NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

MEETING ANNOUNCEMENT

DATE: **Wednesday, June 26, 2024**

LOCATION: Orinda Masonic Hall

TIME: Social time: 6:30 to 7:15 pm; Program: 7:15 to 8:30 pm

SPEAKER: ***Don Medwedeff, Consultant***

TOPIC: ***"Structure, Timing, and Western Extent of the Stockton Arch: Constraints on Neogene strike slip fault offset in the Diablo Range"***

Abstract:

The Eastern Coast Ranges in California's San Francisco Bay Area largely comprise Upper Cretaceous and Cenozoic rocks deposited on or accreted to the Western Margin of North America. The structure of the margin is profoundly modified by eastward thrusting of a wedge of deeply buried Franciscan Complex rocks. The San Andreas transform margin propagated to this latitude at 12-14 Ma. Multiple authors (e.g., Graymer et al., 2002) interpret 175 km of dextral offset on faults east of the San Andreas fault. However, continuity of a newly identified margin perpendicular structural feature disallows large magnitude strike-slip offset east of the San Andreas fault.

In the Central Valley, the Stockton Arch is expressed at the base Miocene unconformity south of the Stockton Fault and is documented by subsurface and gravity data (Sterling, 1992, Imperato, 1995). The Stockton Arch is bound on the north by the Stockton Fault which is one of a number of such faults in the southern Sacramento Valley. The 60 km wide arch extends 80 km transverse to the valley. Erosional truncation of Eocene through Upper Cretaceous strata beneath the Miocene unconformity and an anomalously thick Cretaceous section indicate that the arch formed by Paleogene inversion of a Cretaceous normal fault associated with the Rio Vista rift system (Sterling, 1992, Imperato, 1995).

Although analogous sub-Miocene relationships have been mapped at the surface by multiple geologists it appears to be newly recognized that the arch extended southwestward from the Central Valley to at least as far as the Hayward Fault. The sub-Miocene erosional limit of Eocene strata on the south flank of the arch is a linear feature which strikes ~E-W in the Central Valley and crops out east of the Diablo Range (15 km northwest of Patterson) and west of the Diablo Range (8 km north of Morgan Hill). This piercing line is eroded west of the Calaveras Fault but, a 35 km gap in the preservation of sub-Miocene Eocene strata along the San Andreas Fault between Palo Alto and a point 4 km west of Loma Prieta suggests that uplift related to the Stockton Arch extended to the San Andreas Fault and that cumulative dextral offset across the East Bay is < 30 km (Fig. 3).

Conclusions from this analysis are that, despite the dominance of

 (continued on last page)

NCGS 2024 – 2025 Calendar

September 25, 2024 7:15 pm (6:30 social hour)
John Karachewski
Icelandic Geoscapes

October 30, 2024 7:15 pm (6:30 social hour)
Joint Meeting with Association of Engineering Geologists in Orinda. Speaker TBD.

November 20, 2024 7:15 pm (6:30 social hour)
Dawnika Blatter, California Volcano Observatory, US Geological Survey
Volcanoes to vineyards: the volcanic history of Clear Lake Volcanic Field

January 29, 2025 7:15 pm (6:30 social hour)
Speaker to be determined

February 26, 2025 7:15 pm (6:30 social hour)
Seth Burgess, California Volcano Observatory, US Geological Survey
Using radiometric dating to recast time onto the Pleistocene geologic record of Alaska

March 26, 2025 **7:15 pm (6:30 social hour)**
Greg Croft
Carbon Sequestration in Mid Ocean Ridge Hydrothermal Systems.

April 30, 2025 **7:15 pm (6:30 social hour)**
Speaker to be determined

May 28, 2025 **6:30 pm (annual dinner meeting)**
James Hutton, Topic to be determined

June 25, 2025 **7:15 pm (6:30 social hour)**
Speaker to be determined

New Youtube Channel:

By vote of the Board in May 2023, we returned to in-person meetings only, as of the September 2023 meeting. We will still record the meetings to Zoom for archiving on our new YouTube channel, @NCGS1000 (which you can access now by typing in the entire name @NCGS1000 into the search bar for Google or YouTube). This is where recently recorded talks can be accessed a few days after each meeting, although the May and June 2024 meetings will not be uploaded until about early July. Past talks recorded since September 2022 can be reviewed at any time. Only talks for which authors have given permission for this archiving will be accessible.

Message from the President

The NCGS Board today approved the following list of candidates to stand for election for the next fiscal year (2024-25) that begins on September 1. We announced these candidates at the annual dinner meeting on May 29th and asked for any additional nominations for interested members. The election will be held by voice vote at the June meeting on June 26th, our last meeting of this fiscal year. Please come to the meeting and vote!

President:	Jim O'Brient
President – Elect:	Tom MacKinnon
Past President:	Noelle Schoellkopf
Recording Secretary:	John Karachewski
Field Trip Coordinator:	Will Schweller
Treasurer:	Don Medwedeff
Program Directors:	Paul Henshaw, Greg Bartow
Membership Director:	Tom Barry
Newsletter Editor:	Mark Sorensen
Webmaster/Social Media Director:	Andrew Alden

Memorial Service for Raymond Sullivan

October 27, 1934 – January 13, 2024

Morgan Sullivan contacted us to say that there will be a memorial for Ray on Saturday, July 13th from 11AM to 1PM at the Lucas Valley Community Center, 1201 Idylberry Road, San Rafael.

Website News

From Andrew Alden, NCGS Website Manager/Social Media

The News section of our website's home page, which I added in the redesign, is a handy place for NCGS updates, and I've been posting those. But official Society news is kind of intermittent. To help keep the News section fresh, I'd like NCGS members to begin submitting their own news. For instance, some of us lead walks or are active in related societies. I'm already using those. But all of us (I hope) get to visit places with interesting geology and take cool pictures. Let's use News for sharing more informal announcements. Maybe I'll start asking some of you for this "content." If that makes you say to yourself "oh pick me please," or "I have this great vacation photo," email me. I anticipate taking items down after a month or two.

Which place is best for your item, News or the NCGS newsletter? Here in the newsletter, Mark Sorensen publishes very good articles by NCGS members, with permanent value. They're premium content that come with your dues, restricted to NCGS members (for one year, then public after that). He also includes items that can just as easily go online too, including field photos. The website and social media are open to the public right now and I can revise them on a moment's notice. Together NCGS offers several different places for interesting things you might be doing, whether it's sharing a one-liner or writing an essay on a topic you've mastered.

Meanwhile, I have a few ideas to create more Society news for the News section.

Author (and geologist) D.J. Green to Appear at Orinda Books

Not many novels have an engineering geologist hero, but ***No More Empty Spaces*** does. Long-time AEG member and former Jahns Lecturer, Deb Green's (writing as D. J. Green) debut novel is available wherever books are sold, and she'll be in the Bay Area for an author event, in conversation with her publisher, Brooke Warner, in June.

Save the date, and join Deb at Orinda Books, 276 Village Square, Orinda, CA 94563, on Saturday June 22, 2024, at 2 PM!

