Corrected Dec. 30, 2024

UNITED STATES OF AMERICA
BEFORE THE NUCLEAR REGULATORY COMMISSION

In the matter of Pacific Gas and Electric Company Diablo Canyon Nuclear Power Plant Units 1 and 2	Docket Nos. 50-275, 50-323 Draft Supplemental Environmental Impact Statement December 16, 2024

COMMENTS BY SAN LUIS OBISPO MOTHERS FOR PEACE REGARDING DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR RENEWAL OF OPERATING LICENSES FOR DIABLO CANYON NUCLEAR POWER PLANT, UNITS 1 AND 2

INTRODUCTION

Pursuant to 89 Fed. Reg. 87,433 (Nov. 1, 2024), San Luis Obispo Mothers for Peace ("SLOMFP") hereby submits comments on the U.S. Nuclear Regulatory Commission's ("NRC's") Draft Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 62, for Diablo Canyon Nuclear Power Plant, Units 1 and 2 (NUREG-1437, Supp. 62, Oct. 2024) ("Draft SEIS"). In the Draft SEIS, the NRC Staff purports to provide a thorough and rigorous analysis of the environmental impacts and reasonable alternatives to adding twenty more years to each of Pacific Gas and Electric Company's ("PG&E's") operating licenses for the Diablo Canyon nuclear power plant ("Diablo Canyon").

Unfortunately, however, the Draft SEIS fails to fulfill either of the fundamental purposes of an environmental impact statement as set forth by the National Environmental Policy Act ("NEPA"): first, to ensure that the NRC, as the federal agency responsible for relicensing Diablo Canyon "will have available, and will carefully consider, detailed information concerning significant environmental impacts;" and second, to ensure that "the relevant information will be made available to the larger audience that may also play a role in the decision-making process and implementation of that decision."[1] Key deficiencies are:

- With respect to earthquake risk, the Draft SEIS parrots the analysis submitted by PG&E in its license renewal application and updated seismic analysis conducted in response to S.B. 846 without also evaluating data and analyses submitted by SLOMFP and other organizations in their hearing request on PG&E's license renewal application that demonstrates the risk of an earthquake-induced core damage accident is forty times higher than estimated by PG&E. The Draft SEIS also ignores the fact that the NRC's own Petition Review Board ("PRB"), to which SLOMFP's concerns were referred, considers SLOMFP's claims to be credible and is investigating them. *See* Section 1 below.

- The Draft SEIS' statement of purpose and need is to "provide an option that allows for baseload power generation capability beyond the term of the current nuclear power plant

[1] *Robertson v. Methow Valley Citizens Council,* 490 U.S. 332, 349 (1989).

operating licenses to meet future system generating needs for a period of twenty years."[2] But this the Draft SEIS fails to acknowledge that the California Legislature, through passage of S.B. 846 in 2022[3], has framed a much narrower purpose and timeframe for PG&E's license renewal application: to provide a stopgap to cover a perceived reliability crisis until 2030. *See* Section 2 below.

- Finally, the Draft SEIS fails to address the potentially catastrophic effects on marine life of operating the once-through cooling system at Diablo Canyon for another 20 years. The NRC Staff seems to confuse the State's intention for Diablo Canyon to close after five years (and thereafter to cease harming marine life) with PG&E's intention, as established by the 20-year operating term requested in its license renewal application, to operate Diablo Canyon for four times that length of time.

ABOUT SAN LUIS OBISPO MOTHERS FOR PEACE

Located in San Luis Obispo, California, SLOMFP is a non-profit membership organization concerned with the dangers posed by Diablo Canyon and other nuclear reactors, nuclear weapons, and radioactive waste. SLOMFP also works to promote peace, environmental and social justice, and renewable energy. Founded more than fifty years ago, SLOMFP initially opposed the construction and operation of DCPP due to its location near significant and active earthquake faults. Since then, SLOMFP has monitored and participated in licensing and enforcement proceedings regarding the safety and environmental impacts of operating DCPP. SLOMFP has also brought numerous lawsuits against the NRC for its inadequate regulation of DCPP safety and environmental protection.

For the past two years since passage of California S.B. 846, SLOMFP has consistently and actively opposed the continued operation of Diablo Canyon because it is dangerous, unnecessary, and too costly to California ratepayers and taxpayers. SLOMFP has raised its significant concerns about safety and environmental risks in multiple NRC proceedings, including petitioning for a hearing on PG&E's license renewal application that challenged the adequacy of the application with respect to evaluation of earthquake risk and the testing program for the Unit 1 pressure vessel.[4] SLOMFP and other organizations also petitioned the NRC Commissioners to shut down Diablo Canyon for the same seismic and pressure vessel integrity risks raised in the Hearing Request.[5] The NRC's Petition Review Board is currently investigating SLOMFP's

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[2] Draft SEIS at xxi.

[3] S.B. 846, 2021-2022 Leg. Sess. (Cal. 2022) (enacted Sept. 22, 2022).

[4] Request by San Luis Obispo Mothers for Peace, Friends of the Earth and Environmental Working Group for Hearing on Pacific Gas & Electric Company's License Renewal Application for the Diablo Canyon Nuclear Plant (Mar. 4, 2024) ("Hearing Request").

[5] Petition by San Luis Obispo Mothers for Peace, Friends of the Earth and Environmental Working Group for Shutdown of Diablo Canyon Nuclear Power Plant Due to Unacceptable Risk of Seismic Core Damage Accident (March 4, 2024) ("Seismic Emergency Petition"); Request to the NRC Commissioners by San Luis Obispo Mothers for Peace and Friends of the Earth for a Hearing on NRC Staff Decision Effectively Amending Diablo Canyon Unit 1 Operating License

claims regarding unacceptable seismic risk at DCPP. [6] SLOMFP has also raised its concerns regarding the imprudence, lack of need, and exorbitant and unjustified costs of continuing to operate DCPP before the California Public Utilities Commission ("CPUC").[7]

DISCUSSION

1. Serious Underestimation of Earthquake Risks

As set forth in *Robertson,* the Draft SEIS must review "detailed information concerning significant environmental impacts."[8] It is beyond dispute that the greatest and most-feared environmental impact from any nuclear power plant is the possibility of core meltdown resulting in fires, hydrogen explosions, containment failure, and release of large amounts of radioactive isotopes that will injure humans immediately and contaminate soil for thousands of years. Given Diablo Canyon's location amid a web of earthquake faults on and off the California coast, earthquake risk is an especially serious concern for the government and the residents of California. And that concern is exacerbated by the embrittled condition of the Unit 1 pressure vessel, "perhaps the most important single component in the reactor coolant system."[9] Despite discovering a significant degree of embrittlement in 2003, and despite amending the Unit 1

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to Extend the Schedule for Surveillance of the Unit 1 Pressure Vessel and Request for Emergency Order Requiring Immediate Shutdown of Unit 1 Pending Completion of Tests and Inspections of Pressure Vessel, Public Disclosure of Results, Public Hearing, and Determination by the Commission That Unit 1 Can Safety Resume Operation (Sept. 14, 2023, Corrected Sept 14, 2023) ("Pressure Vessel Emergency Petition").

Dr. Bird has also presented his views to the CPUC's Diablo Canyon Independent Safety Committee and their allied Independent Peer Review Panel. Evaluation of Dr. Bird's claims is now ongoing, both at NRC and at CPUC.

[6] *See* letter from Michael X. Franovich to Diane Curran, et al re: 10 CFR 2.206 Petition Regarding Seismic Core Damage Frequency for Diablo Canyon Nuclear Power Plant, Units 1 and 2, Supplemental Acknowledgement Letter (Dec. 5, 2024) (NRC ADAMS Accession No. ML24317A038) ("Franovich Letter").

[7] SLOMFP has submitting legal briefs and expert testimony on prudency, costs and reliability in both of the CPUC proceedings mandated by S.B. 846: R.23-01-007, Implementing Senate Bill 846 Concerning Potential Extension of Diablo Canyon Power Plant Operations (Filed Jan. 14, 2023) and Application 24-03-018, Application of Pacific Gas and Electric Company to Recover in Customer Rates the Costs to Support Extended Operations of Diablo Canyon Power Plant from September 1, 2023 through December 31, 2025 and for Approval of Planned Expenditure of 2025 Volumetric Performance Fees (U 39 E) (Filed March 29, 2024).

[8] *Robertson,* 490 U.S. at 349.

[9] Final Rule, Fracture Toughness Requirements for Light Water Reactor Pressure Vessels, 60 Fed. Reg. 65,456, 65,457 (Dec. 19, 1995) ("RPV Rule"). As the receptacle that maintains cooling water on the highly radioactive core without any redundant backup, the pressure vessel must be protected against the risk of fracture and failure, which could lead to core melt and catastrophic consequences.

operating license to require an inspection by 2009, the NRC has not required PG&E to inspect the Unit 1 pressure vessel for over twenty years.[10]

Contrary to NEPA's requirement for a vigorous analysis of earthquake risks, however, the Draft SEIS parrots PG&E's seismic risk analysis without addressing or even acknowledging the significant contrary evidence that has been submitted to the NRC by SLOMFP and other organizations.

According to the Draft SEIS, the only recent information available to the NRC was PG&E's seismic update in response to S.B. 846.[11] But the NRC Staff ignores a substantial body of evidence and analyses by Dr. Peter Bird, an eminent and highly qualified seismic expert who is Professor Emeritus of Geophysics and Geology at the University of California at Los Angeles, demonstrating that the risk of an earthquake-caused core damage accident at Diablo Canyon is approximately forty times higher than estimated by PG&E.[12]

Tables 3-31 and F-5 of the Draft SEIS cite the Seismic Core Damage Frequency (SCDF) as 2.96×10^{-5} per year of operation at DCPP. The source of this SCDF estimate is PG&E's 2024

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[10] See Pressure Vessel Emergency Petition and supporting Declaration of Dr. Digby Macdonald, Ph.D.

[11] *See* Draft SEIS at 3-27, which states:

> California State Senate Bill 846 was passed in September 2022 to extend the operation of Diablo Canyon and included a covenant for PG&E to perform an updated seismic analysis. PG&E published the results of that analysis on March 6, 2024 (PG&E 2024-TN10192). The results were not discussed in the ER because they had not been publicly released when the ER was submitted to the NRC. The NRC staff independently reviewed pertinent portions of the updated analysis report to determine whether new and significant information was provided therein that might change the ER's description of the affected geologic environment at and adjacent to the Diablo Canyon site. New information was developed on slip rates for the Hosgri fault and certain other faults. At the primary level of interest (i.e., 10-4 to 10-6 annual hazard level), the Hosgri fault was determined to be the largest contributor to seismic hazard followed by the San Luis Bay, Los Osos, and Shoreline fault sources. PG&E noted that the Hosgri fault contributes about 50–70 percent to total hazard at the 10-4 annual hazard level (PG&E 2024-TN10192). The new slip rate data notwithstanding, the NRC staff concludes that none of these tectonic structures will have impacts on the geologic environment at or adjacent to the Diablo Canyon site that are different from impacts occurring during the current license term since no new faults were reported based on the updated analysis.

[12] Declaration of Peter Bird, Ph.D (March 4, 2024), submitted in support of Hearing Request and Seismic Enforcement Petition. *See also* Supplemental Declaration of Peter Bird, Ph.D (June 7, 2024) (No NRC Accession No. available), submitted in support of Seismic Enforcement Petition); Power Point Presentation by Dr. Bird to Petition Review Board: Correcting 4 False Assumptions That Caused PG&E [2015, 2024] to Seriously Underestimate Seismic Hazard at Diablo Canyon Power Plant (July 17, 2024) (No NRC Accession No. available).

Update to the Seismic Source Characterization (also using conclusions of their 2018 Seismic Probabilistic Risk Assessment to describe the fragility of the plant). This is a very low rate, equivalent to one meltdown per 33,800 years of operation.

In contrast to the NRC's unquestioning acceptance of PG&E's work, Dr. Bird has strongly criticized the methodology of the 2015 and 2024 SSCs, and presented a much simpler and more transparent model in which thrust-faulting under the Irish Hills is the dominant source of seismic hazard at DCPP. His analysis is found in the presentations cited above in note 3, and summarized (with figures and citations) in the attached report entitled High Seismic Hazard and Risk at Diablo Canyon Power Plant Due to Thrust Faulting Under the Irish Hills (rev. Nov. 25, 2024) ("Seismic Hazard Report"). As set forth in his Seismic Hazard Report, Dr. Bird concludes that the total rate of slip on all gently-dipping thrust faults under the Irish Hills is 2.0~2.8 mm/year, that the correct SCDF is at least $1.0\sim1.4\times10^{-3}$ /year of operation, and that the mean time between seismic core damage accidents at DCPP is only 700~1000 years of operation. That is, the added risk of a core meltdown from a 20-year license extension would be 2~3%.

By ignoring Dr. Bird's evidence and analysis, the Staff has grossly underestimated the risk of an earthquake-caused serious accident at Diablo Canyon. By the same token, it wrongly minimizes the value of alternative energy sources that would completely avoid the risk of an earthquake-caused accident. If the NRC considered the true gravity of the earthquake risk to Diablo Canyon, continued operation of the reactors would never survive a weighing of relative costs and benefits.

