COMPARATIVE ANALYSIS OF STRUCTURAL CONTROLS ON GEOTHERMAL ACTIVITY IN WESTERN TURKEY AND THE WESTERN GREAT BASIN, USA: PRELIMINARY RESULTS

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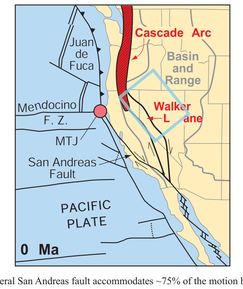
ABSTRACT

Similar to the western Great Basin in North America, western Turkey contains complex systems of active, kinematically related strike-slip and normal fault zones and abundant geothermal activity. In both regions, geothermal activity is focused in a transtensional setting and is largely amagmatic. In western Turkey, the right-lateral North Anatolian fault splits into several branches, and the tectonic regime changes from translation to transtension toward the southwest. Heat flow is higher in the transtensional region south of the Marmara Sea. In the western USA, geothermal activity is greatest in the transtensional setting of the western Great Basin. Here, a system of right-lateral strike-slip faults known as the Walker Lane accommodates ~20% of the Pacific – North American plate motion. As the Walker Lane terminates northward, dextral shear is transferred into extension in the northwestern Great Basin. This strain transfer enhances extension in the western Great Basin, thereby favoring dilation, deep circulation of fluids, and ultimately geothermal activity along fault zones.

Faults are known to be the primary control on geothermal activity in amagmatic transtensional regions, but questions remain concerning the favorable types and parts of faults for geothermal activity. Better characterization of the structural controls in such regions is needed to develop and enhance exploration strategies, particularly the selection of drilling sites in fields without surficial expressions (i.e., blind or hidden fields). Developing better methods of discovering blind geothermal fields is critical for future development, because these systems can represent the bulk of the resource in arid regions and their development minimizes impact on thermal springs in culturally sensitive areas (e.g. Turkey).

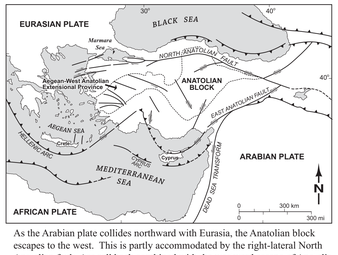
Due to the need to develop alternative sources of clean energy worldwide, we have recently initiated a comparative analysis of geothermal activity in western Turkey and the western Great Basin, USA, through integrated geologic and geophysical investigations. The major goal of this study is to better characterize structural controls on geothermal systems in transtensional amagmatic regions. This project involves 1) detailed geologic mapping and reconnaissance of ~6 geothermal fields in western Turkey; 2) structural analysis of related fault zones in these fields; 3) GIS compilation of geologic, geochemical and geophysical data; and 4) comparative analysis of fields in western Turkey and the Great Basin (USA). Our recent studies have defined several structural settings common to geothermal fields in the western Great Basin, including 1) discrete steps in normal fault zones, 2) belts of intersecting, overlapping, and/or terminating normal faults, and 3) small pull-aparts at the intersection of strike-slip and normal faults. Our initial assessment suggests that similar settings characterize geothermal fields in western Turkey. If certain structural features are common to geothermal systems in both western Turkey and the Great Basin, our findings may serve as a guide to exploration, including targeting of drill sites, in amagmatic transtensional settings throughout the world.

TECTONIC SETTINGS
Western USA



The right-lateral San Andreas fault accommodates ~75% of the motion between the North American and Pacific plates. About 25% of the plate motion is accommodated inland along a system of dextral faults known as the Walker Lane. As the Walker Lane ends northward, dextral shear is transferred to NW-directed extension in the western Basin and Range province, generating a broad region of transtension (shown by blue box).

