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VERTICAL MOVEMENT ALONG THE CERRO PRIETO TRANSFORM FAULT, BAJA CALIFORNIA, MEXICO—A MECHANISM FOR GEOTHERMAL ENERGY RENEWAL

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DISCLAIMER

Data from 53 geothermal wells to depths of 1 to 3 km on either side of the right-lateral Cerro Prieto fault, as well as geophysical data indicate vertical displacements of this fault of 400 to 600 m. This episoidic vertical movement has offset deltaic sandstone reservoirs that are primarily at 1200 m and 1800 m depth and contain 250°C to 345°C water. A major fracture system for convective fluid movement has been thus maintained, with production at 150 megawatts (MW).

While considerable attention has been given to the San Andreas fault system in California,[1,2] the thick sequence of Colorado River deltaic sands, silt, and clays and the previous lack of a regional seismic network in the Mexicali Valley has hampered surface geologic investigations of faults in northern Baja California, Mexico. In addition, research on vertical movements, while recognized as important, has tended to be overshadowed by more easily made observations documenting horizontal movements which amount to tens of km. Precise geodetic surveys in the Imperial Valley 75 km north of the Cerro Prieto geothermal field indicate vertical changes as great as 3.5 cm per year.[3] Previous studies by Elders et al.,[4] and Palmer et al.,[5] have synthesized information indicating a segmented strike-slip (or wrench fault) system in the Imperial Valley. Transform faults of the oceanic genre have been reported in the Gulf of California 200 km south of Cerro Prieto by Lawver et al.,[6] Sharman et al.,[7] and earlier studies. The Cerro Prieto fault and the associated geothermal field lie near the transition between continental type crust of the Imperial Valley and the crust of the embryonic spreading center in the Gulf of California (see Figure 1).

