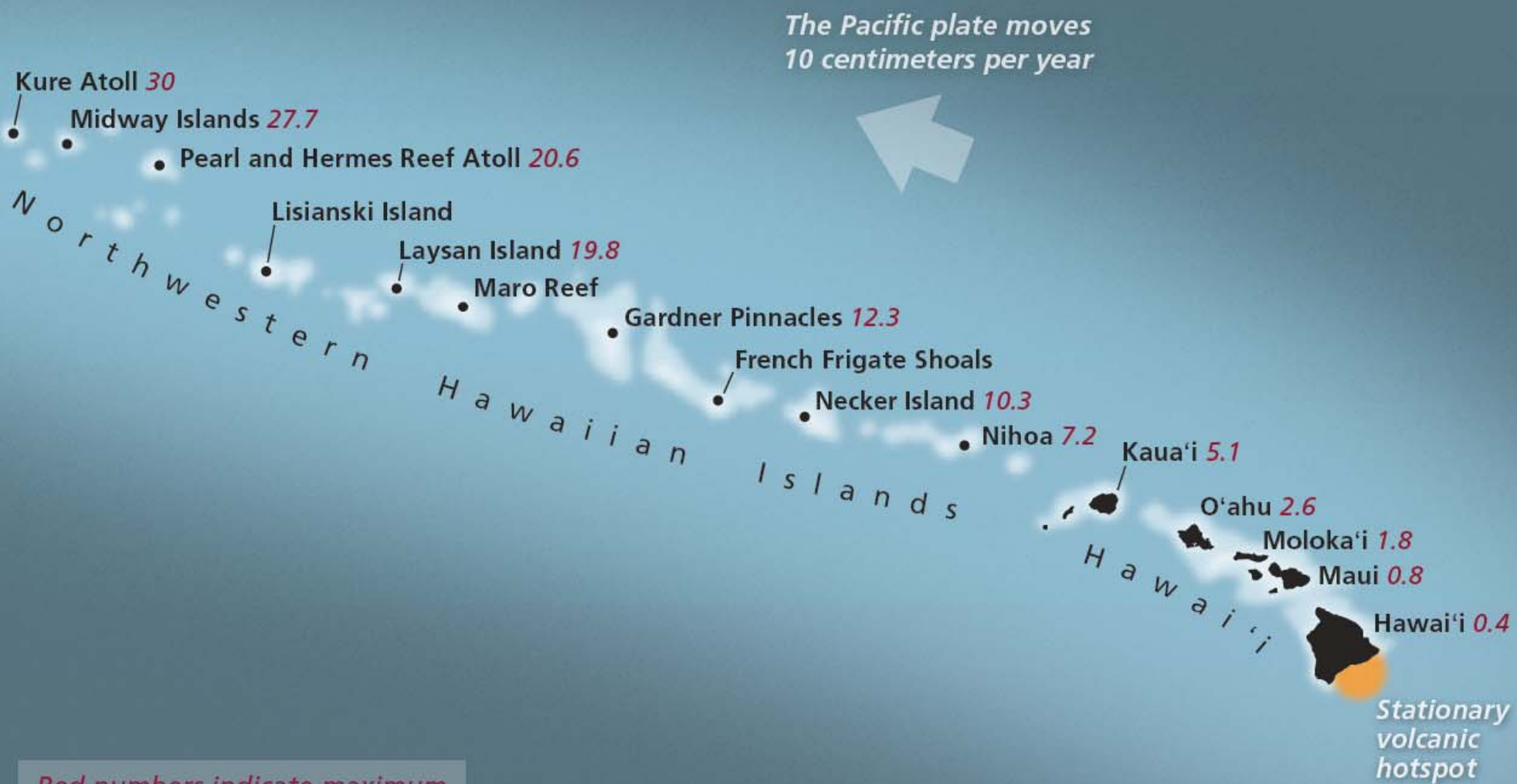
Mountains Unseen

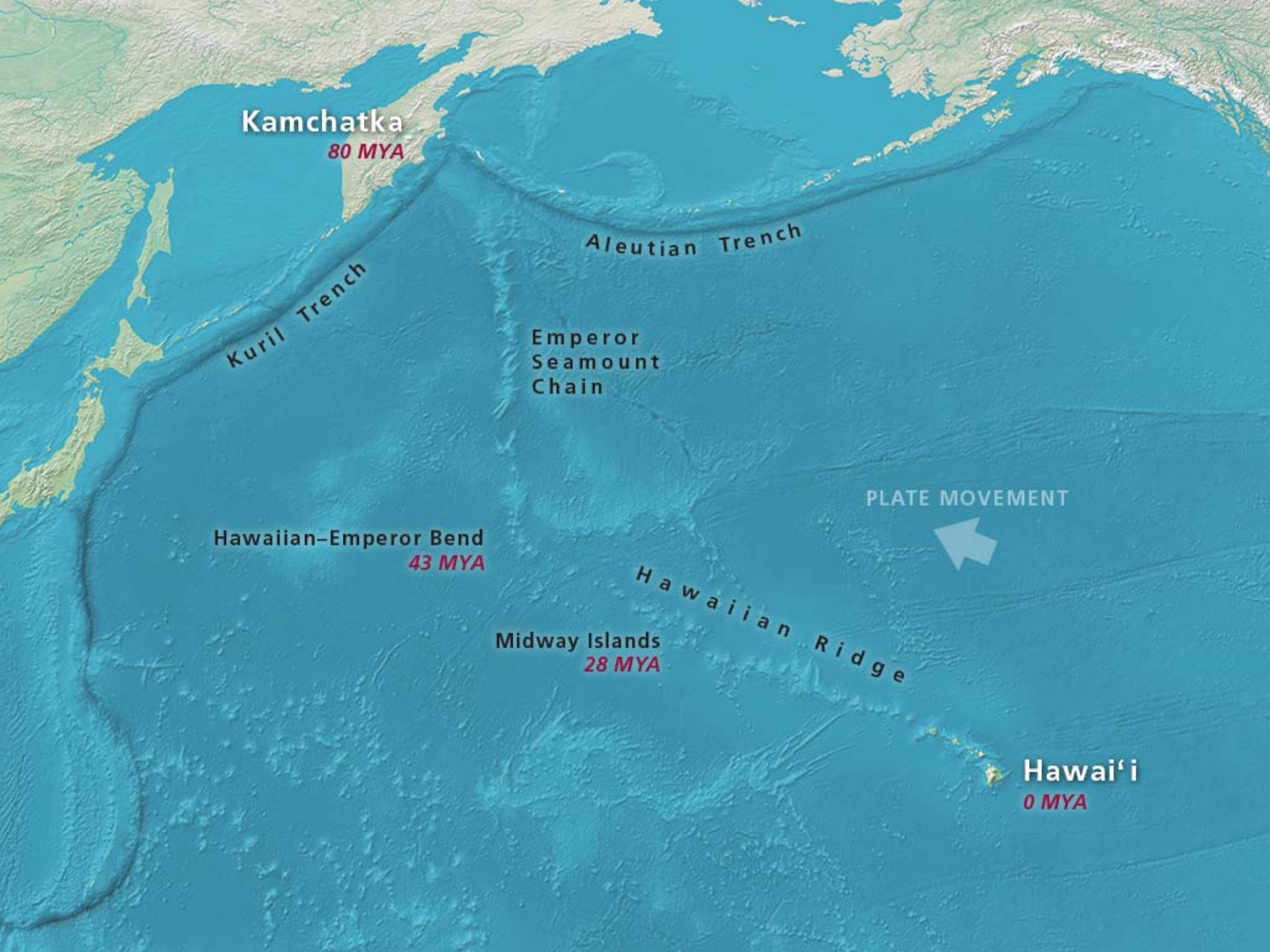
Developing a Relief Map of the Hawaiian Seafloor



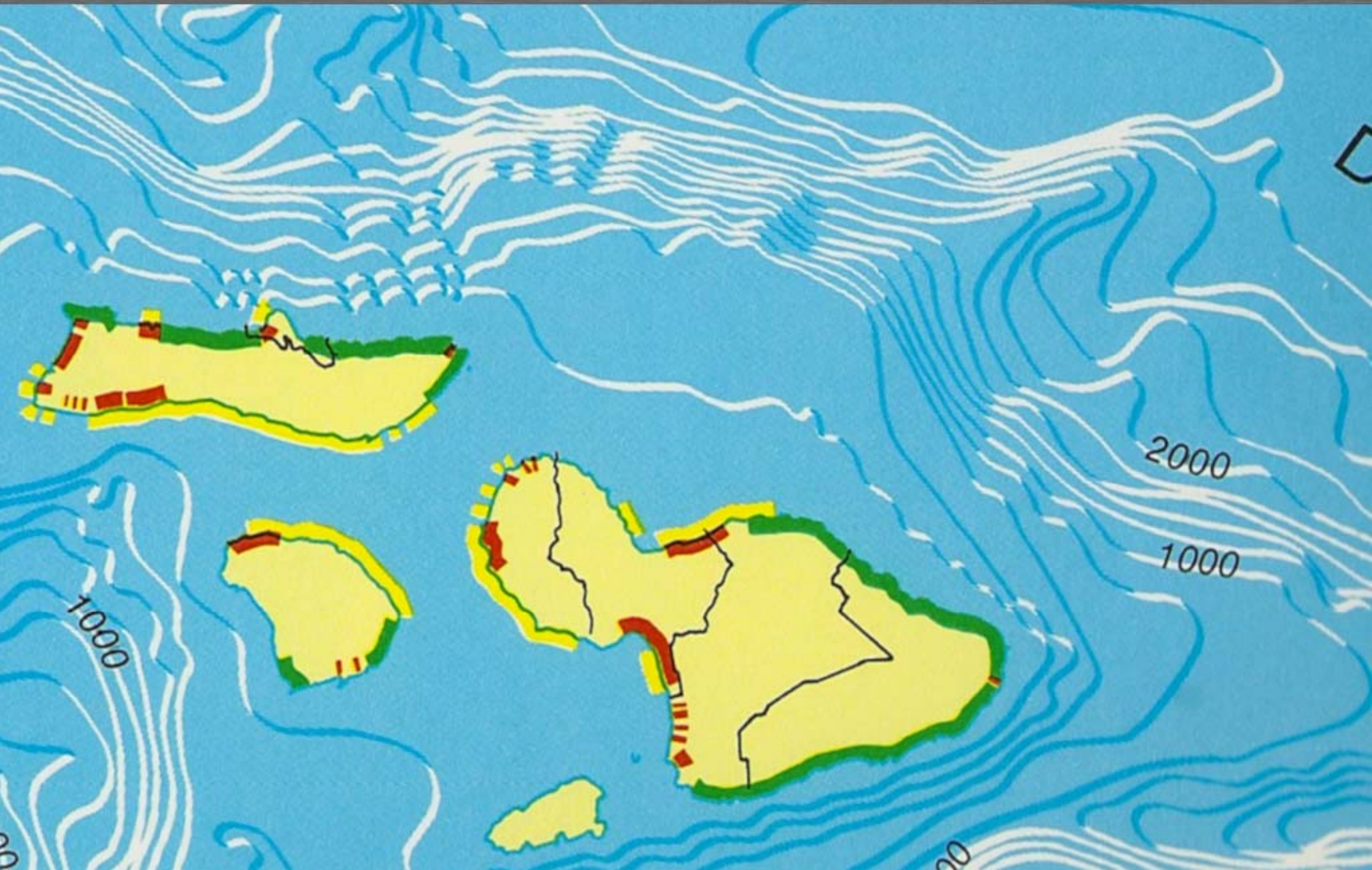
Tom Patterson • US National Park Service
tom_patterson@nps.gov