NEPA requires the NRC to consider all information that is relevant to its decision.[13] Thus, the Staff's disregard of Dr. Bird's work is inexplicable – all the more in light of the fact that the agency's own Petition Review Board considers Dr. Bird's analysis credible and is now reviewing his assertions in depth.[14] And the Staff's unquestioning repetition of PG&E's outdated and inadequate arguments is utterly at odds with the requirements of NEPA and NRC implementing regulations, requiring that in preparing an EIS, the NRC Staff must "*independently* evaluate and be responsible for the reliability of all information used in the draft environmental impact statement.") (emphasis added).[15]

Therefore. in preparing the final version of the SEIS, the NRC Staff must consider all of the evidence and analyses presented to the NRC by Dr. Bird to date, including the documents cited in note 3 above, his declaration in support of these comments, and his Seismic Hazard Report, the Staff must also revisit its weighing of alternatives, taking into consideration the high risk of a devastating and costly earthquake. *See* Attachment A to these comments.

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[13] *See* note 3, *supra.*

[14] *See* Franovich Letter.

[15] 10 C.F.R. § 51.70(b).

2. Inaccurate statement of purpose and need, leading to inadequate and biased consideration of alternatives

A clearly defined purpose and need is a necessary element of an EIS, because the project's goals dictate the range of alternatives. *City of Carmel-By-the Sea v. Dep't of Transp.*, 123 F.3d 1142, 1155 (9th Cir. 1997). *See also Citizens Against Burlingame, Inc. v. Busey*, 938 F.2d 190, 196 (D.C. Cir. 1991) (developing a clear statement of the purpose and need for the action allows the agency to not rule out additional alternatives that may be more environmentally sound).

The Draft SEIS' statement of purpose and need asserts:

> The purpose and need for the proposed action (renewal of operating licenses) is to provide an option that allows for baseload power generation capability beyond the term of the current nuclear power plant operating licenses to meet future system generating needs, as such needs may be determined by State, utility, system, and, where authorized, Federal (other than NRC) decision-makers.[16]

But this extremely broad framing of the purpose and need for continuing to operate Diablo Canyon is inconsistent with the limited purpose of continued operation as established by the California Legislature in S.B. 846: to meet an "urgent" need to fill a perceived five-year insufficiency in grid reliability, thereby providing a "stopgap" that would allow the State to transition to a 100% renewable energy economy by 2030.[17] The CPUC had already determined in 2018 that continued operation of Diablo Canyon was uneconomical in approving PG&E's 2016 application to drop its 2009 application to the NRC for renewal of its operating license and to take Diablo Canyon out of the rate base.[18] And in passing S.B. 846, the Legislature did not think differently. To the contrary, S.B. 846 instructed PG&E to apply for a subsidy from the U.S.

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[16] Draft SEIS at xxi.

[17] As stated in S.B. 846, Section 5:

> Preserving the option of continued operations of the Diablo Canyon powerplant for an *additional five years* beyond 2025 may be necessary to *improve statewide energy system reliability* and to reduce the emissions of greenhouse gases *while additional renewable energy and zero-carbon resources come online, until those new renewable energy and zero-carbon resources are adequate to meet demand.* Accordingly, it is the policy of the Legislature that seeking to extend the Diablo Canyon powerplant's operations for a renewed license is prudent, cost effective, and in the best interests of all California electricity customers. *The Legislature anticipates that this stopgap measure will not be needed for more than five years beyond the current expiration dates*.

Cal. Pub. Res. Code § 25548(b) (emphasis added).

[18] California PUC Decision No. 18-01-022 (January 11, 2018), https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M205/K423/205423920.PDF. Forecasts from PG&E at that time indicated that increases in energy efficiency, distributed generation, and renewable generation, as well as customers moving to community choice aggregation and direct access, would render continued operation of Diablo Canyon unnecessary. *Id.*

Department of Energy ("DOE").[19] Accordingly, PG&E submitted a bid for DOE's Civil Nuclear Credit Program to issue PG&E up to approximately $1.1 billion in credits to reimburse the losses it would incur in operating Diablo Canyon during a four-year award period, from 2023 through 2026. And even taking this subsidy into account, the Legislature was prepared to cancel the project if the costs of continued operation proved too high. For instance, S.B. 846 anticipated that the NRC will conduct a comprehensive seismic review that could result in "seismic upgrades" that are too costly to justify continued operation.[20] Further, the Legislature intended the five-year extension of Diablo Canyon's operation to be consistent with its established goal of having 100 percent of retail sales of electricity be generated from renewable and zero-carbon resources by the end of 2045.[21]

The Draft SEIS completely ignores these clearly-stated goals and limitations in S.B. 846. Not only is the statement of purpose and need inconsistent with S.B. 846, but the Draft SEIS provides no meaningful analysis of alternatives that would satisfy these goals. With respect to the no-action alternative, the Draft SEIS merely states that it "does not meet the purpose and need of the proposed action" because it "does not provide a means of delivering baseload power to meet future electric system needs."[22] This assessment is worthless to the State for purposes of evaluating whether Diablo Canyon is needed to meet short-term reliability demands, as sought by the California Legislature.

Even a cursory review of California's power supply picture makes clear that the state faces no shortage of baseload generation during the period of Diablo Canyon's extended operation. Indeed, the latest reports of the California Energy Commission make clear that solar energy and battery storage additions have come online faster than projected and have already provided a clear and less expensive reliability backstop than could a baseload unit such as Diablo Canyon.

In considering energy alternatives, the NRC Staff makes no effort to identify or analyze alternatives that are consistent with the State's goals and limitations. Instead, the Draft SEIS asserts that:

> It is unlikely that Diablo Canyon's generating capacity could be replaced by a single type of wind, either onshore or offshore. A combination of energy sources . . . such as wind, solar, and battery backup, along with purchased power and demand-side management, could complement each other and reduce intermittent electricity generation issues.[23]

Again, this analysis is so broad as to be worthless for purposes of evaluating alternatives that would meet the State's goals and satisfy its limitations as set forth in S.B. 846.

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[19] S.B. 846, Sec. 3(c) (codified at Cal. Pub. Res. Code § 25233.2(c)).

[20] Cal. Pub. Resources Code § 25548.3(c)(9).

[21] S.B. 846, Sec. 7 (codified at Cal. Pub. Util. Code § 454.53(a)).

[22] Draft SEIS at 2-12.

[23] Draft SEIS at 2-16.

In preparing the final version of the SEIS, the NRC Staff should revise its statement of purpose and need to be consistent with S.B. 846. Instead of treating the no action alternative as a throwaway, the NRC should conduct a thorough evaluation of whether current capacity is adequate to make up for the loss of Diablo Canyon in assuring reliability between 2024 and 2030. There is no shortage of evidence on this issue, given that it has been a key subject of the CPUC proceedings referenced above in note 6. As testified by Rao Konidena, energy market expert and former Principal Advisor with the Midcontinent Independent System Operator (MISO), California has enough power (including storage) to keep the lights on – without the 2,200 MW of Diablo Canyon.[24]

Again and again since the passage of NEPA in 1970, the NRC has issued Environmental Impact Statements attesting to the need, often the urgent need, for particular nuclear power plants during particular time frames. More than half of all of the plants licensed by the NRC were canceled. A number of licensed NRC life-extensions have been closed down during the life for which the NRC found a need. Rancho Seco and San Onofre 2 and 3 are California's examples. No power shortages have resulted from any of these cancelations and closures. Once the nuclear plants' fates were determined and announced, cheaper alternatives – alternatives fully compatible with California's zero carbon goals – have been developed in their place.

This abysmal multidecade record of inadequate assessment of the alternatives to its proposed decision, especially the no-action alternative, is never acknowledged in NRC Environmental Impact statements. Nor has the NRC fundamentally changed its approach. It continues to maintain that its licensing decision merely preserves the nuclear option for other decisionmakers to adopt if they so choose and to require alternatives to be "baseload" like a nuclear plant.

But of course, licensing the continued operation of Diablo Canyon does much more than "preserve the option." The license itself is a multimillion-dollar asset. Once issued, it tends to alter the decisions of the California ISO and the many power suppliers who might develop projects to meet the supply needs of the California market without Diablo Canyon. Furthermore, the issuance of the license extension for Diablo Canyon is one of the actions triggering the release of $1.1 billion in federal subsidies, a $300 million forgivable loan from the state of California and substantially revised ratemaking from the CPUC increasing rates throughout the state. The socio-economic impacts of these rate increases are not so much as mentioned in the SEIS.

The SEIS's restricting its meaningful comparison of Diablo Canyon to baseload alternatives makes the document useless to modern power supply planners like those implementing California's energy transition. As SB 846 repeatedly makes clear, California's interest is in assuring system reliability under the stresses of climate change and wildfire danger. The insight that they are entitled to expect pursuant to NEPA is how Diablo Canyon compares to other

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[24] Testimony by Rao Konidena to the CPUC (June 2023), https://mothersforpeace.org/wp-content/uploads/2023/07/Rao-Konidena-Testimony_Final.1.pdf ; Testimony by Rao Konidena to the CPUC (July 2024), https://docs.cpuc.ca.gov/PublishedDocs/SupDoc/A2403018/7629/537498256.pdf.

alternatives in the world of California's energy realities rather than according to a NEPA template to support nuclear plant life-extensions drawn up in NRC offices. The California realities are 1) the threat of power shortages under extreme conditions that will only occur a few hours per year and 2) the faster-than-forecast development of combinations of flexible alternatives that can meet these short-term stresses far more effectively and inexpensively than a must-run and expensive baseload facility.

California energy realities are shifting rapidly. The NRC should avail itself of the latest available information. This information shows no shortage either of "baseload" capacity or of the dispatchable resources needed to meet peak loads, even unexpectedly high peak loads. As to these, the most recent analyses show no economically rational use for Diablo Canyon, a condition that the SEIS should state or at least discuss if it wants to give meaningful advice to state or other decisionmakers.

Here is an assessment of the current realities against which the no-action alternative should be evaluated. It is based on two August 2024 reports, The CPUC and CEC Joint Agency Reliability Planning Assessment (referred to here as the Joint Agency Report) and the CEC's Draft California Energy Resource and Reliability Outlook (referred to here as the CEC Draft Report).[25]

a. The Joint Agency Report shows that in 2024, California has more than 8,522 MW Net Qualifying Capacity, *i.e.,* the capacity that counts towards resource adequacy. By the end of 2027, the CPUC and CEC estimate that California will have 15,630 MW Net Qualifying Capacity.

b. Based on the Joint Agency combined second and third quarterly report for 2024, California had significant surplus capacity for September 2024: "For September, improvements in supply build and system conditions led to an increase in the surplus of resources expected under average conditions, up to 4,700 megawatts (MW).[26] This is a change from the Joint Agency's December 2023 fourth

[25] *See* Yee Yang, Chie Hong (CEC) and Sarah Goldmuntz (CPUC). August 2024. Joint Agency Reliability Planning Assessment. California Energy Commission. Publication Number: CEC-200-2024-015. As stated in the Abstract, "this report provides the 2024 combined second and third quarterly review of the supply forecast and risks to reliability in the California Independent System Operator (CAISO) territory for 2024 and includes an updated analysis for summer 2024."

See also Yee Yang, Chie Hong, Kristen Widdifield, Liz Gill, Hannah Craig, Angela Tanghetti, Grace Anderson, C.D. McLean, Aloke Gupta, Justin Cochran, Joseph Merrill, Lana Wong, Heidi Javanbakht, and Michael Nyberg. August 2024. California Energy Resource and Reliability Outlook, 2024. California Energy Commission. Publication Number: CEC-200-2024-016. As stated in the Abstract, "This report provides the 2024 combined second and third quarterly review of the supply forecast and risks to reliability in the California Independent System Operator territory for 2024 and includes an updated analysis for summer 2024."

[26] Joint Agency Report, Executive Summary.

quarterly Report[27], which projected "a need for 970 MW of contingency resources under a 2020 equivalent event, and a need for 2,600 MW of contingency resources under 2022 equivalent event." The Joint Agency Report projects at least 15,000 MW of spare capacity by the end of 2027.

c. The Joint Agencies also found that in the event of extreme weather conditions such as occurred in 2020 and 2022, the State would have surplus capacity rather than the shortfalls they had forecast less than a year earlier. According to the Report: "Under a 2020 equivalent event, the September (2024) surplus is 2,200 MW. In a 2022 equivalent event, the September projected shortfall turns into a surplus of 655 MW."[28] In contrast, the December 2023 Joint Agency Report predicted a shortfall of 970 MW for a 2020 equivalent extreme event and a shortfall of 2,606 MW for a 2022 equivalent extreme event[29].

d. The Draft CEC Report indicates that California's Preferred System Plan[30] meets the CPUC's 1 day in 10 years' reliability standard (i.e., one loss of load event - when the grid operator is forced to implement rotating power outages - every 10 years) without DCPP even when imports are restricted during peak demand and all hours of the day.

e. Changes in the cost of extending Diablo Canyon's life as well the cost of alternative ways pf assuring California's reliability also undermine arguments in favor of continued operation. The customer funds wasted in extending Diablo Canyon run to billions of dollars, even without taking the taxpayer supplied subsidies into account. This calculation assumes a mix of seven technologies (efficiency, wind-only, solar, solar plus storage, wind plus storage, geothermal and

[27] Yee Yang, Chie Hong (CEC) and Sarah Goldmuntz (CPUC). December 2023. Joint Agency Reliability Planning Assessment. California Energy Commission. Publication Number: CEC-200-2023-015. As cited in the Abstract, "This report provides the December 2023 fourth quarterly review of the demand forecast, supply forecast, and risks to reliability in the California Independent System Operator territory from 2023 to 2032, as required by SB 846. The report includes an updated analysis and summary for summer 2023."