Here's the link to register for this event (it's free, this just guarantees you'll get a seat):

https://www.orindabooks.com/event/d-j-green-author-no-more-empty-spaces-conversation-brooke-warner-publisher-she-writes-press

More from the author: I hope to see you there, but if you can't make it, perhaps you'll still consider reading the book. After all, how many novels have an engineering geologist as the hero? It's available wherever you like to purchase books, but I'm a big fan of local independent bookstores, so I encourage you going to yours (ask for No More Empty Spaces by D. J. Green, ISBN 9781647426163). If you prefer to shop online, Bookshop.org, matches Amazon's prices AND supports independent bookstores (if you order from them, please choose a bookstore to support). Here's the link, if you'd like to take a look at it on Bookshop.org: https://bookshop.org/p/books/no-more-empty-spaces-d-j-green/20207014?ean=9781647426163.

Email info@geologistwriter.com for more info. See you there!

NCGS Photo of the Month

This month we have a stunning photos of jointed rock from member and counselor Wayne Narr.

Fractures in basement – a structure of organization

Dispelling a common misconception about fracture structure in basement rock.

The uppermost Precambrian surface of unconformity is evident on the granitic plutonic rock in the center of this photograph of an outcrop in central Wyoming. The height of the cliff bordering the lake is about 10 meters. The similarly-colored early Paleozoic clastic strata that overly it, visible as bedded packages at a few locations in the upper part of this photo, are about 2 Billion years younger than the granite. Thus this unconformity represents a significant gap in time.

Many people have the misconception that fractures (joints) in basement rock are "chaotic" or "random in orientation". This notion is clearly incorrect here and at most outcrops of basement rocks I've seen. The joints evident in the basement in this photo are clearly well-organized. They dip normal to the basement surface (essentially vertical dip). The strike of the two dominant joint sets are orthogonal, and the third, lessor-developed set (most evident on the right side of the photo) approximately bisects the trends of the two dominant sets. No exfoliation joints are evident in this exposure, hence the weathering behavior of this basement is distinctly different from granitic rocks that show exfoliation (sheeting) joints such as near Olmstead Point in Yosemite.

UC Berkeley Earth & Planetary Science Weekly Seminar Series

In-person EPS Seminar talks are off for the summer, but will presumably return in the fall for the academic year, on Thursdays at 141 McCone Hall. To join the department's email list, send an email to eps_frontoffice@berkeley.edu. For updated listings of upcoming seminars, go to https://eps.berkeley.edu/seminars-courses/eps-seminars.

For the Rockhounds

For links to upcoming rock and mineral shows, go to www.cfmsinc.org/shows.

USGS Evening Public Lecture Series

The USGS evening public lecture series events are free and are intended for a general public audience that may not be familiar with the science being discussed. Pre-Covid, talks were held at USGS; the talks are now online. **The USGS is currently taking a pause on their Virtual Public Lecture Series. In the meantime, take a look at their archive for their past lectures, at https://www.usgs.gov/public-lecture-series.** To be added to the email notification list for future USGS Public Lecture Series events, please email: wmcesic@usgs.gov.

2023-2024 NCGS Registration and Dues

A 21st Century Innovation Takes Hold

Following a successful pilot for August's field trip, NCGS is converting from last century's check-based system for membership renewal, field trip registration, and dinner meeting registration, to an electronic system. The system is hosted by RegFox, which is a fee-per-use system, with no software or internet costs to the NCGS. The fees per registration, which are 2.99% + $0.99 per registration (or $1.71, $2.49, or $3.24 for 1, 2, and 3-year registrations, respectively), will be covered by the NCGS.

To cover these new fees and increased costs for hall-rental, mailings, web-hosting, and insurance, the board approved an increase in dues beginning September 1st to $25 annually for membership and $25/annually for surcharge for paper mailing.

All registrations will be accessed via this link: https://NCGS.regfox.com/ncgs-landing. This brings up an electronic version of the legacy NCGS Membership page (see attached figure). This page will always be active and a link to it will be included in the Newsletter and sent annually to members whose renewal date has arrived. Funds received are directly deposited in the NCGS account and membership details are immediately available to the Membership Secretary for recording.

Registration for Field Trips or the Annual Dinner Meeting will be accessed from the tabs above the Membership Renewal form. These tabs will be grayed out when inactive and highlighted when active. The electronic system is particularly effective for these time-sensitive reservations, as trip availability and dinner commitments are instantaneously updated for both organizers and attendees.

Final Note: If you are among those unable to use the electronic registration, you can contact me (Don M.) via mail at 146 Roan Drive, Danville, CA 94526.

Regards,
Don Medwedeff
NCGS Treasurer

WE'RE ON FACEBOOK!

CHECK OUT THE MOST RECENT POST: @NCGEOLSOC

ALSO, VISIT TWITTER @NORCALGEOSOC

NCGS Board Meetings

Board meetings (online for now) are open to all NCGS members. If you'd like to attend, please contact Jim O'Brient at j.obrient @ comcast.net. Board meetings generally are on Saturday mornings in Jan., Apr./May, and Aug./Sep. The next meeting will be on **Saturday, September 7, 2024 at 9 a.m., by Zoom**.

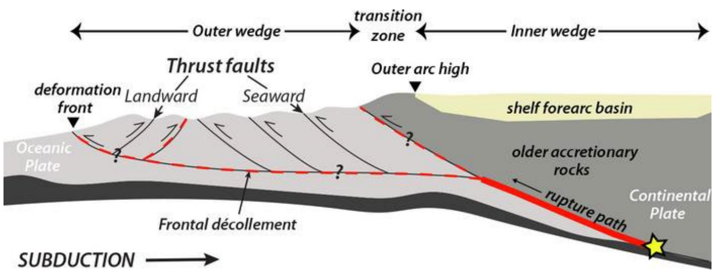
A Great Website to Visit

Last year Dr. Ray Sullivan completed an excellent website – see http://raysullivangeologist.com/. As many of you know, Ray was a longtime professor of geology at San Francisco State University as well as serving in multiple positions with other societies and organizations, and with NCGS as president, program chair, field trip leader and counselor, and co-editor of the Mount Diablo volume recently published with the Geological Society of America. The website has a biography, list of journal and book publications, and a list of projects on which he worked, with some great photos and stories.

Cascadia Subduction Zone, one of Earth's top hazards, comes into sharper focus

Giant earthquakes and tsunamis have hit the western U.S. and Canada—and almost certainly will again

EurekAlert!, June 7, 2024
Source: Columbia Climate School



A schematic cross section of the Cascadia Subduction Zone shows the ocean floor plate (light grey) moving under the North American continental plate, along with other features.