Islands on the Move

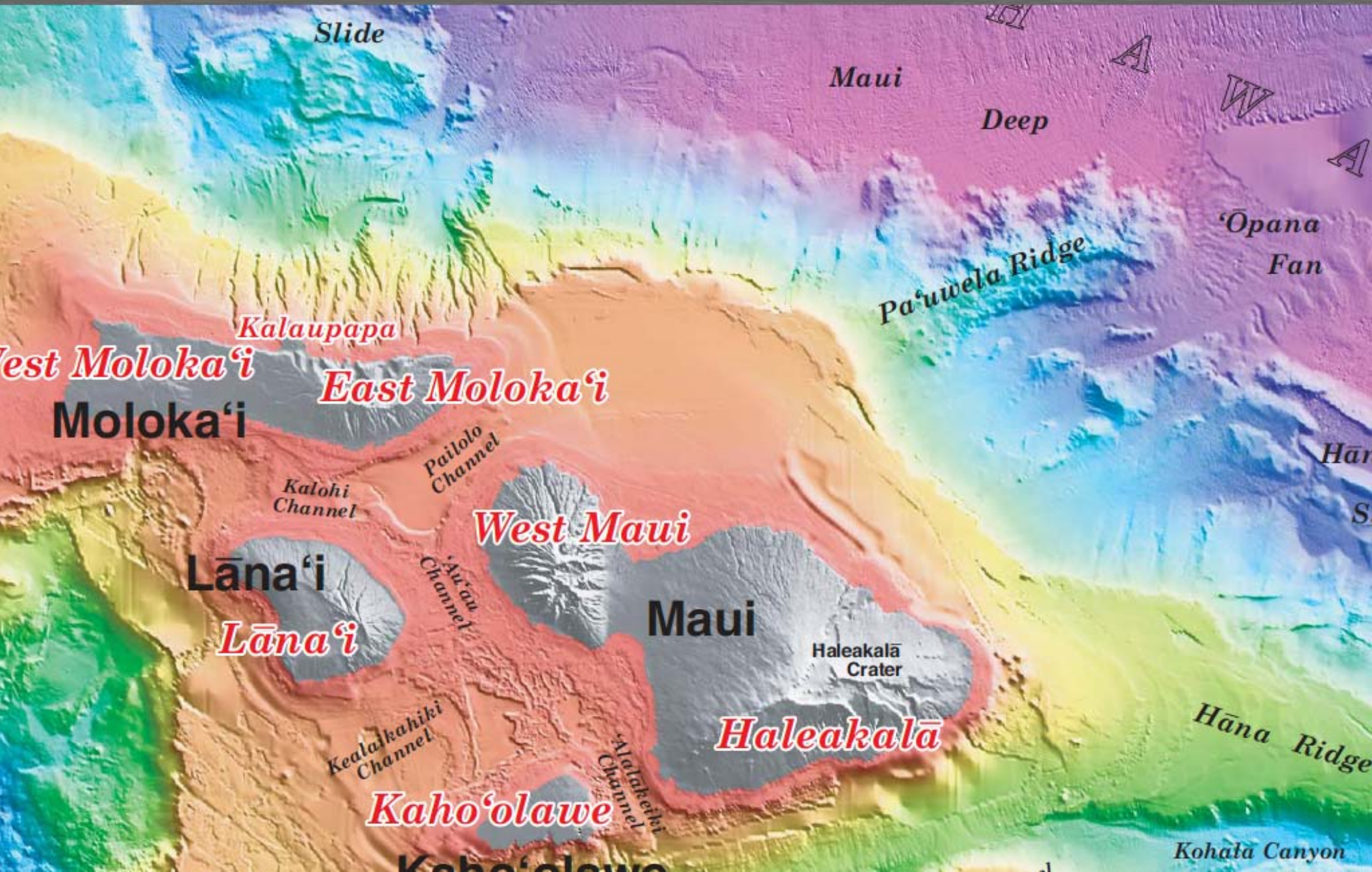



Kamchatka
80 MYA
Aleutian Trench
Kuril Trench
Emperor
Seamount
Chain
PLATE MOVEMENT
Hawaiian–Emperor Bend
43 MYA
Hawaiian Ridge
Midway Islands
28 MYA
Hawai‘i
0 MYA

