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Fault Intersections and Hybrid Transform Faults in the Southern Salton Trough Geothermal Area, Baja California, Mexico

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Abstract

Analysis of 55 wells drilled at the Cerro Prieto Geothermal Field and a suite of geological and geophysical studies throughout the southern Salton Trough from the Mexican-United States border to the Gulf of California clarify two concepts important to geothermal development: 1) increased natural convective fluid flow and better permeability should occur at intersecting faults both regionally and within a producing field, and 2) the Cerro Prieto and Imperial faults are best conceived of as hybrid types having features of both San Andreas style wrench faults and oceanic transform faults.

Introduction

Study of fault intersections and a merging of concepts on San Andreas type wrench faulting with oceanic transform fault theory aid in explaining geothermal resources in the southern Salton Trough. This wedge shaped region (Fig. 1) from Mexicali to the present Gulf of California is bounded on the east by the Craton Margin Lineament which trends approximately N 30°W and on the west by the San Felipe fault zone. The latter fault zone trends N 15° ± 10°W from the city of San Felipe, along the Ometepec Salina where it has 1.5 m of recent vertical offset, and then follows the east side of the local mountain ranges (Sierra Mayor and Cucapa) until intersecting the Cerro

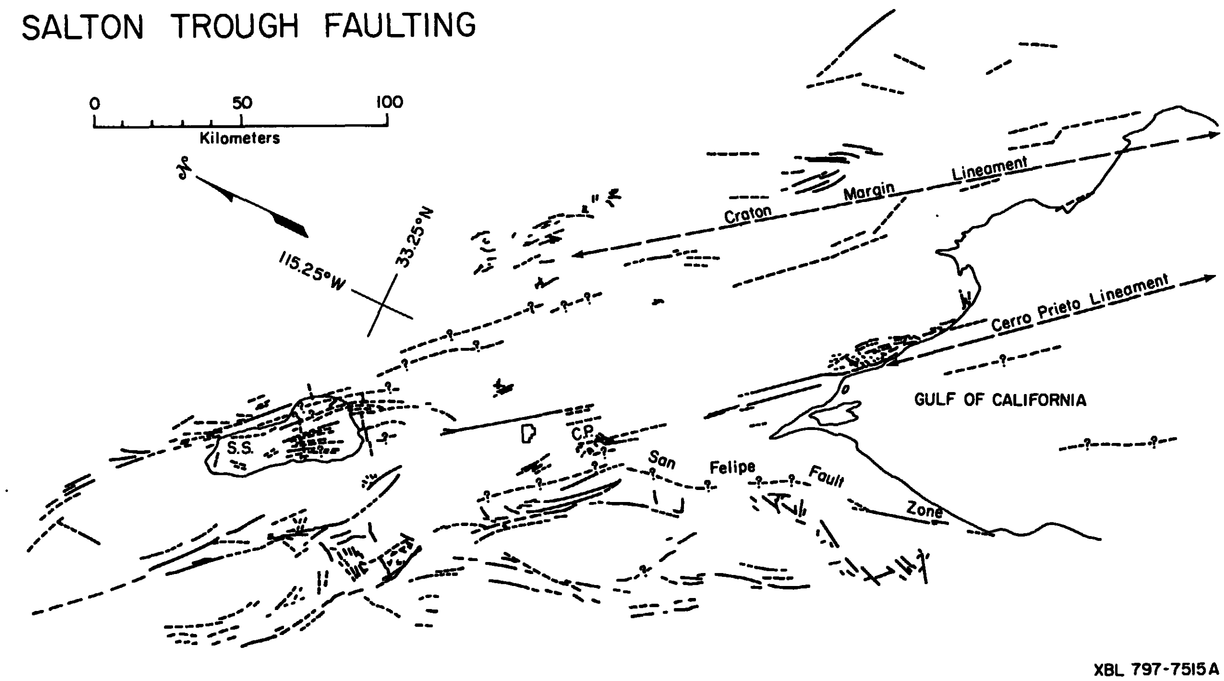

Figure 1: Compilation of faults in the Salton Trough showing the Cerro Prieto Lineament as a major hybrid transform fault zone. Note the prevalent and long NW-SE trending faults with much shorter intersecting faults of NE-SW trends. Faults indicated by lines, dashed where discontinuous or subsurface; - ? - indicates uncertain location. Critial data evaluation from published work; paper in preparation by the authors; S.S. indicates Salton Sea; C.P. is the Cerro Prieto geothermal area.

