EXPLOITATION PROSPECT OF GEOTHERMAL RESOURCES IN HENGDUAN MOUNTAINS, CHINA

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Abstract: There are 1032 hydrothermal systems in Hengduan Mountains (HM) of the south—western part of China. With the estimation of reservoir temperature by various geothermometcra, there are 30 high — temperature hydrothermal systems with average temperature over 150℃ and more than 160 middle—temperature systems with average temperature of 90—150℃. The sum of reservoir thermal energy in 30 high—temperature systems is about 53. 48±1. 95 EJ and in 168 middle — temperature systems is about 149. 59 ± 2. 61 EJ by the volume method estimation. The high—temperature systems are of great power exploitation potentiality.

The Rehai (Hot Sea) —Langpu geothermal field with hot source temperature of 400—600℃ is the beat prospect for exploitation for electrical production.. The low—middle temperature systems can be diretly utilized.

1. INTRODUCTION

Since 1981, the geothermal survey of HM in Qinghai—Xizang Plateau has been carried out by Comprehensive Scientific Expedition. The survey area covers 10^5 km^2 in the west part of Sichuam and north west part of Yannan Provinces. There are 1032 hydrothermal features in this area which are more than one — third of those hydrothermal systems throughout China (Tong, 1994). These hydrothermal area exhibit various manifestation, such as thermal springs, boiling springs, fumaroles, and beatiful sinter depooita. The study area was essentially in its natural state and field work was limited to surface only.

This paper describes the hydrothermal systems in the HM which can provide an acceptable alternative energy resource to promote the local economy.

2. HYDROTHERMAL SYSTEM

2. 1 The Distribution of Hydrothermal Systems

The HM approaching the collision zone between Eurasion and Indian plates underwent serveral orogenic events, and the regional geological structure is quite complex. Tengchong and its neighboring areas are located at the convergence zone between two continental plates, high—temperature metamorphism, intrusions of granitic magma, Late Cenozoic volcanism are the geological characteristics here. Today, the geotectonism in this zone is still quite active, as evidenced by the inteneive geothermal activity and frequent seismic events (Liao et. 1986)

The distribution of hydrothermal systems is controlled by the metamorphic base activity, the layout of the uplifted areas and trough bends, some large faults between the uplift and the trough, and Cenozoic volcanism. Most of hydrothermal systems concentrate in the uplifted areas with higher temperature and intensive hydrothermal activity. Famous Rehai—Langpu field is located at Tengchong volcano—geothermal zone In Tengchong—Gaoligongshan uplift area. Some boiling springs issue along mapr faults or fault intersections. In the Jinshajing fault belt, for example, there is a Chaluo geyser in Batang county, the only one in mainland China except on Xizang Plateau. There are a few hydrothermal systems in trough bends with weak thermal activity and lower temperature. The wall rocks of most reservoirs are composed of crystalline rocks, such as granite, basalts, migmatites or gneisses and occasionally limestones or slated.

2. 2 Chemistry of Thermal Water

The chemical types of thermal waters are mainly bicarbonate type with slight alkalinity or slight acidity, pH 6. 5— 8.5. Most of waters have high bicarbonate about 100 —300ppm (maximum 4560. 78 ppm), low chloride and variable sulphate content. The cations are mainly sodium, silica usually is less than 100 ppm, a low TDS is<1 g/L.

When TDS is lager than 1 g/L the chemical types of water are various in kind, in which an important kind is chloride type. It is seen that slight alkalinity Na—HCO_3—Cl or Na—Cl—HCO_3 types are found in Rehai—Langpu fleld in Tengcheng volcano—geothermal done. The dissolved salts in this water are mainly sodium, chloride and contain high concentrations of silicium, fluorine, arsenic, lithium. rubidium, and cesium. The pH rangs from5 to 9, and TDS is more than 1 g/L.

Relative values of Na, K, and Mg in thermal water over 45℃ are plotted on a triangular diagram (Giggenbach 1988). Most spring waters are close to the Mg—corner marked "immature water" and "partial equilibrium dilution or mixing", the datum of Rehai—Langpu field is plotted near the full equilibrium line (Fig. 1), Most bicarbonate waters reflect shallow or mixing waters. The discharge water of Rehai—Langpu field is likely reflecting deeper origin.