[28] Joint Agency Report, Executive Summary.

[29] Table 5, Yee Yang, Chie Hong (CEC) and Sarah Goldmuntz (CPUC). December 2023. Joint Agency Reliability Planning Assessment. California Energy Commission. Publication Number: CEC-200-2023-015. As cited in the Abstract, "This report provides the December 2023 fourth quarterly review of the demand forecast, supply forecast, and risks to reliability in the California Independent System Operator territory from 2023 to 2032, as required by SB 846. The report includes an updated analysis and summary for summer 2023."

[30] See Administrative Law Judge's Decision 24-02-047 in CPUC Rulemaking 20-05-003 (Feb. 20, 2024), adopting a "Preferred System Plan (PSP) portfolio that meets a statewide 25 million metric ton (MMT) greenhouse gas (GHG) target for the electric sector in 2035". https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M525/K918/525918033.PDF

Combined Cycle Gas w/ Carbon Capture and Storage). The acquisition of these resources would build up to the full replacement of Diablo Canyon. If the acquisition of alternative resources is “right sized,” to meet actual loads instead of supplying Diablo’s 2200MW unnecessarily around the clock, the cost would be 95% less costly than continuing to operate Diablo Canyon. Thus, the assumption that extending Diablo Canyon is reasonable, prudent and cost-effective is wrong and could be very wrong.

3. **Failure to address environmental impacts of once-through cooling system**

The Draft SEIS fails to address the potentially catastrophic effects on marine life of operating the once-through cooling system at Diablo Canyon for another 20 years. The NRC Staff seems to confuse the State’s intention for Diablo Canyon to close after five years (and thereafter to cease harming marine life) with PG&E’s intention, as established by its license renewal application for twenty more years of operation, to operate Diablo Canyon for four times that length of time. The Final SEIS must address the environmental impacts of operating the once through cooling system for the entire twenty years of the license renewal term, including the cumulative impacts of sixty years of entrainment, impingement, and thermal pollution.

Respectfully submitted,

__/signed electronically by/___

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December 16, 2024

UNITED STATES OF AMERICA
BEFORE THE NUCLEAR REGULATORY COMMISSION

In the matter of	Docket Nos. 50-275, 50-323
Pacific Gas and Electric Company	Draft Supplemental Environmental
Diablo Canyon Nuclear Power Plant	Impact Statement
Units 1 and 2	December 16, 2024

DECLARATION OF PETER BIRD, Ph.D

Under penalty of perjury, I, Peter Bird, declare as follows:

1. My name is Peter Bird. I am Professor of Geophysics and Geology, Emeritus at the University of California at Los Angeles (UCLA). On March 4, 2024, I submitted to the U.S. Nuclear Regulatory Commission (NRC) a declaration in support of a petition by San Luis Obispo Mothers for Peace, Friends of the Earth and Environmental Working Group (Petitioners) for shutdown of the Diablo Canyon nuclear power plant (Diablo Canyon) due to the unacceptable risk of a seismic core damage accident. Since then, I have submitted multiple additional documents in the same proceeding.

2. I reaffirm that the facts stated in my March 4, 2024 Declaration and other documents in that proceeding are true and correct to the best of my knowledge and that the opinions expressed therein are based on my best professional judgment. I also affirm that my statement of qualifications in my March 4, Declaration remains the same.

3. I have reviewed the NRC's Draft Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 62, for Diablo Canyon Nuclear Power Plant, Units 1 and 2 (NUREG-1437, Supp. 62, Oct. 2024) ("Draft SEIS"). My views regarding the inadequacy of the Draft SEIS to address the seismic safety risks posed by continued operation of Diablo Canyon are correctly summarized in Section 1 of the Comments by San Luis Obispo Mothers for Peace Regarding Draft Environmental Impact Statement for Renewal of Operating Licenses for Diablo Canyon Nuclear Power Plant, Units 1 and 2 (Dec. 16, 2024).

4. I have summarized my analysis of seismic risk to Diablo Canyon in the attached report, High Seismic Hazard and Risk at Diablo Canyon Power Plant Due to Thrust Faulting Under the Irish Hills (rev. Nov. 25, 2024). I initially submitted this report to the Diablo Canyon Independent Safety Committee on October 31, 2024. It is re-submitted here with a clerical revision to a map.

5. Tables 3-31 and F-5 of the Draft SEIS cite the Seismic Core Damage Frequency (SCDF) as 2.96×10^{-5} per year of operation at DCPP. The source of this SCDF estimate is PG&E's 2024 Update to the Seismic Source Characterization (also using conclusions of their 2018 Seismic Probabilistic Risk Assessment to describe the

fragility of the plant). This is a very low rate, equivalent to one meltdown per 33,800 years of operation.

6. As set forth in my Seismic Hazard Report, I conclude that the total rate of slip on all gently-dipping thrust faults under the Irish Hills is 2.0~2.8 mm/year, that the minimum seismic core damage frequency (SCDF), due to thrust-faulting alone is at least $1.0 \sim 1.4 \times 10^{-3}$ /year of operation. This is about 40 × higher than the stated hazard. It implies that the mean time between seismic core damage accidents at Diablo Canyon is only 700~1000 years of operation. That is, the added risk of a core meltdown from a 20-year license extension would be 2~3%.

I declare that the foregoing facts are true and correct to the best of my knowledge and that the opinions expressed herein are based on my best professional judgment.

Executed in Accordance with 10 C.F.R. § 2.304(d) by Date: December 16, 2024
Peter Bird, Ph.D

High Seismic Hazard and Risk at Diablo Canyon Power Plant Due to Thrust Faulting Under the Irish Hills

(a report prepared at the request of the
Diablo Canyon Independent Safety Committee
of the California Public Utilities Commission,
summarizing arguments, data, and citations
previously submitted to the
U.S. Nuclear Regulatory Commission
in 3 Declarations and 1 oral presentation,
2023-2024)

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ABSTRACT

The crustal basement under Diablo Canyon Power Plant (DCPP) is composed of exotic Franciscan Complex and arc-derived Cretaceous turbidite sandstones, assembled into the accretionary prism of the Farallon\North America subduction zone by systemic and continuous thrust faulting in Cretaceous through Paleogene times.

The Irish Hills are a new isostatically-supported fold/thrust belt created by horizontal crustal shortening since 6~5 Ma. Evidence that the same stress field continues today includes small thrust earthquakes under the Irish Hills, larger thrust earthquakes in the region, stress direction data, and GPS geodesy.

However, the Seismic Source Characterizations (SSCs) by Pacific Gas & Electric Company [*PG&E*, 2015; 2024] concluded that hazard at DCPP from 2 modeled thrust faults and the Local Area Source is less than hazard from the offshore dextral Hosgri fault. Potential hazard from blind thrust faults is essentially dismissed. This biased conclusion is due to their reliance on 4 false assumptions, which I challenge and then correct. Then, I propose 3 independent methods of estimating the total slip-rate of all shallow-dipping thrust faults under the Irish Hills; these methods agree on a range of 2.0~2.8 mm/a.

The simplest and most expedient way to estimate the seismic hazard from such fast and widespread thrust faulting is to choose a model characteristic thrust earthquake and then to compute its recurrence rate. Based on tectonic and geometric similarities, I choose the 1 January 2024 thrust earthquake under the Noto Peninsula in Japan. This event produced Peak Ground Acceleration (PGA) of 100% to 230% of gravity at 5 digital strong-motion seismometers up to 42 km from the rupture.

According to the Seismic Probabilistic Risk Assessment (SPRA) by *PG&E* [2018], such PGA values (and the associated higher spectral accelerations) would likely cause a Seismic Core Damage (SCD) accident (*i.e.*, meltdown) at DCPP. Therefore, SCD Frequency (SCDF) at DCPP is roughly the same as the recurrence rate of the model characteristic earthquake, which is from 1.0×10^{-3} to 1.4×10^{-3} per year of plant operation.

Appendix **A** details other procedural errors in the SSCs of *PG&E* [2015; 2024], specifically the omission of modern deformation modeling, and failure to use globally-calibrated strainrate-to-seismicity conversions, that would have prevented their serious underestimates.

Appendix **B** responds to an unfounded assertion in PG&E's recent letter to NRC regarding the use of the Noto Peninsula earthquake as a model characteristic thrust earthquake for the Irish Hills.

I. INTRODUCTION

During Cretaceous through Paleogene times, the coast of California was the site of a subduction zone which consumed thousands of kilometers of oceanic Farallon plate lithosphere and created the North American volcanic arc, of which the Sierra Nevada plutons are the remaining roots [*e.g.*, *Atwater & Stock*, 1998]. Just east of the former Farallon Trench, there was a wide accretionary prism in constant overturning motion [*Cloos*, 1982] which was fed from both sides. Exotic oceanic rocks (limestones, bedded cherts, basalts, serpentines) were scraped off the subducting Farallon plate and added to North America. At the same time, voluminous graywacke turbidite sands, derived from the North American volcanic arc, were deposited in the trench, and then quickly scraped off the subducting Farallon plate and re-incorporated into North American crust [*e.g.*, *Wakabayashi*, 1999]. This process of systemic and continuous thrust-faulting formed the crustal "basement" on which DCPP now sits.

The present Irish Hills and the San Luis Range are a younger dextral-transpressional orogen that has formed since ~3.5 million years (or mega annus, Ma) [*Page et al.*, 1998], or more likely since 6 Ma [*Austermann et al.*, 2011; *Bird & Ingersoll*, 2022] when the motion of the Pacific plate changed its direction to become more compressional relative to North America. This means that the region can be expected to be cut by a number of both strike-slip and thrust (horizontally compressional) faults.

The persistence of a horizontally compressive thrust-faulting stress regime up to the present is shown by:

(1) The 2003 San Simeon ***m***6.6 and 1983 Coalinga ***m***6.2 earthquake both had thrust mechanisms [Global Centroid Moment Tensor Catalog, *Ekström et al.*, 2012]. This is evidence of highly-compressive horizontal stresses in the Coast Ranges region, suggesting a likelihood of seismic thrust-faulting in other locations as well.

(2) Closer to DCPP, two recent small earthquakes had thrust-faulting mechanisms with the expected SSW-NNE direction of maximum horizontal compression: 2023.12.27 ***m***3.1 at 6.2 km depth under the Irish Hills, and 2024.01.01 ***m***5.4 slightly offshore from the NW end of the Irish Hills (D. J. Weisman, pers. comm., 2024.01.02). This shows that the regional stress regime and orientation documented above also apply in the immediate vicinity of DCPP.

(3) SSW-NNE directions of most-compressive stress shown by data in the World Stress Map [*Mueller et al.*, 1997; *Heidbach et al.*, 2008, 2016], and by interpolation of stress directions using the method of *Bird & Li* [1996], are almost perpendicular to the traces of the regional thrust fault trend (Inferred Coastline, San Luis Bay, and Los Osos fault traces). This strongly suggests that currently these faults are either purely or dominantly thrusts, and that strike-slip is occurring only on the offshore Hosgri and perhaps Shoreline faults.

Given this geologic history and structure, one might expect to read that thrust faulting under the Irish Hills is the major source of seismic hazard to DCPP. However, in *PG&E*'s [2015] SSC, the Los Osos and San Luis Bay thrust faults have seismic hazard contributions (specifically, recurrence rates of PGA over 1 g and spectral accelerations over 2 g which would cause core damage) adding up to less than the hazard from the offshore strike-slip Hosgri fault, and consequently less than half of the total hazard. This imbalance remains uncorrected in the SSC of *PG&E* [2024].

II. CORRECTING 4 FALSE ASSUMPTIONS in the SSCs of *PG&E* [2015; 2024]

One of the reasons that *PG&E*'s [2015; 2024] SSCs seriously underestimated seismic hazard due to thrust faulting is that they were guided by 4 assumptions that are actually false.

<u>#1. The Irish Hills are uplifting as a rigid block, with no internal deformation.</u>

Therefore, PG&E concluded that thrust faulting occurs only at the margins (Los Osos thrust, San Luis Bay thrust) with fault throw (vertical offset) rates equal to marine terrace uplift rates of ~0.2 mm/year, and that thrust faulting occurs nowhere else.

HOWEVER:

The geologic map (**Figure 1**) shows tight folding of Late Miocene sedimentary rocks has occurred since 6~5 Ma. Therefore, the Irish Hills are not rigid, and additional blind thrust faults are active in the interior.

The Pismo syncline is the primary structural feature exposed in the Irish Hills [*PG&E*, 2014]. Here beds have been rotated ~45°, which angle is supported by both mapped surface dips in outcrops (geologic map, ibid), and by the overall dip of unit Tmo Tertiary Miocene Obispo Formation in the borehole-controlled cross-section of Figure 13-17 of the *PG&E* [2015] SSC. This folding began after deposition of the youngest strata in the core of the fold (Tmpm), and prior to deposition of the Squire Member of the (Pliocene) Pismo Formation (Tpps), probably ~5 Ma. This folding implies upper-crustal strains of ~0.8, and mean strain-rates of ~0.8 / 5 Ma = 5×10^{-15} per second (/s). This is ~10× faster than rates of "off-modeled-fault" (or "continuum") deformation that are typical in the long-term neotectonics of the western US [5×10^{-16} /s per *Bird*, 2009]. This high rate of permanent straining implies a high rate of faulting and of earthquakes, even if the relevant thrust fault traces are not always exposed.