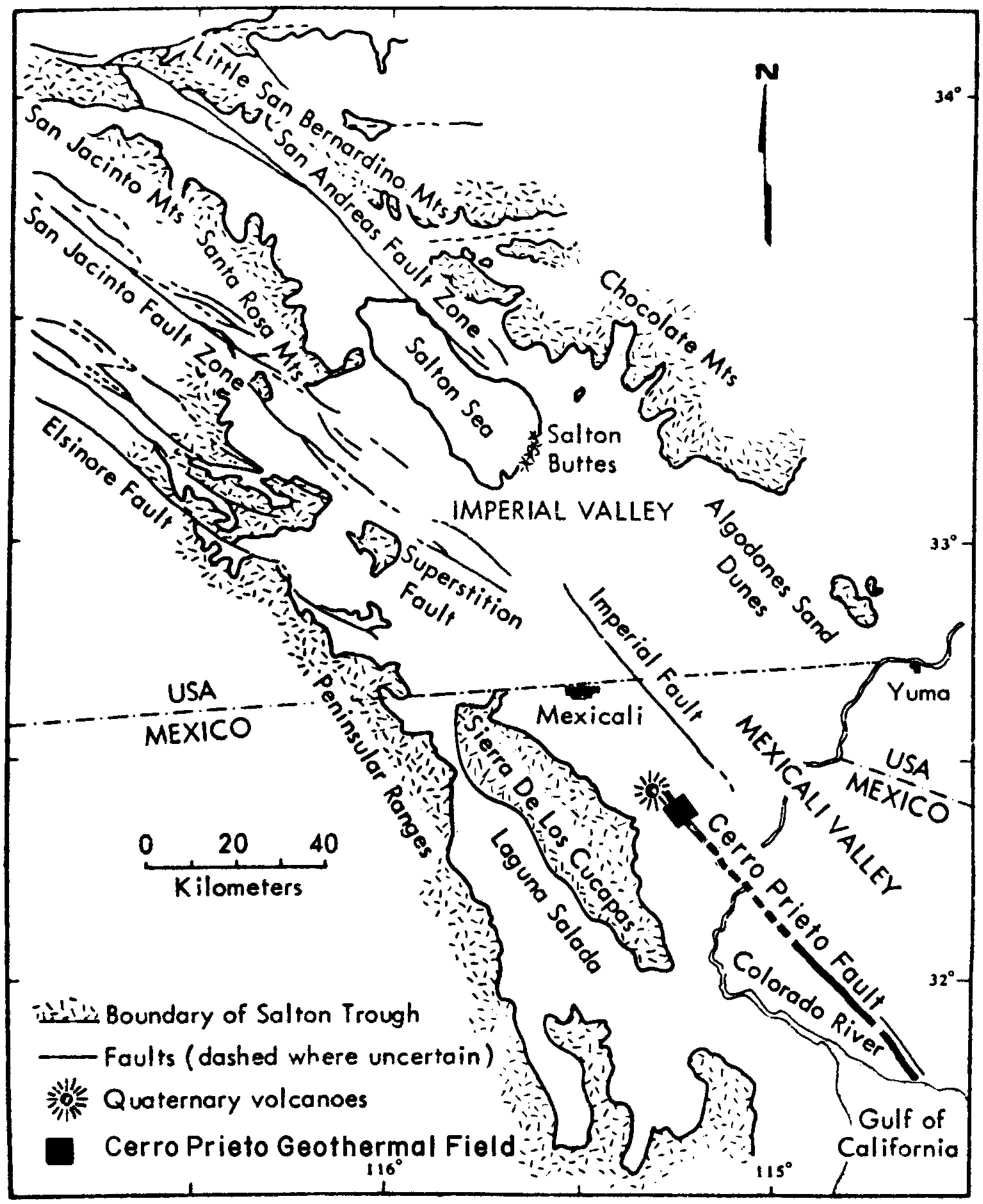

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Figure 1. The Cerro Prieto fault and geothermal field, and other faults in the San Andreas fault system.

Interpretation of a suite of geophysical studies that includes precision gravity, seismic reflection and refraction, aeromagnetics, dipole-dipole resistivity, self-potential and magnetotellurics agrees with a downthrown northeastern block of the Cerro Prieto fault.[3] Well cuttings and geophysical log analyses from production wells, as shown in Figure 2, have revealed a layered system that indicates 580 m of vertical offset of Reservoir A. Mylonitized granodioritic basement penetrated by three wells peripheral to the main field at depths of 2547 m, 2722 m, and 1478 m is believed to be similar to Miocene and older (20 Myr) crystalline basement of the Imperial Valley. The Cerro Prieto basement is markedly shallower than the suggested flat basement at 6 to 7 km for the central Imperial Valley.[4]

Ongoing micropaleotologic studies of well cuttings, along with paleomagnetic and radiometric dating of the nearby Cerro Prieto rhyodacitic volcano may provide a finer scale for determining movement rates. Orlieb[9] reports 15 m of recent vertical movement along a surface scarp 60 km southeast of the geothermal field. This fault, which is readily visible on satellite photograph[10] and Landsat imagery, appears to connect with the Cerro Prieto fault both of which trend N 40° ± 5° W. Although the rates of horizontal deformation have not yet been resolved in the Mexicali Valley, a trilateration study across the Imperial Valley suggests 50 ± 15 mm/yr of relative right lateral slip distributed between the San Andreas, San Jacinto, and Elsinore faults during the period 1973-1977.[11] Since the interaction of cold and thermal waters and hot reservoir rocks in the Cerro Prieto field contribute to silicate and carbonate mineral clogging of microfractures and pore spaces,[12] renewed fracturing along the fault zone must take place to sustain the reservoir. Scanning electron microscope studies of well cores and cuttings testify to repeated sealing, healing and refracturing.

