ATTACHMENT 1

AFFIDAVIT AND CURRICULUM VITAE OF DR. GERHARD JENTZSCH

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Diablo Canyon Power Plant: Estimation of the earthquake hazard

by

Gerhard Jentzsch[1]

1. Objectives and conclusions

(1) This is a follow-up report to my first report of September 1st, 2014. After the publication of the new report on the **Central Coastal California Seismic Imaging Project-2014** in September 2014 (PG&E, 2014a) the new material had to be checked and evaluated with regard to the estimation of the earthquake hazard in central California, esp. near the Diablo Canyon Power Plant (DCPP).

(2) Pacific Gas and Electric Company (PG&E) has collected an enormous amount of new data observed mainly off-shore to investigate the Hosgri Fault as well as the Shoreline Fault and the surrounding fault system. The main results presented show an increased rupture length of the dominating faults which lead to a slight increase of the expected earthquake magnitudes by only 0.2M which in fact means a doubling of the energy release.

(3) But, according to PG&E the results just prove the existing assumptions concerning the power plant and its strength and that it is *seismically safe and able to withstand the largest potential earthquakes in the region* (PG&E, 2014b). My conclusion is different: PG&E fails to disprove the ground shaking values derived by Peck (2013). I believe that the ground shaking (response spectra) presented are underestimating the hazard considerably. I outlined my position in my previous report of September 1st, 2014.

(4) In this second report I check the new data as well as their impact on the estimation of the earthquake hazard. There are a lot of new information, but all the efforts lack in a convincing explanation of the relation between shallow structures and the seismogenic zone, i.e. the realistic estimation of the earthquake hazard which was in fact the motivation for the new investigations.

(5) Therefore, I also concentrated my work on the check of the papers of Hardebeck (2010, 2013) and Leonard (2010), which contain valuable information on the tectonic situation and the relation to earthquake hazard.

(6) Fig. 1 from Hardebeck (2010) provides a lot of information: We see the epicenter distribution of central California, the tectonic situation as well as the named faults. Especially the San Simeon area shows a cluster of epicenters which is widespread and seems to affect the adjacent faults.

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[1] GJ is a retired full professor of Geophysics and was mainly engaged in deformation measurements and analyses (earth tides and long-period seismology) as well as physical volcanology. In addition, he was involved in nuclear safety analyses of power plants and repositories in Europe.

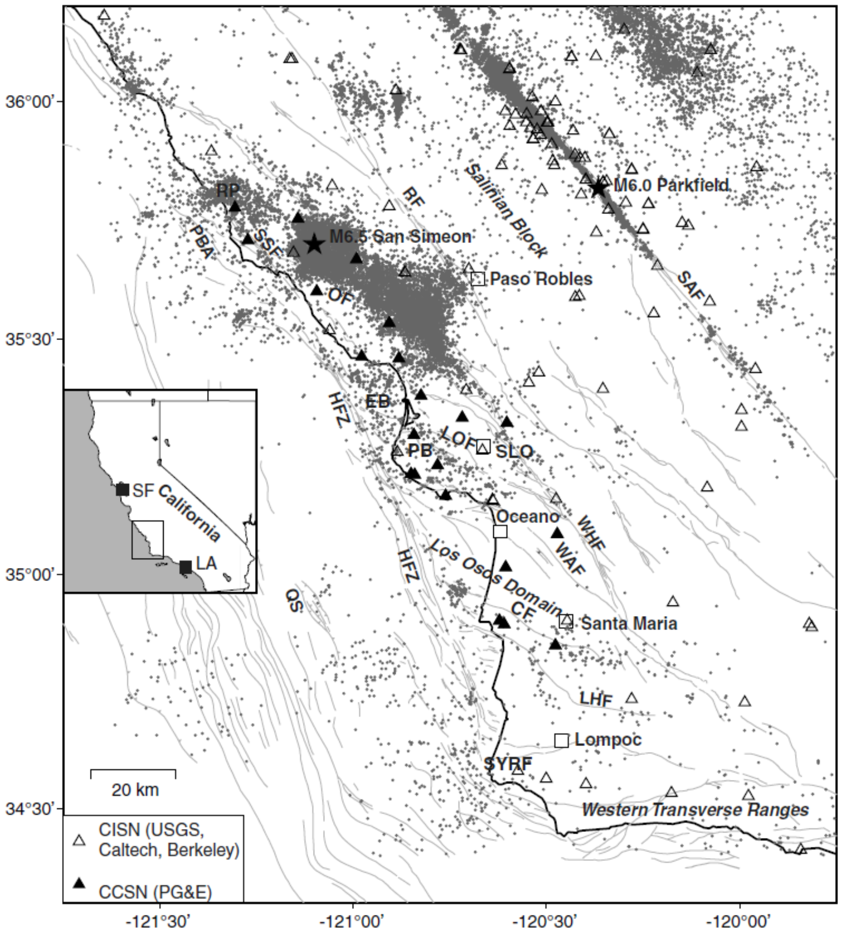


Figure 1. Map of the study area; inset shows the location in the state of California. The open triangles represent the CISN stations, and the solid triangles represent the Pacific Gas and Electric Company (PG&E) Central Coast Seismic Network (CCSN) stations. The gray dots show the CISN catalog earthquake locations, 1 October 1987–31 December 2008. The stars show the 2003 *M* 6.5 San Simeon and 2004 *M* 6.0 Parkfield mainshocks. The gray lines are mapped faults from PG&E (M. McLaren, personal comm., 2006). The open squares are towns. CF, Casmalia fault; EB, Estero Bay; HFZ, Hosgri fault zone; LA, Los Angeles; LHF, Lions Head fault; LOF, Los Osos fault; OF, Oceanic fault; PB, Point Buchon; PBA, Piedras Blancas antiform; QS, Queenie Structure; RF, Rinconada fault; RP, Ragged Point; SAF, San Andreas fault; SF, San Francisco; SLO, San Luis Obispo; SSF, San Simeon fault; SYRF, Santa Ynes River fault; WAF, Wilmar Avenue fault; WHF, West Huasna fault.

