GEOTHERMAL TECTONICS OF THE IMPERIAL VALLEY AS DEDUCED FROM EARTHQUAKE OCCURRENCE DATA

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ABSTRACT

An analysis of spatial and temporal change in the mode of earthquake occurrence allows identification of regions where episodes of tensional strain release have occurred. Temporal analysis of the coefficients in the recurrence relation log (NC) = a-b (MAG) is required because in regions like the Imperial Valley the average values of the coefficients in this equation are dominated by events involved with the release of regionally accumulating shear strain. The spatial distribution of this average b coefficient can only indicate major structural provinces. We have conducted a detailed temporal decomposition for two areas, one centered on the presumed region of spreading at the southern end of the Salton Sea and one centered approximately on the Heber geothermal anomaly. We conclude based on b coefficient temporal change that the events of Oct. 27, 1963 located at the Niland geothermal anomaly involved tensional strain release.

INTRODUCTION

Major geothermal reservoirs can be expected in areas where crustal dilation is presently active. Minor geothermal occurrences can be expected along well defined zones where shear stress is being locally released by lateral faulting. It is often difficult to determine the nature of stresses acting in an area without a detailed analysis of the geology. Remote determination is normally only possible through the use of earthquake seismogram first motions.

We have recently completed a correlation of the magnitude-frequence of occurrence relation to tectonic setting for the Imperial Valley and surrounding areas. Similar correlations have previously been established for oceanic regions (Francis, 1968, Francis and Porter, 1971, Northrop and Mattox, 1972). The geothermal importance of this newly established correlation is that it may provide the geothermicist with a highly cost-effective regional exploration aid. To demonstrate this possible utility consider the data presented here for the Imperial Valley geothermal province.

DISCUSSION

Spatial Variation

Fortunately areas prospectively interesting from the geothermal standpoint tend to be active seismically. The Imperial Valley is no exception. This is important for if we are to study the variation in the coefficients that define the magnitude-frequency (i.e. rate of recurrence) relation within a small area we must require a statistically adequate number of events per unit area. This condition is met in the Imperial Valley for areas larger than 600 square miles (1,560 km^2). Figure 1 shows the spatial variation of coefficient b of

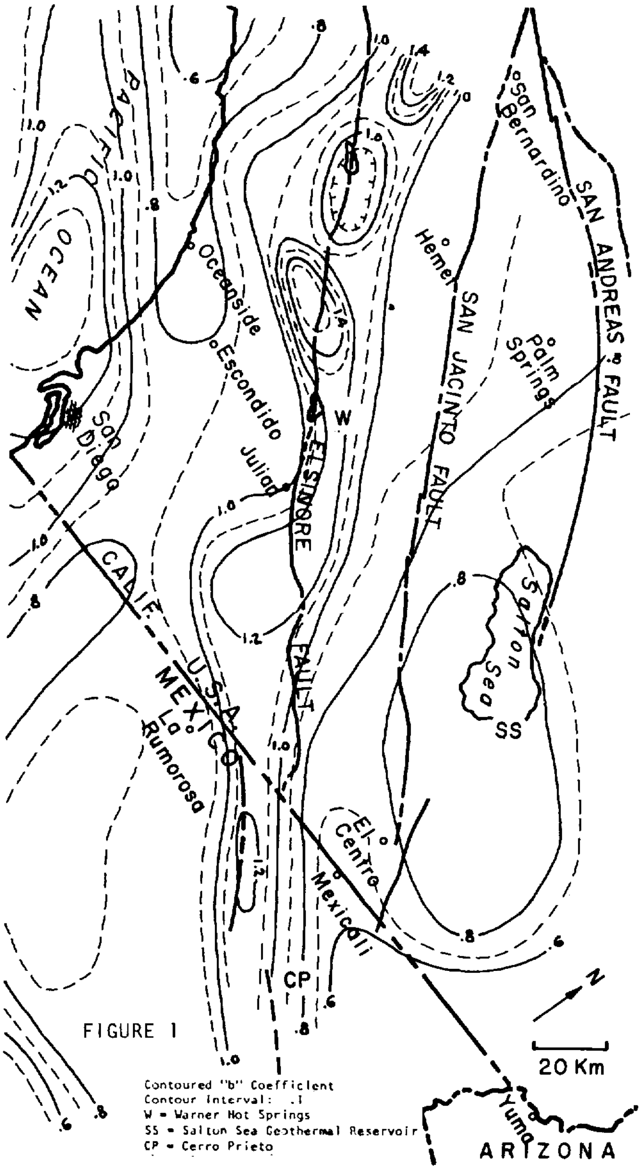


FIGURE 1

Contoured "b" Coefficient
Contour Interval: .1
W = Warner Hot Springs
SS = Salton Sea Geothermal Reservoir
CP = Cerro Prieto

the magnitude-frequency relation for part of southern California and northern Mexico. The area depicted includes the Imperial Valley.