Also, rigid-body uplift would not produce crustal thickening. Therefore, if the Irish Hills were a rigid block, they would have a <u>positive</u> isostatic gravity anomaly. However, gravity data (**Figure 2**) shows a <u>negative</u> isostatic gravity anomaly, indicating more than simple Airy compensation by crustal roots (more than the typical Airy ratio of 6:1).

THEREFORE:

The Irish Hills are being deformed by numerous unmapped and/or blind thrust faults in addition to the 2 thrust faults modeled by PG&E. One prominent possibility (**Figure 3**) is the Inferred Coastline thrust fault (my term) passing offshore DCPP along the southwest coast of the Irish Hills, and dipping under the plant. The inferred location of this fault trace is based on: (1) the southwestern front of the Irish Hills is a topographic scarp with a smooth arcuate shape, mirroring the slightly-lower scarp on the northeast which has been formed by slip on the Los Osos thrust fault; (2) the documented uplift of marine terraces on the northeast side, relative to the continental shelf; (3) intense deformation of Miocene rocks in the plant area, which could be due to a forced fold over a blind thrust fault tip; and (4) the tectonic implausibility of the San Luis Bay thrust fault simply terminating (just south of DCPP) without a connection to the Hosgri fault. (Actually, PG&E did suggest that the San Luis Bay thrust fault may terminate by merging with the Shoreline fault, but the slip rate of the Shoreline is so low that this is not plausible.)

The crustal "basement" under the folded sedimentary rocks of the Irish Hills is mainly Franciscan Complex, which contains numerous Cretaceous-Paleogene thrust faults available for reactivation. Slip on those thrust faults would not reach the surface (allowing for mapping) because such slip would encounter and fold the layered Neogene sedimentary rocks of the Pismo syncline. Thus, there are an unknown number of "blind" thrust faults active, such as those that produce devastating earthquakes under the Zagros Mountains of Iran, or in Nepal.

<u>#2. Active thrust faults may dip at any angle.</u>

PG&E assigned alternative model dips of 30°, 50°, and 80° for the Los Osos thrust fault, with a combined weight of 70% to the dips of 50° to 80° in their logic-tree. They also assigned alternative dips of 45° to 75° for the San Luis Bay thrust fault.

HOWEVER:

125-year-old Mohr/Coulomb friction theory shows that thrusts never form at dips steeper than 45°, and most commonly dip at ~25° for rock friction coefficient of 0.85 [*Byerlee*, 1978; **Figure 4**]. This result comes from the simple formula:

$$(\textit{thrust dip}) = \frac{1}{2}\arctan\left({}^{1}\!/\!_{f} \right)$$

where f is the coefficient of friction. This equation is derived from classic Mohr's-circle analysis of shear stress and effective normal stress acting on all possible planes within a uniform rock material, which predicts the orientation of the plane(s) that should break first.

THEREFORE:

Dips of 50° or 80° are mechanically impossible; such faults would not slip under the present horizontal compressive stress regime. Instead, some new thrust fault would form with dip ~25°.

There are also important implications for the metric "seismic potency rate" (per m of fault trace) which is defined as = (slip rate) × (down-dip width of the seismogenic portion of the fault).

This important measure of earthquake generation varies as $1/\sin^2$(dip) when throw-rate is held constant (as in these 2 SSC studies, where it is fixed at the marine terrace uplift rate).

Compared to reasonable estimates (obtained with dip of 25°), an assignment of 50° dip reduces seismic potency rate by a factor of 3.3×. An assignment of 80° dip reduces seismic potency rate by factor of 5.4×.

Thus, PG&E underestimated seismic potency of these 2 thrusts (which were the only ones they modeled) by large factors.

#3. Geologic structures older than ~0.33 Ma are irrelevant to seismic hazard estimation.

PG&E based the throw-rates of the San Luis Bay thrust fault and the Los Osos thrust fault on vertical offsets of marine & fluvial terraces with Upper Pleistocene ages, typically ~0.12 Ma.

PG&E never attempted to model the uplift and folding of sedimentary rocks in the Irish Hills which occurred since 5 Ma.

HOWEVER:

A detailed statistical analysis of geologic constraints on fault offset rates in the western United States by *Bird* [2007] found that the probability of "inapplicability" of a dated offset feature to neotectonics (defined in that paper, and shown in **Figure 5**) is equally low for all offset features up to 3 Ma (late Pliocene) in age, and almost as low for features of 5-6 Ma (Miocene/Pliocene boundary, or the time at which the Irish Hills began to form).

Furthermore, that study concluded that a single offset feature is very rarely enough to make the fault offset rate "well-constrained;" instead, 4 offset features are needed to achieve a 50%-chance that the rate is "well-constrained," and 7 offset features are needed to guarantee it (**Figure 6**).

Thus, PG&E was negligent and unprofessional in failing to consider additional geologic constraints from older offset features, such as the once-planar Obispo Formation beds. PG&E should have created one or more structure models showing how this formation (and overlying sedimentary rocks) came to be bent into the present Pismo syncline and other folds in the center of the Irish Hills (**Figure 7**).

THEREFORE:

All the structures in the Irish Hills, which formed since 5 Ma, should have been studied and modeled to provide geologic constraints on the rates of thrust-faulting. It is strikingly negligent that they never considered or attempted this.

#4. GPS geodetic velocities are not useful for site-specific seismic hazard estimation.

PG&E operated a GPS receiver at DCPP, and *PG&E* [2015] reported the shortening direction across the Irish Hills as ~N15°E (**Figure 8**), but did not report the shortening rate. The *PG&E* [2024] update added no new geodetic information, even though an additional 9 years of data should have greatly reduced all uncertainties!

When questioned on this point at recent DCISC meeting, the PG&E representative explained that GPS velocity profiles cannot be used to measure fault heave rates unless the profile of GPS stations extends far from the fault on both sides, and that the coastline near DCPP makes this impossible.

HOWEVER:

Seismicity has been successfully forecast using only strain-rates from GPS velocity data (onshore) and plate-tectonic models (offshore), both in southern California [*Shen et al.*, 2007] and globally [*Bird et al.*, 2010; *Bird & Kreemer*, 2015; **Figure 9**]. Therefore, GPS data are very useful for forecasting continental seismicity. Any deformation model used in SSC should fit GPS strain-rate constraints (within their uncertainties).

Furthermore, the problem of unavailable GPS velocities offshore is less serious in the case of thrust faults that dip away from the coast; theoretical models of dislocation patches in elastic half-spaces show that most of the interseismic strain occurs above the hanging wall, which in this case means on-land.

And, even if a GPS velocity profile across the Irish Hills does not record all of the interseismic heave rate, it still provides a useful lower limit on the rate of crustal shortening.

THEREFORE:

Models of neotectonic deformation, informed and guided by GPS velocity data, should be used in the estimation of seismic hazard. Specifically, *Shen & Bird* [2022] computed a suite of kinematic finite-element (F-E) models of neotectonics across the western US based on geodetic, geologic, & stress data with program NeoKinema. Their preferred model, which has been incorporated into the 2024 update of the USGS National Seismic Hazard Model, shows long-term-average convergence of crustal blocks on both sides of the Irish Hills/San Luis Range region at velocities of ~1 mm/a, for a total of ~2 mm/a of local horizontal convergence rate.

III. ESTIMATING the TOTAL RATE of THRUST FAULTING UNDER the IRISH HILLS

The neotectonic uplift rate of the Irish Hills has been determined by PG&E (or possibly by its contracted consultants) to be approximately 0.2 mm/year, based on topography and ages of uplifted marine terraces compared to a global sea-level history. This is basic geologic data, and we are willing to stipulate that this uplift rate is approximately correct.

However, these throw rates (vertical offset rates) for the bounding Los Osos and San Luis Bay thrust faults are compatible with much higher slip-rates if the dips of these faults are shallow. Also, thrust faulting on additional unmapped blind thrusts (*e.g.*, Inferred Coastline thrust, and other unknown thrust faults within the Franciscan Complex basement) makes additional contributions to hazard. Fortunately, there are 3 ways to estimate the total rate of thrust fault slip in the Irish Hills without necessarily knowing the exact positions of each active fault plane.

Method #1: Isostatic:

> The neotectonic uplift rate of the whole Irish Hills region is uniform at 0.2 mm/a. However, active thrust faulting must explain not only this increase in topography, but also an increase in crustal thickness that is much greater.
>
> "Isostasy" means "equal standing" or, more clearly, "standing still when vertical loads are equal." Because the asthenosphere acts tectonically like a viscous fluid, vertical columns of lithosphere will rise or fall until their gravitational loads (per unit area) on horizontal surfaces in the asthenosphere are equal. If a hilly region (like the Irish Hills) has extra mass above sea level (relative to adjacent terranes), it must have a compensating mass-deficiency at depth. The most common finding is that elevated regions have "crustal roots" meaning unusually thick crust beneath them. This satisfies isostasy because all crustal rocks are less

dense than all mantle rocks. While there are alternative models (*e.g.*, Pratt isostasy in which variations in mantle lithosphere are important), simple Airy isostasy balances all vertical columns at the depth of the (deepest) Moho. The quality of this "rule of thumb" can be checked by measuring surface gravity on a grid of points, and then computing the "isostatic gravity anomaly" which will be near zero if Airy isostasy applies. In fact, isostatic gravity anomalies in the western US can be loosely described as 0±50 mGal. A positive value indicates "undercompensation" (deficient crustal roots) and a negative value indicates "overcompensation" (crustal roots thicker than expected). Seismic refraction studies by George P. Woolard and others have shown, since the early 20th century, that global plots of crustal thickness *vs.* surface elevation show a trend line with a slope of ~6.

As we have seen, simple Airy isostasy implies that the ratio of crustal thickening to topographic rise is about 6. Therefore, a simple isostatic model for the total rate of thrust-fault slip under the Irish Hills is at least:

$$(0.2 \text{ mm/year uplift}) \times 6 / \sin(25° \text{ dips}) = 2.8 \text{ mm/year}$$

If this crustal thickening is occurring on a single thrust fault of dip 25°, then its rate of slip should be 2.8 mm/a. Or, if the crustal thickening is driven by two oppositely-vergent and overlapping thrust faults then each should have a slip-rate of ~1.4 mm/a. Obviously, more complex models with more thrust faults can be devised, but the implication for total strain and seismicity due to thrust-faulting will remain unchanged.

Method #2: Thrust fault heave rate

I provide one example in **Figure 7**: Throw of the Obispo Formation at the San Luis Bay-Inferred Coastline thrust fault is 1.6~2.2 km since 5 Ma, implying throw-rate of 0.32~0.44 mm/year, and fault slip rate of 0.76~1.04 mm/year.

If thrusting in the Irish Hills has been symmetrical(?), then a minimum total thrust slip-rate by this method would be 1.52~2.08 mm/year. (However, this estimate neglects any internal blind thrusts, so it is only a lower-limit estimate.)

Method #3: GPS geodetic horizontal shortening rate

Our national-scale GPS-based deformation models (cited above) produced estimates of ~2 mm/a of long-term-average horizontal crustal shortening across the Irish Hills. Therefore, total thrust fault slip rate under the Irish Hills would be (~2 mm/year) / cos(25°) = ~2.2 mm/year.

Since NeoKinema models are complex (although well-accepted), another approach is to look directly at the GPS site velocities. This means looking at interseismic relative velocities, not the long-term-average velocities which are provided by modeling. Interseismic velocities are always spatially smoother, so there is a possibility that they may not capture the full rate of tectonic deformation when the dataset is spatially limited by an adjacent shoreline. I apply this approach to the geodetic dataset that was used as input by

Shen & Bird [2022] and all other USGS-sponsored modelers who participated in the 2022 Update to the National Seismic Hazard Model.

Using these raw GPS velocities, we see that station DCAN (Diablo Canyon) is converging at 0.4 mm/a with respect to DAPK (Prefumo Cyn., mid-Irish Hills) and converging at 1.1 mm/a with respect to CHOR (on Hwy 1, NNE of DCAN). Alternatively, site 2110 (slightly NNE of Point San Luis) is converging at 1.7 mm/a with respect to DAPK (half-way across the Irish Hills), and converging at 2.4 mm/a with respect to CHOR (across the full width of the Irish Hills). One way to summarize these results is to note that the average of the DCAN-CHOR interseismic shortening rate with the 2110-CHOR interseismic shortening rate is 1.8 mm/a. Allowing for the bias that interseismic rates may underestimate near a coastline, these interseismic rates tend to support the long-term-average shortening rate of 2 mm/a across the Irish Hills that the *Shen & Bird* [2022] NeoKinema model predicts.

IV. A MODEL CHARACTERISTIC THRUST EARTHQUAKE

Each time a false assumption in the PG&E SSCs was removed, thrust-faulting activity (seismic potency rate) in the Irish Hills went up by a large factor. It is important to estimate how these factors combine, and how high seismic hazard (and seismic core damage frequency, SCDF) may be at DCPP. This could be done with a new SSC study and a new SPRA study, except that we cannot afford years of time and millions of dollars.

Instead, we will use a much simpler method to show that the lower limit on seismic hazard (and SCDF risk) due to thrust-faulting alone is much higher than the total hazard claimed by PG&E. We will do this by adopting a characteristic great thrust earthquake for this tectonic setting, and then estimating its frequency in the Irish Hills.