Credit: U.S. Geological Survey

Off the coasts of southern British Columbia, Washington, Oregon and northern California lies a 600-mile-long strip where the Pacific Ocean floor is slowly diving eastward under North America. This area, called the Cascadia Subduction Zone, hosts a megathrust fault, a place where tectonic plates move against each other in a highly dangerous way. The plates can periodically lock up and build stress over wide areas—eventually to be released when they finally lurch against each other. The result: the world's greatest earthquakes, shaking both seabed and land, and generating tsunamis 100 feet high or more. Such a fault off Japan caused the 2011 Fukushima nuclear disaster. Similar zones exist off Alaska, Chile and New Zealand, among other places. At Cascadia, big quakes are believed to come roughly every 500 years, give or take a couple hundred. The last occurred in 1700.

Scientists have long been working to understand the Cascadia Subduction Zone's subterranean structures and mechanics, in order to delineate places most susceptible to quakes, how big they might be and what warning signs they might produce. There is no such thing as predicting an earthquake; rather, scientists try to forecast probabilities of multiple scenarios, hoping to help authorities design building codes and warning systems to minimize the damage when something happens.

A newly published study promises to greatly advance this effort. A research vessel towing an array of the latest geophysical instruments along almost the entire zone has produced the first comprehensive survey of the many complex structures beneath the seafloor. These include the geometry of the down-going ocean plate and overlying sediments, and the makeup of the overriding North American plate. The study was just published in the journal Science Advances.

"The models currently in use by public agencies were based on a limited set of old, low-quality 1980s-era data," said Suzanne Carbotte, a marine geophysicist at Columbia University's Lamont-Doherty Earth Observatory, who led the research. "The megathrust has a much more complex geometry than previously assumed. The study provides a new framework for earthquake and tsunami hazard assessment."

With funding from the U.S. National Science Foundation, the data was gathered during a 41-day cruise in 2021 by Lamont's research vessel, the Marcus G. Langseth. Researchers aboard the ship penetrated the seafloor with powerful sound pulses and read the echoes, which were then converted into images, somewhat similar to how physicians create interior scans of the human body.

One key finding: the megathrust fault zone is not just one continuous structure, but is divided into at least four segments, each potentially somewhat insulated against movements of the others. Scientists have long debated whether past events, including the 1700 quake, ruptured the entire zone or just part of it—a key question, because the longer the rupture, the bigger the quake.

The data show that the segments are divided by buried features including big faults, where opposing sides slide against each other perpendicular to the shore. This might help buffer against movement on one segment translating to the next. "We can't say that this definitely means only single segments will rupture, or that definitely the whole thing will go at once," said Harold Tobin, a geophysicist at the University of Washington and coauthor of the study. "But this does upgrade evidence that there are segmented ruptures."

The imagery also suggests the causes of the segmentation: the rigid edge of the overriding North American continental plate is composed of many different kinds of rocks, formed at different times over many tens of millions of years, with some being denser than others. This variety in the continental rocks causes the incoming, more pliable oceanic plate to bend and twist to accommodate differences in overlying pressure. In some places, segments go down at relatively steep angles, in others at shallow ones.

The researchers zeroed in on one segment in particular, which runs from southern Vancouver Island alongside Washington state, more or less ending at the Oregon border. The subterranean topography of other segments is relatively rough, with oceanic features like faults and subducted seamounts rubbing up against the upper plate—features that might erode the upper plate and limit how far any quake may propagate within the segment, thus limiting the quake's size. In contrast, the Vancouver-Washington segment is quite smooth. This means that it may be more likely to rupture along its entire length at once, making it potentially the most dangerous section.

Also in this segment, the seafloor is subducting under the continental crust at a shallow angle relative to the other segments. In the other segments, most of the earthquake-prone interface between the plates lies offshore, but here the study found the shallow subduction angle means it probably extends directly under Washington's Olympic Peninsula. This might magnify any shaking on land. "It requires a lot more study, but for places like Tacoma and Seattle, it could mean the difference between alarming and catastrophic," said Tobin.

With funding from the U.S. Geological Survey, a consortium of state and federal agencies and academic institutions has already been poring over the data since it became available to sort through the implications.

As for tsunami hazard, that is "still a work in progress," said Kelin Wang, a research scientist at the Geological Survey of Canada who was not involved in the study. Wang's group is using the data to model features of the seafloor off Vancouver Island that might generate tsunamis. (In general, a tsunami occurs when the deep seafloor moves up or down during a quake, sending a wave to the surface that concentrates its energy and gathers height as it reaches shallower coastal waters.) Wang said his results will go to another group that models tsunamis themselves, and after that to another group that analyzes the hazards on land.

Practical assessments that could affect building codes or other aspects of preparedness may be published as early as next year, say the researchers. "There's a whole lot more complexity here than was previously inferred," said Carbotte.

Journal Reference: Seismic Imaging of Cascadia megathrust morphology, *Science Advances*. Publication Date: 7-Jun-2024.

What the geologic record reveals about how oceans were oxygenated 2.3 billion years ago

Earth's "Great Oxidation Event" was spread over 200 million years, according to recent discoveries

EurekAlert! June 12, 2024
Source: University of Utah

About 2.5 billion years ago, free oxygen, or O_2, first started to accumulate to meaningful levels in Earth's atmosphere, setting the stage for the rise of complex life on our evolving planet.

Scientists refers to this phenomenon as the Great Oxidation Event, or GOE for short. But the initial accumulation of O_2 on Earth was not nearly as straightforward as that moniker suggests, according to new research led by a University of Utah geochemist.

This "event" lasted at least 200 million years. And tracking the accumulation of O_2 in the oceans has been very difficult until now, said Chadlin Ostrander, an assistant professor in the Department of Geology and Geophysics.

"Emerging data suggest that the initial rise of O_2 in Earth's atmosphere was dynamic, unfolding in fits-and-starts until perhaps 2.2. billion years ago," said Ostrander, lead author on the study published June 12 in the journal Nature. "Our data validate this hypothesis, even going one step further by extending these dynamics to the ocean."

His international research team, which is supported by the NASA Exobiology program, focused on marine shales from South Africa's Transvaal Supergroup, yielding insights into the dynamics of ocean oxygenation during this crucial period in Earth's history. By analyzing stable thallium (Tl) isotope ratios and redox-sensitive elements, they uncovered evidence of fluctuations in marine O_2 levels that coincided with changes in atmospheric oxygen.

These findings help advance the understanding of the complex processes that shaped Earth's O_2 levels during a critical period in the planet's history that paved the way for the evolution of life as we know it.

"We really don't know what was going on in the oceans, where Earth's earliest lifeforms likely originated and evolved," said Ostrander, who joined the U faculty last year from the Woods Hole Oceanographic Institution in Massachusetts. "So knowing the O_2 content of the oceans and how that evolved with time is probably more important for early life than the atmosphere."

The research builds on the work of Ostrander's co-authors Simon Poulton of the University of Leeds in the U.K and Andrey Bekker of the University of California, Riverside. In a 2021 study, their team of scientists discovered that O_2 did not become a permanent part of the atmosphere until about 200 million years after the global oxygenation process began, much later than previously thought.

The "smoking gun" evidence of an anoxic atmosphere is the presence of rare, mass-independent sulfur isotope signatures in sedimentary records before the GOE. Very few processes on Earth can generate these sulfur isotope signatures, and from what is known their preservation in the rock record almost certainly requires an absence of atmospheric O_2.

