R E P O R T

TO THE

SACRAMENTO MUNICIPAL UTILITY DISTRICT

ON

SEISMIC HAZARD AT THE CLAY SITE
(RANCHO SECO SITE)

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By PERRY BYERLY

August 30, 1967

Report to the Sacramento Municipal Utility District on Seismic Hazard at the Clay Site.

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Seismic Hazard at the Clay Site.

Introduction.

In estimating the likelihood of earthquakes in the area I shall consider two aspects.

1) The record of the intensity of earthquakes felt in the area in the recorded past, considering that the future will be like the past in geologic action. Changes in geologic regime do not occur abruptly (in a few hundred years).

2) Epicenters located in the area which might indicate the presence of active faults along wich surface displacement might occur.

Technical Terms Used.

Focus: The point in the earth at which the earthquake disturbance starts - in the idea of earthquake cause held in the United States, this is the point where a fault starts to break.

Epicenter: The point on the surface of the earth above the focus. (It is only rarely that an earthquake is accompanied by a definite surface fault break.)

Intensity: The intensity of the earthquake at a particular place is measured at that place by the shock's effects on the geologic terrain there, the works of man there, and the effects on people there.

For a given earthquake, the intensity varies from place to place, in general being greater a) nearer the epicenter, b) on loose ground, c) on water soaked ground, d) where ground is already unstable, as some hill slopes, e) where the works of man are shoddily built, and f) in the lower ranges of intensity, on the awareness and sensitivity of the persons present at the place. The intensity measures the damage caused by, and the minor effects of the earthquake regardless of which of the above criteria is the cause. Table 1 presents the intensity scale in use now in the United States. (See next page.)

Magnitude: The Richter Scale in theory gives a single number to describe a given earthquake. Hopefully it bears a definite relation to the energy released at the source. It is obtained in a number of different ways at present and varies somewhat with the seismographic station reporting it. Fundamentally it involves the measurement of the amplitude and perhaps the period of a certain seismic wave recorded on a seismograph. It was defined originally as the logarithm to the base ten of the maximum amplitude recorded on a Wood-Anderson seismograph one hundred kilometers from the epicenter. Thus, a shock of magnitude eight should in no sense be thought of as "twice" one of magnitude four. The relation between magnitude and energy is quite uncertain, and the relationship of damaging potential of the earthquake as a function of its total energy and the distance from the source is known.

Table I

MODIFIED MERCALLI INTENSITY SCALE OF 1931
(Abridged)

1. Not felt except by a very few under specially favorable circumstances. (I Fossi-Forel Scale.)

2. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Fossi-Forel scale.)

3. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel scale.)

4. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably. (IV to V Rossi-Forel scale.)

5. Felt by nearly everyone, many awakened. Some dishes, windows, etc. broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel scale.)

6. Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel scale.)

7. Everybody runs outdoors. Damage <u>negligible</u> in buildings of good design and construction; <u>slight</u> to moderate in well-built ordinary structures; <u>considerable</u> in poorly built or badly designed structures; some chimneys broken. Noticed by persons

driving motorcars. (VII Rossi-Forel scale.)

8. Damage slight in specially designed structures; considerable in ordinary substantial builds with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed. (VIII+ to IX Rossi-Forel scale.)

9. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX+ Rossi-Forel scale.)

10. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from riverbanks and steep slopes. Shifted sand and mud. Water splashed (slopped over banks.) (X Rossi-Forel scale.)

11. Few, if any,(masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

12. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into air.

"Modified Mercalli Intensity Scale of 1931", by Harry O. Wood and Frank Neumann, Bulletin of the Seismological Societ of America, Vol. 12, No. 4, December 1931.

Seismic History of the Area.

For early earthquakes we depend on two earthquake catalogs: (References 1 and 2 which together cover the period 1769 through 1928.) The thoroughness of the coverage depends of course on the scatter of population, the existence of diary keepers, the existence of newspapers, the existence of church records, etc.

From 1929 on we depend on references 3 and 4 which give an excellent record kept by the United States Coast and Geodetic Survey. For the earthquake of April 18, 1906, we have in addition reference 5.

To define the "area" we need to take into account the location of towns in existence for a long time, from which early records are available. In general we are guided by the map accompanying the Sacramento Municipal Utility District report of June, 1965, entitled "Clay Plant Site". Sacramento, Jackson and Lodi are key points in older records. In general the area is a circle of about 25 miles radius although Sacramento is a few miles farther.

In general we shall consider only shocks for which the intensity at some point in the area was over IV, that is, the effect was something more than rattling windows. We take V and above: moveable objects were displaced or overturned, etc.

In Table II we list such shocks with comments.

Table II.

1850, August 4.

"Smart shocks in Sacramento ". Reference 1 calls it V.

1857, January 9. (The great Fort Tejon earthquake.)