3. PRELIMINARY ASSESSMENT OF GEOTHERMAL RESOURCE

It is important to calculate reservoir temperature when geothermal resource are assessed by volume method. In this paper, the reservoir remperature is calculated by Na — K — Ca, Na/K, SiO_2, and K/Mg geothermometers. The chemical compositions of the high temperature water8 are listed in the Table 1. In the Figure 1, the waters plotting in the area marked partially equilibrated waters. K/Mg temperatures are likely to reflect conditions at shallower levels, with Na/K temperaturm those at considerable depth. Data points in the " immature area " may then be unsuitable for the evaluation of Na/K equilibration temperatures. The reservoir temperature of maximum, minimum, and most likely is determined by the values of geothermometer temperatures and geologic, geophysical data, and the reservoir temperatures of immature waters are based on the contrast maps of geothermometer temperatures (Guo, 1994). There are about 30 high—temperature hydrothermal system with mean temperature≥150℃ in which 6 occure in west Sichuam

Table 1 Chemical Compositions of the Spring waters in the Hligh Temperature Areas (ppm)

Hydrothermal Area	T (℃)	PH_F/PH_L	Na	K	Ca	Mg	Li	CO_3	HCO_3	Cl	SO_4	F	SiO_2	TDS (g/L)
Lanniba	93	8/7.8	88.0	4.9	2.14	0.11	0.12	0	130	3.47	32.3	12.0	143	0.278
Ruili	95	8/7.8	380	31.0	2.98	0.63	2.23	0	874	26.7	19.0	17.0	156	1.104
Humeng	94	8/7.8	135	10.6	6.72	0.36	0.52	0	253	38.2	37.1	13.0	153	0.522
Longwozhai	96.5	8/7.8	148	7.4	5.12	4.83	0.52	0	250	24.3	54.2	12.0	102	0.448
Langpu	96.2	7.5/6.3	640	50	1.14	0.80	2.10	0	984	307	35.0	10.5	150	1.703
Rehai	95.5	8/8.0	840	120	0.10	0.02	8.30	0	1168	698	31	20	450(150)	2.811
Rauzhilua—Xiao tang	96.8	7.5/7.8	210	15	214	0.30	0.96	0	434	45	12	11.5	158(138)	0.688
Helshenhe	77.5	7/7.1	290	21	19.Y	3.04	1.40	0	719	59	21	11.5	115	0.911
Ruidium	87	7.5/8.1	410	45.0	4.45	4.20	2.20	36.3	895	140	31.2	7.04	129	1.270
Balazhang	97	/9.3	220	20	0.9	0.02	2.10	141	306	5.0	31.2	14.0	295	0.954
Quanqiaohe	97	/8.9	73.4	5.62	1.32	1.05	0.47	18.8	102	61.2	31.0	15.4	154	0.369
Yongxin	97	/9.02	94.0	4.85	2.51	1.52	0.53	31.2	69.a	28.0	38.2	13.6	144	0.399
Malutinnba	96	/7.95	127	12.8	2.12	/	0.53	0	209	12.5	68.2	20.1	181	0.544
Yanshandeng	94.5	7.5/8.45	175	16.4	15.3	1.43	0.73	9.51	410	13.7	45.1	530	184	0.675
Yuhuzhen	68.8	8/8.6	637	434	2.01	3.12	0.94	18.4	1125	34.8	409	7.63	102	1.831
Xingfu	95	8.5/9.6	126	13.3	0.21	0.10	1.08	100	28.6	12.2	326	18.5	244	0.579
Niuji—Sanpy	74.3	7/8.2	299	47.a	15.6	9.5	1.99	0	619	22.6	185	6.91	181	1.050
Yunnancheng	99	7.5/8.66	146	15.6	9.50	4.52	0.36	37.4	241	44.0	50.1	14.0	136	0.593
Sanmei	84	7.5/8.2	152	20.4	17.70	7.21	1.36	10.0	259	16.0	200	6.25	123	0.680
Mengman	99	7.5/9.8	265	30.7	1.05	0.32	0.50	140	98.3	56.0	160	25.6	224	0.973
Bingleng	94	/8.3	140	13.9	1.01	0.25	0.06	0	273	25.0	41.5	11.0	160	0.535
Manzhao	97	7.5/8.3	118	11.4	0.75	0.51	0.21	18.7	212	17.4	37.2	14.6	150	0.486
Nanhe	96	8.5/9.9	177	23.4	0.12	0.11	1.20	31.5	329	33.0	31.0	16.1	201	0.701
Xiaojiebengman	100.7	7.5/8.52	90.5	8.03	1.01	0.11	0.15	12.5	146	11.0	27.5	15.3	154	0.393
Menplng	102.2	7.5/8.4	235	23.1	6.92	1.80	0.24	0	165	26.2	332	1.70	191	0.951
Chaluo	88	7.0/9.34	332	36.8	2.01	/	2.94	153	503	43.a	34.4	20.0	316	1.210
Zhangke	90	a.8/	375	33.0	1.98	/		116.06	699.38	41.a	20.0	14.0	120	1.058
Ganyingkuo	90	9/9.28	956	95.5	0.43	0.32	3.89	231	1802	50.0	46.1	9.31	217	4.610
Qukailong	86.5	8.0/8.6	485	52.5	9.51	7.85	6.80	49.0	1260	63.2	39.6	5.21	117	1.550
Yulinhe	85	7.5/8.1	387	48.9	29.5	18.5	3.55	0	709	286	52.0	3.06	162	1.370
Kenbachagu	71	/7.0	272	24.65	46.75	2.37	/	0	895	41.44	2.00	2.40	83.09	0.921