For the first half of Earth's existence, its atmosphere and oceans were largely devoid of O_2. This gas was being produced by cyanobacteria in the ocean before the GOE, it seems, but in these early days the O_2 was rapidly destroyed in reactions with exposed minerals and volcanic gasses. Poulton, Bekker and colleagues discovered that the rare sulfur isotope signatures disappear but then reappear, suggesting multiple O2rises and falls in the atmosphere during the GOE. This was no single 'event.'

"Earth wasn't ready to be oxygenated when oxygen starts to be produced. Earth needed time to evolve biologically, geologically and chemically to be conducive to oxygenation," Ostrander said. "It's like a teeter totter. You have oxygen production, but you have so much oxygen destruction, nothing's happening. We're still trying to figure out when we've completely tipped the scales and Earth could not go backwards to an anoxic atmosphere."

To map O_2 levels in the ocean during the GOE, the research team relied on Ostrander's expertise with stable thallium isotopes. Isotopes are atoms of the same element that have an unequal number of neutrons, giving them slightly different weights. Ratios of a particular element's isotopes have powered discoveries in archaeology, geochemistry and many other fields.

Advances in mass spectrometry have enabled scientists to accurately analyze isotope ratios for elements farther and farther down the Periodic Table, such as thallium. Luckily for Ostrander and his team, thallium isotope ratios are sensitive to manganese oxide burial on the seafloor, a process that requires O_2 in seawater. The team examined thallium isotopes in the same marine shales recently shown to track atmospheric O_2 fluctuations during the GOE with rare sulfur isotopes.

In the shales, Ostrander and his team found noticeable enrichments in the lighter-mass thallium isotope (203Tl), a pattern best explained by seafloor manganese oxide burial, and hence accumulation of O_2 in seawater. These enrichments were found in the same samples lacking the rare sulfur isotope signatures, and hence when the atmosphere was no longer anoxic. The icing on the cake: the 203Tl enrichments disappear when the rare sulfur isotope signatures return. These findings were corroborated by redox-sensitive element enrichments, a more classical tool for tracking changes in ancient O_2.

"When sulfur isotopes say the atmosphere became oxygenated, thallium isotopes say that the oceans became oxygenated. And when the sulfur isotopes say the atmosphere flipped back to anoxic again, the thallium isotopes say the same for the ocean," Ostrander said. "So the atmosphere and ocean were becoming oxygenated and deoxygenated together. This is new and cool information for those interested in ancient Earth."

The study, titled "Onset of coupled atmosphere–ocean oxygenation 2.3 billion years ago," was published in the June 13 edition of *Nature*. Authors include Ostrander's colleagues at Woods Hole Oceanographic Institution, University of California, Riverside, University of Johannesburg, University of Leeds, University of Southern Denmark, and Université de Lorraine. Funding came from NASA's Exobiology program and the American Chemical Society.

Journal Reference: Onset of coupled atmosphere–ocean oxygenation 2.3 billion years ago, *Nature*. DOI: 10.1038/s41586-024-07551-5. Publication Date: June 13, 2024.

Subduction zone splay faults compound hazards of great earthquakes

A study finds evidence that splay fault uplift in the Alaskan-Aleutian subduction zone generated additional tsunami activity in half of the last eight earthquakes

EurekAlert! May 20, 2024
Source: Virginia Tech

Groundbreaking research has provided new insight into the tectonic plate shifts that create some of the Earth's largest earthquakes and tsunamis.

"This is the first study to employ coastal geology to reconstruct the rupture history of the splay fault system," said Jessica DePaolis, postdoctoral fellow in Virginia Tech's Department of Geosciences. "These splay faults are closer to the coast, so these tsunamis will be faster to hit the coastline than a tsunami generated only from a subduction zone earthquake."

Subduction zones around the world, areas where one tectonic plate shifts under another, create the largest earthquakes – those over magnitude 8.0 – triggering tsunamis and altering ecosystems in their wake. DePaolis, along with Tina Dura, assistant professor of natural hazards, and colleagues from the United States Geological Survey, found evidence that splay faults, the crustal faults connected to the subduction zones, may shift during subduction zone earthquakes and contribute to local coastal destruction and ecological change more regularly than previously realized.

Such a shift of the splay fault underwater can create a tsunami that could reach the nearest shores in 30 minutes or less, DePaolis said.

Published in the *Journal of Geophysical Research: Solid Earth*, the study should affect hazard awareness at subduction zones around the world. Splay faults exist at subduction zones bordering Ecuador, Cascadia, Chile, and Japan, suggesting they may contribute to tsunami hazards at those locations as well.

When tectonic plates shift at a subduction zone, it occurs miles under the ocean surface. Because splay faults are connected to these zones, their location makes researching them a challenge.

Fortunately, secondary, or surface level, effects of these shifts have been geologically recorded on Montague Island in Prince William Sound in Alaska, making it the only current land mass to sit atop a splay fault to exhibit such effects in its soil.

Typically, the resultant lifting of land from the tectonic plate shifting beneath it, called uplift, from subduction zone earthquakes can be as much as 1 to 3 meters. This is true for most onshore locations impacted by the 1964 earthquake, which hit 9.2 on the Richter scale. However, on Montague Island, splay faults created 11 meters of uplift and initiated drainage of a coastal lagoon, effectively altering its ecosystem from a marine lagoon to a freshwater bog.

"The island is kind of stuck in the middle of these splay faults, so anytime these splay faults rupture, it's actually recording the uplift," DePaolis said. "It has this exaggerated uplift that's just not common in subduction zone-only earthquakes."

DePaolis and her team examined the effects of the splay fault ruptures on Montague Island. By analyzing 42 sediment cores, they found stratigraphic evidence of the

1964 earthquake and a secondary shift caused by the splay fault. They noticed there was a clear sedimentary change from pre-earthquake lagoon silt to post-earthquake rooted soil.

"There are definitely islands that uplift with subduction zone earthquakes, but they don't necessarily have faults going through them causing that exaggerated uplift, so it's a really unique place," said Dura, an affiliated faculty member of the Global Change Center and the Fralin Life Sciences Institute.

Researchers have believed that a secondary shift from the splay faults was possible. But that idea has been only theoretical until now because this is the first known land mass to record the stratigraphic evidence.

Team members also utilized diatoms, a type of siliceous microalgae preserved within the sediments that is sensitive to changes in salinity, to reconstruct the paleoenvironmental changes that occurred following the 1964 earthquake. They found a clear shift from a highly saline marine lagoon environment out of the reach of tides, indicating uplift of the coast.

Comparing the findings of the 1964 earthquake core samples to samples deeper in the coastal stratigraphy, the research team discovered sedimentary and diatom evidence of three other instances where the splay fault ruptured. This evidence correlated with four of the last eight documented subduction zone earthquakes in the region.