"Very Severe at Sacramento" (Ref. 1)

"San Francisco Bulletin", Jan. 9, 1857: "By Magnetic Telegraph: Earthquake felt in Sacramento: A smart shock of earthquake was experienced here this morning at half past seven o'clock. No damage was caused."

1864, May 20.

"Very severe at Sacramento". Higher than IV?

1868 October 21. (The Haywards earthquake.)

V in Sacramento where plaster was cracked. (Water in river receded, shoaling ships, then came back with a rush.)

1869, December 27. (Origin in Nevada, near Virginia City.)

Ref. 2 says no damage in Sacramento.

Ref. 1 says houses thrown down -- denied by Ref. 2.

The "Sacramento Union" for this date says "Door bells were rung and chandeliers and everything else that could do so swung to and fro." No damage mentioned.

1872, March 25. (The great Owens Valley Earthquake.)

Sacramento: "Severe, but no damage done." Sutter Creek: Severe.

1881, April 10.

Ione: V?

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1889, May 19. (Centered near Antioch.)

V at Lodi where goods were shaken from shelves.

Sacramento: "quite severe -- no damage".

Ione: "Many awakened."

1892, April 19. (Centered in Solano County.)

VI at Sacramento where one chimney went down and some plaster.

1892, April 21. (Centered near Winters).

VI in Sacramento where many chimneys were thrown down and windows were broken. Books were thrown from shelves.

1902, May 19.

Probably V at Sacramento and Ione.

1909, June 22.

VI at Sacramento: Plaster down.

1915, October 2. (Pleasant Valley, Nevada, earthquake)

V at Sacramento.

1933, June 25. (Center near Wabuska, Nevada.)

V at Lodi where plaster was cracked and goods thrown from shelves.

V at Lockeford where plaster was cracked.

V at Herald where small objects were moved.

V at Sacramento where vases were overturned.

IV at Ione, Martell, and Ryde.

1948, December 29. (Verdi earthquake.)

V at Sloughhouse where books fell.

V at Sacramento and Galt where objects were disturbed.

IV at Jackson, Lodi, and Elk Grove.

1952, July 21. (Kern County earthquake.)

V at Sacramento where small objects were disturbed.

IV - V at Lodi. (Plaster cracked in one instance.)

II - III at Jackson.

1954, July 6. (Fallon earthquake.)

V at Lodi, Sacramento, and Galt.

IV at Sloughhouse.

1954, August 23. (Fallon, Nevada, shock.)

V at Lodi and Clements where objects were disturbed.

IV - V at Jackson and Sacramento.

1954, December 16. (Fairview Peak - Dixie Valley, Nevada, earthquake.)

High V - low VI at Jackson. (Vases overturned, books and pictures fell)

Low VI at Sacramento where a reservoir roof partially collapsed, plaster cracked, power cables were broken, vases overturned.

V at Sloughhouse where objects shifted, also at Lodi.

1955, October 23. (Walnut Creek shock.)

V at Ryde where knick-knacks fell.

V at Acampo, felt by all; pendulum clocks stopped.

IV at Victor and Waterman. Not felt at Jackson, Sloughhouse, Mather Field, West Sacramento.

1966, September 12. (Verdi epicenter.)

VI at Sacramento where plaster was cracked, furniture was shifted, windows were cracked.

V at places listed below. A special detailed study of this recent shock was made for this report.

Dillard, packaged goods off shelves.

Fish Hatchery (NNW of Clay) A fork fell from wall.

Florin, a lamp was knocked over.

Ione Valley, brushes shaken off shelf.

Latrobe, plants shifted on shelf - - pushed back by observer.

Lockeford, packages thrown from shelves.

Martell, a crack in corner of building between cement blocks.

Mather Field (southwest corner Bradshaw and California Streets), cans toppled from shelves.

Sloughhouse, cans shaken from shelves.

Thornton, a few packages fell from shelves.

Valley Springs, a jar of pickles fell and broke.

Wallace, a flower pot fell over.

At Clay and Lodi the intensity was IV, creaking of house at Clay was reported. At other towns in the area the intensity was IV and less. Jackson had an intensity of IV.

We see that the city of Sacrmanto tends to show intensities somewhat greater than Sierran foothill towns. This is consistent with the geologic foundation as discussed by Richter (reference 6) where the intensity he predicts is one grade lower at the Clay site than in Sacramento. He predicts IX in Sacramento and VIII in the Clay region. This is based on geologic foundation rather than past experience. I have included Sacramento in the list only because there are many reports from it in the early days.

In Table II we see that Sacramento has felt a shock of intensity definitely a high VI on April 21, 1892, (the Winters earthquake). Also there was a shock of intensity VI on April 9, 1892, (another shock centering in Solano County). There have been a few shocks of intensity low VI in Sacramento: December 16, 1954, (Fairview Peak, Nevada, shock), and September 12, 1966 (Verdi earthquake).