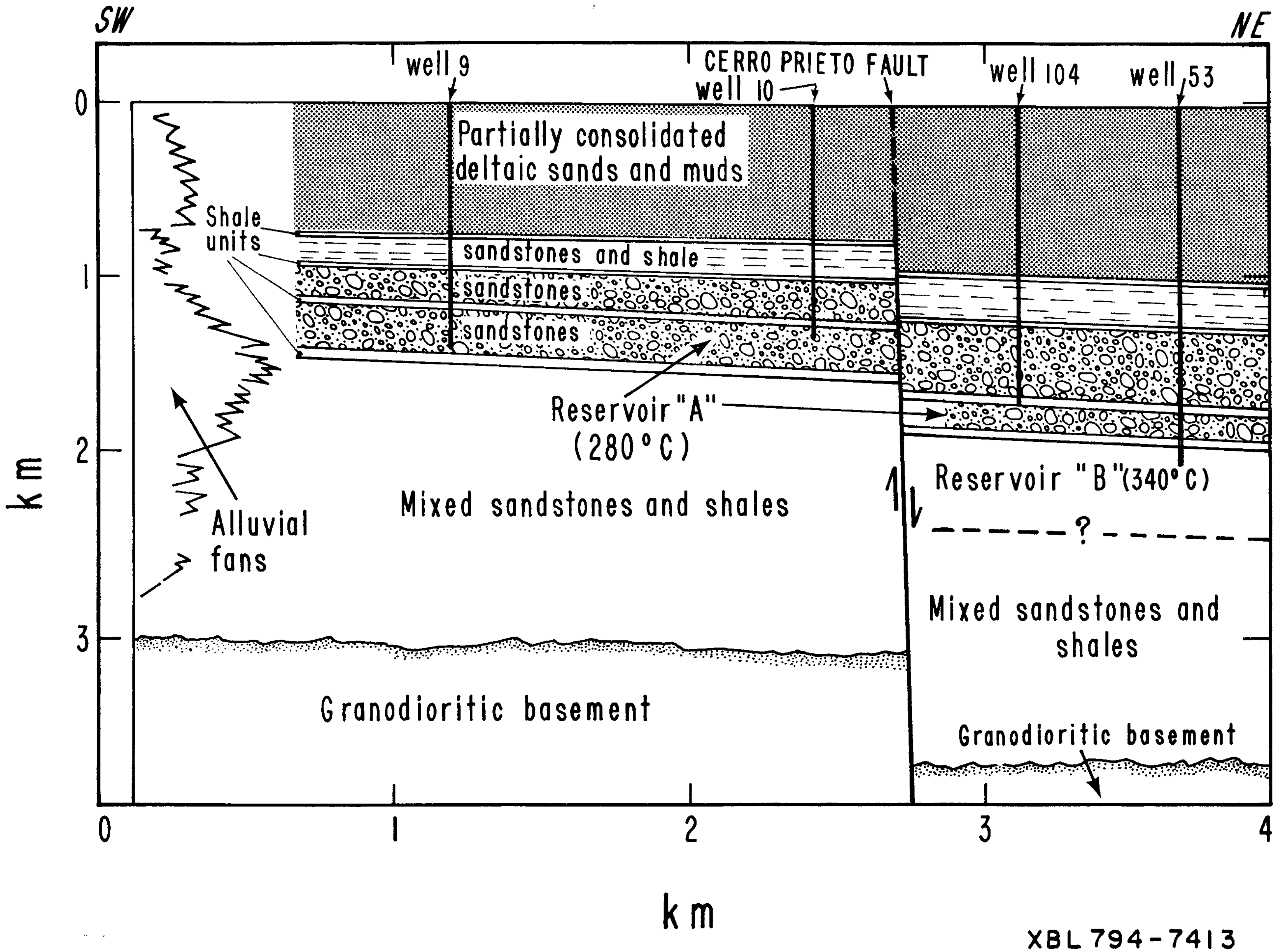

Figure 2. Simplified geology of the Cerro Prieto geothermal field, Baja California, Mexico. Note the 400 to 600 m vertical displacement downthrown to the NE along the Cerro Prieto fault. Interpretation based on logs from 53 wells, in addition to geophysical surveys.

The Cerro Prieto fauls is a result of regional tectonism and serves as a direct link between a deep heat source and the geothermal reservoir in deltaic channel and fringe bar sandstones.

Dynamics of strike-slip faults in the San Andreas system have been reevaluated by Dickinson and Snyder,[13] Koide and Bhattacharji,[14] and by Freund,[15] as to whether or not they are transform faults. Drilling by Mexican scientists along the active Cerro Prieto fault segment has provided a new datum, namely, well-documented vertical displacement as a mechanism for redistributing regional strain. Perhaps the Cerro Prieto fault may best be considered a hybrid style between the Gulf of California transform faults and the very long portions of San Andreas transcurrent system. A characteristic of such a hybrid would be a vertical to horizontal movement ratio of 1:5 or 1:10, with geothermal fluids rather than leaking magma. Future geothermal energy exploration in sedimentary sequences may find it advantageous to focus on such deep seated hybrid faults as the one at Cerro Prieto.

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REFERENCES

1. Crowell, J. C., ed., Spec. Report 118; Calif. Div. Mines & Geology; 258 p. (1975)

2. Blake, M. C. Jr., Campbell, R. H., Dibblee, T. W. Jr., Howell, D. G., Nilsen, T. H., Normark, W. R., Vedder, J. C., and Silver, E. A., Amer. Assoc. Petrol. Geol. Bull., 62, 344-372 (1978).

3. Goldstein, N., Majer, E., McEvilly, T., Wilt, M., Corwin, R., Lofgren, B., and others, First Symposium on the Cerro Prieto Geothermal Field, Abs. and papers; Lawrence Berkeley Laboratory, Univ. California, 48 p. (1978).

4. Elders, W., Rex, R., Meidev, T., Robinson, P. T., and Biehler, S., Science 178, 15-24 (1972).

5. Palmer, T., Howard, H. H., and Lande, D. P., Lawrence Livermore Lab., Univ. California, 11 p. (1975).

6. Lawver, L., Williams, D., and VonHerzen, R., Nature 257, 23-28 (1975).

7. Sharman, G., Reichle, M., and Brune, J., Geology 4, 206-210 (1976).

8. Noble, J. E., Mañon, M. A., Lippmann, M. J., and Witherspoon, P. A., AIME Conference, Denver, SPE 6763, 14 p. (1977).

9. Orlieb, L., Geol. Soc. Amer., Abs., Toronto, 218(1978)

10. Stone, R. O., Carter, L. D., and VonderHaar, Zeitschr. Geomorph. Suppl. v. 18, 156-174 (1973).

11. Savage, J., Prescott, W., Zisowski, M., and King, N., Amer. Geoph. Union Trans., 59, 1051 (1978).

12. Elders, W., Hoagland, J., and Olson, E. R., Geothermal Res. Council Trans., 2, 177-180 (1978).

13. Dickinson, W. R. and Snyder, W. S., J. Geophys. Res., 84, 561-572 (1979).

14. Koide, H. and Bhattacharji, S., in Energetics of Geological Processes, 46-66 (Springer-Verlag, 1977).

15. Freund, R., Tectonophysics, 21, 93-134 (1974).