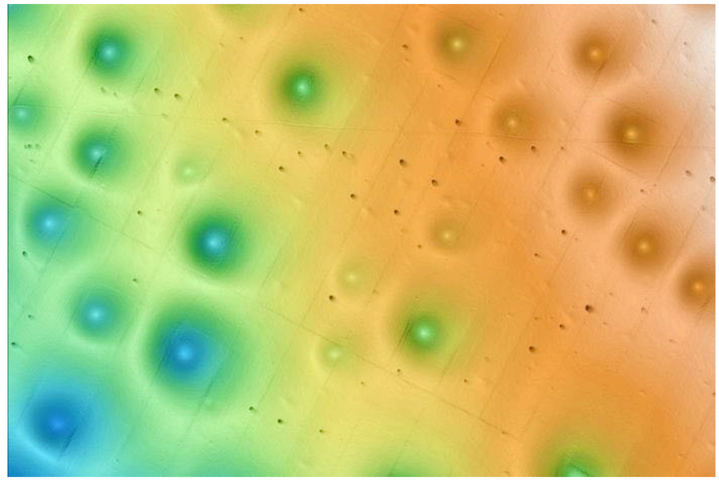
"There's a huge amount of displacement on these faults that can create those really quick, local, large tsunamis," DePaolis said. "So you have that local tsunami coming in really quickly and right behind that, you're going to have the tsunami that was created by the subduction zone itself. All of a sudden you're having these massive and destructive tsunamis kind of coming in rapidly one after another."

Journal Reference: *Journal of Geophysical Research Solid Earth.*

New research reveals that prehistoric seafloor pockmarks off the California coast are maintained by powerful sediment flows

Data from MBARI's advanced underwater robots point to erosion during intermittent sediment flows as the mechanism maintaining these circular depressions for hundreds of thousands of years

EurekAlert! (from AAAS), 21-May -2024
Source: Monterey Bay Aquarium Research Institute



New research on a field of pockmarks—large, circular depressions on the seafloor—offshore of central California has revealed that powerful sediment flows, not methane gas eruptions, maintain these prehistoric formations. this work by a team of researchers from MBARI, USGS, and Stanford University provides important information to guide decision-making about responsible use and management of the seafloor off California, including site assessments for the development of offshore wind farms. Credit: © 2019 MBARI

New MBARI research on a field of pockmarks—large, circular depressions on the seafloor—offshore of Central California has revealed that powerful sediment flows, not methane gas eruptions, maintain these prehistoric formations. A team of researchers from MBARI, the United States Geological Survey (USGS), and Stanford University published their findings today in the Journal of Geophysical Research: Earth Surface. This work provides important information to guide decision-making about responsible use and management of the seafloor off California, including site assessments for the development of offshore wind farms.

The Sur Pockmark Field—an area about the size of the city of Los Angeles that is located off the coast of Big Sur, California—contains more than 5,200 circular depressions. These formations are approximately 200 meters (656 feet) across, roughly the distance of two football fields, and five meters (16 feet) deep. Past research in other parts of the world has suggested that similar large seafloor depressions were formed and maintained by methane gas bubbling up through the sediments. With wind farms slated for construction offshore of Central California, resource managers were concerned about how the presence of methane gas might impact the stability of the seafloor in this region.

The data collected by MBARI researchers and their collaborators found no evidence of methane at this site. Instead, the research team has proposed that sediment gravity flows—similar to an avalanche of mud, sand, and water moving along the seafloor—that have occurred in this region intermittently for hundreds of thousands of years maintain these seafloor formations.

"There are many unanswered questions about the seafloor and its processes," said MBARI Senior Research Technician

Eve Lundsten, who led this work. "This research provides important data about the seafloor for resource managers and others considering potential offshore sites for underwater infrastructure to guide their decision-making."

The research team deployed MBARI's advanced underwater robots to study the Sur Pockmark Field. First, autonomous underwater vehicles (AUVs)—torpedo-shaped, self-guided robots—mapped the region. Previous maps of the seafloor were collected by sonar mounted on ships, but the distance between the ocean surface and the seafloor resulted in low-resolution data. AUVs can travel closer to the seafloor to visualize the terrain below in much greater detail. MBARI's seafloor mapping AUVs also carried technology to profile the sub-bottom layers of sediment below the seafloor. These maps then guided sampling with MBARI's remotely operated vehicle (ROV) Doc Ricketts. Operated by the research team in the control room aboard an MBARI research vessel, the ROV Doc Ricketts collected sediment samples to reconstruct the history of individual pockmarks.

These pockmarks are located on the continental margin, a dynamic section of the seafloor that connects the relatively shallow continental shelf to the deep sea. Sediment gravity flows can move massive amounts of material through this region intermittently. The data and samples collected by MBARI technology helped the research team piece together the history of sediment movements over this part of the seafloor.

The team found multiple layers of sandy deposits, called turbidites, in the sediment samples taken from the pockmarks and the sub-bottom images of the pockmark field. These deposits indicated that large sediment gravity flows in the region have occurred intermittently for at least the last 280,000 years. These sediment gravity flows appear to cause erosion in the center of each pockmark, maintaining these unique underwater morphologic features over time.

"We collected a massive amount of data, allowing us to make a surprising link between pockmarks and sediment gravity flows. We were unable to determine exactly how these pockmarks were initially formed, but with MBARI's advanced underwater technology, we've gained new insight into how and why these features have persisted on the seafloor for hundreds of thousands of years," said Lundsten.

Seafloor pockmarks have been found elsewhere around the world. In those locations, pockmarks have been associated with the release of methane gas or other fluids from the seafloor. Bubbling methane could potentially cause the seafloor to be unstable, which could pose risks for structures on the seafloor, like the anchors for offshore wind turbines. In October 2018, the U.S. Bureau of Ocean Energy Management (BOEM) announced areas offshore of Central California for potential wind energy leasing. MBARI quickly moved to conduct this research to answer critical questions about the stability of the seafloor to guide development of offshore wind energy in California.

"Expanding renewable energy is critical to achieving the dramatic cuts in carbon dioxide emissions needed to prevent further irreversible climate change. However, there are still many unanswered questions about the possible environmental impacts of offshore wind energy development," said MBARI President and CEO Chris Scholin. "This research is one of many ways that MBARI researchers are answering fundamental questions about our ocean to help inform decisions about how we use marine resources."

Because of the extensive efforts of MBARI, USGS, BOEM, and NOAA as part of the interagency Expanding Pacific Research and Exploration of Submerged Systems (EXPRESS) cooperative research campaign, the Sur Pockmark Field is now one of the best-studied areas of seafloor on the west coast of North America. However, there are still many questions to answer about these pockmarks, including how these features were initially formed hundreds of thousands of years ago.

Funding for this work was provided by the David and Lucile Packard Foundation, BOEM, and USGS.

Background

The seafloor plays an important ecological and societal role. It provides vital habitat for marine life and supports our modern infrastructure. However, we still have a lot to learn about seafloor processes. MBARI has an active research program that uses advanced robots to study and map the seafloor offshore of Central California. MBARI's Continental Margin Processes Team, led by Senior Scientist Charlie Paull, investigates how the morphology of the continental margin—where the continental shelf transitions to the abyssal plain—is sculpted and changed over time.