In SSC and PSHA studies that include fault seismic sources with very incomplete information, it is traditional to assume a periodic characteristic earthquake model. While this is only an approximation of the chaotic earthquake dynamics in the real Earth, it has the advantage of allowing simple arithmetical conversions between the triad of basic parameters: slip per earthquake, long-term geologic slip-rate, and earthquake recurrence interval. For example, to compute the recurrence interval for large characteristic thrust-faulting earthquakes under the Irish Hills, it is sufficient to divide the mean coseismic slip in the characteristic earthquake by the long-term tectonic slip-rate of thrusts under the Irish Hills.

The Noto Peninsula on the northwest coast of Japan is tectonically analogous to the Irish Hills:

- Both are elliptical blocks of crust now being uplifted from beneath shallow seas between two conjugate intraplate thrust faults [*Toda & Stein*, 2024].
- Both occur within crust that formed in a subduction setting, with significant input of arc-derived graywacke clastic sediments.
- Both experienced an extensional phase prior to the present compressional phase. The opening of the Sea of Japan was Miocene, preceding present AM-OK plate convergence [*Bird*, 2003]. The future Irish Hills region experienced a brief episode of crustal melting, volcanism, and uplift due to formation of a slab window after the 28 Ma disappearance of

the Farallon plate at this latitude [*Nicholson et al.*, 1994; *Wilson et al.*, 2005]. The Edna normal fault (and others) were active during this Miocene episode, but not after. In Late Miocene the region cooled and subsided, and remained tectonically quiet until 6-5 Ma.)

- Both include active thrust faults that were accidentally omitted from their respective national seismic hazard models because they are either blind or under water.

The primary difference is that horizontal convergence in the Noto Peninsula is faster (~10 mm/a *vs.* ~2 mm/a), allowing us a better opportunity to observe its seismicity in our brief historical datasets. Further discussion of these similarities and differences is in Appendix **B**.

On 1 January 2024, at 07:10 UTC, a very large earthquake occurred beneath the Noto Peninsula on the northwest coast of Ishikawa Prefecture, Japan. Its magnitude was 7.6 on the moment-magnitude scale used by the Japan Meteorological Agency, and 7.5 on the moment-magnitude scale used by USGS. This thrust-faulting shock achieved a maximum JMA seismic intensity of Shindo 7 and Modified Mercalli intensity of IX (Violent) [*Wikipedia*, 2024]. These intensities are very high.

We learned 2 essential facts from this 2024.01.01 ***m***7.5 earthquake [*Toda & Stein*, 2024]:

(1) We have the advantage of the finite-fault solution (*USGS*, 2024; **Figure 10**), which maps the amount of coseismic slip onto the active fault plane. This study showed maximum slip of 3.7 m under the center of the Noto Peninsula, with a mean slip that I visually estimate as 2.0 m (or 2000 mm) within the seismogenic depth range, under the part of the fault trace that parallels the Noto Peninsula.

(2) Peak ground accelerations (PGA; **Figure 11**) at 5 strong-motion seismometers were 1.0~2.3 g as far as 42 km from the rupture.

V. CONCLUSION: SEISMIC CORE DAMAGE FREQUENCY at DCPP:

The two SSC studies by *PG&E* [2015; 2024] seriously underestimated the seismic hazard from thrust-faulting under the Irish Hills because they relied on 4 demonstrably false assumptions.

Three independent analytic methods give values for the total slip-rate on all shallow-dipping thrust faults under the Irish Hills: 2.8 mm/year, ~2.0 mm/year, or 2.2 mm/year.

Using the 2024.01.01 Noto Peninsula earthquake as a characteristic thrust earthquake (with its 2 m of mean slip) yields recurrence times for great thrust earthquakes under the Irish Hills of 715 years, 1000 years, or 910 years, respectively.

This raises the question of whether PGA of 1.0~2.3 g will cause seismic core damage (SCD) at Diablo Canyon Units 1 & 2? Answering this question quantitatively becomes technical and difficult, given that spectral accelerations critical to individual component failures are typically twice as large as PGA; that is, perhaps 2.0~4.6 g at vibration frequencies of 5~10 Hz for the Noto Peninsula earthquake analog.

The 2018 SPRA [*PG&E*, 2018] is the most recent available to me. Within this document, Table 5.4-4 (page 65) shows how PG&E's overall SCDF of 2.8×10^{-5} /yr was obtained. In principle, it should be possible to use this information to estimate the probability of SCD at each level of shaking. My interpretation of the table is that the probability of SCD is ~6% at 2 g, rising to ~73% at 3 g and to >98% at 4 g. The problem is that the acceleration levels quoted in this table are not clearly identified; are they PGAs or (more likely) spectral accelerations? The context in this SPRA report suggests that they are spectral accelerations: the introductory section "3.1.3 Seismic Hazard Analysis Results and Insights" only discusses 5 Hz spectral accelerations, and the primary graphs that it refers to ("Figure 3-1 - Reference Rock Hazard by Source for 5 Hz Spectral Acceleration" and "Figure 3-4 - 5 Hz Control Point Mean and Fractiles Horizontal Hazard") are plots of 5 Hz spectral acceleration.

Therefore, my interpretation of this report is that a PGA event of 1.0 g would produce 5 Hz spectral accelerations of ~2 g, and incur ~6% chance of SCD. However, a PGA event of 1.5 g would produce 5 Hz spectral accelerations of ~3 g, and incur a ~73% chance of SCD. And the peak Noto-earthquake observation of PGA of 2.3 g would produce spectral accelerations of ~4.6 g, and incur >98% chance of SCD at DCPP.

It will probably be controversial exactly which of the Noto Peninsula seismograms give the median and worst-case forecasts of shaking at DCPP. The paragraph above shows that this is a critical point. Clearly these questions need to be resolved by independent experts, preferably in a revised SSC study followed by a revised SPRA study. In the meantime, for purposes of evaluating the acceptability of PG&E's two SSCs, it is sufficient to assume that the levels of shaking seen in the Noto Peninsula earthquake will cause seismic core damage at DCPP if and when they occur in the Irish Hills of California.

Assuming that such a great thrusting earthquake <u>would</u> cause seismic core damage at DCPP, its seismic core damage frequency (SCDF) is at least

1.4×10^{-3} /year, or 1.0×10^{-3} /year, or 1.1×10^{-3} /year, respectively.

[This is before the hazard contributions from strike-slip faults like the Hosgri and Shoreline are added.]

APPENDIX A. MISSING PROCEDURAL STEPS in the SSCs by *PG&E* [2015; 2024]

Another fundamental problem with PG&E's [2015; 2024] seismic risk analyses (besides logic guided by false assumptions) is the subjective (*i.e.*, committee-based, not algorithm-based) creation of "fault geometry" models to support the 2015 and 2024 SSCs. These kinematically incomplete models also biased PG&E's [2018] SPRA. Their fault geometry models do not meet basic scientific standards for objectivity and reliability because are not geometrically self-consistent, nor are they consistent with GPS and regional stress directions. They did not take account of, or make use of, then-published and available scientific developments in:

-measurement of crustal motion by permanent and campaign Global Positioning System (GPS) receivers [*e.g.*, *Shen et al.*, 2003; *Kreemer et al.*, 2003, 2014; *Kreemer*, 2016]; or

-computer modeling (including kinematic finite-element models) of such data, in combination with geologic and stress data, to compute long-term crustal strain rates and fault slip rates [*e.g.*, use of program NeoKinema: *Bird*, 2009; *Field et al.*, 2013, 2014; *Parsons et al.*, 2013]; or

-recent initiatives in seismic hazard estimation which do not assume that a complete inventory of active faults is available, but instead compute the expected seismicity across the map area from crustal long-term (permanent, not elastic) strain rates and fault slip rates (if and where available) using a calibration of global shallow seismicity categorized by plate-tectonics [*Bird & Kagan*, 2004; *Bird & Liu*, 2007; *Bird et al.*, 2009; *Bird et al.*, 2010]. Two motivations for the development of such models were that: (a) a number of recent large earthquakes in the California region have occurred in places where no seismogenic fault, or only short disconnected faults had been recognized (Landers 1972 ***m***7.3, Hector Mine 1999 ***m***7.1, El Mayor-Cucupah 2010 ***m***7.2, Ridgecrest 2019 ***m***6.5 + ***m***5.4 + ***m***7.1); and (b) the discovery that the global distribution of shallow earthquakes shows that they spread in bands of half-width 257 km [*Bird & Kagan*, 2004] around plate boundary faults of the Continental Transform Fault (CTF) type.

In particular, *PG&E* [2015; 2024] should have used the globally-calibrated strainrate-to-seismicity conversion (see paragraph above) to obtain the seismic moment rate for their Local Area Source component. By using a seismic moment based on microseismicity in a few quiet decades between seismic crises, they seriously underestimated it.

In 2012, I participated in a Senior Seismic Hazards Analysis Committee (SSHAC) Level-III workshop sponsored by Pacific Gas & Electric Co. (PG&E) and run by Lettis Consultants International, regarding seismic hazard at the Diablo Canyon Power Plant. I presented results on both strike-slip and compressional deformation rates affecting the region, which were derived from my latest NeoKinema computer models of neotectonics. (These models were prepared for the Southern California Earthquake Center's project Unified California Earthquake Rupture Forecast version 3, and also for the US Geological Survey's 2013 Update to the National Seismic Hazard Model.) At that time, I offered to share my modeling codes and methods with the TI team, at no cost to them, but that offer was declined.

APPENDIX B. Dismissal of PG&E's Objection to the Noto Peninsula Earthquake Model

On 24 October 2024, PG&E submitted PG&E Letter DCL-24-103 to the Petition Review Board of the Nuclear Regulatory Commission (nrc.gov ADAMS Accession # ML24298A234) which contained Enclosure 2, a technical report by Lettis Consultants International, Inc., entitled "Phase 1 Review of the Tectonic and Geomorphic Setting of the January 1, 2024, M7.5 Noto Earthquake, Noto Peninsula, Japan" (56 pages). Herein I will refer to this as the "LCI report."

The principal subject of the LCI Report was the 2024.01.01 Noto Peninsula earthquake, and whether this could be accepted as a model characteristic thrust earthquake for the setting of the Irish Hills in California (as I have suggested). Here I will quote some of their concerns in italic type, followed by my responses. Points of agreement or common knowledge will not be included. For example, LCI agrees that the Noto Peninsula is an inverted fault-bounded basin that has been uplifted between oppositely-vergent thrust faults, and that the start of its compressional phase was 4-3 Ma, similar to the 5 Ma initiation of the Irish Hills.

LCI Report: "*The San Luis-Pismo Block* [in the Irish Hills] *is interpreted to have been uplifted as a rigid block during the late Quaternary by reverse slip on both the Los Osos fault and Southwestern Boundary zone faults."*
Response: LCI acknowledges that this idea of a rigid block is copied from *PG&E* [2015]. I have refuted it in previous sections of this report.

LCI Report: "*The Q1 terrace* [in the Irish Hills] *is almost flat, with a relatively gentle shoreline slope, which along the southwestern coastline of the Irish Hills is locally steeper, possibly reflecting increased colluvial and/or alluvial cover (AMEC, 2011a)."*
Response: This increased slope could also be interpreted as due to continuing forced folding of the hanging-wall of the blind Inferred Coastline thrust (my term).

LCI Report: "*Compared to the Noto Peninsula faults that are readily identifiable from their acute geomorphic expression on the seafloor, the relative lack of expression of the Irish Hills bounding faults indicates that despite exhaustive investigation from detailed topographic, bathymetric, geologic, and geophysical investigations onshore and offshore, these faults are not directly analogous to those generating uplift along the Noto Peninsula." [Section 4.2.1]*
Response: This difference in fault-scarp expression is expected based on the fact that horizontal shortening in the Noto Peninsula is about 5× faster than in the Irish Hills (~10 mm/a *vs.* ~2 mm/a), whereas the initiation ages are similar (4-3 Ma *vs.* 5 Ma). The Noto Peninsula thrusts have slipped further, and are currently slipping faster, so they have more prominent scarps. This is not an important distinction.

OVERVIEW: PG&E's cover letter to NRC first describes Enclosure 2 (the LCI Report) and then states that, *"This study shows significant differences between the two regions and refutes the Petitioners' claims that the Noto earthquake is a direct corollary for potential earthquakes and hazard models for DCPP."* However, there is no basis for this statement in the LCI Report, which instead details dozens of similarities between the Noto Peninsula and the Irish Hills.

