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Advisory Committee on Reactor Safeguards
U. S. Nuclear Regulatory Commission
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Subject: Meeting of ACRS Sub-Committee on GETR
Sunol, California, June 16-17, 1980

Dear Dr. Kerr,

Since the November 14th meeting of the GETR sub-committee, the positions of the NRC staff and of GETR and their consultants with respect to seismic design parameters and danger of damage to the GETR reactor structure by faulting have closely approached each other. The agreed upon design criteria, if I understand correctly, is a 0.75 g effective horizontal acceleration related to a possible earthquake on the Calaveras fault, and a 0.6 g seismic event plus a one meter offset occurring simultaneously on an as yet undiscovered or undeveloped shear, related to a somewhat illusive Verona fault.

It seems to me to be generally accepted that the greatest seismic danger arises from the proximity of the reactor to the Calaveras fault, approximately 3.5 kilometers to the west. At the November 14th meeting Dr. Charles Richter testified that the largest vertical acceleration which would be expected at the site is about 0.5 g from an earthquake in the magnitude 6-7 range on the Calaveras fault. At the Sunol meeting Dr. William Hall, consultant for the staff recommended using an acceleration of 0.6 to 0.75 g for use in anchoring to REG. guide 1.60 spectra or NUREG-CR 0098 spectra, with 0.6 g being the most reasonable and 0.75 g suggested for conservatism. It seems to be generally agreed that no fault motion would be transmitted to the site from movement on the Calaveras fault.

Much of the discussion related to seismic design centered on the characteristics of the B1-B3, B2 and H shears which are presumed to be components of a Verona Fault zone. For this zone Dr. Hall favors a value of 0.35 to 0.40 g horizontal acceleration as being most reasonable, but selected a value of 0.6 g for conservatism, coupled simultaneously with a fault motion of one meter in any arbitrary direction. Mr. John Reed of Jack R. Benjamin and Associates presented a

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detailed probability analysis of the effects of a postulated Verona fault earthquake and offset. His model was based on the interpretation of data from trenches in the reactor site area. The trenches show no shears cutting Holocene deposits between the B1-B3 shear to the northeast of the reactor and the B2 shear to the southwest. Dating [by improved methods] of the soils beneath the reactor further suggests no shearing has occurred there in the last 120,000 to perhaps 300,000 years, or somewhere in the range of 10^{-5} to 10^{-6} years. Assuming the probability of an offset developing between existing shears B1 and B2 to be about ten percent and the probability of hitting the 72-foot diameter reactor to be about $6x10^{-2}$, the probability of a newly developed shear hitting the reactor is in the range of $3x10^{-7}$ to $6x10^{-6}$ per year. Another probability model was developed by L. L. L. -- Terra Corp., consultants to the staff, and comments on the assumptions made in calculating probabilities were given by Dr. D. B. Slemmons, consultant to the U. S. Geological Survey. Although there seemed to be some disagreement about the best probability model to be used, it was agreed that all models gave approximately the same results. Hence, the probability analysis would indicate that the assumed seismic and fault displacement requirements related to the Verona system are conservative to highly conservative.

The U. S. Geological Survey adopts a more extreme position, suggesting that a sudden offset as great as 3 meters might occur beneath the reactor, based on their interpretation of the largest observable displacements on the B1-B3, B2, and H shears and on a re-interpretation of the limiting ages between displacements imposed by interpretation of the ages of various soil horizons. An extensive presentation by Dr. R. J. Shlemon, a recognized soils expert, convinced me, at least, that the bounding ages for displacement events and the one meter maximum displacement in a single event determined by his work were more reasonable than the assumptions presented by the U.S.G.S.

My views with respect to the inappropriateness of using the San Fernando earthquake as a model for expected events on the Verona shear system were set forth in my letter after the November 14, 1979 meeting of the GETR sub-committee. In this respect I am in agreement with Drs. Page and Thompson, and nothing presented at the June, 1980 meeting in any way weakened this opinion. To review briefly, the GETR site and the Verona shear system lie at the southwest margin of the rhomboid-shaped Livermore basin, filled with Miocene and younger sediments. Deep alluvium near the center of the basin suggests that subsidence may still be continuing there. The south and southwest margins seem to show recent and perhaps continuing uplift relative to the basin center, about ten kilometers to the northeast of GETR. The length, width, and nature at depth of the Verona shear system are all unknown at present. However, an origin of the observed shears by faulting is compatible with the regional stress anticipated for this part of the basin. The major fault systems bounding the Livermore basin, i.e. the Calaveras on the west and the Greenville system on the east, exert a clockwise rotational strain and an effective north-south compression on the sediments within the Livermore basin. The Verona system of shears at the southwest edge of the basin dip into the sediments toward the basin center. Whether these combine at depth into one master thrust fault, or represent widely dispersed motions on small shears in response to the north-south compression, is not yet known.