The Sur Pockmark Field is located offshore of Big Sur, California, along the continental margin at a depth of 500 to 1,500 meters (approximately 1,600 to 5,200 feet). Some of these pockmarks were initially discovered by MBARI scientists in 1998 during a seafloor survey using ship-mounted multibeam sonar. Additional ship surveys conducted by MBARI collaborators at the USGS and NOAA in 2018 showed that the pockmarks extend southward into the region off Morro Bay. These surveys have revealed more than 5,200 pockmarks spread out over 1,300 square kilometers (500 square miles), making this area the largest known pockmark field in North America.

The seafloor offshore of this remote stretch of the Central California coastline has historically been one of the least-studied regions of the continental margin off the west coast of North America. Past research by MBARI, BOEM, and USGS examined the biological communities within the Sur Pockmark Field. This new research aimed to understand the geological processes that form and maintain pockmarks within the field.

The research team used mapping AUVs developed by engineers in MBARI's Seafloor Mapping Lab to visualize a portion of the Sur Pockmark Field in greater detail.

Bathymetric surveys by these underwater robots mapped 317 of the 5,251 pockmarks at one-meter resolution. At this fine resolution, it became apparent the pockmarks have very smooth, gradually-sloped sides. The pockmarks are on average 156 meters (512 feet) across, nearly circular in shape, and fairly evenly spaced apart. Additionally, the AUVs were outfitted with a chirp sub-bottom profiler that uses sound to reveal layers of sediment below the seafloor surface. Chirp profiles captured portions of the subsurface below approximately 200 pockmarks at the site.

These surveys captured an assortment of detailed seafloor data that would not be visible from ship-based mapping with multibeam sonar. That data allowed targeted sampling of pockmarks within the field.

The Continental Margin Processes Team conducted 30 dives with two of MBARI's ROVs to get a closer look at 21 pockmarks within the field. The team recorded 185 hours of seafloor video footage inside and adjacent to pockmarks. MBARI's ROV Doc Ricketts also collected 107 vibracores—a 1.5-meter (five-foot) core of sediment dislodged into a metal tube by high-frequency vibrations—and 433 pushcores—a shallower 24-centimeter (9.4-inch) sample of sediment—within and around five pockmarks.

A USGS cruise on the research vessel M/V Bold Horizon in 2019 collected deeper piston and gravity cores up to 7.5 meters (25 feet) in length. The piston cores were taken inside pockmarks and at background sites adjacent to but outside of the pockmarks for comparison.

Importantly, the research team found no evidence of methane gas in any of the samples or data that they collected. Instead, the subsurface profiles and sediment samples indicated that the pockmarks contain alternating layers of fine and coarse sediment.

The sandy deposits, or turbidites, were the key to unlocking the surprising story of massive sediment gravity flows passing over the whole area. Fine sediment on the seafloor was deposited slowly over time, then intermittent large sediment gravity flows left a characteristic layer of coarse sand. It appears these flows erode the pockmark centers, leaving behind sandy deposits across multiple pockmarks in the region at the same time.

Scientists have only recently begun to understand the patterns of erosion and deposition by sediment gravity flows in underwater canyons and channels. The Sur Pockmark Field is bordered by two channels—the Lucia Chica Channel to the north and the San Simeon Channel to the south—but is otherwise broad and open terrain.

Exactly how currents and sediments move over the dimpled surface of the Sur Pockmark Field is still unknown. However, the research team has proposed the unique seafloor morphology in this area may create flow patterns that erode the pockmark centers. In this region, sediment gravity flows are episodic, occurring tens of thousands of years apart. The last one was approximately 14,000 years ago. Computer modeling will be required to confirm if an unconfined flow passing over the pockmark field carries sufficient energy to erode and maintain the pockmarks.

Journal Reference: Pockmarks Offshore Big Sur, California Provide Evidence for Recurrent, Regional, and Unconfined Sediment Gravity Flows, *Journal of Geophysical Research Earth Surface.* DOI:10.1029/2023JF007374. Publication Date 21-May-2024.

Ancient ocean slowdown warns of future climate chaos

Ocean circulation enables tolerable climate

EurekAlert! June 13, 2024
Source: University of California – Riverside

When it comes to the ocean's response to global warming, we're not in entirely uncharted waters. A UC Riverside study shows that episodes of extreme heat in Earth's past caused the exchange of waters from the surface to the deep ocean to decline.

This system has been described as the "global conveyer belt," because it redistributes heat around the globe through the movement of the ocean waters, making large portions of the planet habitable.

Using tiny, fossilized shells recovered from ancient deep-sea sediments, the study in the Proceedings of the National Academy of Sciences demonstrates how the conveyor belt responded around 50 million years ago. At that time, Earth's climate resembled conditions predicted by the end of this century, if significant action is not taken to reduce carbon emissions.

Oceans play a crucial role in regulating Earth's climate. They move warm water from the equator toward the north and south poles, balancing the planet's temperatures. Without this circulation system, the tropics would be much hotter and the poles much colder. Changes in this system are linked to significant and abrupt climate change.

Furthermore, the oceans serve a critical role in removing anthropogenic carbon dioxide from the atmosphere. "The oceans are by far the largest standing pool of carbon on Earth's surface today," said Sandra Kirtland Turner, vice-chair of UCR's Department of Earth and Planetary Sciences and first author of the study.

"Today, the oceans contain nearly 40,000 billion tons of carbon — more than 40 times the amount of carbon in the atmosphere. Oceans also take up about a quarter of anthropogenic CO_2 emissions," Kirtland Turner said. "If ocean circulation slows, absorption of carbon into the ocean may also slow, amplifying the amount of CO_2 that stays in the atmosphere."

Previous studies have measured changes in ocean circulation in Earth's more recent geologic past, such as coming out of the last ice age; however, those do not approximate the levels of atmospheric CO_2 or warming happening to the planet today. Other studies provide the first evidence that deep ocean circulation, particularly in the North Atlantic, is already starting to slow.

To better predict how ocean circulation responds to greenhouse gas-driven global warming, the research team looked to the early Eocene epoch, between roughly 49 and 53 million years ago. Earth then was much warmer than today, and that high-heat baseline was punctuated by spikes in CO_2 and temperature called hyperthermals.

During that period, the deep ocean was up to 12 degrees Celsius warmer than it is today. During the hyperthermals, the oceans warmed an additional 3 degrees Celsius.

“Though the exact cause of the hyperthermal events is debated, and they occurred long before the existence of humans, these hyperthermals are the best analogs we have for future climate change,” Kirtland Turner said.

By analyzing tiny fossil shells from different sea floor locations around the globe, the researchers reconstructed patterns of deep ocean circulation during these hyperthermal events. The shells are from microorganisms called foraminifera, which can be found living throughout the world’s oceans, both on the surface and on the sea floor. They are about the size of a period at the end of a sentence.