After Tong Wei et, (1994).

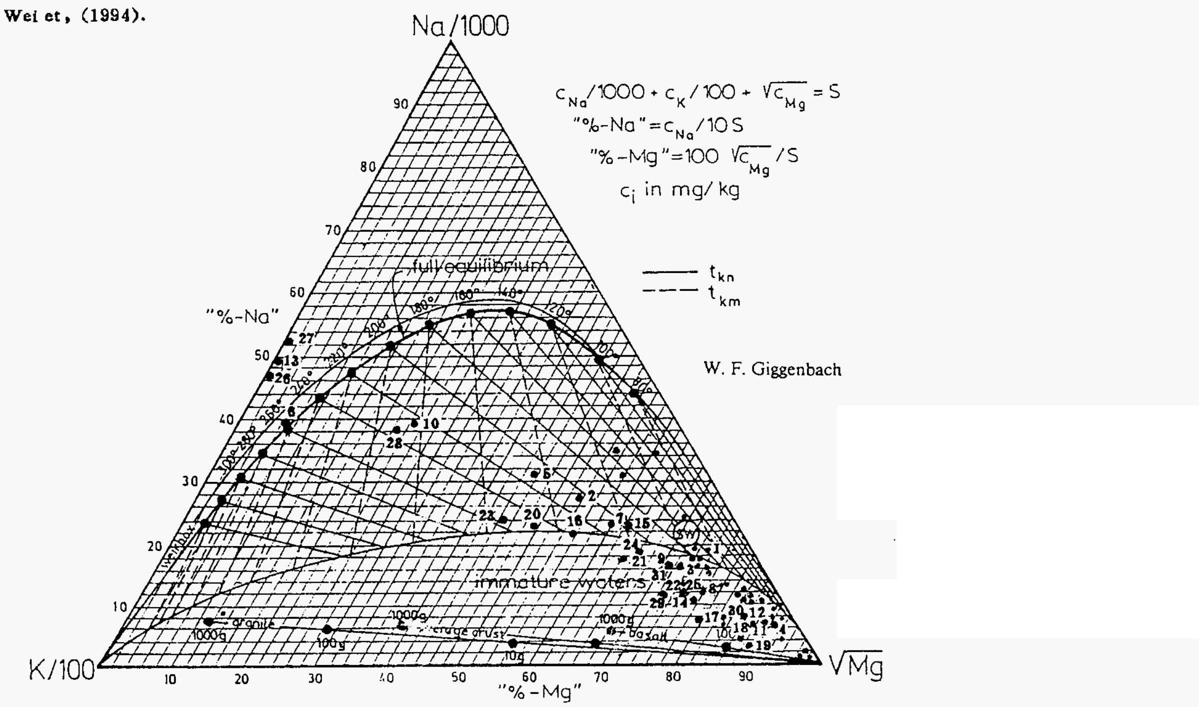

Fig. 1 Relative Na, K, Mg— contents of geothermas waters

1. Lanniba 2. Ruili 3. Humeng 4. Longwozhai 5. Langpu 6. Kehai 7. Pauzhihua—Xiaotang 8. Heishenhe 9. Ruidium 10. Balazhang 11. Quanqiaohe 12. Yongxin 13. Malutfanba 14. Yanshandeng 15. Yuhuzhen 16. Xingfu 17. Niuji—Sanpy 18. Yunnancheng 19. Sanmei 20. Mengman 21. Bingleng 22. Manzhao 23. Nanhe 