Fig. 1. Central California with all the known faults. (from Hardebeck, 2010).

2. New data and new considerations

(7) With the new report on the Central California Coastal Seismic Image Project-2014 (CCCSIP, PG&E, 2014a) an abundance of data is presented as well as new considerations on the fault geometries and interconnections (chapters 1-12). Unfortunately, the chapter on the interpretation of these data and the conclusions about the earthquake hazard (chapter 13) is the shortest one and, thus, also the scientific foundation of the conclusion that for the estimation of the earthquake hazard would be no changes necessary, is simply poor.

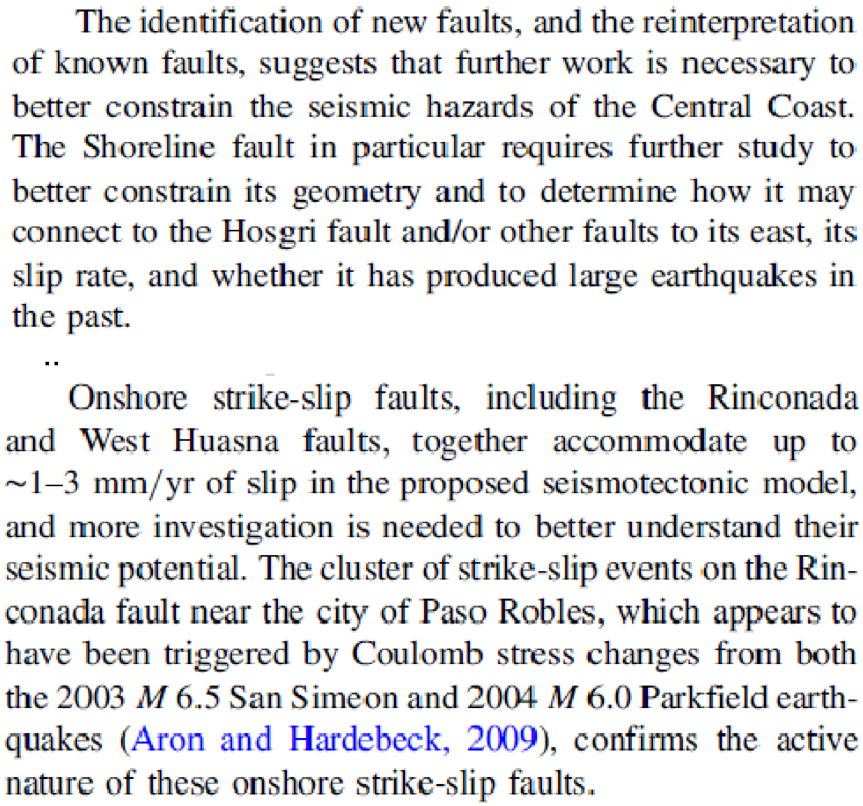
(8) It must be stressed at this point, that in the individual chapters under the paragraph *Limitations*, PG&E confesses that the reflection seismic data (high energy – HESS as well as low energy – LESS) does not reach down deep enough to connect the near-surface information to the seismogenic zone of the crust. Therefore, the first conclusion is that the measurements are very interesting and good for studying the shallow crust, but they are (nearly) worthless for the seismic hazard assessment.

(9) We have to raise the questions:

- what are the consequences of the now longer shoreline fault for groundmotion?
- how does the shoreline fault interconnect with the other faults (Hosgri, San Luis Bay, Los Osos) and what does this mean for groundmotion?
- what does a possible interconnection of the San Simeon mean for groundmotion?

(10) I would like to refer to the work of Hardebeck (2010, 2013) as well as to the paper of Leonhard (2010) which form the basis for the estimation of new fault lengths and new magnitude estimation.

(11) Hardebeck (2013) presents a tectonic model which shows clearly that the Shoreline Fault is connected to the Hosgri Fault. She also includes results from geodetic measurements providing crustal deformation velocities (horizontal) in the order of up to 5 mm/yr and proposes new research to improve the estimation of the seismic hazard. In her first paper (Hardebeck, 2010, p. 1048) we can read:



The identification of new faults, and the reinterpretation of known faults, suggests that further work is necessary to better constrain the seismic hazards of the Central Coast. The Shoreline fault in particular requires further study to better constrain its geometry and to determine how it may connect to the Hosgri fault and/or other faults to its east, its slip rate, and whether it has produced large earthquakes in the past.

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Onshore strike-slip faults, including the Rinconada and West Huasna faults, together accommodate up to ~1–3 mm/yr of slip in the proposed seismotectonic model, and more investigation is needed to better understand their seismic potential. The cluster of strike-slip events on the Rinconada fault near the city of Paso Robles, which appears to have been triggered by Coulomb stress changes from both the 2003 *M* 6.5 San Simeon and 2004 *M* 6.0 Parkfield earthquakes (Aron and Hardebeck, 2009), confirms the active nature of these onshore strike-slip faults.

(12) She followed her recommendation and published a second paper (2013) in which she demonstrates the interconnection between Hosgri and Shoreline faults as already seen in the tectonic model (Fig. 13 of her 2010-paper):