FIGURES

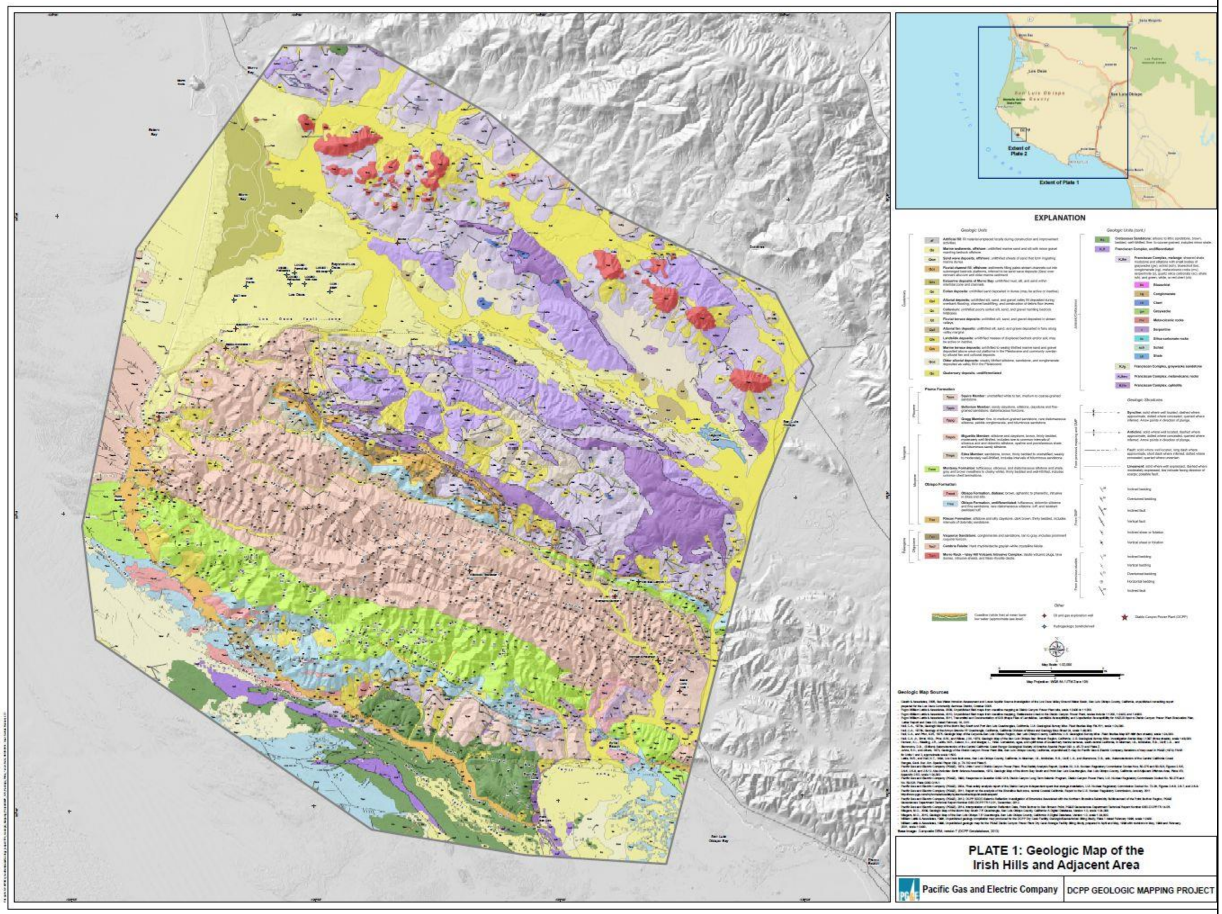


Figure 1. Geologic map of the Irish Hills region [*PG&E*, 2014]. The large Pismo syncline fold in the southwestern half of the region can be identified by a single strip of beige color, surrounded by matched strips of green color, matched strips of light blue color, and matched strips of purple color. Dips in both limbs of this fold average ~45°.

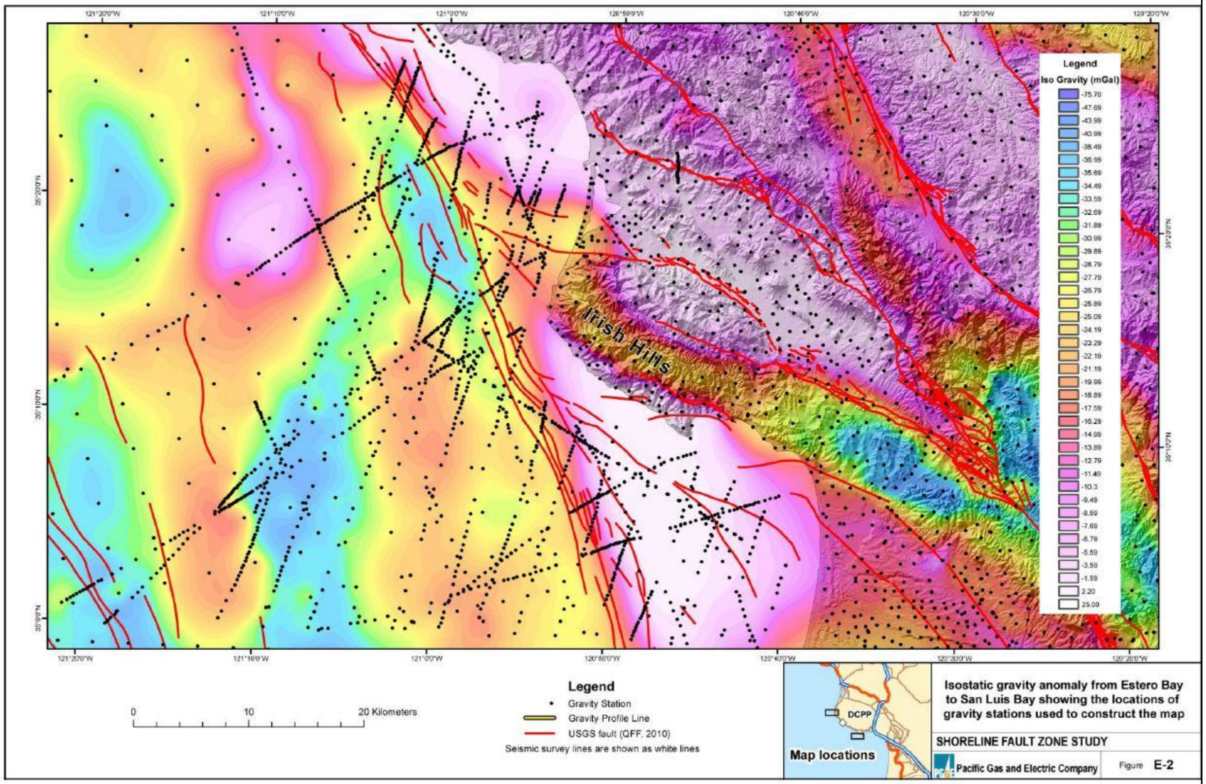
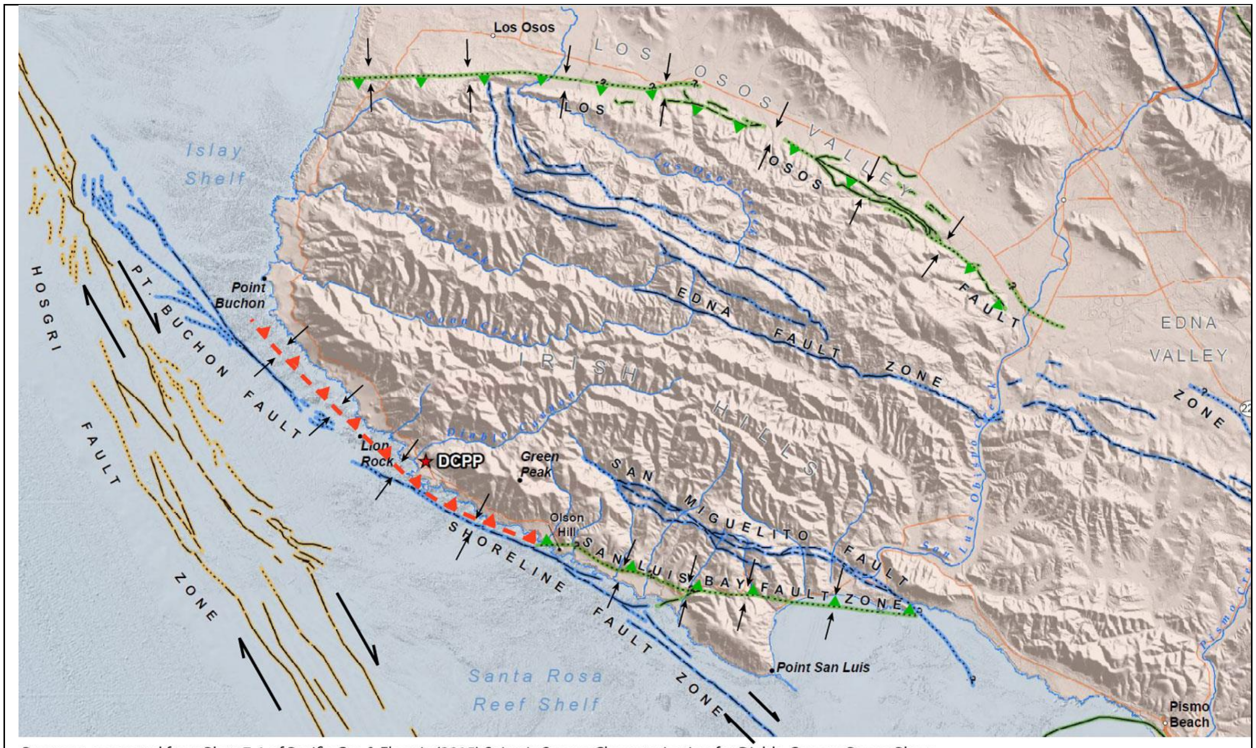


Figure 6-2. Large-Scale Residual Isostatic Gravity Anomaly Map Showing a Negative Gravity Anomaly Coincident with the Irish Hills (modified from Langenheim et al., 2008 and PG&E, 2011, Figure E-2)

Figure 2. Isostatic gravity anomaly map of the Irish Hills region [*PG&E*, 2024]. Note that negative values (about -22 mGal) are typical in the Irish Hills. These negative values indicate that the hills are "over-compensated" meaning that their supporting crustal roots are thicker than would be predicted by simple Airy isostasy.



Basemap excerpted from Plate 7-1 of Pacific Gas & Electric (2015) Seismic Source Characterization for Diablo Canyon Power Plant;
Inferred Coastline thrust fault trace (in red) added by P. Bird, 2024.06.19. Triangle symbols show direction of dip of thrust faults.

Figure 3. Detail of the fault-trace map of *PG&E* [2015], edited to show the dip-directions of thrust faults (with triangles), and the slip-directions of dextral faults (with paired arrows) and to add my proposed Inferred Coastline thrust fault trace, continuing the fault system which PG&E recognized as the San Luis Bay fault zone. Colors of different fault traces have no importance, except to separate them visually.

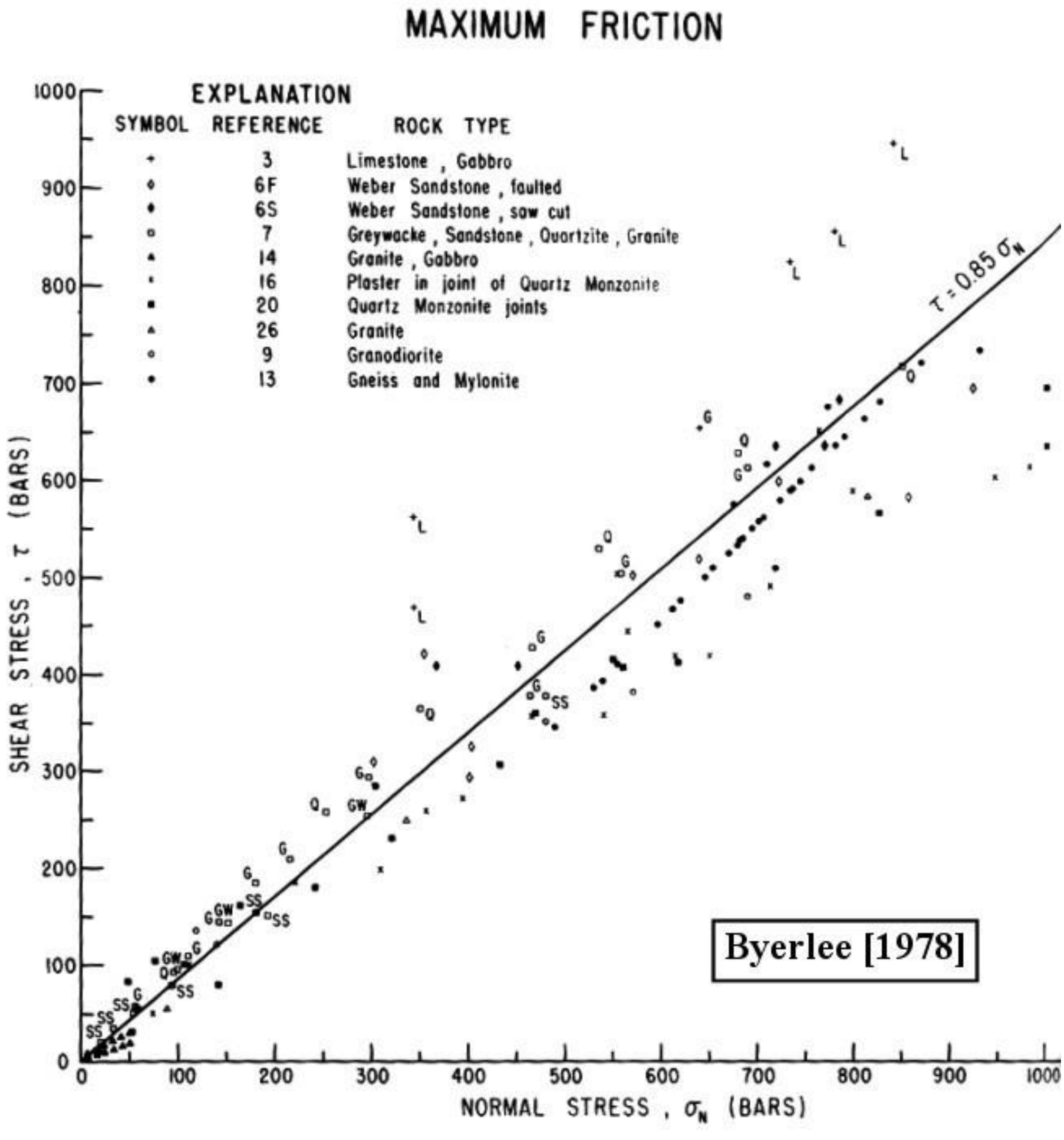


Figure 5

Shear stress plotted as a function of normal stress at the maximum friction for a variety of rock types at normal stresses to 1000 bars.