24. Xiaojiebengman 25. Menping 26. Chaluo 27. Zhangke 28. Ganyingkuo 29. Qukailong 30. Yulinhe 31. Kenbachaqu

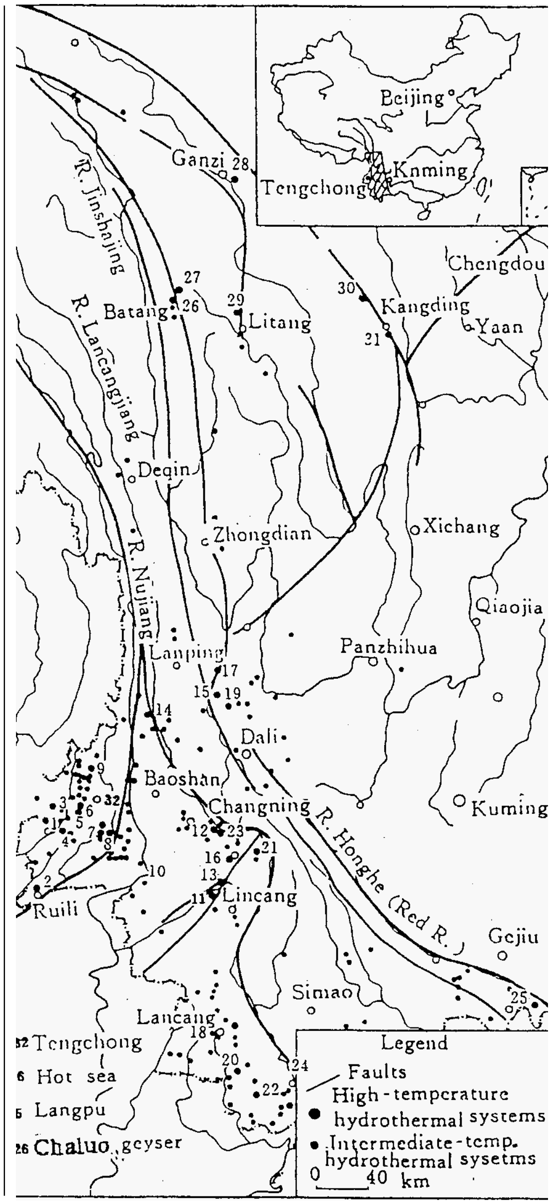

Fig. 2 The distribution of hydrothermal systems in HM
The number's same hydrothermal area as Fig. 1.

and 23 occure in uplift belt of west Yannan. The 168 middle—temperature hydrothermal system with mean temperature 90—150℃, 131 of which are located at uplifted area (Fig. 2).