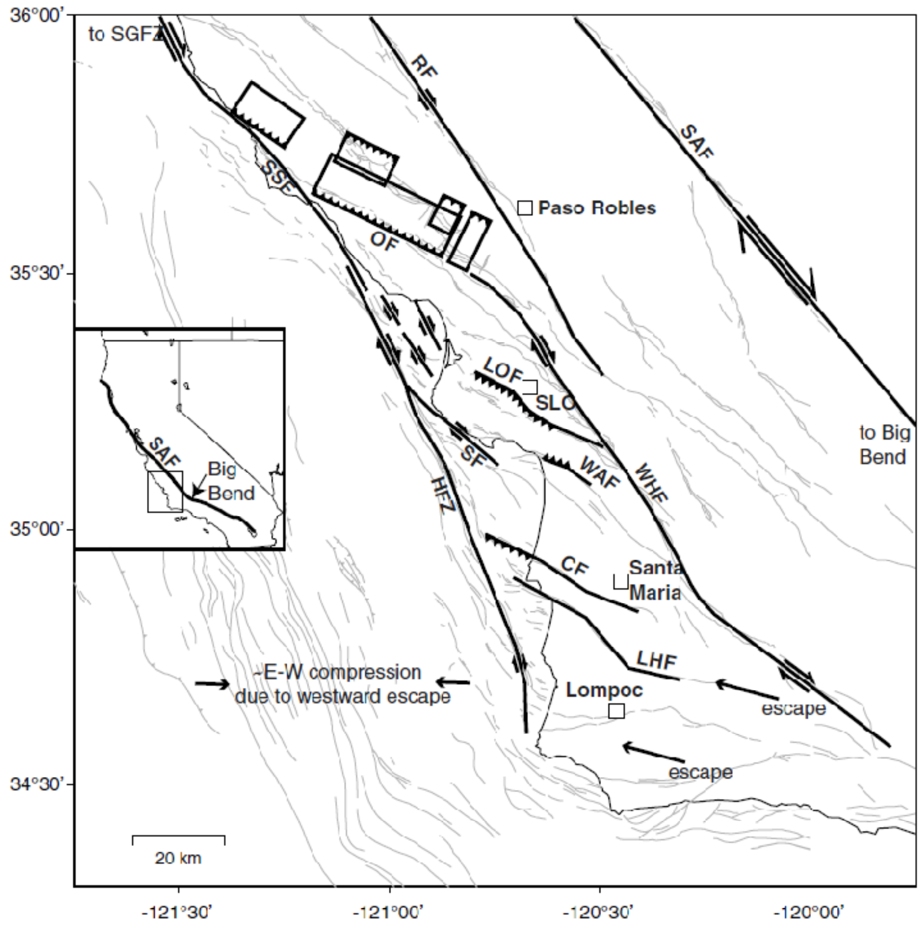


Figure 13. Tectonic model, with simplified faults. Interpreted fault features from the seismicity in this study, as well as other important structures, are shown as thick black lines. Strike-slip direction arrows and thrust faulting barbs are shown where sense of slip is constrained by seismicity. The relative sizes of the arrows are meant to reflect relative slip rates implied by the model, but they are not to scale. The inset shows the proximity of the study area to the Big Bend in the San Andreas fault. SF, Shoreline fault seismicity trend. Other abbreviations are as in Figure 1.

Fig. 2. Tectonic model (from Hardebeck, 2010).

(13) These results are derived from the evaluation of earthquake data, e.g. the recordings of events and their relocation. Ideally, the hypocenters (sources) of the earthquakes along a fault lie on a plane which forms the source area. In nature, the situation mostly is not that easy, but natural data is much more reliable than artificial seismic data from experiments which do not allow to look at depths that are interesting. Earthquake data provide not only geometries but also process information like the determination of the stress field and, thus, hints to slip rates which are compared to long-term slip rates derived from the structure information (offsets).

(14) To answer the above raised questions, I come to the following conclusions:

(15) The consequences of the now longer shoreline fault for ground motion are obvious: The longer the fault, the more energy can be built up – and the bigger are the magnitudes of the events to be expected. Here, the paper of Leonard (2010) should be considered: He introduces several formulas to estimate the magnitudes from the fault geometry. Two of them describe the situation for strike-slip and dip-slip:

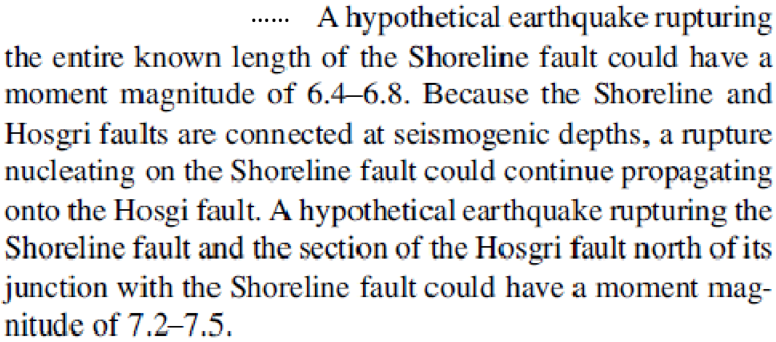
(1) M = 3.99 + log10(area) for strike-slip

(2) $M = 4.00 + \log10(\text{area})$ for dip-slip[2]

(16) If we assume an earthquake of magnitude 6.5 we can derive the rupture area, and, using the seismogenic depth, we can derive the length of the fault. As appendage (1) I add the table from Chapter 13 of the report, in which updated fault parameters like length and dip are summarized.

(17) M6.5 with seismogenic depth of 12 km reveals a fault length of 27 km. Using M6.7 leads to 43 km. This is in accordance with the experience that 0.2M is responsible for a doubling of the energy released for which a doubling of the source area is needed. Thus, the probability of a bigger earthquake is accepted.

(18) Concerning the interconnection of the shoreline fault with the Hosgri fault I would like to follow Hardebeck (2013). On page 461 we can read (see also Fig. 3):



> ...... A hypothetical earthquake rupturing the entire known length of the Shoreline fault could have a moment magnitude of 6.4–6.8. Because the Shoreline and Hosgri faults are connected at seismogenic depths, a rupture nucleating on the Shoreline fault could continue propagating onto the Hosgi fault. A hypothetical earthquake rupturing the Shoreline fault and the section of the Hosgri fault north of its junction with the Shoreline fault could have a moment magnitude of 7.2–7.5.

(19) Under most favorite conditions such an energy release of M6.8 would cause a groundshaking of intensity of over IX corresponding to accelerations of up to 1.24 g (compare Table 1 of my previous report; see Appandage 2) which amounts to 12 m/s^2 – much above the value of 4 m/s^2 (about 0.4 g) for the design earthquake[3].

(20) Similar considerations can be performed for San Luis Bay and Los Osos faults, but I consider the possible ground motion smaller than for the case of Shoreline and Hosgri faults.

(21) With regard to the San Simeon fault I would not like to go into details because the results for the Shoreline and Hosgri are controlling the case.