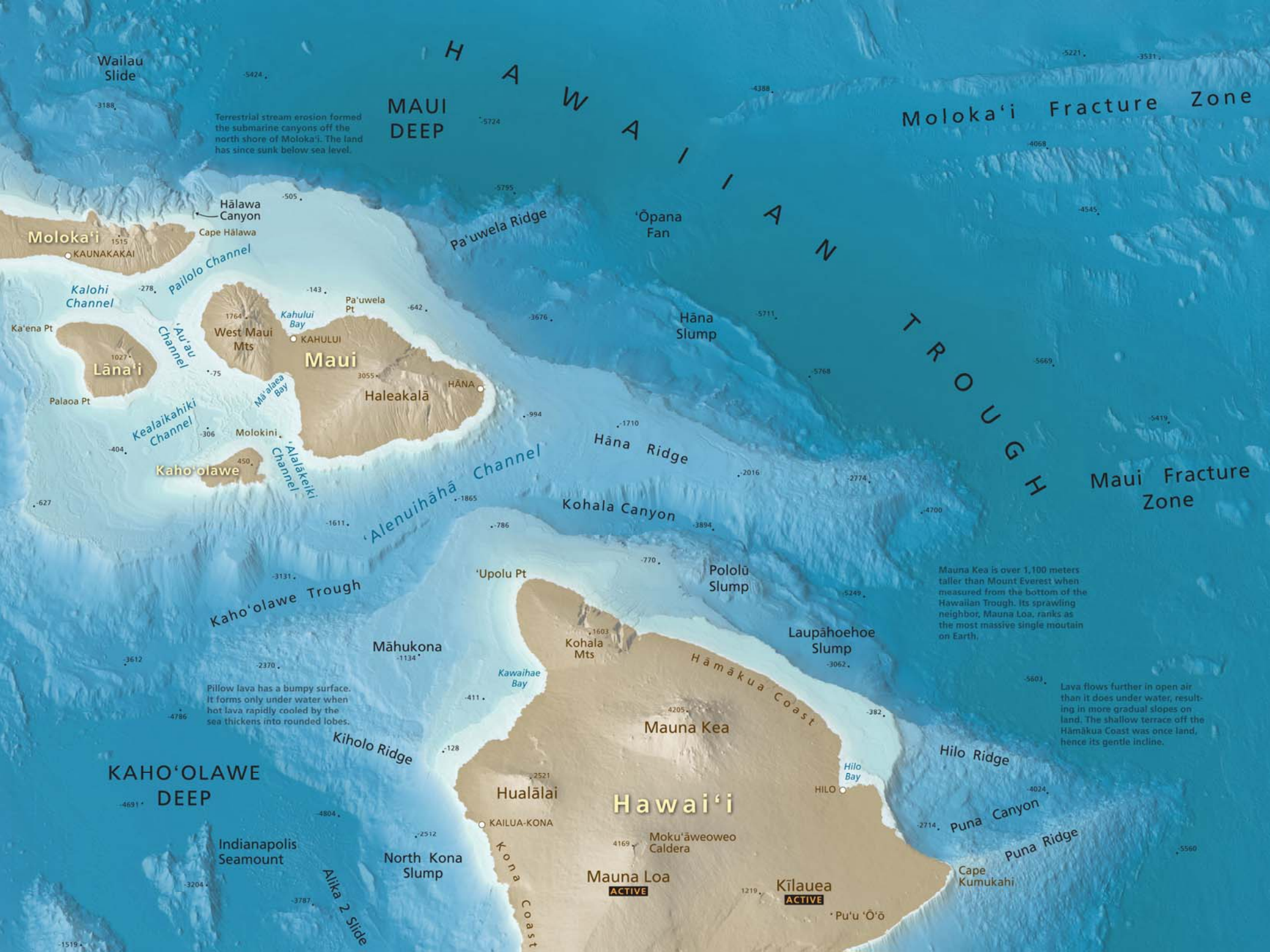
Atlas of Hawaii, 1973

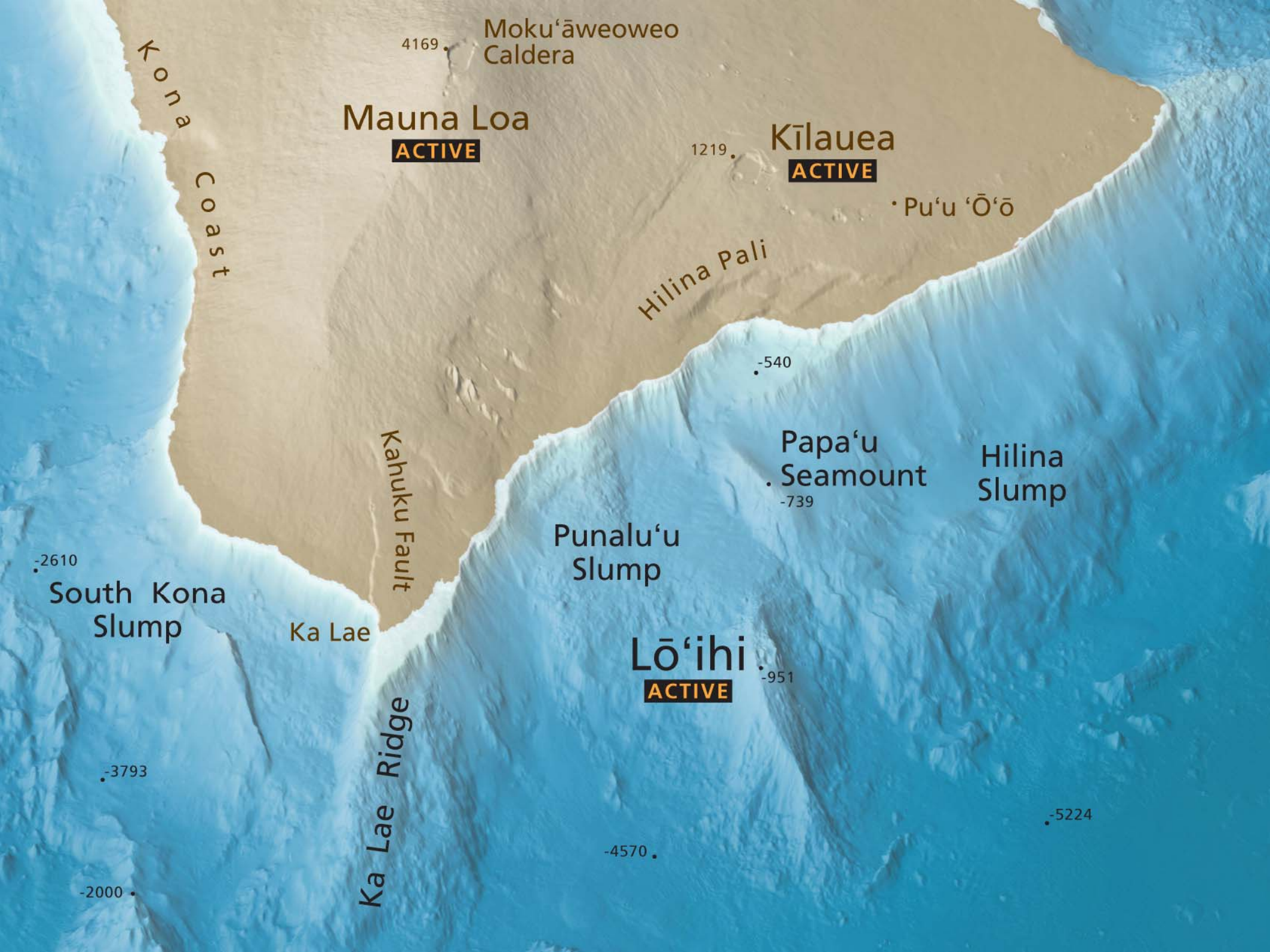


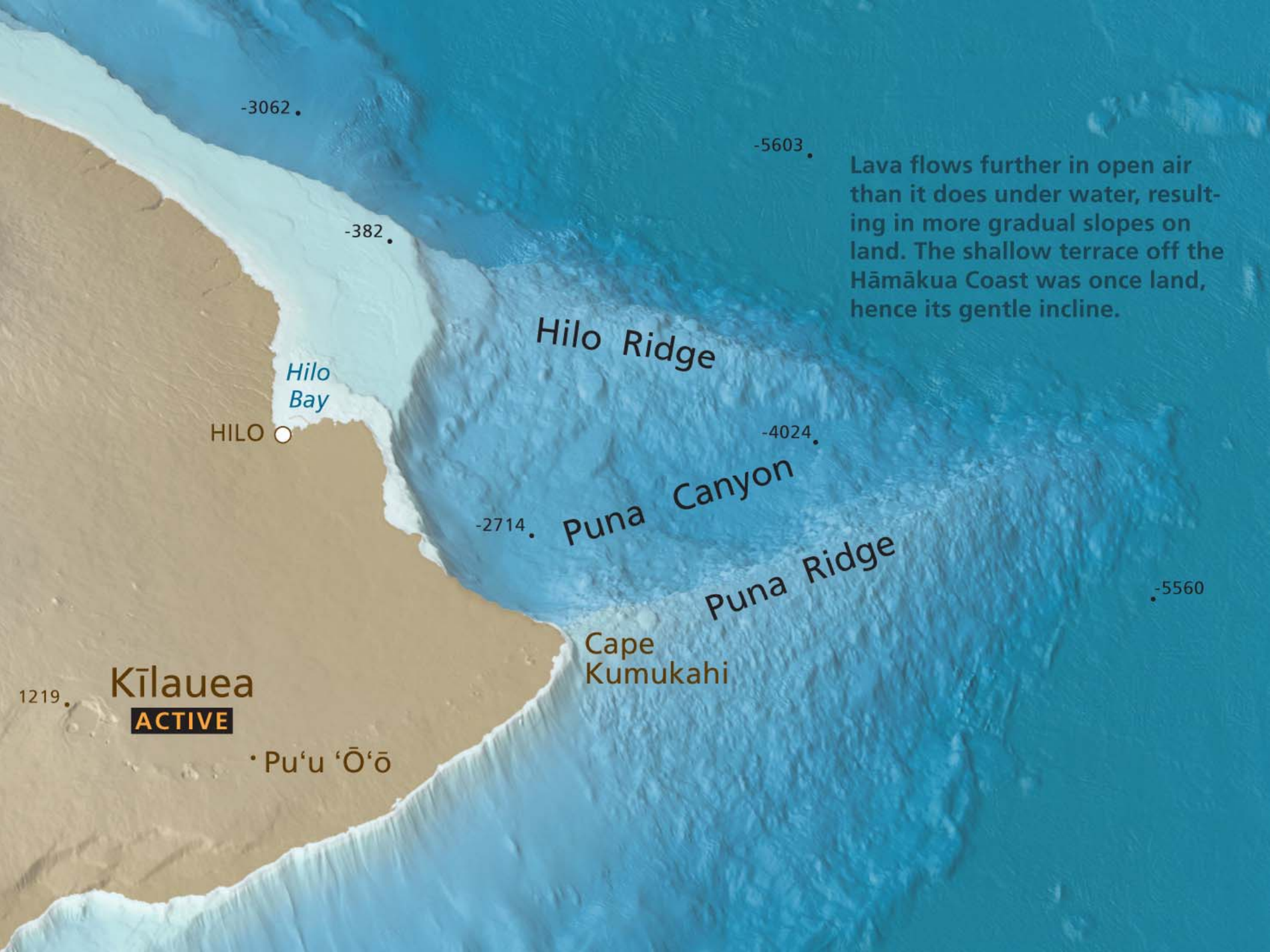
Hawaii's Volcanoes Revealed, 2003

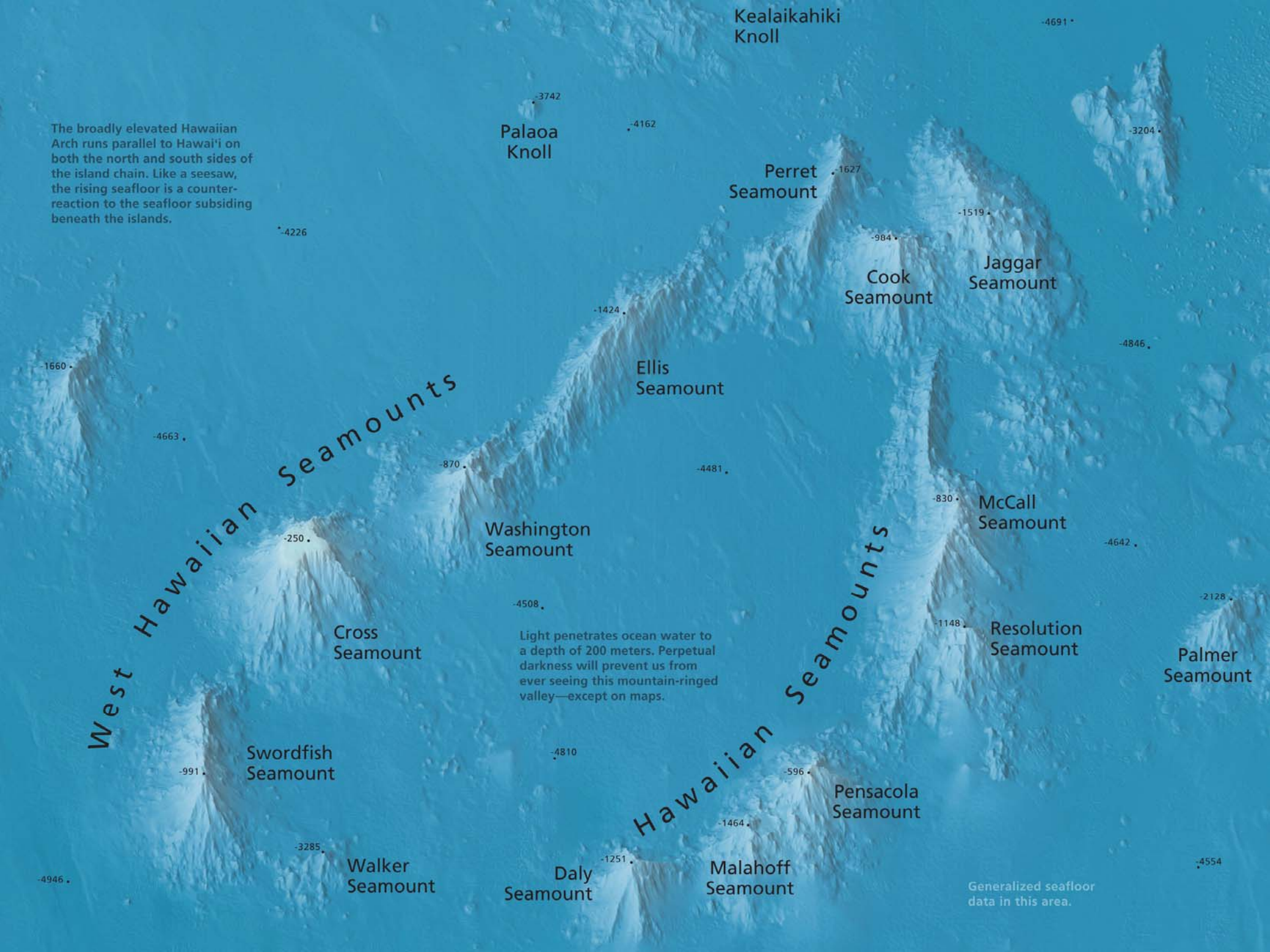


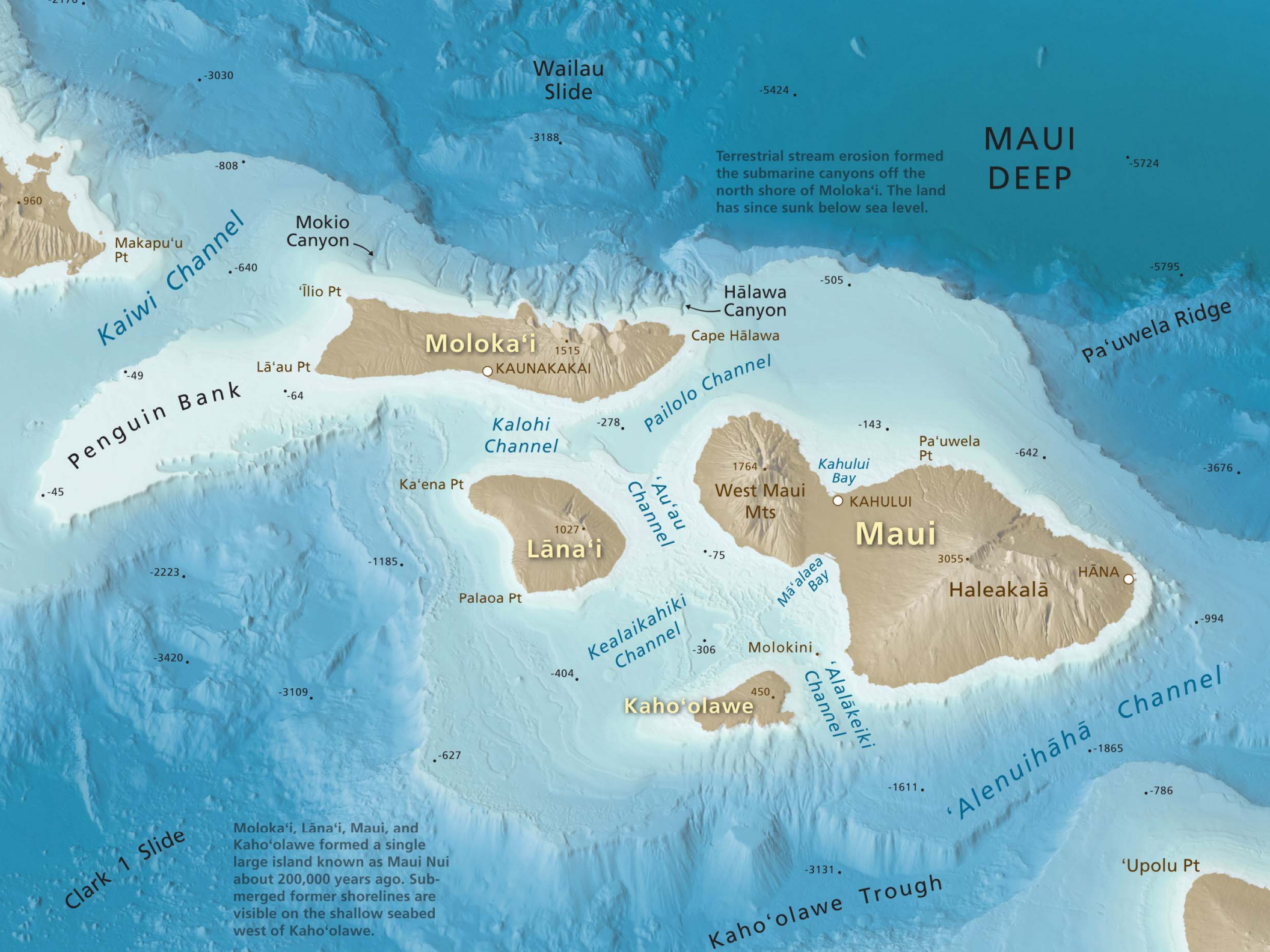
Seafloor Map of Hawai'i

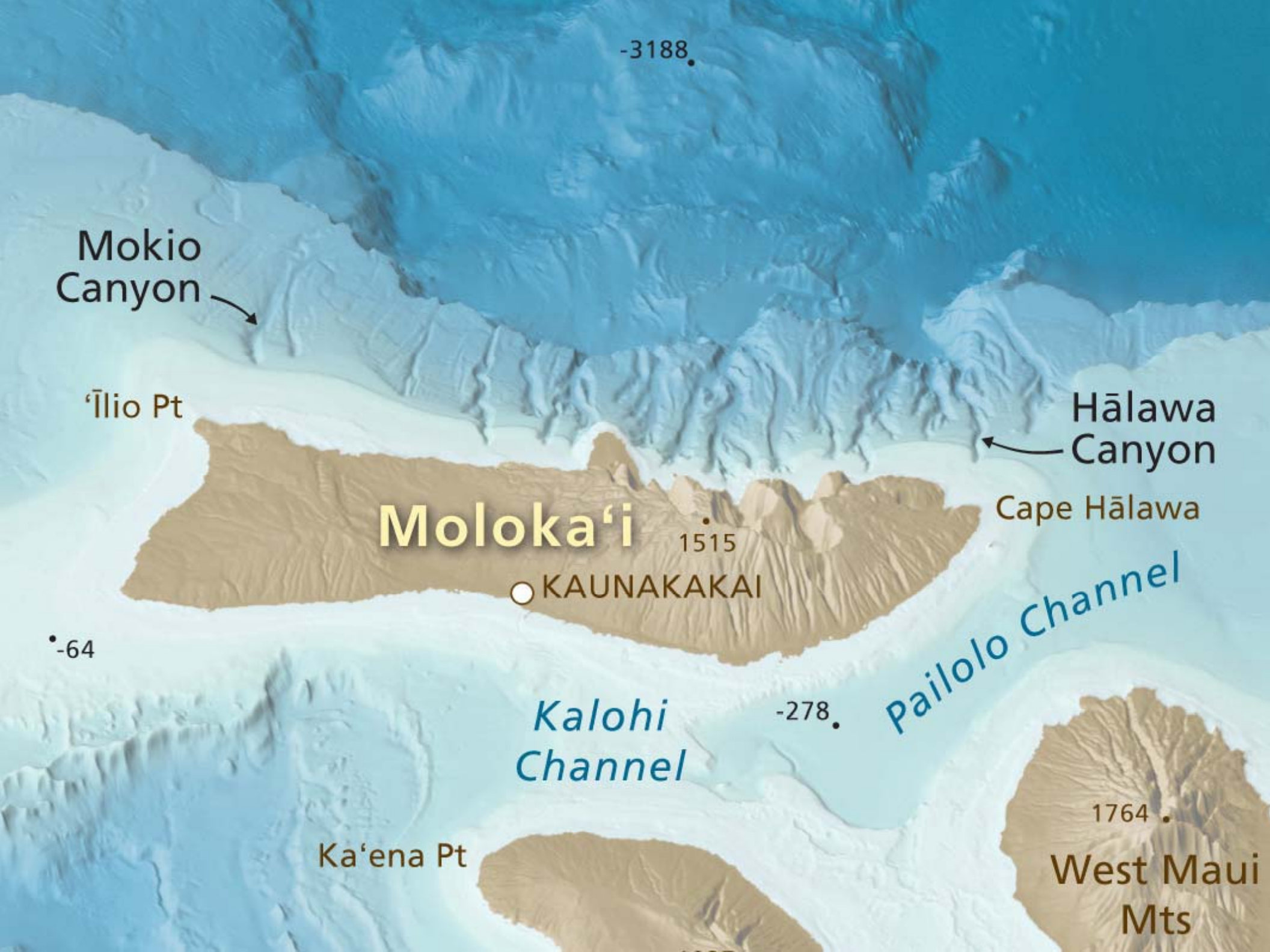

Wailau Slide
MAUI DEEP
HAWAIIAN TROUGH
Moloka'i Fracture Zone
Terrestrial stream erosion formed the submarine canyons off the north shore of Moloka'i. The land has since sunk below sea level.
Hālawa Canyon
Cape Hālawa
Moloka'i
KAUNAKAKAI
Pailolo Channel
Kalohi Channel
Pa'uwela Ridge
'Ōpana Fan
Pa'uwela Pt
Kahului Bay
West Maui Mts
KAHULUI
Maui
Ka'ena Pt
'Au'au Channel
Lāna'i
Hāna Slump
Palaoa Pt
Ma'alaea Bay
Haleakalā
HĀNA
Kealaikahiki Channel
Molokini
'Alalākeiki Channel
Kaho'olawe
Hāna Ridge
'Alenuihāhā Channel
Kohala Canyon
Maui Fracture Zone
Kaho'olawe Trough
'Upolu Pt
Pololū Slump
Mauna Kea is over 1,100 meters taller than Mount Everest when measured from the bottom of the Hawaiian Trough. Its sprawling neighbor, Mauna Loa, ranks as the most massive single moutain on Earth.
Māhukona
Kohala Mts
Laupāhoehoe Slump
Kawaihae Bay
Hāmākua Coast
Pillow lava has a bumpy surface. It forms only under water when hot lava rapidly cooled by the sea thickens into rounded lobes.
Mauna Kea
Lava flows further in open air than it does under water, resulting in more gradual slopes on land. The shallow terrace off the Hāmākua Coast was once land, hence its gentle incline.
Kiholo Ridge
Hilo Ridge
Hilo Bay
KAHO'OLAWE DEEP
Hualālai
Hawai'i
HILO
KAILUA-KONA
Puna Canyon
Puna Ridge
Moku'āweoweo Caldera
Indianapolis Seamount
North Kona Slump
Kona Coast
Mauna Loa
ACTIVE
Kīlauea
ACTIVE
Cape Kumukahi
Alika 2 Slide
Pu'u 'Ō'ō

