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ACTIVE FAULTS AND GEOTHERMAL POTENTIAL OF THE FUJIAN AREA, (P.R. CHINA)

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ABSTRACT

The province of Fujian lies over the western part of a shallow active thrust (listric thrust) extending from Fujian Province to the east up to Taiwan. Within this thrust high angle faults have developed representing mostly reactivated, pre-existing faults which form a network of intersecting NE and NW trending faults. The NW trending faults are caused by extensional and shear movement and control the ascent of deeper, heated groundwater, and are associated with low temperature systems. Among the NW faults, the Jiulongjiang Fault is the most active one and constitutes the best prospects. It is postulated that shallow crustal thrusts are unfavourable for the development of high temperature systems.

Introduction

A collection and analysis of all relevant seismic data, satellite images, aeromagnetic and geologic data has led to the hypothesis that a large scale, crustal to sub-crustal thrust (listric active fault) exists beneath the Eurasian Plate, extending from the province of Fujian beneath the Taiwan Straits to Taiwan (Wan and Chu, 1984). This low angle crustal detachment dips gently to the east; earthquake hypocenters indicate a depth of 5 to 20 km for the thrust beneath Fujian Province whereas beneath Taiwan it may lie at depths greater than 50 km (see Fig. 2). Over the thrust a series of faults have developed coinciding mostly with pre-existing faults; these high-angle faults define a aetwork of NE and NW trending active faults which are shown in Fig. 1.

Major NE trending faults in Fujian, namely the Changle-Zhaoan Fault (R3 in Fig.1) and the Zhenghe-Dapu-Fengshun Fault (R2 in Fig.1) dip SE at an intermediate to high angle of about 40 to 70" (Lin, 1981). These are caused by compressive-shear, reverse faulting in response to the recent tectonic stress field (Lin, 1980). The seismicity along the Changle-Zhaoan Fault is slightly greater than that associated with the Zhenghe-Fengshun Fault (total energy released between 1972 and 1982 was 1.4 x 10^{19} and 1.1 x 10^{19} erg respectively, and the inferred average slip rates are 0.11 and 0.076 cm/yr respectively; Wan and Chu, 1984).

All NW trending faults in Fujian are high angle faults (Lin, 1981); they are tensional shear, dextral or sinistral strike-slip faults. Among this group, the most active one is the Jiulongjiang River Fault (N5 in Fig.1), and the second most active is the Yongan-Jinjiang Fault (N4 in Fig.1). The energy released by earthquakes associated with each fault between 1972 and 1982 was found to be about 1.3 x 10^{18} and 1.05 x 10^{18} erg respectively; average slip rates were about 0.12 and 0.04 cm/yr for each fault (Wang and Chu, 1984). Other NW trending faults in Fujian are less active.

The Jiulongjiang River Fault clearly shows sinistral strike-slip as documented by the lateral separation of more than 2 km of existing geomorphological features. This separation is the largest of all active faults in Fujian. The main fault of the Jiulongjiang fault zone, however, is associated only with micro-earthquake activity, i.e. deformation is released by stable slip presumably due to deep infiltration of meteoric waters along the fault plane.

Distribution of hot springs in Fujian and their association with active faults

A total of 171 thermal springs have been found in Fujian, and data were collected by Tang Yangfu (personal communication). A statistical analysis showed that about 68% of all thermal springs are controlled by NW trending, tensional-shear faults which are parallel to the direction of the present day maximum compressive stressfield as defined by the fault plane solutions of seismic first motions (see also Fig. 1). This setting is similar to that of thermal springs elsewhere in China where about 68% of the low temperature prospects are also controlled by tensional or tensional-shear faults and where the horizontal angle between the strike of the faults and the direction of the maximum compressive stressfield is less than 45"; often both directions are parallel (Wan, 1982).