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[2] The difference between the numbers 3.99 and 4.00 are negligible compared to all the errors involved.

[3] Here I assumed an epicentral distance of the earthquake from DCPP of 10 km as a reference which is in fact too big in the present case of about 5 km and half a kilometer for the Hosgri and Shoreline faults, resp. This estimation is based on the new data and differs from the estimation I gave in my previous report.

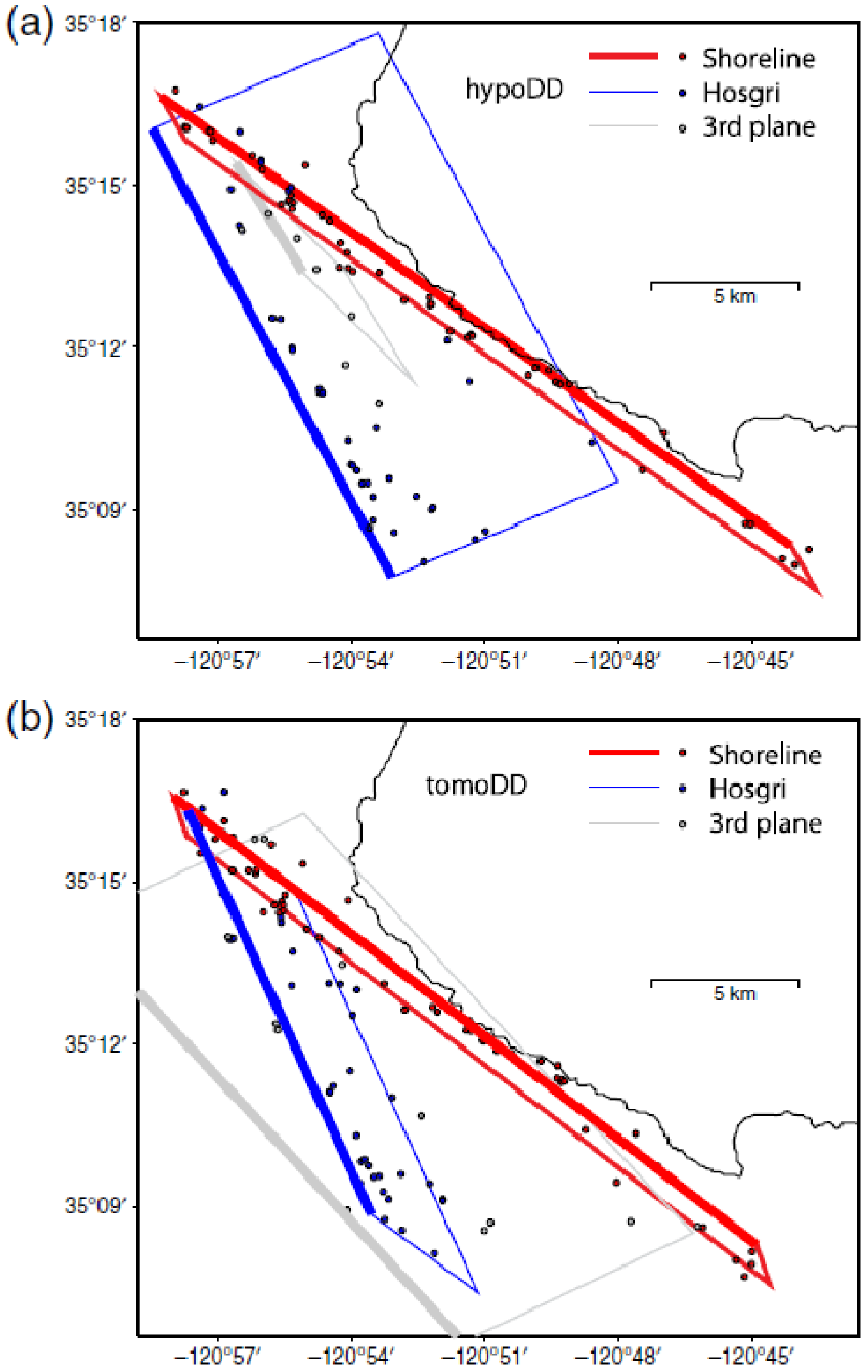


Figure 4. Earthquake relocations and Optimal Anisotropic Dynamic Clustering (OADC) fault plane solutions. The mean fault plane orientation for each of the three planes identified by the OADC algorithm is shown projected into map view, with the top edge indicated by a thicker line. Earthquake locations, circles, with the color matching the color of the plane to which OADC assigns the event. (a) Earthquake locations found using hypoDD. (b) Earthquake locations found using tomoDD. The color version of this figure is available only in the electronic edition.

Fig. 3. Fault plane intersection Hosgri and Shoreline (from Hardebeck, 2013).

3. The role of the site conditions

(22) With the term ‘Site Conditions’ the properties of the soil / rock below the site down to a couple of 100 meters are summarized. We observe different reactions to ground shaking (seismic wave) if the rock below is soft/weak or strong/hard. We call it the response function or damping. In both cases the high frequencies are not affected, but the deeper frequencies. And between 1 Hz and 10 Hz we find a resonance peak. Thus, if the rock is hard, the resonance is quite small, and in case of the soft rock we find a strong resonance which may even lead to an apparent amplification of ground shaking.

(23) The relations of site conditions and response spectra are best demonstrated by figures from the Earthquake Engineering Handbook by Chen & Scawthorn (2003): Fig. 4 shows the peak ground acceleration for soft rock. Important is the variance both for the horizontal acceleration and the so-called return period which is a measure for the earthquake repeatability.