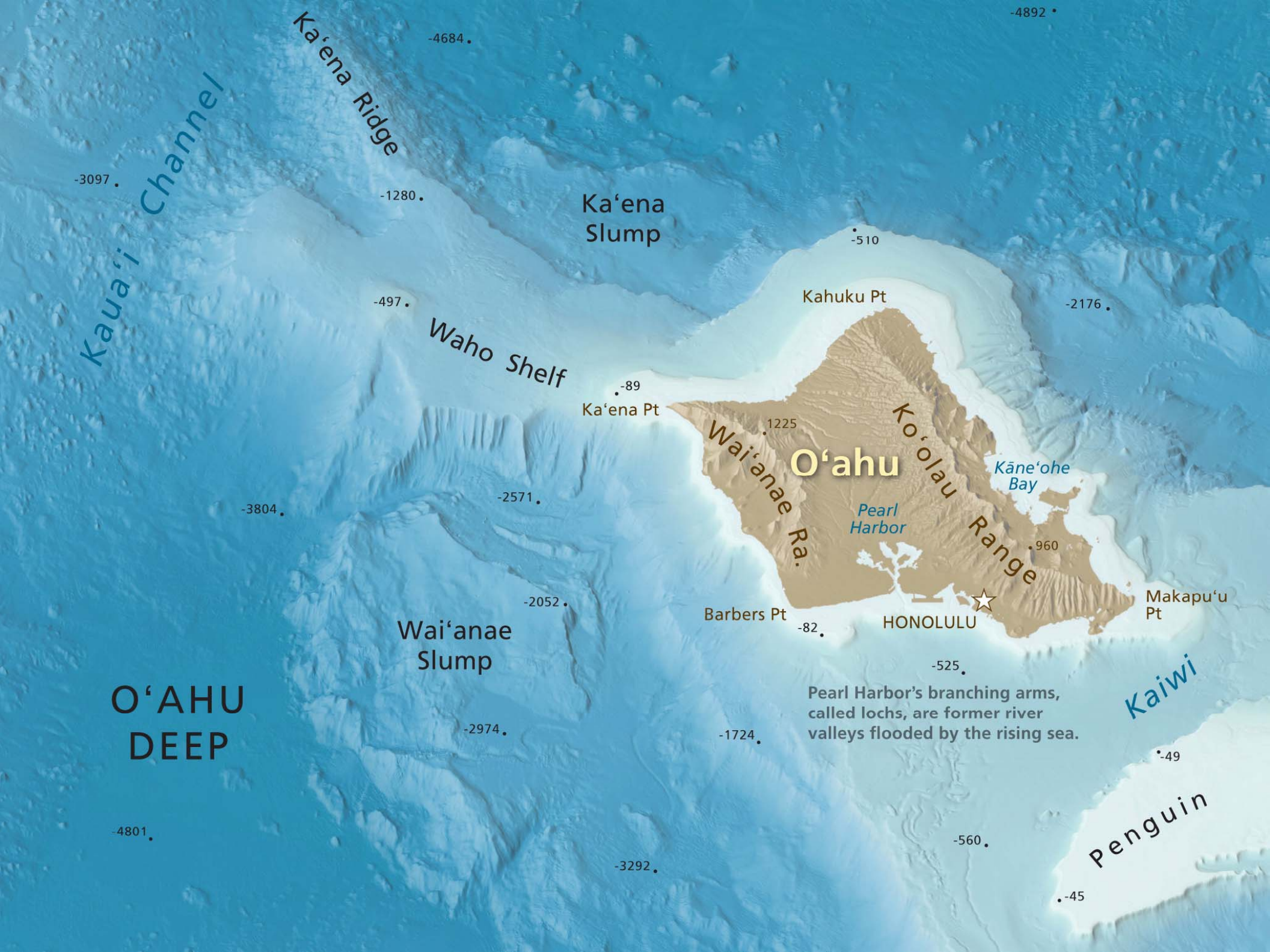

Moku‘āweoweo Caldera
4169
Kona Coast
Mauna Loa
ACTIVE
Kīlauea
1219
ACTIVE
Pu‘u ‘Ō‘ō
Hilina Pali
-540
Papa‘u Seamount
-739
Hilina Slump
Kahuku Fault
Punalu‘u Slump
-2610
South Kona Slump
Ka Lae
Lō‘ihi
-951
ACTIVE
Ka Lae Ridge
-3793
-5224
-4570
-2000

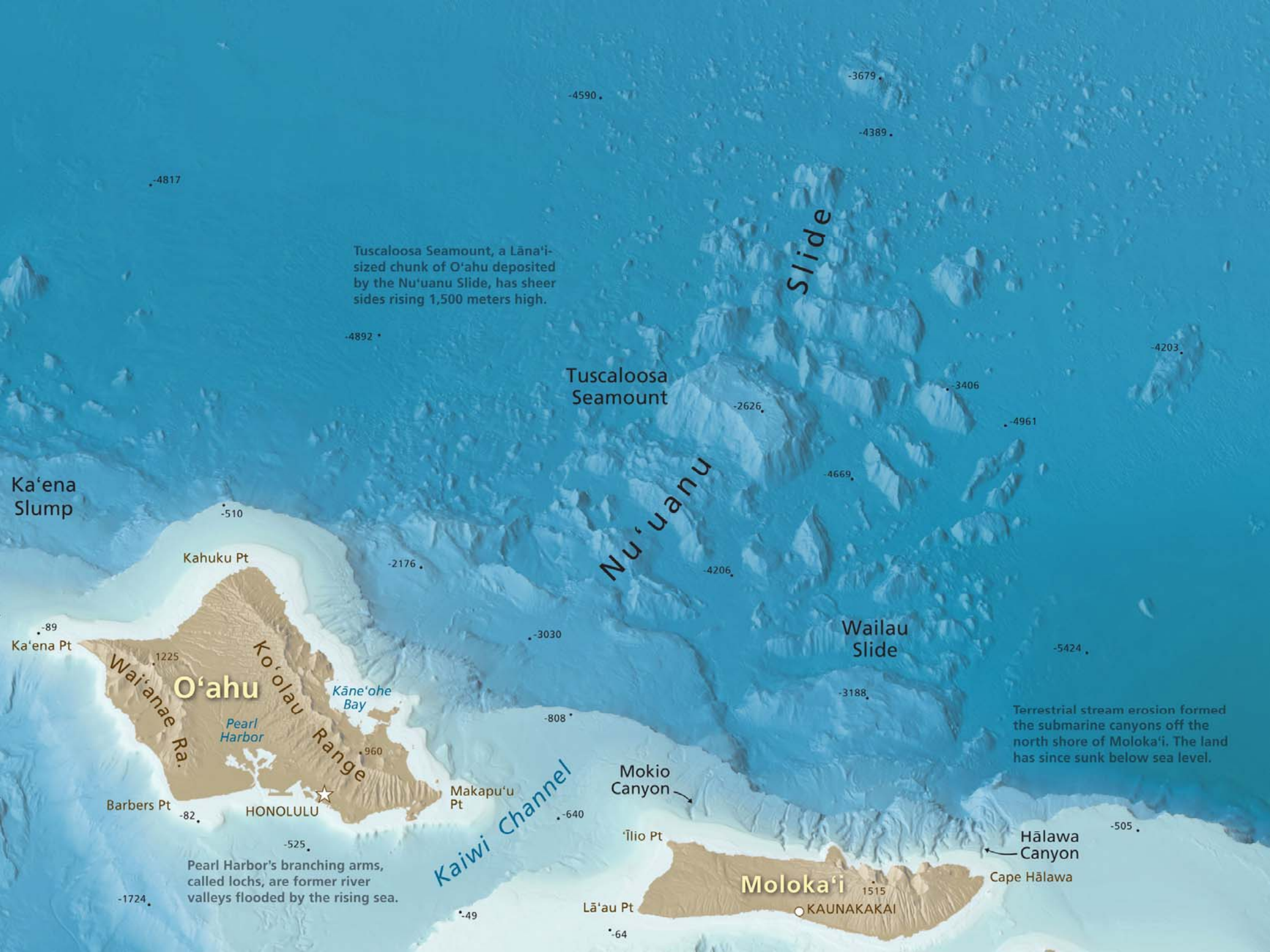

-3062
-5603
Lava flows further in open air than it does under water, resulting in more gradual slopes on land. The shallow terrace off the Hāmākua Coast was once land, hence its gentle incline.
-382
Hilo Ridge
Hilo Bay
HILO
-4024
-2714
Puna Canyon
Puna Ridge
-5560
Cape Kumukahi
Kīlauea
ACTIVE
1219
Pu'u 'Ō'ō


Kealaikahiki Knoll
-4691
-3742
Palaoa Knoll
-4162
-3204
The broadly elevated Hawaiian Arch runs parallel to Hawai'i on both the north and south sides of the island chain. Like a seesaw, the rising seafloor is a counter-reaction to the seafloor subsiding beneath the islands.
Perret Seamount
-1627
-1519
-4226
-984
Cook Seamount
Jaggar Seamount
-1424
-4846
-1660
Ellis Seamount
West Hawaiian Seamounts
-4663
-870
-4481
-830
McCall Seamount
Washington Seamount
-250
-4642
-4508
-2128
Cross Seamount
-1148
Resolution Seamount
Light penetrates ocean water to a depth of 200 meters. Perpetual darkness will prevent us from ever seeing this mountain-ringed valley—except on maps.
Palmer Seamount
Hawaiian Seamounts
-4810
Swordfish Seamount
-991
-596
Pensacola Seamount
-1464
-3285
Walker Seamount
-1251
-4554
-4946
Daly Seamount
Malahoff Seamount
Generalized seafloor data in this area.