Using the observed heat output of 166 springs in Fujian (there were no data for 5 springs) and coaputing mean output for areas of 30 x 30 km, a contour map of natural output of thermal springs was constructed for the Fujian region which is shown in Fig. 3. Comparing the heat output pattern of this map with the seismicity pattern based on the occurrence of historic earthquakes observed during the last 1000 years (Wan and Chu, 1984), it was found that all seismicity is concentrated in areas showing an elevated natural heat output. Thermal springs with high heat output are concentrated south of 26°N along several faults, i.e. the NW trending Juilongjiang River Fault, the NE trending Changle-Zhaoan Fault in the Zhangzhou-Xiamen area (see Fig. 3). Thermal springs with high heat output can also be found in the Yongan area along the Yongan-Jinjiang Fault and in the Yongtai area along the Mingjiang River Fault.

The statistical analysis of the heat discharged by individual springs showed that about 83% of the total heat is discharged by springs located over NU trending active fault zones whereas 11% of the total heat is discharged by springs located over NE trending active faults. The heat diecharged by all springs along the Jiulongjiang River Fault amounts to about 46% of the heat discharged by all thermal springs in the Fujian Region.

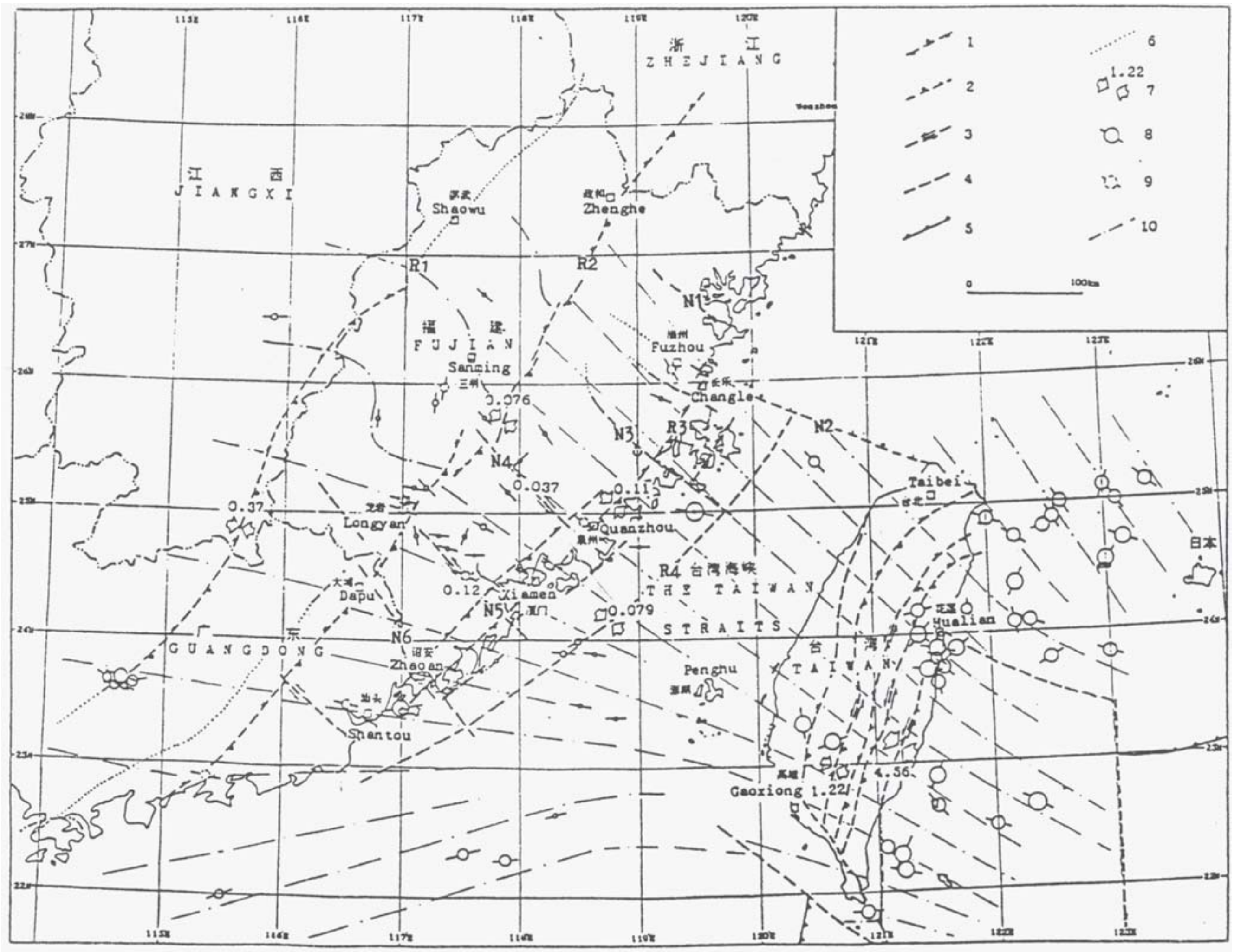

Fig. 1: SKETCH MAP OF ACTIVE FAULTS

1-5 Active faults
2. Normal fault
3. Strike-slip fault showing sense of relative motion and rate of movement in cm/yr
4. Fault, type unknown
5. Subduction zone, teeth on overriding plate
6. Non-active fault, according to existing seismic data
7. Direction and rates of relative motion in cm/yr
8. Simplified fault plane solution; the area of the circle is proportional to the magnitude of earthquake (large circle M_s 6-8, small circle $M_s < 6$); small lines on the outside of each circle show the direction of maximum principal compressive stress.
9. Dashed circle shows the fault plane solution for weak earthquakes.
10. Trace of maximum principal compressive stress.

R1. Shaowu-Heyun Fault (not related to the listric active fault system of Fujian and Taiwan)
R2. Zhenghe-Dapu-Fengshun Fault
R3. Changle-Zhaoan Fault
R4. Fujian-Guangdong (offshore) Fault

N1. Sanduao Bay Fault (not related to the listric active fault system of Fujian and Taiwan)
N2. Minjiang Rivet-Jilong Fault
N3. Xinghuawan Bay Fault
N4. Jin-jiang-Yongan Fault
N5. Jiulongjian River Fault
N6. Dongshan-Yongding Fault

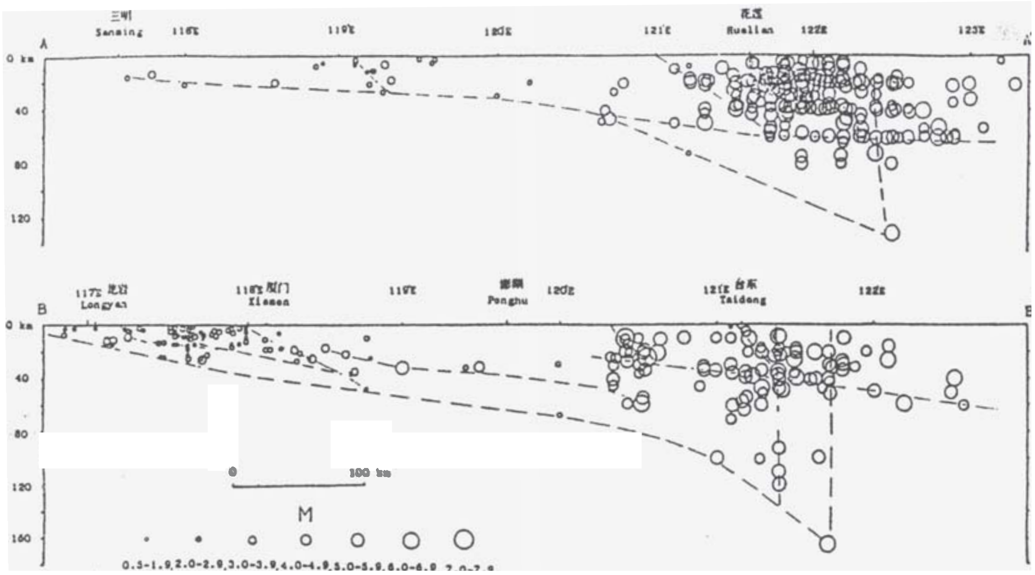

Fig. 2: SECTIONS OF DISTRIBUTION OF EARTHQUAKE FOCI BENEATH FUJIAN AND TAIWAN. (A scale for the magnitude of the earthquakes is shown in the lower part of the second section.)