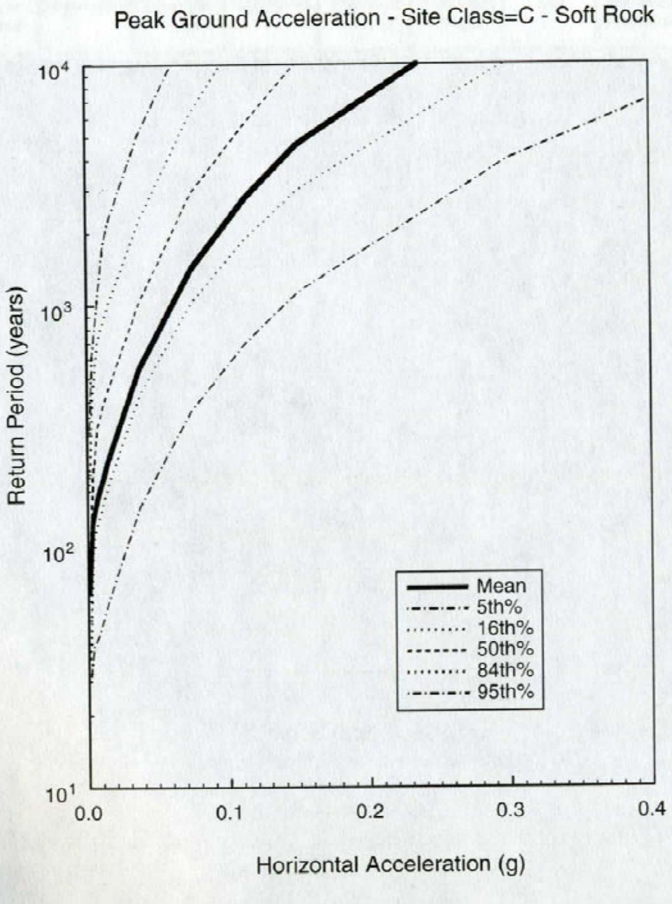


FIGURE 8.14 Example of a peak ground acceleration (PGA) hazard curve on a soft rock site class for a logic-tree seismotectonic model in a low seismicity region of Eurasia. Mean estimate and confidence intervals are shown by different line types in the legend of the figure.

Fig. 4. From Chen & Scawthorn, p. 8.28. Note scatter of confidence intervals in terms of horizontal acceleration and return period.

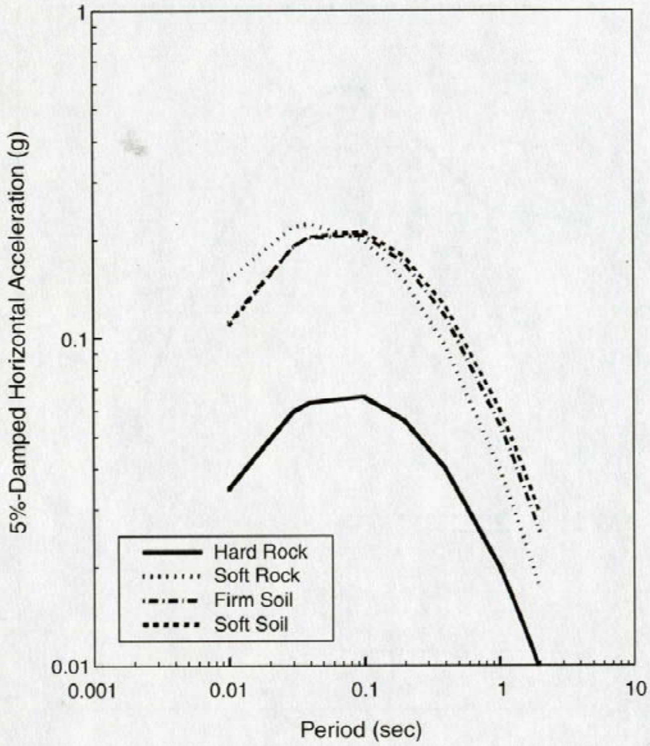


FIGURE 8.15 Example median uniform hazard response spectra (UHS) for a moderate seismicity site for various site classes.

Fig. 5. Uniform hazard spectra for different rock and soil classes; note the stable center period of about 0.1 sec (or 10 Hz) and the strong difference in horizontal acceleration (from Chen & Scawthcorn, 2003, p. 8.29.

(24) The Earthquake Engineering Handbook by Chen & Scawthorn (2003) covers all aspects of engineering seismology. There is no use of additional sophisticated methodology to describe the earthquake hazard. Concerning the real situation in California I would like to recommend the publications of the USGS.

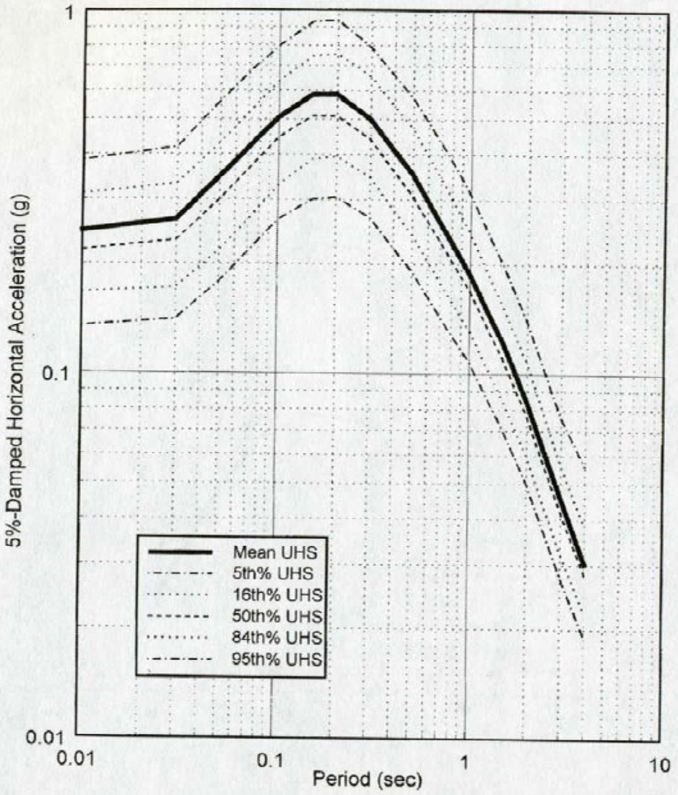


FIGURE 8.16 Example uniform hazard response spectrum for a single site class showing confidence limits obtained from a fully probabilistic application of the PSHA methodology. Note that because of lognormal distributions in many parameters used in PSHA, the mean estimate is always higher than median estimate.

