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SUBSIDENCE DETECTION AT CERRO PRIETO GEOTHERMAL FIELD BY PRECISION GRAVITY STUDIES

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Previous reports on the precision gravity effort at Cerro Prieto have emphasized the conduct of the gravity surveys conducted there, the data reduction procedures used, and the precision obtained. We wish to summarize this past work, and then proceed to our recent findings concerning the possibility of geothermally induced subsidence.

A permanent network of 60 gravity stations has been established in and adjacent to the producing field, with ties made to bedrock in the Sierra Cucapah and on Cerro Prieto volcano. Each station in the network has been occupied three or four times annually in separate loops, with four readings taken at each occupation. The first survey was made in early 1978, and the most recent one in the winter of 1980-81. The data collected from the four surveys (the initial survey and the three repetitions) were reduced to observed gravity differences by 1) calibrating the data; 2) removing tidal and drift effects; and 3) substracting algebraically the average value of each station occupation from the value on Cerro Prieto volcano. Standard deviations calculated for the differences for entire surveys ranged from 8 to 12 microgals, and standard errors for compared values from year to year for individual stations were on the order of 8-15 microgals. Thus any changes exceeding values of about 15 to 20 microgals are clearly significant. Attainment of these precision follows careful culling of the data for mistaken and extreme values, which increased the precision of the first two surveys significantly.

Two sets of results are evident from comparison of station from year to year. The first result is the unmistakable subsidence associated with the Victoria earthquake of 1980. The maximum subsidence was associated with more than 80 microgals of gravity change in the southeastern part of the field, compared with the volcano base station. This equates to about 30 to 45 cm subsidence (depending on the model chosen), a value range corroborated by the leveling efforts of Comisión Federal de Electricidad. The major anomaly is spatially associated with, and occurs east of, the Cerro Prieto Fault, but smaller changes of 20 microgals or more are found in the older part of the field west of the fault. Three possible causes could account for the observed gravity variations: 1) liquefaction and lurching of surficial materials; 2) actual tectonic changes; and 3) subsidence of deeper channelways in the producing zones wich show net mass loss but had not yet subsided completely because of their fundamental strenght. In the latter case, the earthquake would have weakened the zones involved. It is probable that some of the subsidence can be attributed to geothermal causes because of the close spatial associations between the geothermal field and the resulting anomalies. Some tectonic component apparently rose with regard to the Sierra Cucapah, as shown by a decrease in gravity of 20 microgals. And, some component of subsidence cannot be ruled out due to surficial changes, on the basis of available data.

The other result which is significant and perhaps of more importance to geothermal production, is the significant change at several stations in the older part od the field. These can only be identified by comparing the first and third year data, the changes in one year being too small to be significant. The pattern of the changes is elliptical in a northwesterly-southeasterely direction, parallel to the structural grain and faulting in the region. Although some natural recharge of the field is taking place, apparently it is not keeping pace with production. This subsidence is most likely geothermal in origin because of its local development and presence within the field. Electrical production during the interval from early 1978 to early 1980 was at 75 megawatts; with increased production and continued lack of reinjection, the phenomenon may increase in magnitude over a biannual interval.

Some gravity changes were also observed in the northeaster part of the study area between early 1979 and early 1980. The stations involved are well outside the field, and closer to the Imperial Fault than any others in the network. The Mexicali eartquake of October, 1979, is the probable cause of these changes, which are again observable in CFE and DETENAL leveling data.