“As the creatures are building their shells, they incorporate elements from the oceans, and we can measure the differences in the chemistry of these shells to broadly reconstruct information about ancient ocean temperatures and circulation patterns,” Kirtland Turner said.

The shells themselves are made of calcium carbonate. Oxygen isotopes in the calcium carbonate are indicators of temperatures in the water the organisms grew in, and the amount of ice on the planet at the time.

The researchers also examined carbon isotopes in the shells, which reflect the age of the water where the shells were collected, or how long water has been isolated from the ocean surface. In this way, they can reconstruct patterns of deep ocean water movement.

Foraminifera can’t photosynthesize, but their shells indicate the impact of photosynthesis of other organisms nearby, like phytoplankton. “Photosynthesis occurs in the surface ocean only, so water that has recently been at the surface has a carbon-13 rich signal that is reflected in the shells when that water sinks to the deep ocean,” Kirtland Turner said.

“Conversely, water that has been isolated from the surface for a long time has built up relatively more carbon-12 as the remains of photosynthetic organisms sink and decay. So, older water has relatively more carbon-12 compared to ‘young’ water.”

Scientists often make predictions about ocean circulation today using computer climate models. They use these models to answer the question: ‘how is the ocean going to change as the planet keeps warming?’ This team similarly used models to simulate the ancient ocean’s response to warming. They then used the foraminifera shell analysis to help test results from their climate models.

During the Eocene, there were about 1,000 parts per million (ppm) of carbon dioxide in the atmosphere, which contributed to that era’s high temperatures. Today, the atmosphere holds about 425 ppm.

However, humans emit nearly 37 billion tons of CO_2 into the atmosphere each year; if these emission levels continue, similar conditions to the Early Eocene could occur by the end of this century.

Therefore, Kirtland Turner argues it is imperative to make every effort to reduce emissions.

“It’s not an all-or-nothing situation,” she said. “Every incremental bit of change is important when it comes to carbon emissions. Even small reductions of CO_2 correlate to less impacts, less loss of life, and less change to the natural world.”

Journal Reference: Sensitivity of ocean circulation to warming during the Early Eocene greenhouse, *Proceedings of the National Academy of Sciences.* DOI: 10.1073/pnas.2311980121 Publication Date: 3-Jun-2024.

Earth scientists describe a new kind of volcanic eruption

The Kīlauea volcano erupted like a stomp-rocket in 2018, new research shows

EurekAlert! May 27, 2024
Source: University of Oregon

No two volcanic eruptions are exactly alike, but scientists think a series of explosive eruptions at Kīlauea volcano fit into a whole new category.

By analyzing the dynamics of 12 back-to-back explosions that happened in 2018, researchers describe a new type of volcanic eruption mechanism. The explosions were driven by sudden pressure increases as the ground collapsed, which blasted plumes of rock fragments and hot gas into the air, much like a classic stomp-rocket toy.

Researchers from the University of Oregon, United States Geological Survey and China’s Sichuan University report their findings in a paper published May 27 in Nature Geoscience.

The particular string of explosions at the summit of Kīlauea was part of a sequence of events that included lava flows erupting from lower on the flank of the volcano.

Those lava flows destroyed thousands of homes and displaced residents on the Island of Hawai'i for months.

Understanding exactly what happened in past volcanic eruptions, colloquially called "hindcasting," allows volcanologists to make better forecasts about future eruptions and give more accurate warnings to people in an eruption's path.

For the most part, explosive volcanic eruptions are either primarily driven by rising magma, vaporized groundwater, or some combination of the two, according to Josh Crozier, who did this research as a doctoral student at the UO. But these eruptions didn't quite fit the mold.

"These eruptions are quite interesting in that they don't really seem to involve either of those," Crozier said. "The eruptive material contained very little that looked like fresh magma that was blasted out, but there's no evidence for significant groundwater being involved, either."

The Hawaiian Volcano Observatory, part of the U.S. Geological Survey, keeps close tabs on Kīlauea. The volcano is covered with scientific instruments, from ground sensors that measure the shaking of the earth to tools that analyze the gases released from the volcano.

"A cool thing about these eruptions is that there were a bunch of them in sequence that were remarkably similar; that's relatively unusual," said Leif Karlstrom, a volcanologist at the UO. "Typically, volcanic eruptions don't happen with as much regularity."

So the team had more data than usual to work with, and they could dig deeper into the specific dynamics of the eruptions. Putting all that data into a variety of atmospheric and subsurface models, the scientists pieced together a new story about what happened on Kīlauea during the string of events in 2018.

Before each explosion at the summit, magma was slowly draining from an underground reservoir. (This magma was feeding lava flows 40 kilometers away, on the eastern flank of the volcano.) As the reservoir depleted, the ground above it — the crater within the caldera at the volcano's summit — suddenly collapsed.

That quickly increased the pressure in the reservoir. And because there was a pocket of accumulated magmatic gas sitting at the top of this reservoir, the pressure increase squeezed the magmatic gas and bits of rubble through a conduit and blasted them out of a vent in Kīlauea's crater.

The researchers compare the eruption dynamic to a stomp-rocket toy, where stepping on an air bag connected to a hose launches a projectile into the air.

"The 'stomp' is this whole kilometer-thick chunk of rock dropping down, pressurizing the pocket, and then forcing material directly up," Crozier said. And the 'rocket' is, of course, the gas and rocks erupting from the volcano.

Caldera collapse is fairly common, Crozier notes. So while this is the first time scientists have specifically spelled out this specific stomp-rocket mechanism, it's probably not the only time it's occurred.

The study was able to link geophysical observations to the properties of the volcanic plume in the atmosphere. "This link is very rare," said Joe Dufek, a volcanologist at the UO. "It points to new ways for us to observe eruptions and to combine sensor measurements with computer simulations to better assess hazards from eruptions."

The fact that this was a series of smaller eruptions may have made it easier to see the underlying mechanism, Dufek said. Other complex processes weren't overshadowing the stomp-rocket component.

But that's not to say that Kīlauea is simple. A typical textbook drawing of a volcano shows magma moving upwards through chambers at different depths. But it's rarely that straightforward, and a volcano like Kīlauea, decked out in scientific instruments, provides an opportunity to dig into the details.

"This is an example, and there's an increasing number of these, where the pathways of magma ascent are quite geometrically complex," Karlstrom said. "It gives us a much more nuanced picture of what volcanic plumbing systems look like."

Journal Reference: Explosive 2018 eruptions at Kilauea driven by a collapse-induced stomp-rocket mechanism, *Nature Geoscience*. DOI: 10.1038/s41561-024-01442-0. Publication Date: 27-May-2024.

Beach erosion will make Southern California coastal living five times more expensive by 2050, USC study predicts

Southern California's iconic sandy coastlines are vanishing at an alarming rate, and it's a warning sign for coastal communities worldwide, new USC research suggests

EurekAlert! May 22, 2024
Source: University of Southern California

Rising sea levels and urban development are accelerating coastal erosion at an alarming rate in Southern California with significant ripple effects on the region's economy, a USC study reveals.