Fig. 6. Response spectrum for a specific rock/soil class with error bars (confidence limits); note period of the maximum response and the scatter in amplitude (from Chen & Scawthorn, 2003, p. 8.30.

4. Two examples

(25) I cannot understand the provided estimations of ground shaking caused by earthquake sources very near to the DCPP: I consider them as by far too small. In order to support my opinion I point to two earthquakes of similar magnitudes which occurred north and south of the DCPP site, the **Loma Prieta earthquake** of Oct 17, 1989, M_w of 6.9, and the **Northridge earthquake** of January 17, 1994, M_w of 6.7.

(26) Both earthquakes caused not only many casualties but also very big damage on buildings which were even reinforced on the basis of the experiences of earlier events. Concerning Northridge the USGS writes on its homepage:

> Felt throughout much of southern California and as far away as Turlock, California; Las Vegas, Nevada; Richfield, Utah and Ensenada, Mexico. The maximum recorded acceleration exceeded 1.0g at several sites in the

area with the largest value of 1.8g recorded at Tarzana, about 7 km south of the epicenter.

(27) (http://earthquake.usgs.gov/earthquakes/states/events/1994_01_17.php). At an only 7 km distance from the source the acceleration measured was 1.8 g! How can the acceleration at much closer distances estimated for DCPP be less than 0.5 g?

(28) I think that these examples support my critique about the under-estimation of the hazard and, especially, about the ground shaking. Thus, 0.4 g for the design earthquake is simply ridiculous. The value has to be much higher, also in the sense of the NRC regulations which require the licensee to evaluate the strongest potential event that could occur nearest to the plant.

5. Conclusions

(29) The estimation of an acceleration of less than 0.5 g at the DCPP-site is not at all conservative: It is simply far too small. The acceleration to be expected is around 1 g or higher, if we follow the earthquake hazard given by different sources. Further, if we look at the earthquake hazard map of the USGS, we find at the site a 2% probability of exceedance of an acceleration between 0.4 g and 0.8 g in 50 years. The earthquake hazard involved at the site is also shown in the hazard map of the USGS (Appendage 3, USGS Earthquake Hazard Program, 2014).

(30) **All this leads to the firm conviction that the earthquake hazard estimations for the Diablo Canyon site are not at all conservative but simply too small. Thus, the *Different Professional Opinon* provided by Peck (2013) should be taken very serious pointing at the weak points of the licensing process of DCPP.**

Signature **Date**

October 8th, 2014

Gerhard Jentzsch, Dr. and Professor (ret.)

References:

Chen, WF, and C. Scawthorn (Eds.), 2003. Earthquake Engineering Handbook. CRC Press, Washington DC.

Hardebeck, J.L., 2010. Seismotectonics and fault structure of the California central coast, Bulletin of the Seismological Society of America **100 (3)**: 1031–1050.

Hardebeck, J.L., 2013. Geometry and earthquake potential of the Shoreline fault, Central California, Bulletin of the Seismological Society of America **103 (1)**: 447–462.

Leonard, M., 2010. Earthquake fault scaling: self-consistent relating of rupture length, width, average displacement, and moment release, Bulletin of the Seismological Society of America **100**: 1971-1988

Peck, M., 2013. Different Professional Opinion – Diablo Canyon Seismic Issues. Nuclear Regulatory Commission, 42p.

PG&E, 2014a. Central Coastal California Seismic Imaging Project-2014. Download: http://www.pge.com/en/safety/systemworks/dcpp/seismicsafety/report.page, Sept. 11, 2014.

PG&E, 2014b. Advanced Seismic Research Confirms Earthquake Safety at Diablo Canyon - Studies Provide an Unprecedented View into the Earth near Avila Beach Power Plant, September 10, 2014.

USGS, 2014. Earthquake Hazard Program (taken from homepage USGS).

Appendage (1)

Table 1-1 from Chapter 13 of the Seismic Report

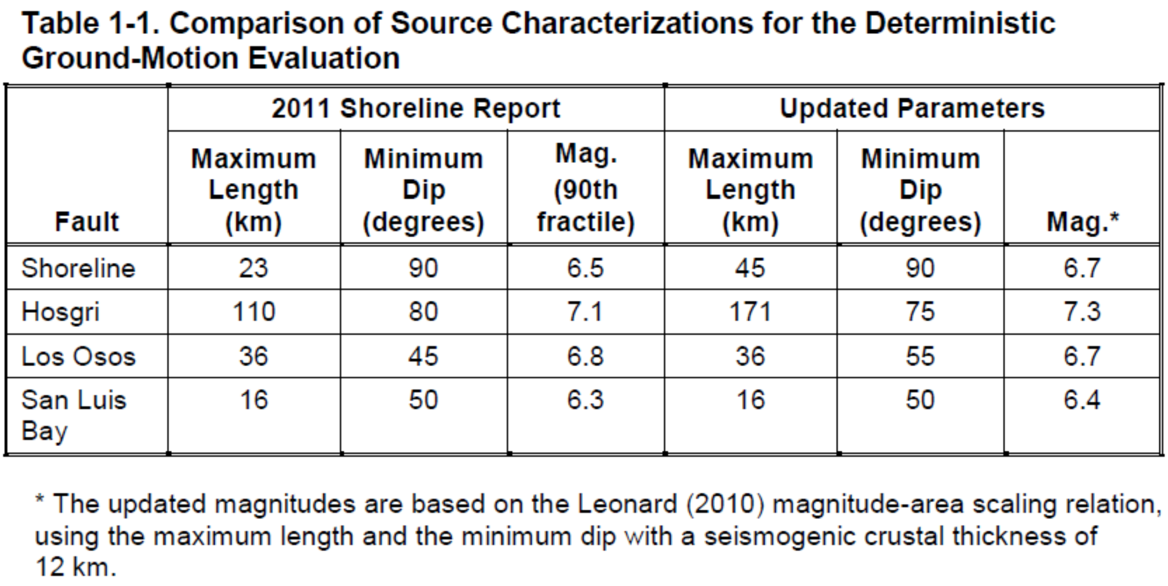


Table 1-1. Comparison of Source Characterizations for the Deterministic Ground-Motion Evaluation