Considerable debate during the past fifteen years centered on the origin of the geothermal reservoir located at the southeast end of the Salton Sea. Airborne magnetics suggest a recent intrusive body is responsible (Griscom and Muffler, 1971). Minor faulting, earthquake swarms and the generally thin nature of the crust in the area have led some to suggest that an active spreading center is responsible (Eleders and others, 1972). The work on the variation of the b coefficient in oceanic areas has clearly demonstrated that where active spreading is occurring the b value takes on a high value (e.g. 1.7). Fig. 2 is a computer plot of the magnitude-frequency relation for the 600 square mile area essentially centered on the geothermal anomaly in question. The b coefficient is .85 suggesting that if spreading is occurring it is very localized either in time or space. It is quite clear from Fig. 1 that the main stress release mechanism at work in the region of the geothermal anomaly involves lateral movement which is consistent with the presence of the San Andreas fault in the area in question.

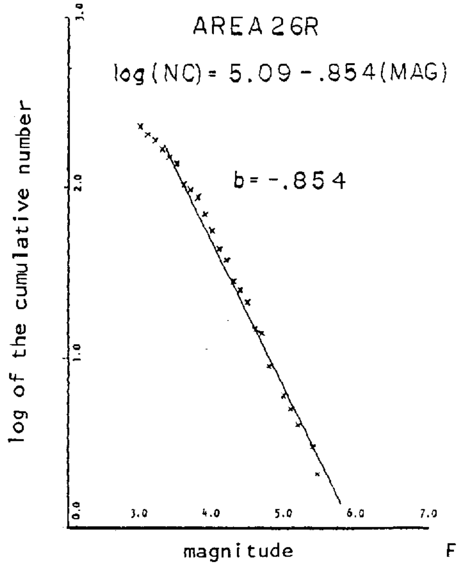


FIGURE 2

Consider Warner Hot Springs which is located north of Julian and just east of Lake Henshaw. In this area, Fig. 1 indicates that the b coefficient is approaching 1.2, significantly higher than the .85 determined for the geothermal area at the southeast end of the Salton Sea. This high value would suggest that the Warner Hot Springs geothermal occurrence is at the margin of the zone of rifting where stress is released through normal faulting. Some workers feel that the Elsinore fault, located a few miles to the west of Warner Hot Springs, does in fact have geologic features indicative of dip-slip motion (Threet, 1974). The elevated temperatures at Warner Hot Springs are therefore most likely due to deep circulation along faults rather than the more regional effect of crustal thinning as is probably the case in the area of lower b coefficient located in the center of the rift (i.e. the Salton Trough).

Cerro Prieto 20 miles south of Mexicali, Mexico, is a presently producing geothermal reservoir in the middle of a zone of transition in the value of the b coefficient. This transition zone continues northwestward for more than one hundred miles. This lineament in the b coefficient map is one of the striking features of Fig. 1. The fact that it parallels the most seismically active fault in the region (the San Jacinto) attests to its tectonic significance. Our present feeling is that this transition in mode of strain release represents a transition from a continental mode to the southwest to an oceanic mode to the northeast. This contention is borne out by a coinciding transition in the gravity field (Kelm, 1971; Biehler, et al, 1964) which most investigators feel is brought about by a transition from continental crustal thickness to the southwest to oceanic crustal thickness to the northeast. The possible conclusion of geothermal significance is that Cerro Prieto may be located at the hinge point of this major transition and that the deep seated heat source has exploited a zone of intrinsically weak crust.

Temporal Variation

Due to the episodic nature of earthquakes associated with spreading, the likelihood exists that for relatively short periods of time the b coefficient could take on values well above the long term average. Figure 3 shows three areas of equal size within the Imperial Valley where temporal "b-scans" were conducted. The data presented are for a window length of five years. The determined b coefficient is plotted above the year that represents the beginning year of the time window. The solid curve is drawn between points where at least six magnitude values are represented within the magnitude window 3.5 to 5.5.

The three areas cover respectively, the southern Salton Sea area, the Heber area and the San Jacinto fault zone. Each has an area of approximately 630 sq. miles. The average values for these plots clearly are consistent with the data presented in Figure 1. Each plot does however indicate periods in time when the b coefficient for the areas in question exceed a value of 1.