Wailau Slide
-3030
-5424
-3188
MAUI DEEP
-5724
Terrestrial stream erosion formed the submarine canyons off the north shore of Moloka'i. The land has since sunk below sea level.
-808
960
Makapu'u Pt
Kaiwi Channel
Mokio Canyon
-640
'Īlio Pt
-505
-5795
Hālawa Canyon
Pa'uwela Ridge
Moloka'i
1515
KAUNAKAKAI
Cape Hālawa
Lā'au Pt
-49
-64
Penguin Bank
Pailolo Channel
Kalohi Channel
-278
-143
Pa'uwela Pt
-642
-3676
1764
West Maui Mts
Kahului Bay
KAHULUI
Maui
-45
Ka'ena Pt
'Au'au Channel
1027
Lāna'i
-75
3055
HĀNA
-1185
-2223
Ma'alaea Bay
Haleakalā
Palaoa Pt
-994
Kealaikahiki Channel
-306
Molokini
-3420
-404
'Alalākeiki Channel
450
Kaho'olawe
-3109
'Alenuihāhā Channel
-627
-1865
-1611
-786
Clark 1 Slide
Moloka'i, Lāna'i, Maui, and Kaho'olawe formed a single large island known as Maui Nui about 200,000 years ago. Submerged former shorelines are visible on the shallow seabed west of Kaho'olawe.
-3131
'Upolu Pt
Kaho'olawe Trough

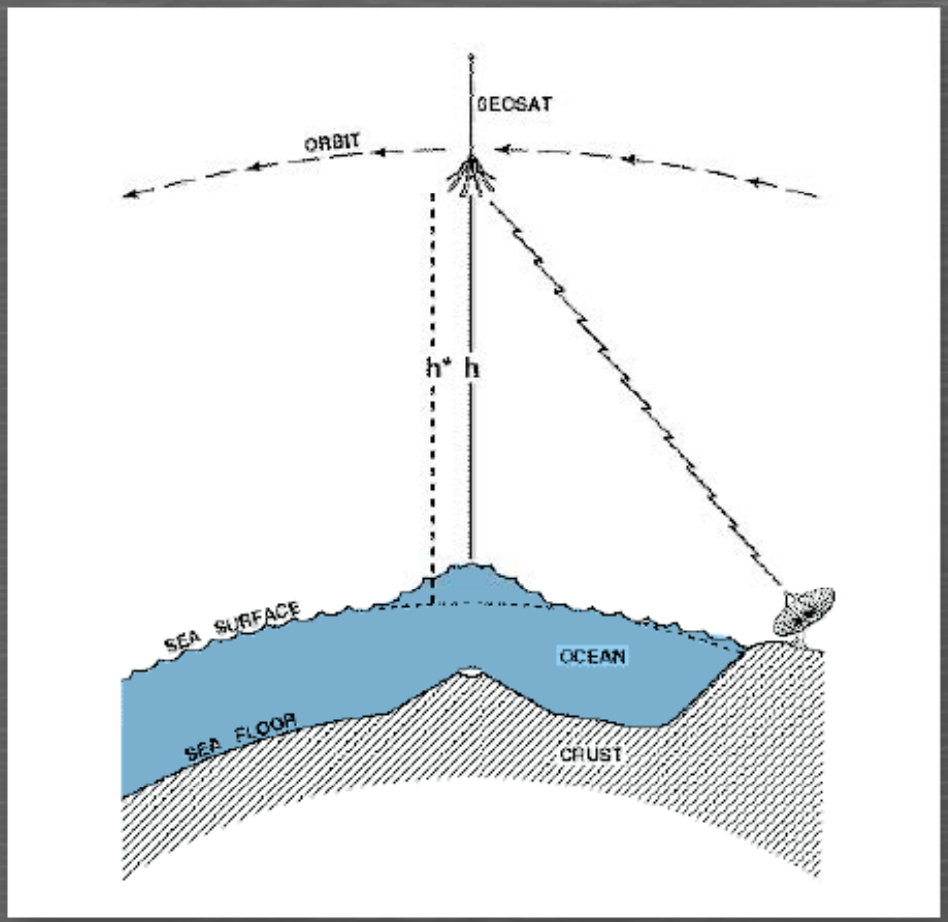

-3188
Mokio
Canyon
ʻĪlio Pt
Hālawa
Canyon
Moloka‘i
1515
Cape Hālawa
KAUNAKAKAI
-64
Pailolo Channel
Kalohi
Channel
-278
1764
Ka‘ena Pt
West Maui
Mts


-4892
-4684
Ka'ena Ridge
Kaua'i Channel
-3097
-1280
Ka'ena Slump
-510
Kahuku Pt
-2176
-497
Waho Shelf
-89
Ka'ena Pt
1225
Wai'anae Ra.
Ko'olau Range
O'ahu
Kāne'ohe Bay
Pearl Harbor
-3804
-2571
960
-2052
Barbers Pt
-82
HONOLULU
Makapu'u Pt
Wai'anae Slump
-525
Pearl Harbor's branching arms, called lochs, are former river valleys flooded by the rising sea.
Kaiwi
O'AHU DEEP
-2974
-1724
-49
Penguin
-4801
-560
-3292
-45


-3679
-4590
-4389
-4817
Tuscaloosa Seamount, a Lāna'i-sized chunk of O'ahu deposited by the Nu'uanu Slide, has sheer sides rising 1,500 meters high.
Nu'uanu Slide
-4892
-4203
Tuscaloosa Seamount
-3406
-2626
-4961
-4669
Ka'ena Slump
-510
Kahuku Pt
-2176
-4206
-89
Ka'ena Pt
-3030
Wailau Slide
-5424
1225
Wai'anae Ra.
O'ahu
Ko'olau Range
Kāne'ohe Bay
Pearl Harbor
-3188
-808
960
Terrestrial stream erosion formed the submarine canyons off the north shore of Moloka'i. The land has since sunk below sea level.
Mokio Canyon
Makapu'u Pt
Barbers Pt
-82
HONOLULU
-640
-505
Kaiwi Channel
'Īlio Pt
Hālawa Canyon
-525
Pearl Harbor's branching arms, called lochs, are former river valleys flooded by the rising sea.
Moloka'i
1515
Cape Hālawa
-1724
Lā'au Pt
KAUNAKAKAI
-49
-64