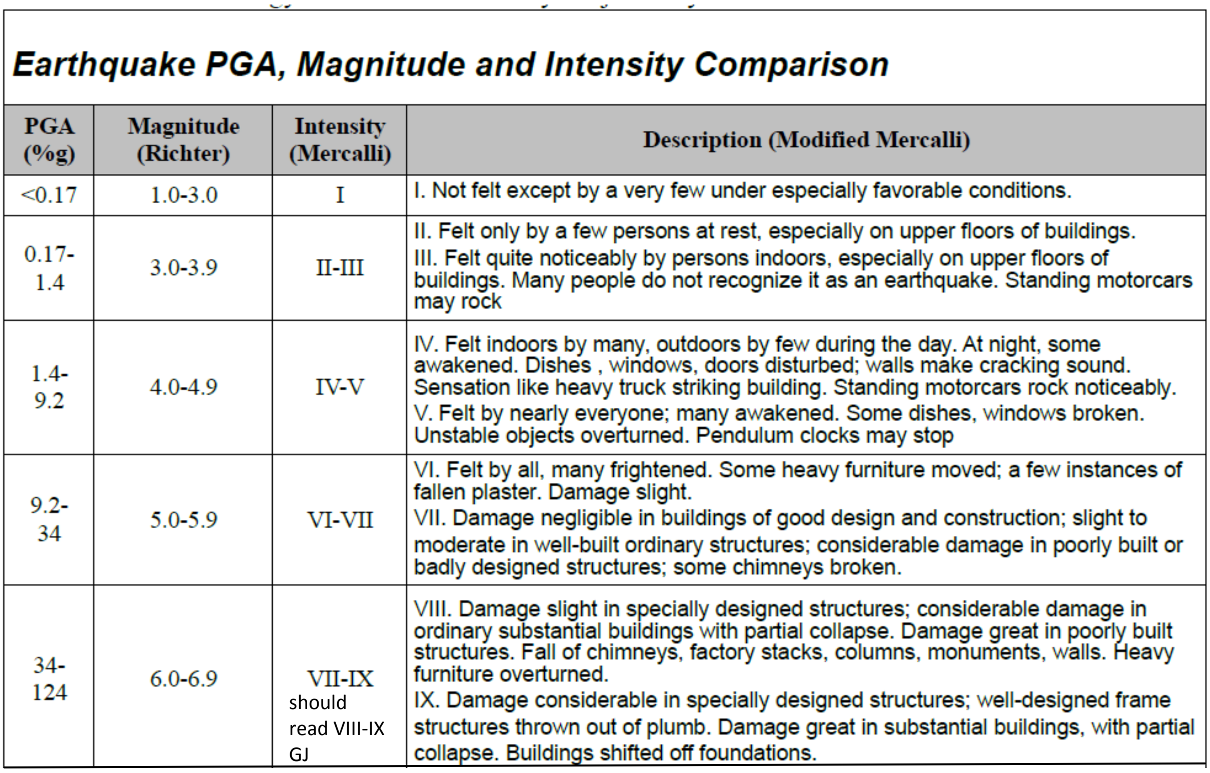
Fault	2011 Shoreline Report			Updated Parameters		
	Maximum Length (km)	**Minimum Dip (degrees)**	**Mag. (90th fractile)**	**Maximum Length (km)**	**Minimum Dip (degrees)**	**Mag.***
Shoreline	23	90	6.5	45	90	6.7
Hosgri	110	80	7.1	171	75	7.3
Los Osos	36	45	6.8	36	55	6.7
San Luis Bay	16	50	6.3	16	50	6.4

* The updated magnitudes are based on the Leonard (2010) magnitude-area scaling relation, using the maximum length and the minimum dip with a seismogenic crustal thickness of 12 km.

Appendage (2)

Table 1 taken from the Report by G. Jentzsch (Sept. 1st, 2014):
Diablo Canyon Power Plant: Estimation of the earthquake hazard

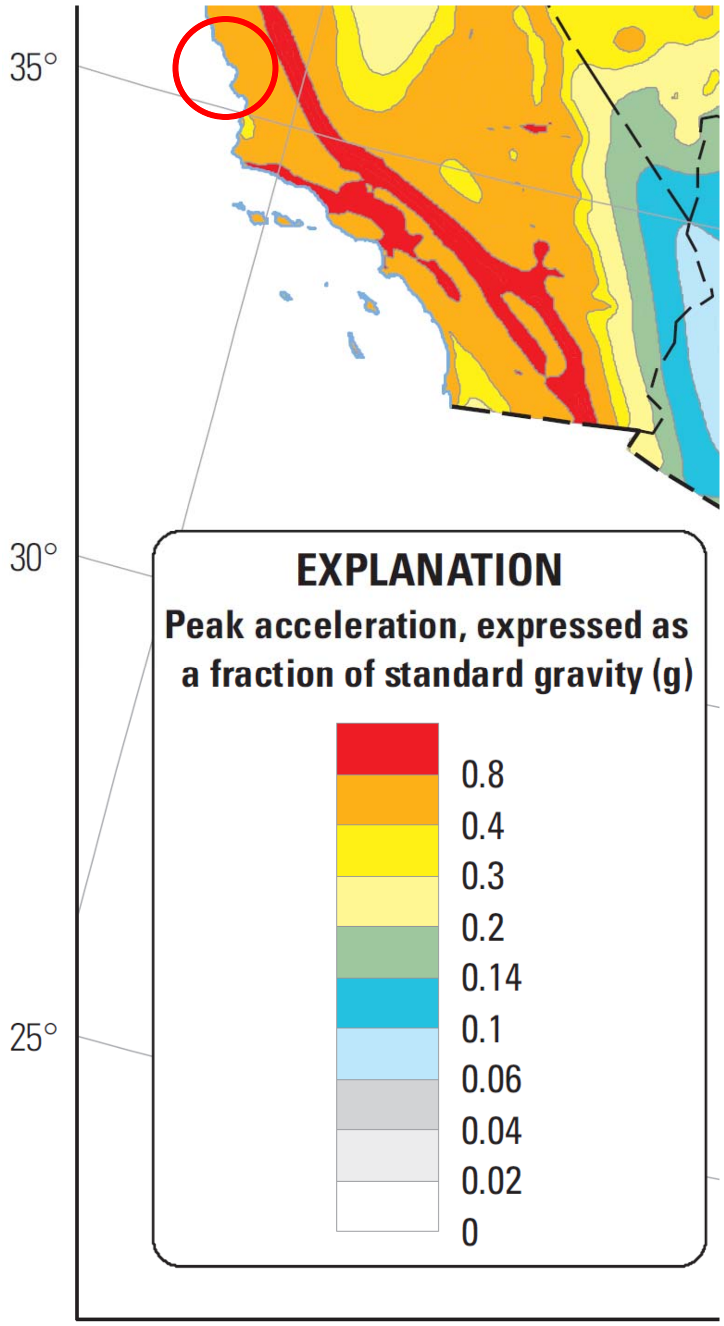
Table 1. Earthquake Magnitude and Intensity: *Earthquake PGA, Magnitude and Intensity Comparison* (excerpt of a table compiled by Jim Rich, Island County Dept. Emergency Management, 7/23/2013, with Eric Brooks, Deputy Director).