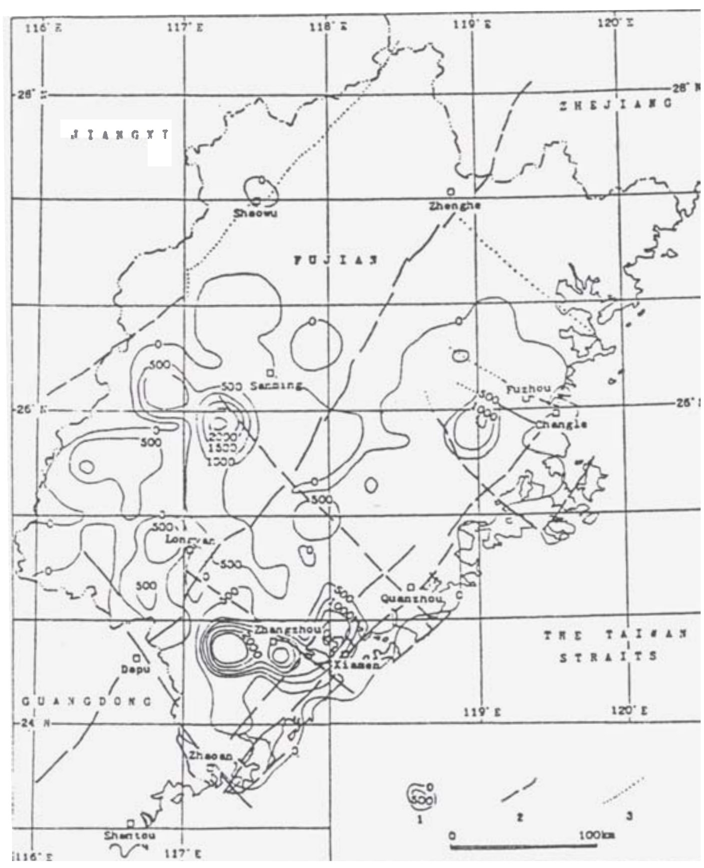

Fig. 3: CONTOUR MAP OF HEAT FLOW OF SPRINGS, FUJXAN

1. Contours of heat discharged (kcal/sec) per unft area (30 x 30 km) by thermal springs; contour interval is 500 kcal/sec.
2. Actfve fault zone.
3. Non-active fault, fnferred from seismicity patterns based on hfstorfc earthquakes during the last 1000 yr.

Discussion of the Fujian thermal activity

It is possible that the development of the active thrust in the upper lithosphere has impeded the ascent or development of crustal or deeper melts. Conditions for development of crustal melts are unfavourable since the cutting depth of the thrust is rather shallow, i.e. 5 to 20 km depth beneath the Fujian Region where likely crustal temperatures are probably around 150 and 600°C respectively. Although the thrust might reduce confining pressures, fusion of crustal rocks is unlikely. A similar explanation has been given for inferred thrusts beneath the Andes and the Rocky Mountains (Jordan et al., 1983).

The setting, however, is favourable for the development of low temperature hot water systems. In the Fujian Region the natural topography in the west is higher than that in the east; the fault plane of the listric thrust in the west is shallower than in the east. With the existing network of high angle faults we have a setting which is favourable for deep penetration of meteoric waters. These heated-up fluids preferably ascend along active NW trending faults, which explains the concentration of hot springs along the active, NW trending Jiulongjiang fault zone; other areas with a concentration of thermal prospects are the Yongan–Jinjiang area and the Mingjiang River.

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