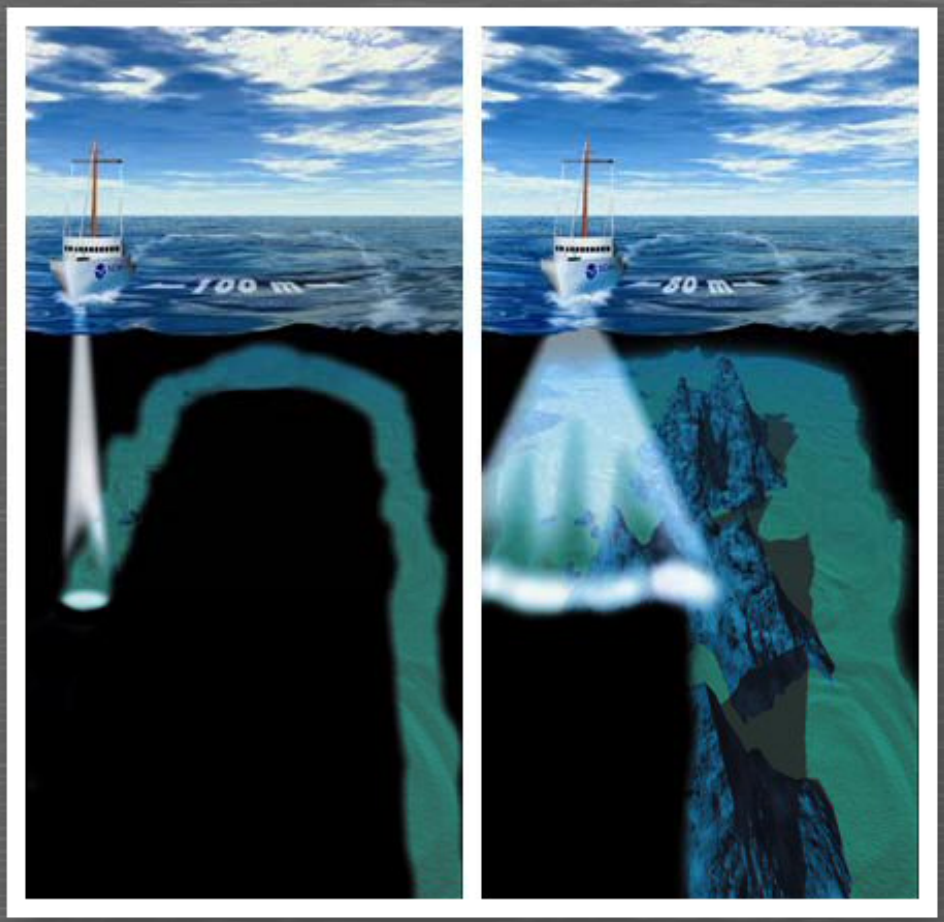
Bathymetry Data

Satellite Radar Altimetry



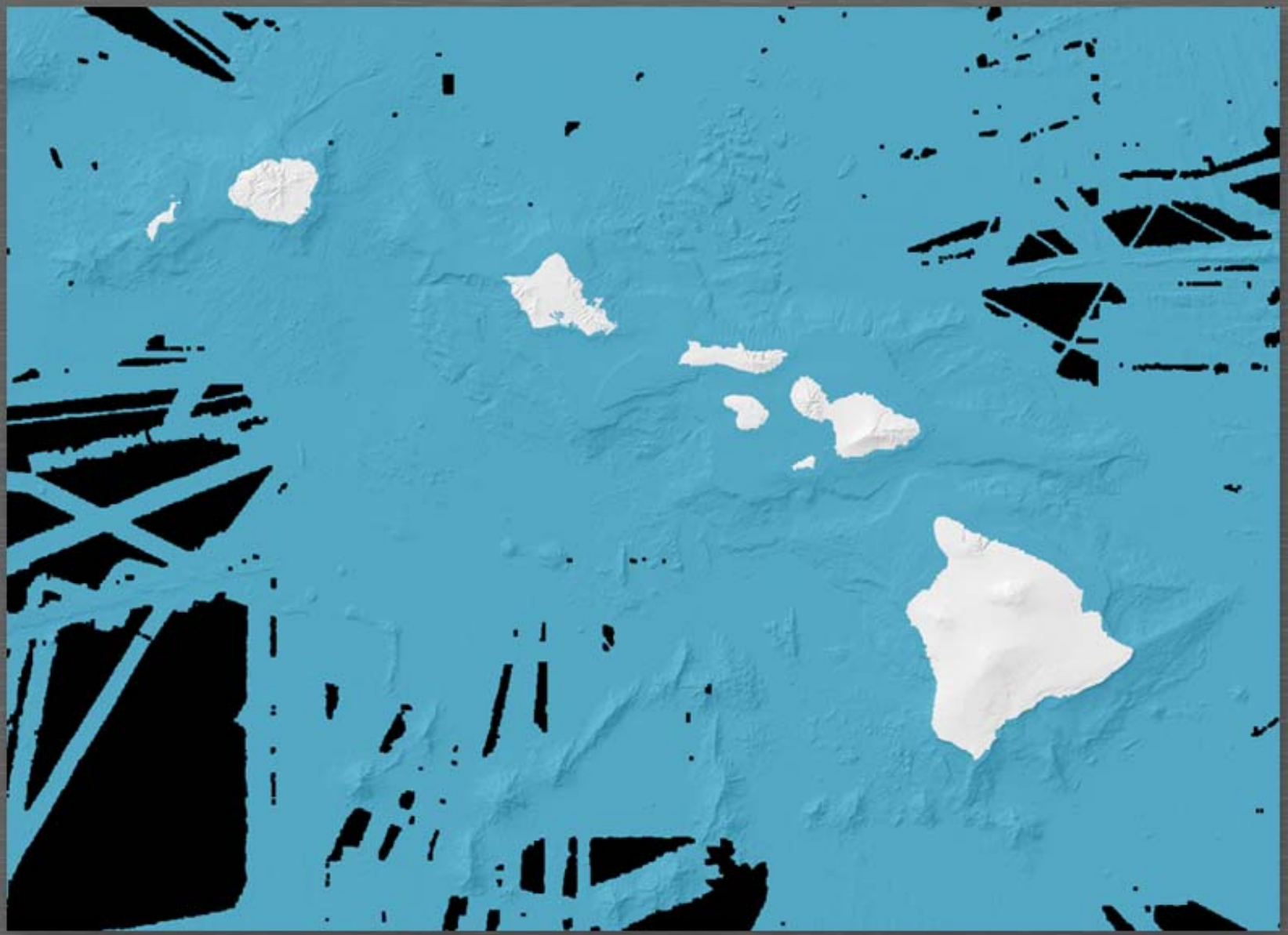
Sandwell and Smith, 1997

Single and Multibeam Sonar



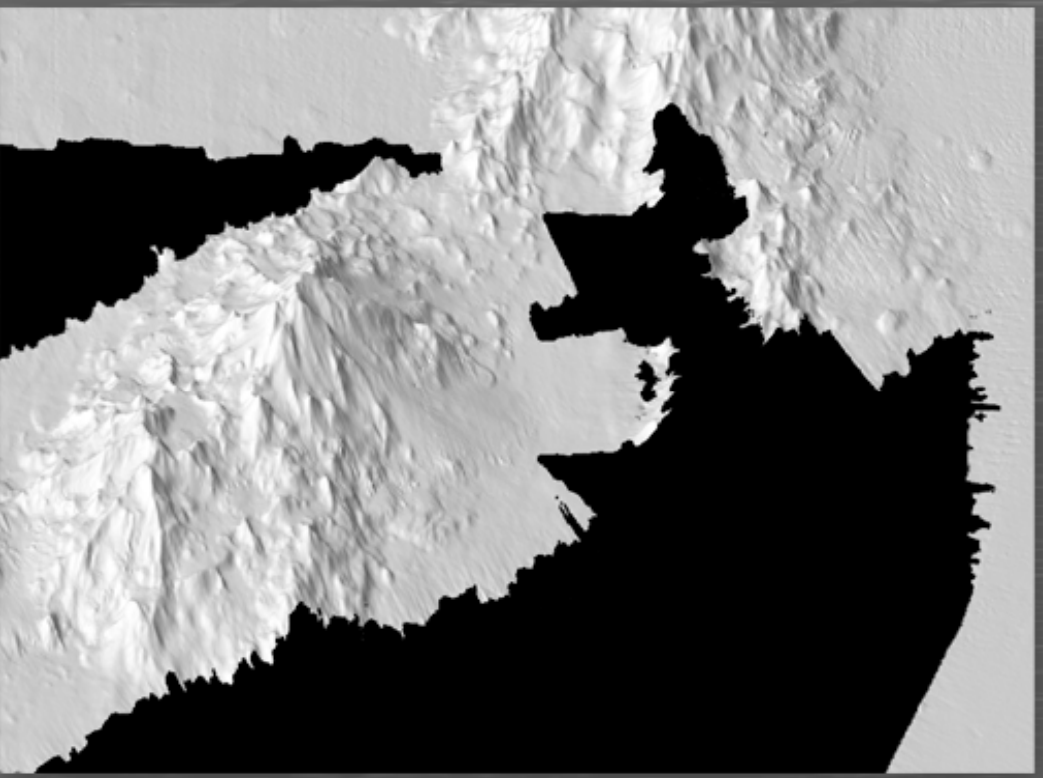
NOAA Office of Coast Survey

Multibeam Coverage (blue)