Figure 4. Reproduction of Figure 5 from *Byerlee* [1978], showing results of decades of laboratory tests on the friction of diverse rock types. Note that a friction coefficient (slope) of 0.85 is typical. This result is loosely referred to as "Byerlee's Law." There was no pore pressure in these experiments, so the horizontal axis label "NORMAL STRESS" could also be interpreted as "EFFECTIVE NORMAL STRESS."

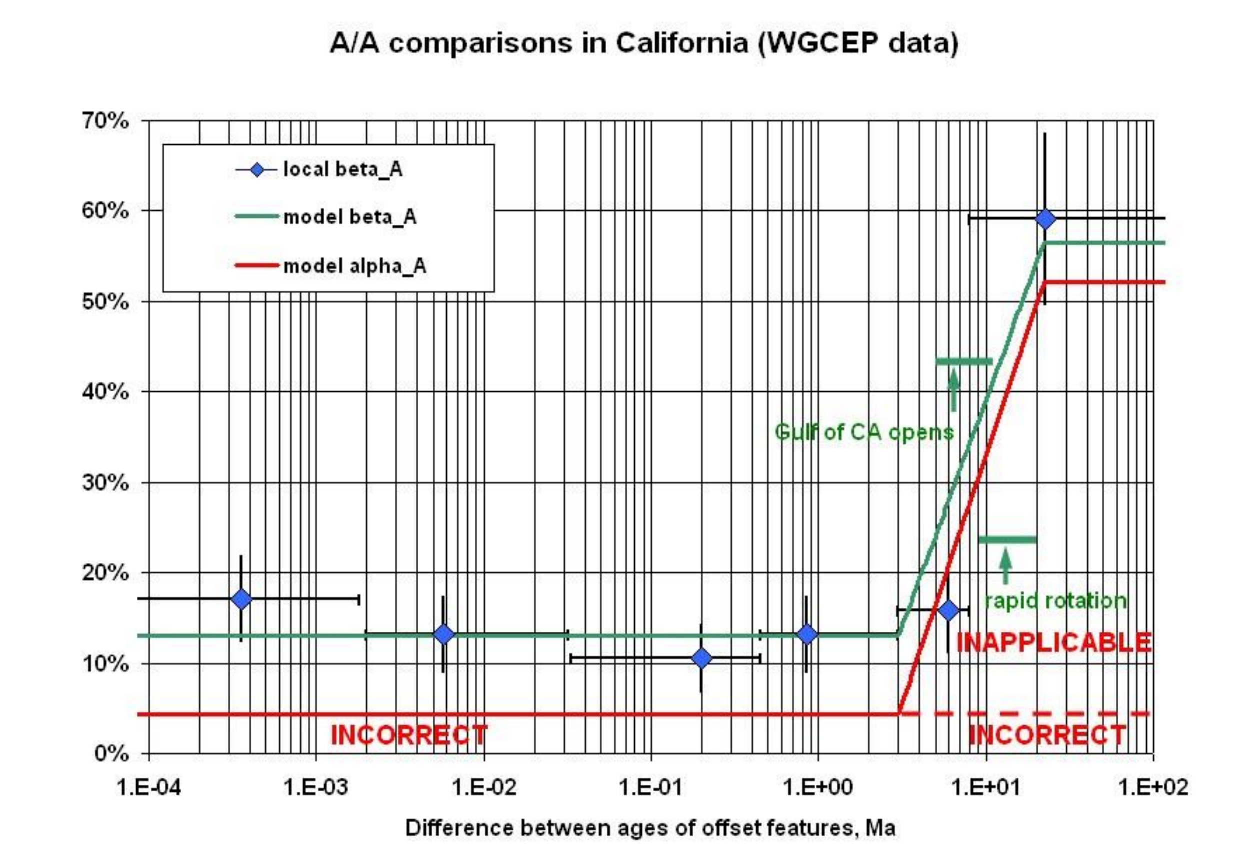


Figure 5. Reproduction of Figure 8 of *Bird* [2007], showing how the chance of "inapplicability to neotectonics" (vertical axis) varies with the difference between the ages of two sets of piercing points along the same fault. In California, "inapplicability to neotectonics" is only a problem for offset features older than 5 Ma. All younger features are equally relevant.

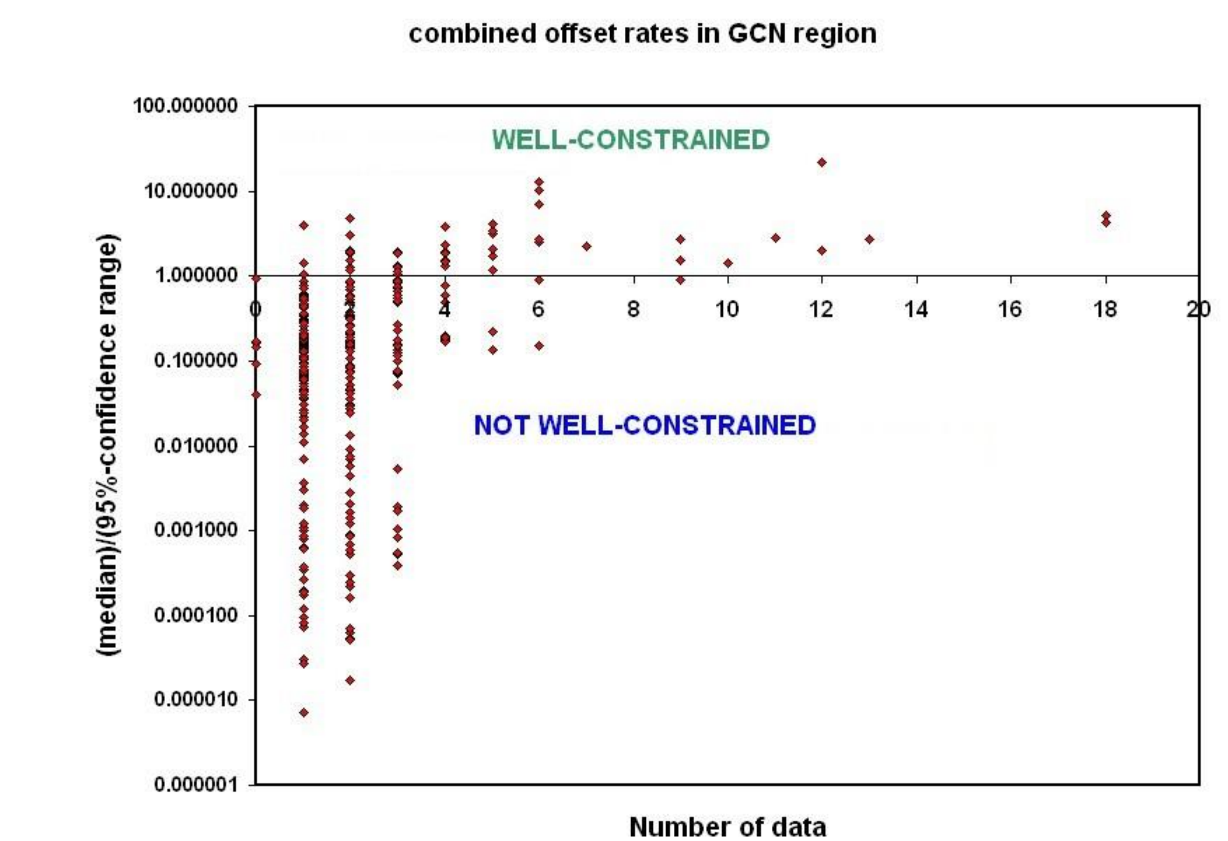


Figure 6. Reproduction of Figure 9 of *Bird* [2007], showing results from a study of dated fault offsets across the Gorda-California-Nevada orogen (GCN region). The resulting fault offset rate is only "well-constrained" (as defined by the vertical axis label) when more than 4 pairs of offset features are used in a combined statistical analysis. Therefore, a single dated offset feature (as used by *PG&E* [2015; 2024]) is not enough.

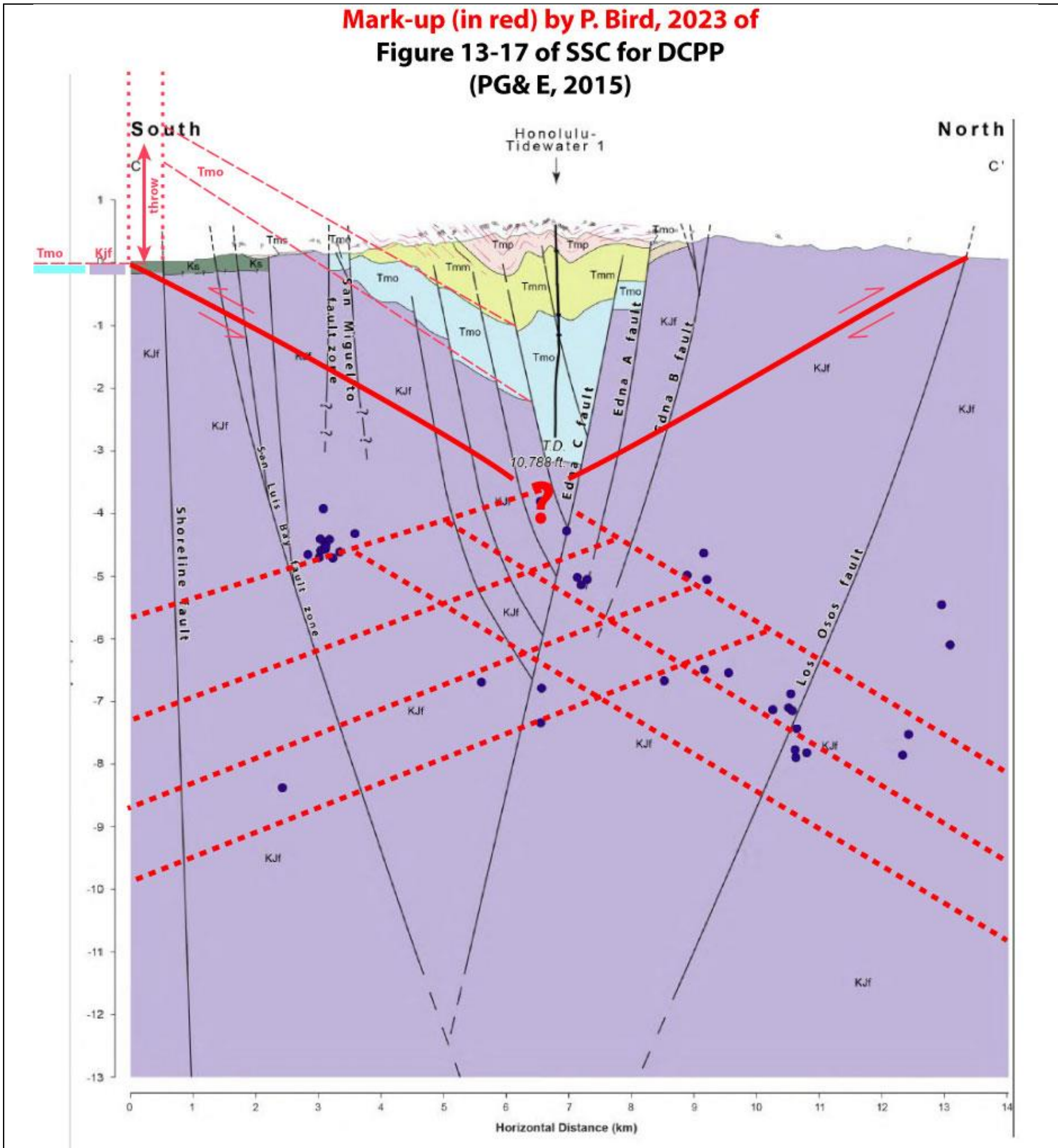


Figure 7. Mark-up (in red) of geologic cross-section Figure 13-17 from *PG&E* [2015]. The basis for the steep dip shown (in black) for the Los Osos thrust fault is weak, and I suggest an alternative dip of 25°. I also add the Inferred Coastline thrust fault (continuing along the line of the San Luis Bay thrust fault) on the left side with dip of 25°. Dashed red lines suggest how these two thrusts may have offset each other during 5 m.y. of finite strain, to create a suite of shallow-dipping blind thrust faults. This model explains the deep microseismicity better than PG&E's model. At top left, throw (vertical offset) of the Inferred Coastline thrust is labelled, based on apparent offset of geologic unit Tmo (Tertiary Miocene Obispo Formation).