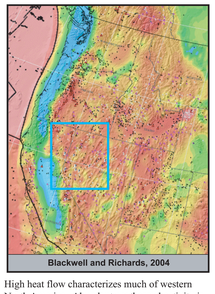
Western Turkey



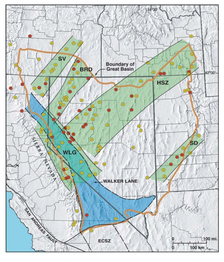
As the Arabian plate collides northward with Eurasia, the Anatolian block escapes to the west. This is partly accommodated by the right-lateral North Anatolian fault. Arc roll back combined with the westward escape of Anatolia induces N-S extension in western Turkey. Thus, western Turkey lies within a broad transtensional setting.

TECTONIC CONTROLS OF GEOTHERMAL SYSTEMS IN THE WESTERN GREAT BASIN, USA

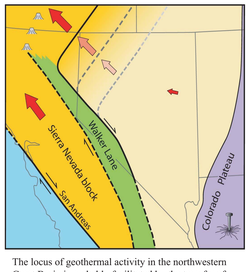
Volcanism in the western Basin and Range province generally ended 10 to 3 Ma. Most of the geothermal activity in this region is therefore amagmatic. High heat flow characterizes much of western North America. However, the most abundant geothermal activity is focused in the northwestern Great Basin directly north of the northern end of the Walker Lane. The prolific geothermal activity in this region results from enhanced dilation on NNE-striking normal faults induced by a transfer of NW-directed dextral shear from the Walker Lane to NW-directed extension in the northwestern Great Basin (i.e., western Basin and Range province). Although faults clearly control most of the geothermal activity in this region, relatively few detailed investigations have been conducted on the specific structural controls of individual systems. Because knowledge of such structures would faciliate exploration models, we have been conducting detailed analyses of several fields over the past ~4 years. This work involves detailed geologic mapping, structural analysis, geophysical investigations, and geochemical studies.



High heat flow characterizes much of western North America. Abundant geothermal activity is limited, however, to only a few regions, including the Cascades arc (magmatically induced) and northwestern Great Basin (amagmatic in origin).

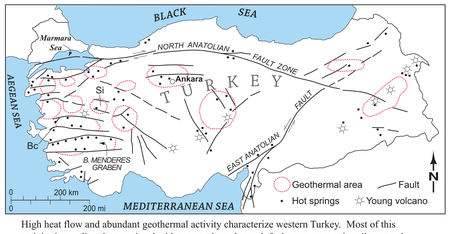


Geothermal fields in the Great Basin generally occur in four major NNE-trending belts oriented approximately perpendicular to the current extension direction. These belts radiate from the dextral shear zone of the Walker Lane and are concentrated in the northwestern Great Basin near the terminus of the Walker Lane.

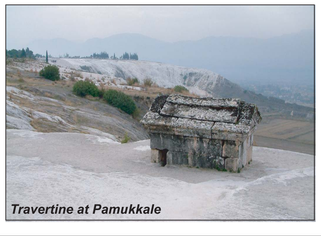


The locus of geothermal activity in the northwestern Great Basin is probably facilitated by the transfer of northwest-directed dextral shear from the Walker Lane to northwest-directed extension in the Great Basin. Enhanced extension in this region increases dilation on normal fault zones, thus facilitating deep circulation of hydrothermal fluids.

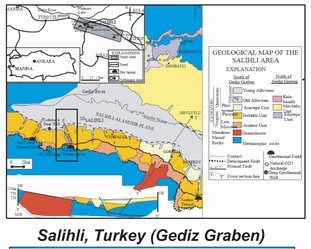
TECTONIC CONTROLS OF GEOTHERMAL SYSTEMS IN WESTERN TURKEY



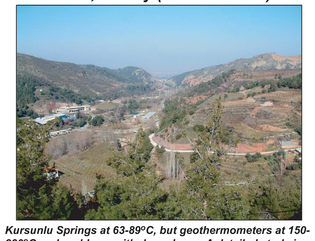
High heat flow and abundant geothermal activity characterize western Turkey. Most of this activity is not directly associated with magmatism. Instead, faults appear to primarily control geothermal systems in western Turkey. However, the structural controls on individual geothermal systems have generally not been studied in detail. Further, the structural settings favorable for geothermal activity have generally not been characterized.