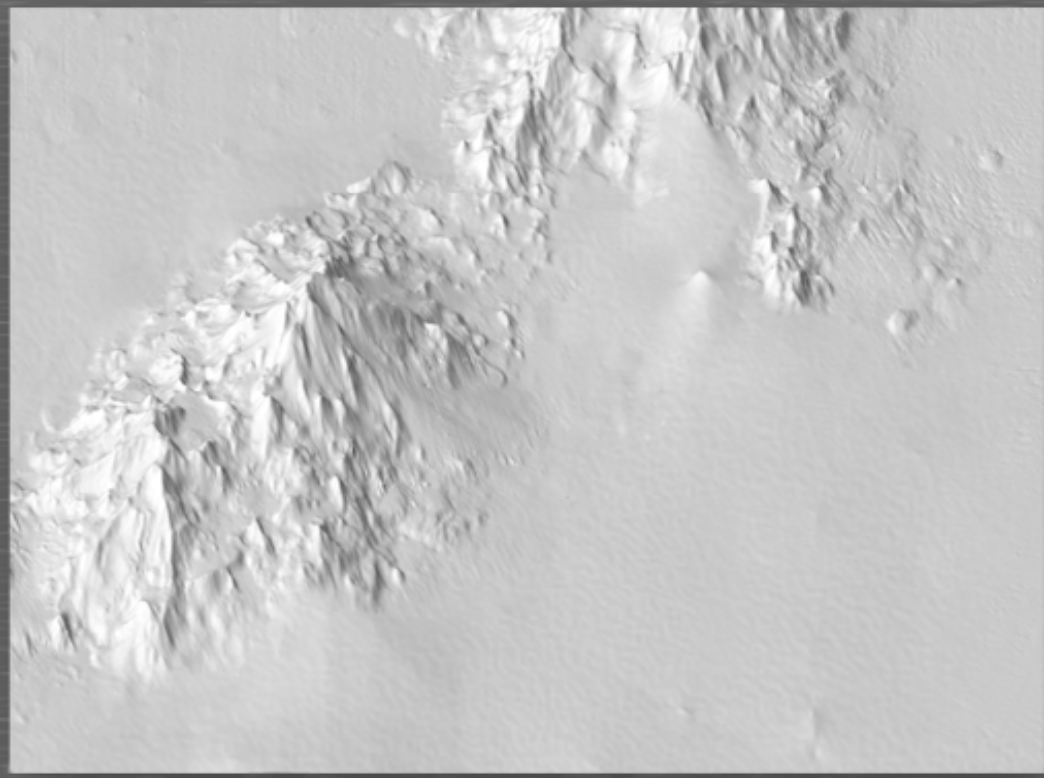


Filling Holes

Original Multibeam Data

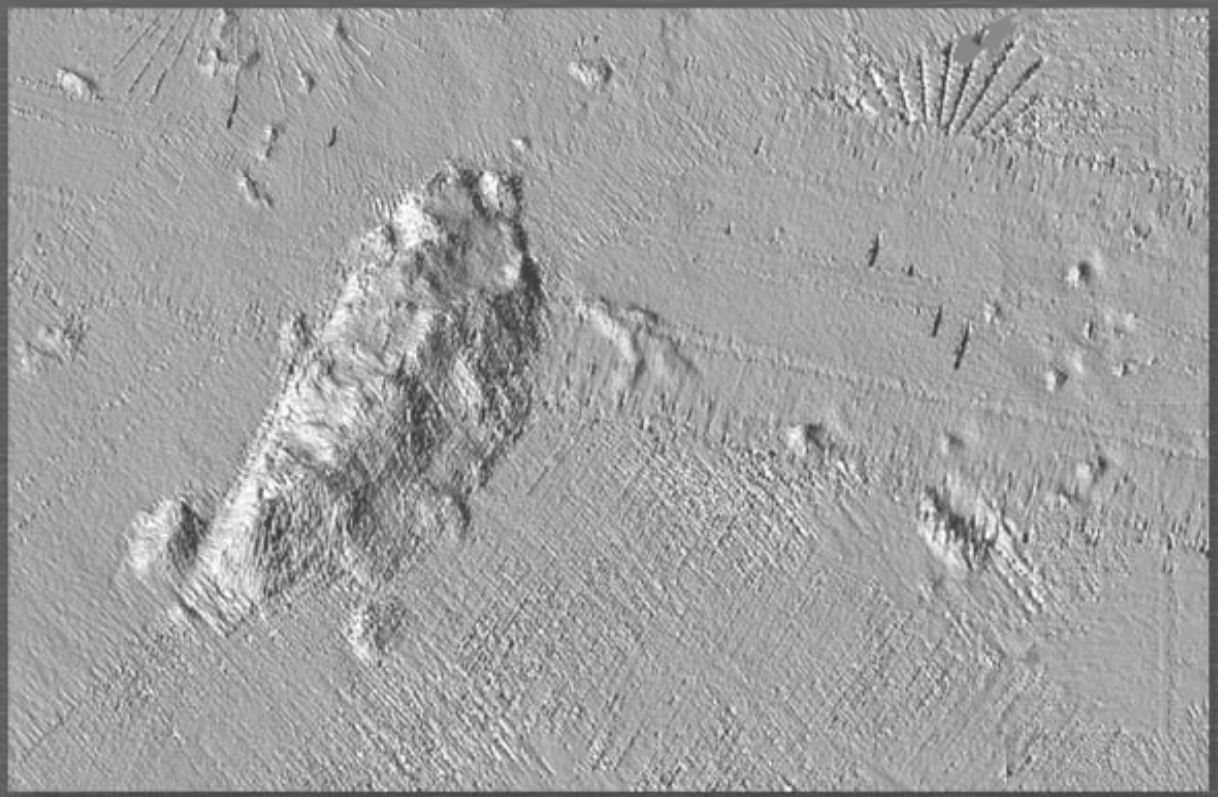


Patched with Satellite Altimetry Data



Smoothing Data Artifacts

Original Multibeam Data



Final Map

Map Design

Berann, 1968

Berann, 1977

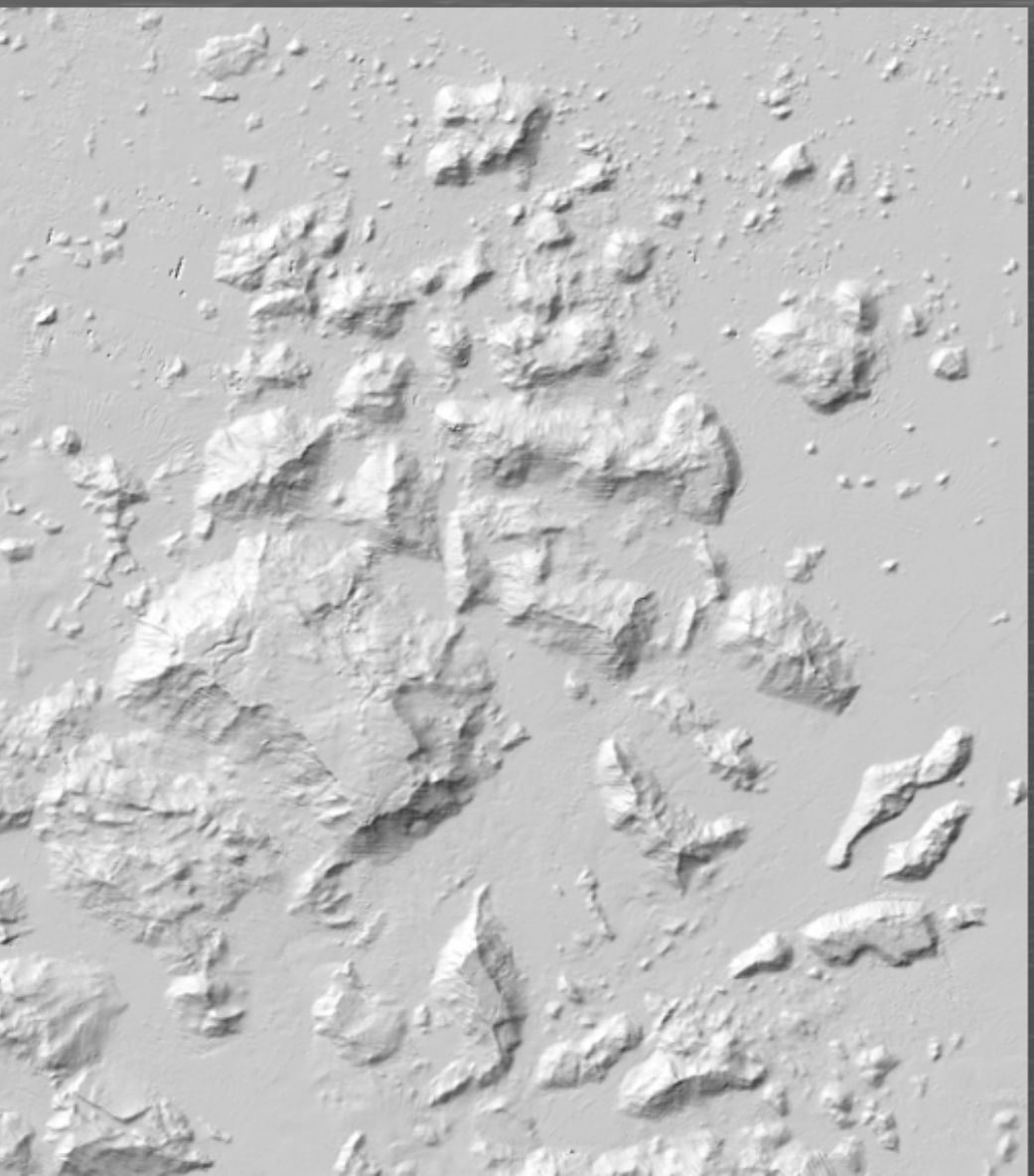
Tóth, 1981

Tóth, 2008

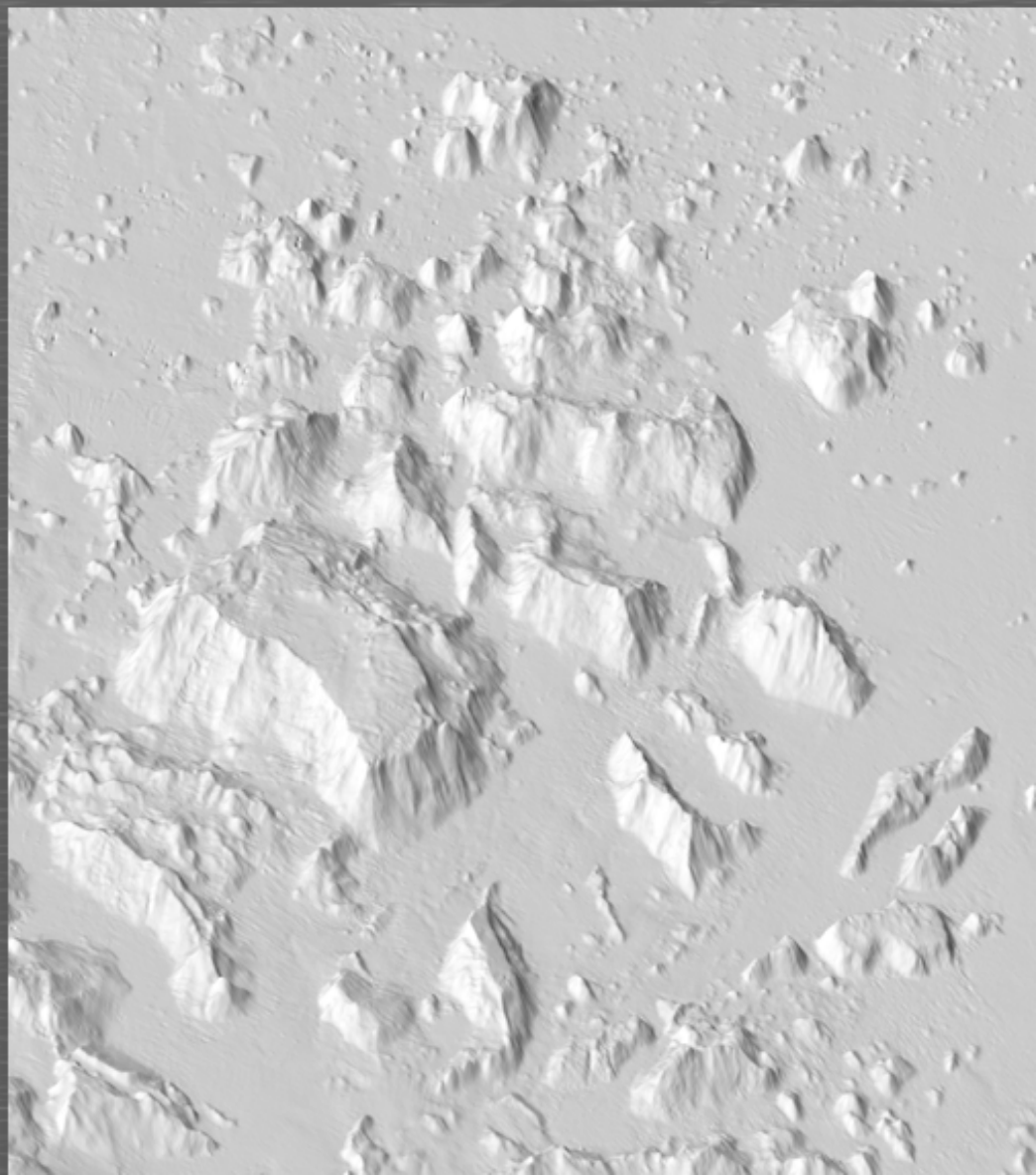
Maps courtesy of National Geographic, except Berann, 1977, published by the US Office of Naval Research.

Relief Presentation

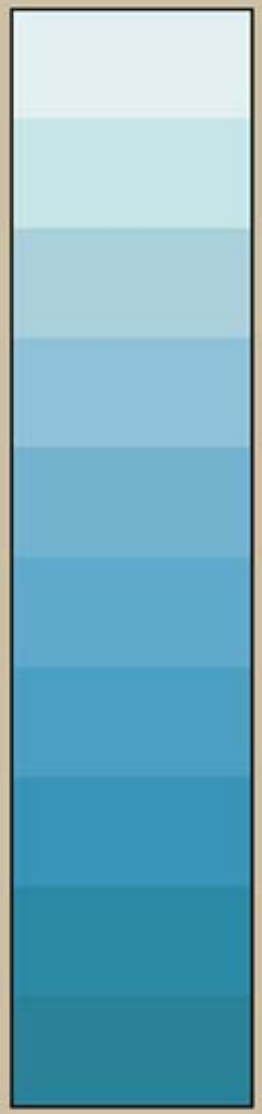
Conventional Shaded Relief



Plan Oblique Relief



Bathymetric Tints



Depth in meters	RGB color	CMYK color
Sea level to -100	226r 240g 241b	10c 1m 4y 0k
-100 to -200	198r 229g 231b	21c 1m 8y 0k
-200 to -500	170r 208g 219b	33c 7m 11y 0k
-500 to -1,000	143r 195g 217b	42c 10m 9y 0k
-1,000 to -2,000	115r 179g 207b	53c 15m 11y 0k
-2,000 to -3,000	95r 169g 204b	61c 19m 10y 0k
-3,000 to -4,000	75r 159g 195b	69c 23m 13y 0k
-4,000 to -5,000	56r 148g 185b	75c 29m 16y 0k
-5,000 to -5,500	43r 138g 166b	80c 33m 26y 1k
-5,500 to -6,000	42r 130g 152b	81c 36m 32y 3k

Thank You

www.shadedrelief.com/hawaii