Prieto Lineament 6 km north of the Cerro Prieto Volcano. Research by Gastil and Krummenacher (1977) in Sonora has shown the Cerro Prieto fault zone lineament to be a major regional feature. The San Felipe fault zone and the Cerro Prieto Lineament, which trends N40° ± 5°W are confirmed by seismic reflection data (publication in progress by Cerro Prieto, C.F.E.). The Cerro Prieto geothermal field is currently producing 150 megawatts and is 12 km southeast of this major fault intersection.

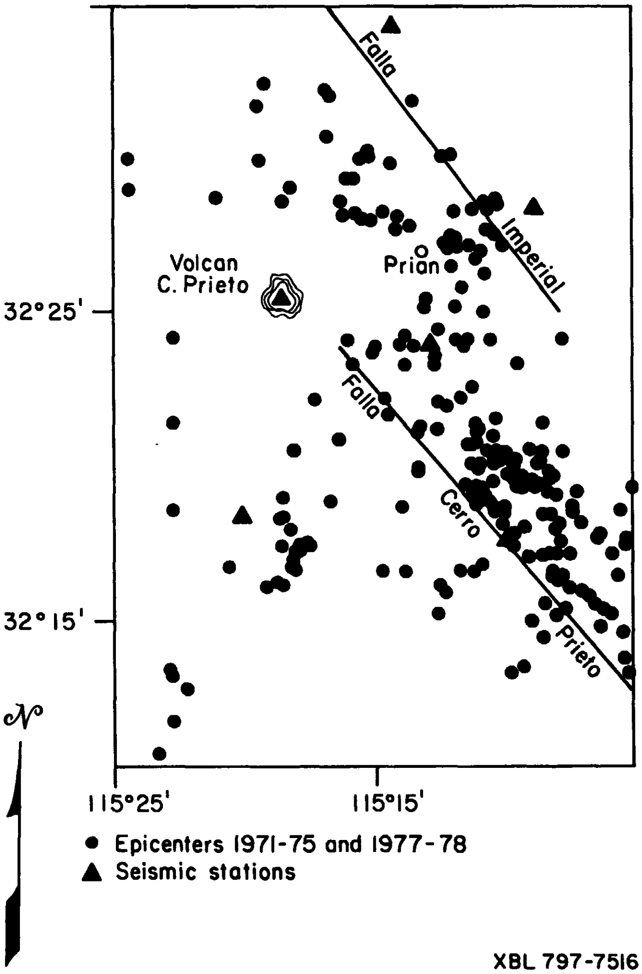

Figure 2: Microseismic studies illustrating the active movement along the northwestern terminus of the Cerro Prieto hybrid transform fault and the north to northeasterly shift to the Imperial hybrid transform fault (data from Albores and others, 1979).

Fundamental to the regional geothermal history is the idea that the Cerro Prieto fault and the Imperial fault exhibit characteristics of both wrench faults and oceanic transform faults; hence they are informally termed hybrid transform faults. Freund (1974) discussed in detail 16 differences between wrench faults and transform faults. Important characteristics of hybrid transforms are: a) episodic strike-slip movement, b) obliquely intersecting shorter normal faults, often in clusters of fault shear zones, c) a tendency to be linear rather than curved, d) an active shear zone up to 200 m wide in the basement yet only 10 m near the surface, e) a lack of splayed fault segments at their terminations. They have no equivalent of oceanic fracture zones (i.e. a non-active fault extension), and they do not link clearly defined spreading centers. Such faults are capable of deep penetration into the crust to serve as conduits for heat flow. Thickness of the crust ranges from 7 to 11 km in the northern Gulf of California (Phillips, 1964) to as great as 32 km at the Mexican-United States border. (Biehler and others, 1964).