The study, published in Communications Earth & Environment, predicts that Southern California's coastal living costs will surge fivefold by 2050 as a direct result of beach erosion. This erosion will require more frequent and costly beach nourishment projects to maintain the state's treasured shorelines, consequently driving up the cost of living along the coast.

“Our study presents compelling evidence of the rapid deterioration of Southern California’s coastal landscapes,” said Essam Heggy, a geoscientist in the Ming Hsieh Department of Electrical and Computer Engineering/Electrophysics at the USC Viterbi School of Engineering and the study’s corresponding author.

“The challenges facing Southern California mirror a growing threat shared by coastal communities worldwide. The environmental and economic implications of coastal erosion reach far beyond California’s shores and demand interdisciplinary, global solutions,” he said.

Coastal erosion: Cost of living sure to surge as sandy beaches disappear

To predict future changes along California’s sandy coastlines, the researchers focused on the Gulf of Santa Catalina, which stretches over 150 miles from the Palos Verdes Peninsula in Los Angeles County to the northern tip of Baja California in Mexico.

They used a combination of historical and recent satellite images as well as advanced algorithms to analyze coastline movement and predict future erosion based on different trends and environmental factors.

The study predicts a tripling of erosion rates by 2050, increasing from an average of 1.45 meters per year to 3.18 meters by 2100. Consequently, the annual sand requirement for beach nourishment could triple by 2050, with costs rising fivefold due to the global increase in sand prices. This will exacerbate economic and logistical pressures on coastal communities.

Beach nourishment is adding sand to an eroded beach to rebuild it and create a wider barrier against waves and storms.

“Our investigation suggests that coastal problems start inland due to the rapid growth of cities along the coast, which compromise inland sediment replenishment of sandy beaches,” said Heggy, whose research focuses on understanding water evolution in Earth’s arid environments.

“As our beaches shrink, the cost of maintaining them will rise. Finding innovative solutions is key to securing a sustainable future for our shores and local economies,” he said.

Coastal erosion in California: A case study for a global problem

Coastal cities in Southern California and those in North Africa bordering the Mediterranean Sea face a common challenge: a semi-arid climate year-round coupled with the growing threats of rising sea levels and eroding shorelines.

A significant portion of Earth’s landmass, roughly 41%, falls under arid or semi-arid classifications, and these areas support over a third of the global population.

To understand this global challenge, the researchers focused on two specific locations: Corona del Mar in Orange County, Calif. — an example of the typical Southern California coastline — and Hammamet North Beach in Tunisia. Both are densely populated and share similar climates, prone to increasing droughts, flash floods and unpredictable rainfall patterns. These characteristics mirror the challenges faced by countless coastal communities worldwide.

The findings showed that the average rate of shoreline retreat in these areas varies. In Southern California, beaches are receding between 0.75 and 1.24 meters per year. In Hammamet North Beach, the retreat rate ranges from 0.21 to about 4.49 meters annually.

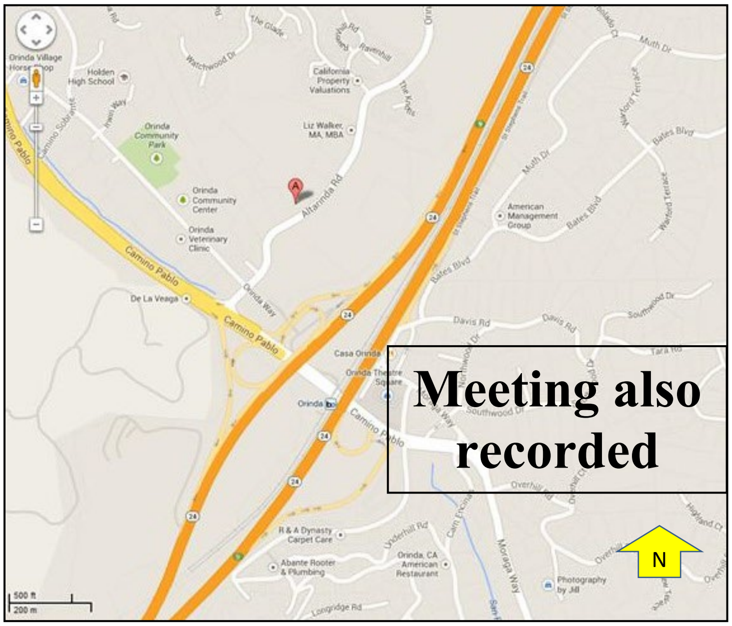
“While beach nourishment can temporarily combat erosion, however, it presents significant challenges for developing countries,” said Oula Amrouni, a sedimentologist at the National Institute of Marine Sciences and Technologies at the University of Carthage, Tunis, Tunisia, and one of the study’s co-authors. “The high cost of acquiring the right sand, with the specific grain size, quality and composition, and the technical complexity of extracting and laying it are major hurdles. Additionally, worsening erosion in previously stable areas compels more frequent nourishment projects, straining already limited budgets and leading to unplanned expenditures for many communities.”

About the study

Co-authors of the study include Oula Amrouni and Abderraouf Hzami of the National Institute of Marine Sciences and Technologies at the University of Carthage, Tunis, Tunisia.

This research is supported by the Arid Climates and Water Research Center at USC under contract from the NASA Jet Propulsion Laboratory (AWD#00630), the USC Zumberge Research and Innovation Fund, and the USC Sea Grant.

Journal Reference: *Communications Earth & Environment,* 22-May-2024. Article Title: **Shoreline retreat and beach nourishment are projected to increase in Southern California,.** DOI: 10.1038/s43247-024-01388-6.



Meeting also recorded

(Continued from Page 1)

strike-slip motion in both earthquake focal mechanisms and geodetic data, (1) the geologic fabric and seismic velocity structure of the Bay Area is dominated by Late Cretaceous and Tertiary dip-slip structures, and (2) although many of these older faults have been reactivated by the modern oblique stress field, it is the Paleogene vertical motions, rather than Neogene lateral motions, that generated most of the observed stratigraphic variation across East Bay faults.

Biography: Don received his Ph.D., M.Sc., and B.S. in geological science from Princeton University (1988), Queen's University in (1983), and The University of Michigan (1981), respectively. As part of his studies, Don analyzed compressional structures in the Southern Appalachians, Canadian Rockies, and the California Coast Ranges.

After university, Don held technology positions for 30 years at ARCO and Chevron. There he both developed structural analysis and kinematic restoration tools and applied them to interpret structural geometry and kinematics on 5 continents and Australia. Don has authored or coauthored 14 journal articles and 30 conference presentations.

Don is a member of GSA, AAPG, AGU, and NCGS and is now an independent research geologist living above vertically-dipping Pliocene sediments on the southwest limb of Mt. Diablo. He seeks to contribute to the Northern California seismic hazard community by refining geologic models of East Bay.

Northern California Geological Society
c/o Mark Sorensen
734 14th Street, #2
San Francisco, CA 94114

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