At Jackson in the foothill area, the Nevada earthquake of December 16, 1954, had an intensity of a low VI or high V, but the damage was less than in Sacramento.

For the shock of September 12, 1966, the intensity at Jackson was only IV, as it was at Clay.

In the Kern County earthquake of July 21, 1952, the intensity was V in Sacramento but only II - III at Jackson.

I feel that if we anticipate an intensity of VI at the Clay site we are definitely on the safety side. I suspect that intesity V is as high as will be experienced.

Epicenters.

We turn to reference 8 for epicenters in the region. The location of epicenters is reported since 1941 in this Bulletin.

I have searched for epicenters between latitudes $38^{\circ}.0$ and $38^{\circ}.6$, and longitudes $120^{\circ}.7$ to $121^{\circ}.7$. This area includes roughly Sacramento, Jackson and Lodi.

This area includes only one epicenter. It is rated as only "fair" as to location. It is

1961, August 2. Magnitude 2.5

38° 10' N, 121° 40' W.

This is near Rio Vista and Isleton and does not bear on our problem. The geologic data presented by Bechtel indicates that there are no active faults in the region of the Clay site and this is supported by the lack of epicenters for this short period.

Conclusions.

There is no reason to fear the breaking of a fault in the Clay site area. This is supported by the earthquake history of the area as well as by the lack of epicenters in the area for the last 25 years.

The earthquake shaking to be expected will come from shocks centering in other areas such as the San Andreas fault zone approximately 100 miles to the west. From the historical record and from knowledge of geologic foundation, we need fear no shocks of intensity greater than intensity VI. Hershberger (reference 9) draws a graph which suggests that the acceleration accompanying such an earthquake may be about 50 cm/sec^2 or 0.05 of gravity.

After reviewing my original report and recent exploration data obtained by Bechtel Corporation, I feel that the suggested surface acceleration of 0.1 g for design of Class I structures and 0.2 g for safe shutdown is most conservative. This

design value would correspond to an intensity of high VI to low VII on Hershberger's curve and should offer a large margin of safety for a reactor at the Clay site.

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References.

1) * Holden, Edward S., "A Catalogue of Earthquakes of the Pacific Coast, 1769 to 1897", Smithsonian Institution Miscellaneous Collections, 1087, Washington, 1898.

2) * Townley, Sidney D. and Allen, Maxwell W., "Descriptive Catalog of 1928", Bulletin of the Seismological Society of America, Vol, 29, No. 1, January, 1939

3) * "United States Earthquakes", an annual publication of the U.S. Coast and Geodetic Survey.

*Note that references 1 and 2 and reference 3 before 1931 use the Rossi Forel intensity scale rather than the Modified Mercalli Scale given in Table 1. Relations between the two scales in the range pertinent to our study are (reference 7)

Modified Mercalli	IV	V	VI	VII	VIII
Rossi-Forel	IV-V	V-VI	VI-VII	VIII-	VIII+

4) "Abstracts of Earthquake Reports for the Pacific Coast and Western Mountain Region", a quarterly issued by the U. S. Coast and Geodetic Survey.

5) "Report of the State Earthquake Investigation Commission, The California Earthquake of April 18, 1906", in two volumes and an atlas, published by the Carnegie Institution of Washington, 1908.

6) Richter, Charles F., "Seismic Regionalization", Bulletin of the Seismological Society of America, Vol. 49, No. 2, pp. 123-162, April, 1959,

7) Richter, Charles F., "Elementary Seismology", W. H. Freeman and Company, San Francisco, 1958.

8) "Bulletin of the Seismographic Stations", a quarterly issued by the Seismographic Station of the University of California, Berkeley.

9) Hershberger, John, "A Comparison of Earthquake Accelerations with Intensity Ratings", Bulletin of the Seismological Society of America, Vol. 46, No. 4, October, 1956.

ADDE"DUM TO THE REPORT ON "SEISMIC HAZARD AT THE CLAY SITE"

by Perry Byerly

I have been asked why I did not include the April 18, 1906 earthquake in Table II.

As stated on page 4, I was primarily looking for moveable objects displaced or overturned and as I interpret this no such effects were reported from the area in question. Oscillation of chandeliers and pendulums as well as slopping of water are resonance phenomena and often occur when earthquakes are barely felt. (The inclusion of reference 5 indicates that this earthquake was considered.)

However, I agree there should be an entry in the table for this famous earthquake. It should read

1906, April 18

Galt: "the shock lasted 45 seconds.

Ione: "awakened and alarmed people. No objects overthrown."

Sacramento: Chandeliers oscillated - clock stopt (sic), water was thrown from tank. One observer rated it V-VI Rossi-Forel which is V Modified Mercalli (Richter).

On the isoseismal map (reference 5) Clay is included in the V-VI Rossi-Forel area.

This addition in no way alters the conclusions of the report.