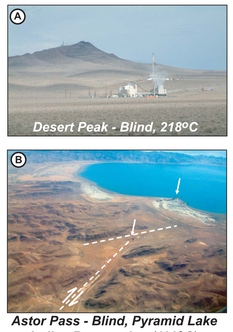
STRUCTURAL CONTROLS, WESTERN TURKEY



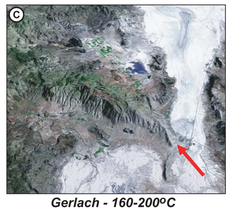
Salihli, Turkey (Gediz Graben)



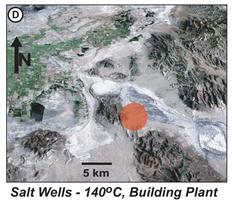
Kursunlu Springs at 63-89°C, but geothermometers at 150-230°C and problems with draw-down. A detailed study is therefore underway. Initial work suggests the field is controlled by the intersection of an E-W normal fault with a N-S fault and also by a major step in the range-front fault.



Astor Pass - Blind, Pyramid Lake Indian Reservation (100°C)

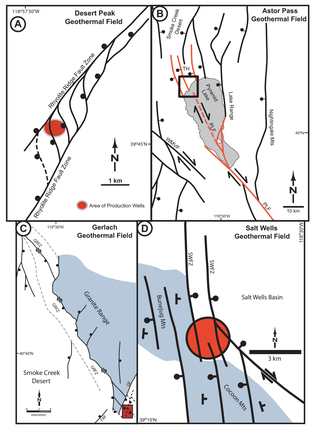


Gerlach - 160-200°C



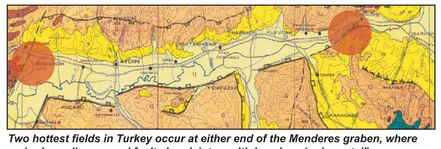
Salt Wells - 140°C, Building Plant

STRUCTURAL CONTROLS, WESTERN GREAT BASIN, USA

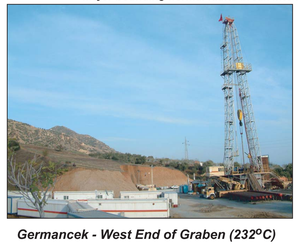


A major question is what types of faults or parts of individual fault zones are most favorable for geothermal activty. Our detailed geologic mapping, structural analysis, and geophysical investigations have shown that many fields occupy discrete steps in normal fault zones or lie in belts of intersecting, overlapping, or terminating normal faults. A. Desert Peak geothermal field occupies a small step in a major normal fault zone, where several minor steeply dipping faults link the en echelon major segments and provide a subvertical conduit of highly fractured rock. B. Geothermal fields in the Pyramid Lake region (Astor Pass) lie near the northern end of the right-lateral Pyramid Lake fault in a region of strain transfer between dextral shear and regional extension. Geothermal activity is focused at the intersections of dextral-normal oblique-slip faults. C. The Gerlach geothermal field occurs at the terminus of two intersecting and terminating range-front faults, where horsetailing of both fault zones generates a broad area of highly fractured rock. D. The Salt Wells geothermal field occurs in the overlap zone between two oppositely dipping normal fault sytems, as well as in a possible pull-apart near the intersection of a NW-striking right-lateral fault with a northerly striking normal fault zone. The structural settings favoring geothermal activity all involve subvertical conduits of highly fractured rock along fault zones oriented approximately perpendicular to the least principal stress. Features indicative of these settings that may be helpful in guiding exploration include: 1) major steps in range-fronts, 2) interbasinal highs, 3) mountain ranges consisting of relatively low, discontinuous ridges, and 4) lateral terminations of mountain ranges.

Menderes Graben



Two hottest fields in Turkey occur at either end of the Menderes graben, where major bounding normal faults break into multiple splays (or horsetail).



Germancek - West End of Graben (232°C)

Kilzedere - East End of Graben (242°C)