The Cerro Prieto hybrid-transform and its intersection with the San Felipe basin and range style fault zone has three important features: 1) a shift in regional tectonic activity from the locked end of the Cerro Prieto fault to the Imperial fault, which is 11 km to the northeast and trends N 36°W, 2) formation of fault blocks along the hybrid transform as well as in the region between them, and 3) localization of a major geothermal field i.e. Cerro Prieto at the intersection of the hybrid transform and crosscutting faults. Microseismic studies, as shown in Figure 2, and a self-potential survey (Corwin and others, 1978) support a north to northeasterly trending fault between the Cerro Prieto and Imperial faults.

The 55 wells drilled at the Cerro Prieto geothermal field and the geophysical interpretations provide details on both the role of fault intersections, and on the hybrid transform fault shift that is occurring today. Well No. 103 is very productive, hot, >350°C, and lies at the intersection of one of the NE-SW faults and the Cerro Prieto fault (Figure 4). There are at least 7 similar faults in the Cerro Prieto Field spaced 200 to 300 m apart with vertical displacements of 40 to 250 m. A simplified geologic section through the field (Figure 3) indicates 400 to 600 m of vertical offset across the Cerro Prieto fault. Mylonitized granodioritic basement was reached at 2547 m and 2722 m in two wells west of the main field and at 1478 m in one well to the southwest. Subsurface stratigraphy gives clues to the role of faulting. For example, well No. 757 drilled through a litholgic sequence, at a depth between 600 m and 934 m, that is not found in the main production field 3 km to the southeast. These units were: 85 m of siltstone, underlain by 95 m of 50% siltstone and 50% silty sandstone units 3 to 9 m thick, followed by 145 m of nearly pure sandstone. The upper siltstone was highly densified by mineral precipitation and the well bottom temperature in the sandstone was approximately 100°C. Such a sequence suggests a rapid infilling of an actively subsiding block.

Earlier ideas of pull-apart basins in the Salton Trough (see Elders and others, 1972; alos Dibblee, 1977) can thus be refined. Fault blocks between the hybrid transform faults that occur en echelon appear to be 1 to 4 km on a side. Oblique intersection of major faults, such as the Imperial and Cerro Prieto, with fault shear zones may indicate sites for the most productive wells. However, these wells may be located in downthrown blocks with appropriately hot production zones 1 km or