Similar deep sediment-filled basins in southern California also reflect north-south compression. These basins are petroliferous and have been extensively drilled. Numerous thrusts have been identified related to uplifts of faulted segments both within and at basin margins. Some of the thrusts in sediments are known to be active and are characterized by slow, aseismic creep, in some cases shearing off well casings intersected by the faults in a period of a few tens of years. These occurrences have been well publicized, but I am unaware of any record of sudden surficial displacement related to movement on the shears. These observations would favor a slow creep type of motion during the generation of the Verona shears which likewise are related to the deep sediments of the Livermore trough. This model seems much more realistic than that of the San Fernando earthquake, related to upthrusting of crystalline rocks along a major fault in a great bend of the San Andreas fault, a region characterized by high rates of tectonic movement and seismic activity. For these reasons I believe the occurrence of a magnitude 6 earthquake on a Verona fault is improbable and therefore highly conservative.

The stress field giving rise to faulting is such that, for a given depth the compressive stress perpendicular to the fault surface is greatest for thrust faults, least for "normal" or gravity faults, and intermediate for strike-slip faults. Faults with large displacement develop a well defined shear surface or zone, very thin compared to the active length of the fault. Because of the relatively high compressive stress across the fault, and the work involved in forming discrete shears, this relationship is particularly characteristic of thrust faults.

The set of shears identified as the Verona fault zone appears to have a maximum strike length of about eleven kilometers. If it is assumed that the fault zone is bounded by the B1-B3 and H shears, the zone is one kilometer wide at the surface. Using the dip of the shears found in the trenches, the shear zone is about 400 to 500 meters thick. If the dip steepens to 45°, the thickness of the fault zone could be larger, up to about 800 meters. The length to width ratio is thus far out of line with what one sees in well exposed examples of thrust faults such as the Coast Range and Log Springs faults of the northern California coast ranges, the Champlain and Pine Mountain thrusts of the Appalachians, and many others.

If the Verona shear system is a well organized thrust fault at depth, it has had only small displacement since deposition of the exposed portion of the Livermore gravels, so small that the movement has not been concentrated in a principal disruption plane, but is distributed along widely spaced shears. This is not the normal behavior of an historically active seismic fault, nor does it suggest that large sudden surface displacements are to be expected at the GETR site.

At the Sunol meeting W. L. Ellsworth made an important presentation on the seismicity of the Livermore valley, California, region, 1969-1979. Fault-plane analyses of the small earthquakes observed give results compatible with the regional strain field characterized by north-south compression, confirming the inference that the Verona shear system could be related to a thrust fault at depth. For that decade, virtually all the significant seismic activity lay outside the Livermore basin, being concentrated on the Calaveras and Greenville faults to the north of the basin, and to the south of the basin on the Calaveras and a broad seismically active zone south of the Las Positas fault. Fault plane solutions of small events within the basin indicate dominantly strike-slip movements compatible with movement on the bounding Calaveras, Greenville and possibly Las Positas faults, but four of the displayed events were characteristic of thrust faulting, reflecting north-south to northeast-southwest compression. Two thrust type movements at depths of four and six kilometers could have originated on a single "Verona" fault dipping 45° to the northeast.

The seismic activity for the past decade in the vicinity of the "Verona" fault has a northeast-southwest alignment, parallel to the Las Positas fault, and if I interpret the data correctly, includes both strike slip and thrust faults. One thrust fault determination is northwest of GETR and between the presumed trace of the Verona fault and Calaveras fault. Whether this is properly a part of an already wide "Verona system" is a matter for speculation. In any case, at the present information level the data represent both thrust and strike-slip fault motions on apparently localized shears within and near the base of the sediments in the Livermore basin and do not necessarily correspond with extensive discrete thrust faults and strike slip faults. It is quite possible, however, that another two data points could define a discrete Verona thrust fault at depth. In any case, the U.S. Geological Survey is to be commended for carrying out this study. It is extremely important that this and similar programs be continued for areas surrounding nuclear plant sites in seismically active regions.

With regard to the landslide investigation required by the staff, it is my understanding that the plan submitted by GETR for accomplishing the investigation has been approved by the staff. The investigation has two objectives: 1) to analyze the probability of major landslides occurring along the existing shears found by trenching and 2) the possibility of large local landslides developing on the hills above the reactor.

With respect to the danger from local landsliding one can observe that the hills above the reactor show the typical rounded slopes and local "cattle track" microterraces characteristic of hills developed on sedimentary rocks in this part of California and related to slow, intermittent soil creep. No landslide scars of significant size were noted. Tests directed toward the determination of movement of the toe of larger shears should, of course, make allowance for surficial creep. A determination of the engineering characteristics of the materials in the hill, and of materials from the shear zones, if they can be obtained, should give definitive answers to the probability of landslide hazard.

Respectfully submitted.

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