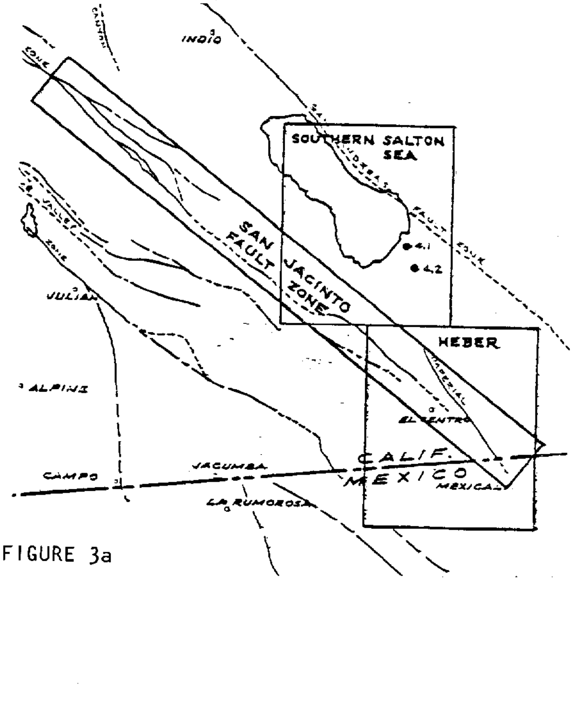
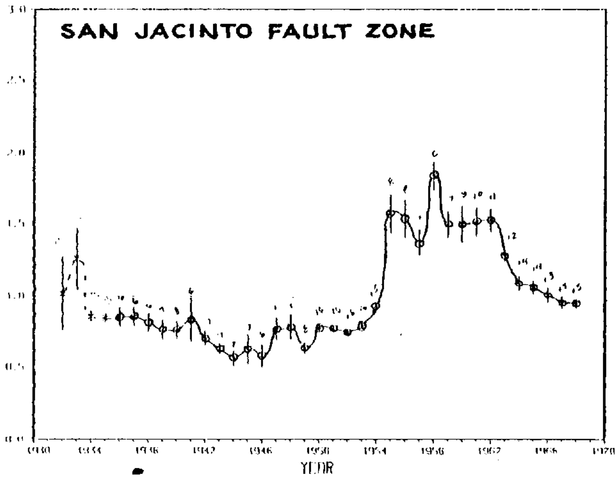
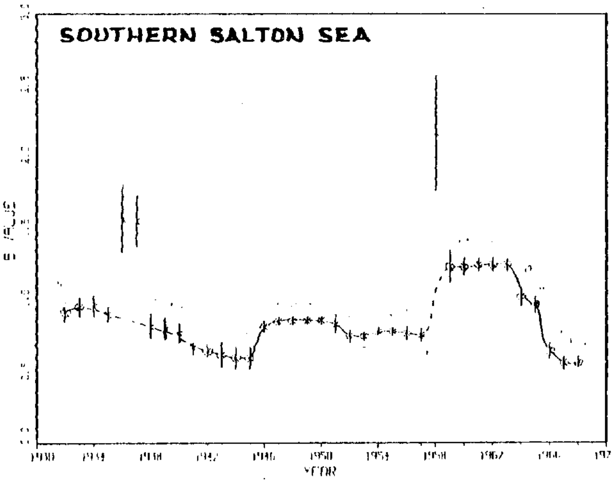


FIGURE 3a

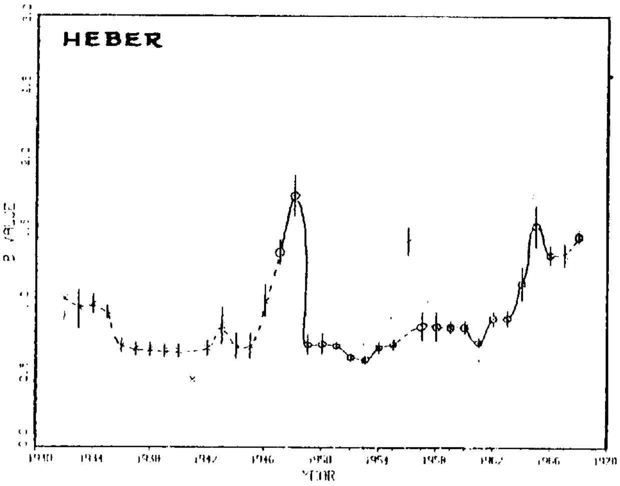
FIGURE 3b B VALUE VARIATION IN TIME



B VALUE VARIATION IN TIME



B VALUE VARIATION IN TIME



We are particularly interested in the change in b coefficient indicated for the southern Salton Sea area for the period of time 1957-1966. During this period of time 13 geothermal wells were drilled and tested in this area raising the question of whether this activity could have changed the mode of earthquake occurrence in this particular area. In order to establish our ability to delimit this b coefficient anomaly in space and time we reduced the surface area to that of the spreading center suggested by Elders and others (1972) and decreased the scan window length sequentially down to three years. The results of this analysis indicate that nine events that occurred in late 1963 were primarily responsible for the increase in b coefficient. The largest of these, within our magnitude window, are of magnitude 4.1 and 4.2. Both occurred on Oct. 27, 1963 and in terms of the argument developed here, involved tensional strain release. Both events fall within the established productive limits of the so-called Wiland geothermal anomaly. The authors are not aware of first motion studies on these particular events. However it is likely that this is the swarm reported by Thatcher and Brune (1971).

Although the Heber data seems to suggest a recent trend toward increasing b coefficient values no determination of the events causing this apparent trend has been completed.

Concerned about the implications of the southern Salton Sea analysis an attempt was made to demonstrate that temporal variations in the b coefficient do not occur in all portions of the Valley. A 630 square mile swath encompassing the San Jacinto fault zone from the Mexican border to an area approximately 14 miles south of Hemet was analyzed on the same basis as the other areas. Again the average value is consistent with Figure 1 but surprisingly b coefficients higher than the value of 1 are observed for the time period between 1955 and 1966. Figure 1 suggests that the events associated with these higher values occur in the portion of the area that lies to the north of the Salton Sea.

ACKNOWLEDGMENT

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