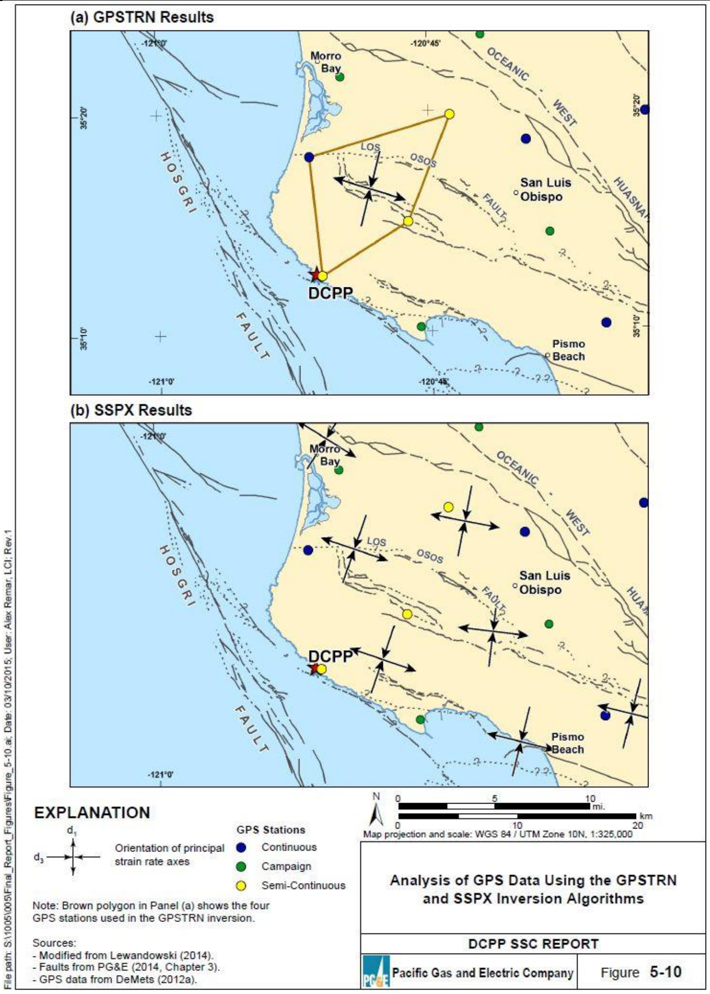


Figure 8. Reproduction of Figure 5-10 from *PG&E* [2015], showing how two alternative networks of GPS geodetic stations were used to estimate a plausible azimuth of ~N15°E for the most-compressive strain-rate axis. However, their figure is misleading because a generic strike-slip strain-rate tensor symbol was used to show strain-rate orientations, whereas in fact the GPS data indicate almost pure thrust faulting. That is, the WNW-ESE-trending pair of arrows in each symbol should be ignored.

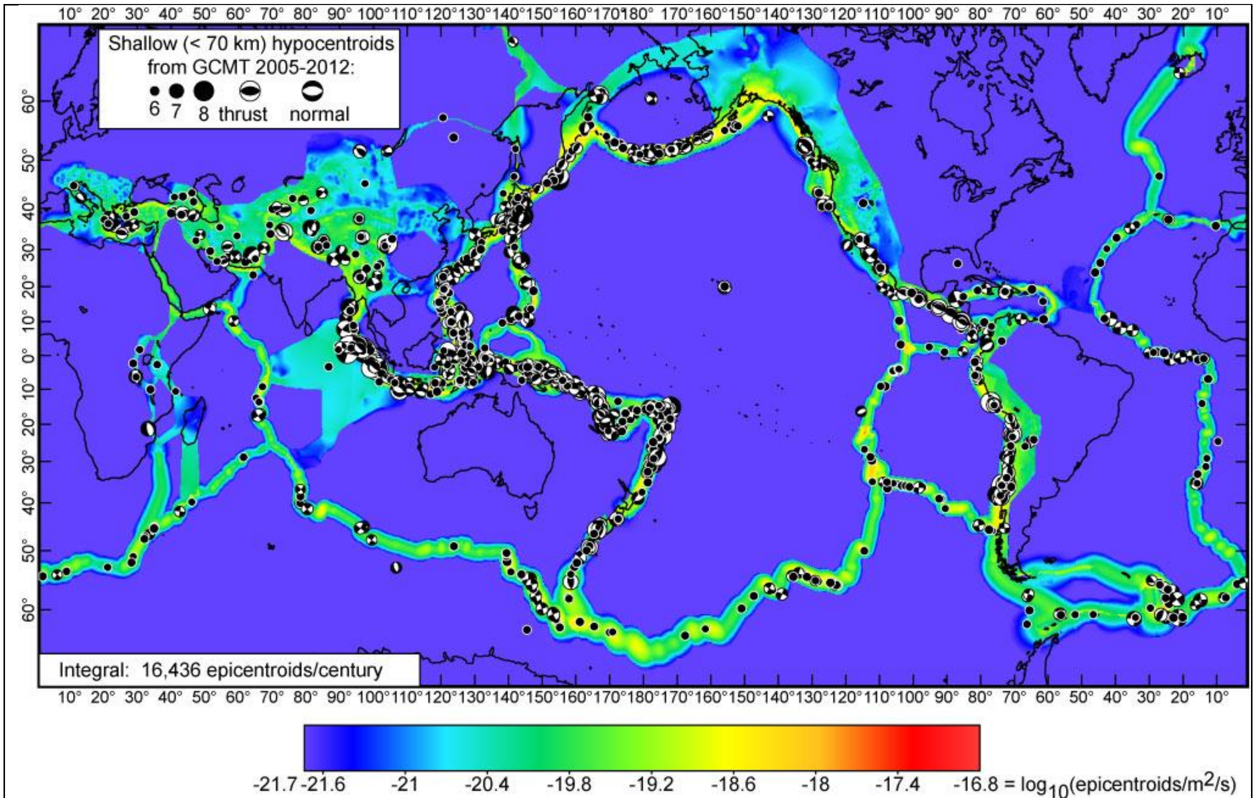


Figure 9. Global forecast of shallow seismicity by *Bird & Kreemer* [2015], shown with colors on a logarithmic scale to represent variation over 5 orders of magnitude. This forecast was based on continental strain-rates from GPS geodetic velocities, and on oceanic plate tectonics, and did not use the catalog of historic earthquakes. However, the similarity to actual recorded earthquakes in 2005-2012 (shown with black dots or focal mechanisms) is very strong. This result demonstrates the value of GPS geodetic data for the forecasting of continental seismicity.

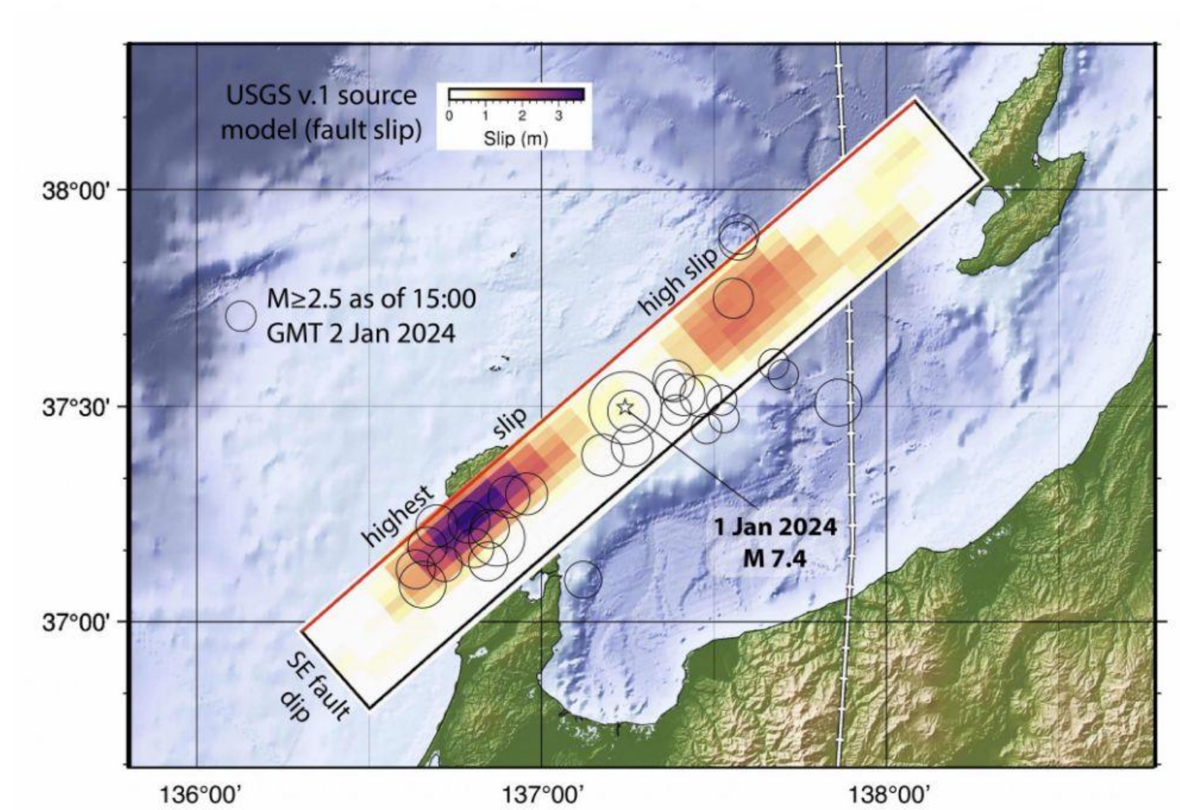


Figure 10. Reproduction of a figure from *Toda & Stein* [2024], showing the slip pattern of the 2024 Noto Peninsula earthquake (based on the USGS finite-fault solution), superposed on topography. Note that this earthquake ruptured bilaterally from a hypocenter with low slip; if it had only propagated to the SW, the magnitude and rupture length would have been less. Also note that the mean slip (within the seismogenic depth range) in the Noto Peninsula portion of the rupture is about 2 m.

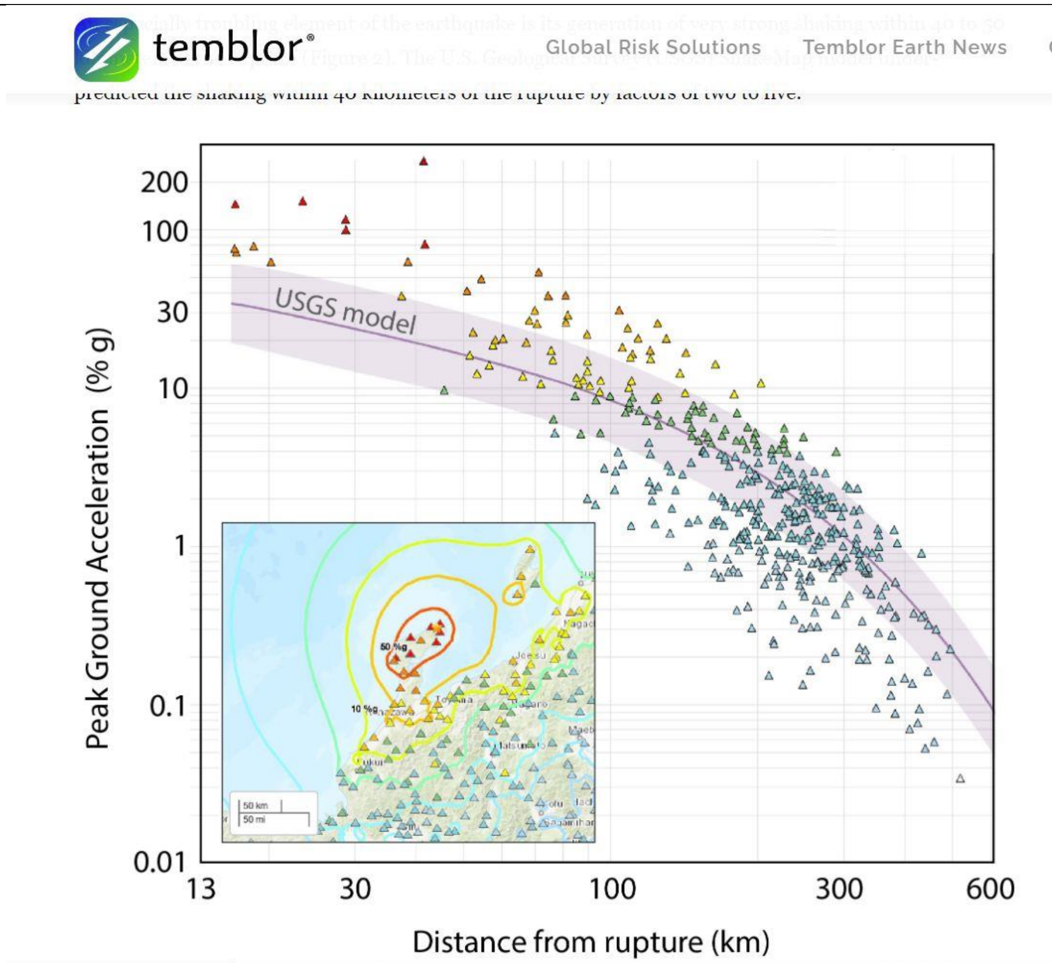


Figure 11. Reproduction of a figure of *Toda & Stein* [2024], showing iso-intensity contours (inset map) and the PGA-versus-distance graph for the 1 January 2024 Noto Peninsula earthquake. Note that PGA of 100% to 230% of gravity were recorded at 5 digital strong-motion stations on the Noto Peninsula, up to 42 km from the rupture. It is also apparent that the standard USGS "ShakeMap" model of the attenuation of PGA with distance is not applicable to this thrust earthquake.

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