Earthquake PGA, Magnitude and Intensity Comparison

PGA (%g)	Magnitude (Richter)	Intensity (Mercalli)	Description (Modified Mercalli)
<0.17	1.0-3.0	I	I. Not felt except by a very few under especially favorable conditions.
0.17-1.4	3.0-3.9	II-III	II. Felt only by a few persons at rest, especially on upper floors of buildings. III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motorcars may rock
1.4-9.2	4.0-4.9	IV-V	IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes , windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motorcars rock noticeably. V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop
9.2-34	5.0-5.9	VI-VII	VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
34-124	6.0-6.9	VII-IX should read VIII-IX GJ	VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.

Appendage (3)



Section of US Hazard Map, USGS Earthquake Hazard Program (2014):

The DCPP site is marked by a red circle; as can be seen, the expected peak accelerations are between 0.4 and 0.8 g, corresponding to 390 to 780 gals or 0.39 to 0.78 m/s².

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Laboratory for Applied Geophysics
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06. Juli 1946:	born in Taucha near Leipzig, Germany
Presently:	work free-lance running my company and consulting
December 2013:	end of mandate as consultant of the German government
December 2009	appointment by the German Federal Ministry of the Environment as member of the Commission for Disposal of Nuclear Waste (and various subcommittees) of the German Ministry of the Environment.
September 2011	retirement from university as well as most of other commitments
April 2003	appointment as member of an international team led by IEER (Institute for Energy and Environmental Research, Takoma Park, Maryland, USA) to check the research of ANDRA concerning a repository for nuclear waste at Bure, France (on-going)
March 2003	start of the company GRAVITY CONSULT GmbH
November 2001	appointment as member of the Scientific Advisory Board of the governmental German Committee for Disaster Reduction (DKKV)
February 1999	appointment by the German Federal Ministry of the Environment as member of the German siting committee to develop a procedure for the search for a site of the German nuclear repository *(completed December 2002)*
14. November 1996	appointment Full Professor for Applied Geophysics at the Institute for Geosciences of the University of Jena
April 1996	research stipendium of JSPS (Japanese Society for Promotion of Sciences) for a two weeks stay at *Earthquake Research Institute* of the University of Tokyo (Prof. H. Ishii)
15. April to 13. November 1996	deputy Professor for Applied Geophysics at the Institute for Geosciences at the University of Jena
December 1993	appointment as member of the Advisory Board for the Termination of Nuclear Energy Use of the Provincial Ministry for the Environment of Lower Saxony (until 1998)
August 1991	appointment as *Fellow* of the IAG (Internationale Association of Geodesy)
07. September 1990	Professor for General Geophysics at the Institute for Geophysics, Technical University of Clausthal
26. Juni 1987	Professor for Applied Geophysics (Angewandte Geophysik) at the Geological Institute of the University of Bonn
12. Juni 1985	Habilitation for Geophysics
01. Februar 1977 to 31. Januar 1987	Assistent (until 1981) and Assistence Professor (Hochschulassistent) at the Institute for Geophysical Sciences, Free University of Berlin
02. Juli 1976	doctoral examination

01. Februar 1972 to 31. Januar 1977	scientific co-worker of Prof. Dr. O. Rosenbach, Institute for Geophysik
Januar 1972	Exam (Diploma) in Geophysics
Summer 1966	start at the Technical University at Clausthal: study of Physics
17. Februar 1966	graduation from Highschool (Abitur) in Offenbach / Main
Research Interests:	deformation and seismology (Earth tides, global dynamics, seismological network in East-Thuringia, Geodynamic Observatory Moxa), seismic hazard assessment, physical volcanology
Publications:	more than 50 papers during the past 5 years; 25 of them in reviewed journals
National and international activities	as chairman of working groups (IAG), convenor of special sessions (EGS Meetings, Earth Tide Symposium, national meetings), reviewer for the German Research Soc. and different scientific journals
2003 - 2005:	President of the German Geophysical Society
2003 – 2011	President of the Earth Tide Commission of the IAG
Memberships:	German Geophysical Society, Geologische Vereinigung, European Geophysical Union, American Geophysical Union

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Remark: Besides the memberships in the Advisory Board of the Ministry of the Environment, Lower Saxony, the German siting committee and the DKKV, as well as the co-operation in the IEER international advisory group,

- I wrote numerous reports concerning the earthquake hazard of sites of nuclear installations in Germany (from 1990 until present);
- during an official visit in 2001 concerning the US nuclear repository plans I talked to many individuals and organisations, as well as NGO's in Washington, D.C., and Las Vegas, and
- I visited the US-project Yucca Mountains, where a nuclear repository was under construction;
- In 2001 I also joined an official visit of the Swedish nuclear repository project at Oscarsham, and I talked to many individuals from national organisations and NGO's .