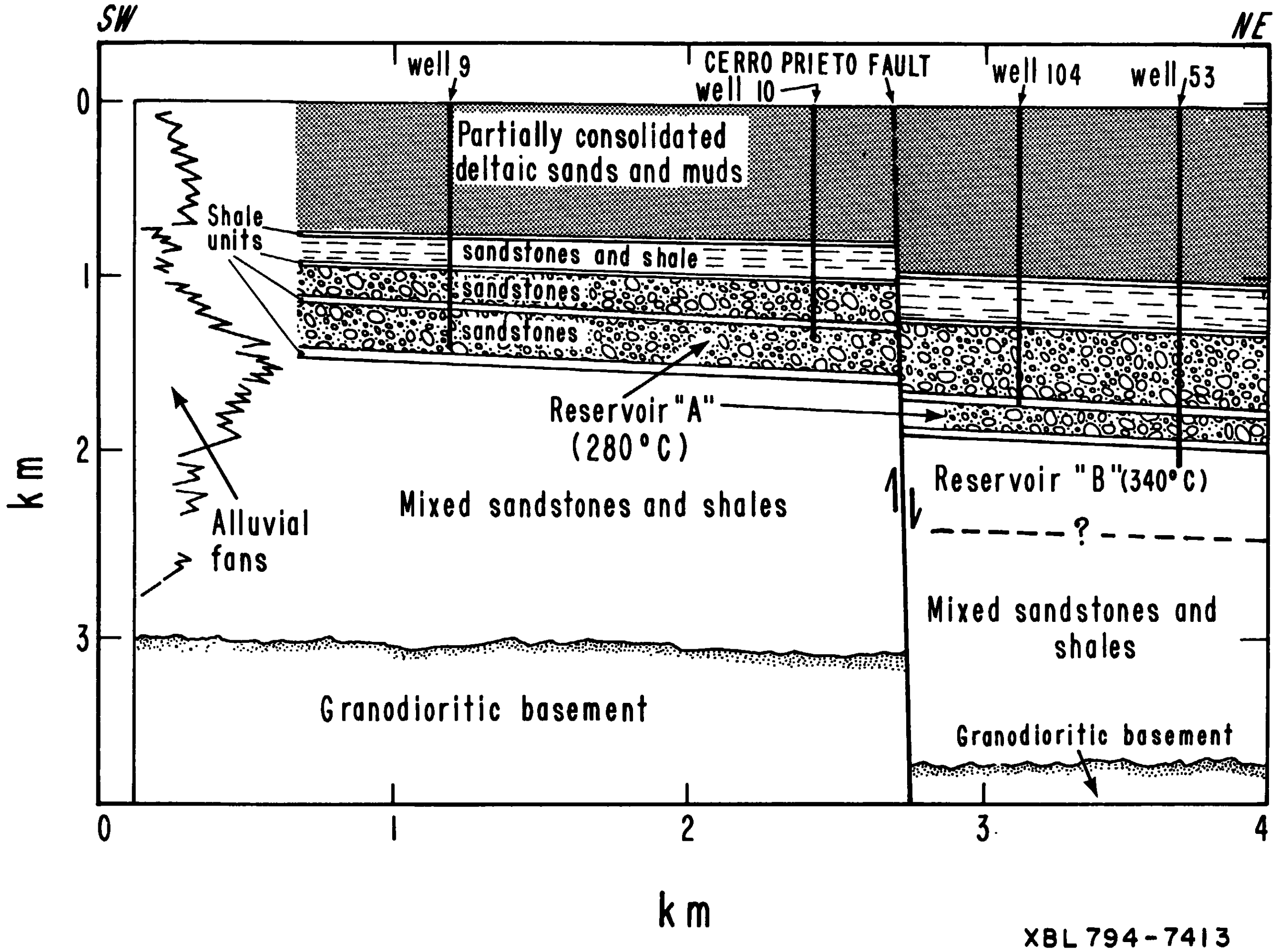

Figure 3: Simplified geologic section across the earliest developed portion of the Cerro Prieto Geothermal field, Baja California, Mexico. Interpretation based on well logs and geophysical surveys.

more deeper than in wells within a few hundred meters of the hybrid transform fault. Ongoing research and continued drilling between the Cerro Prieto and Imperial faults will clarify ideas presented herein. There are also suggestions of major fault intersections with shorter faults near geothermal areas at East Mesa, Desert Hot Springs, Coso and Roosevelt Hot Springs.

Acknowledgements

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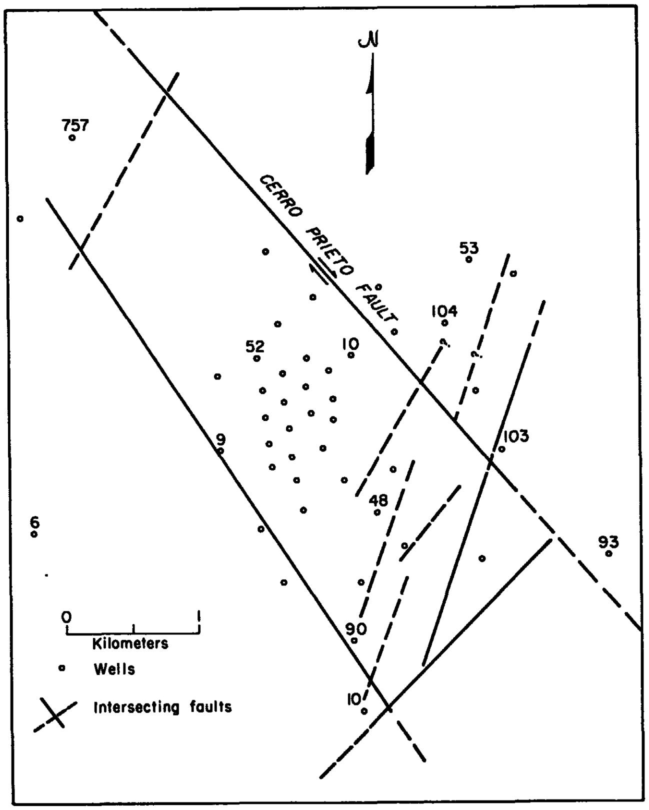

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Figure 4: Location of known faults in the vicinity of the Cerro Prieto field, showing the intersecting faults and the location of wells and the very production well No. 103.

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