The formula for calculating reservoir thermal energy by volume method is $Q=\rho C \cdot a \cdot d\,(\theta-\theta_o)$, where Q is reservoir thermal energy in J; ρC is volumetric specific heat of rock plus water in 2.7 J/cm^3℃; a is reservoir area km^2; d is reservoir thickness km, most of a, b are based on Brock et. (1978); θ is reservior temperature℃; θ_o is reference temperature (average annual air temperature). When the formula are executed Monte Carlo multiplication operation, the parameters of a, d, and θ are inputed according to the sample formula of triangular probability and ihe parameters of ρC, θ_o are assumed to be constant. The sum of reservoir thermal energy of the 30 high—temperature systemis is about 53.48 ± 1.95 EJ, and in the 168 middle—temperature systems is about 149.59 ± 2.61 EJ.

The thermal resource (wellhead thermal energy) of each high, middle—temperature systems depends on recovery factor of each system, it is assumed to be 5% for all system in HM, which times the reservoir thermal energy of system to obtain thermal resource.

According to the formula (Brook et. ,1978), the electrical energy of high—temperature system and beneficial heat of middle—temperature system is obtained (table 2).

4. EXPLOITATION PROSPECT OF GEOTHERMAL RESOURCES

In order to utilize the geothermal resources of this region in a rational way it will be necessary to consider the economic impacts regarding tourism as well as commercial exploitation for electricity and other direct uses.

The best prospect for the generation of electricity from the geothermal resources is the Rehai—Langpu geothermal field located at the Tengchong — Gaoligongshan uplifted area. The Rehai — Langpu field of Tengchong County is situated Latitude 24° 55—57′ N, and longitude 98°24—26′ E, at an altitude of 1600m. It is a famous boiling springs area with the highest discharge temperature of 96℃ at the surface. The Late Cenozoic volcanic activities were quite violent, and lasted Curing whole Pleistocene period. Magneto — telluric and Micro — earthquake studies show that a magmatic heat source occurs below 7 km depth (Liao, 1993). Based on the total natural heat flow of 1.77×10^8 W, for the Rehai — Langpu field, it is inferred that there is a magmatic heat source temperature of about 400—600℃ (Guo, 1994). The magmatic heat source appears to be a cooling intrusion (Fig, 3). The thermal water contains high chloride and is of the $Na-Cl-HCO_3$ or $Na-HCO_3-Cl$ type. The Giggenbach's triangular diagram of Na, K, and Mg in thermal water obtain equilibrium water temperature of Rehai—Langpu fleld to be about 260℃ (Fig. 1). It's reservoir thermal energy is about 13.26 ± 1.09 EJ by volume method and the exploitation potentiality may be not less than electricity energy of 5×10^4 kw (table 2).

West Sichuan is at high elevation, cold, and has abundant domestic animals. Based on the predominat resource and economic consideration, the utilization of thermal resource should be geothermal freezing, and space heating.

Most of HM regions are abundant in natural resources. Direct utiliaztion of low to middle temperature systems, such as geothermal stoving, roasting rubber, pulp — boiling, and sanatoriums, is ideal. The specific geographic landscape of HM is enhanced by the beauty of the geothermal features, including beautiful travertine formations. In the future. the area's rich geothermal features will certainly be important for the HM area's tourist industry.

5. CONCLUSIONS

The best prospect for the generation of electricity from the geothermal resources of high—temperature system is lacated at the Tengchong Geoligongshan uplifted area where the Rehai (Hot Sea) — Langpu geothermal field is an ideal target. Direct utilization of low to middle temperature systems in HM is ideal, and the area's rich geothermal features are HM area's tourist industry.

6. ACKNOWLEDGEMENTS

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Table 2 Locations, Temperatures, Areas, Thicknesses, and Energies of High-Tempernture hydrothermal Systems in HM

Province long. E	lat. N	Hydrolhermal area	Temp ℃ Mix. spr./Annu. air	Temp., ℃ mix.	most likely	min.	Area/Thickness, km²/km mix	most likely	min	Reservoir thermal energy EJ	Wellead therm. energy EJ	Wellhead available work EJ	Electrical energy Mw. for 30a
west yunnan													
97°55′	24°47′	Lanniba	93/19.2	130(I)	158(A)	172(H)	1/1	2/1.5	3/2.5	1.20±0.36	0.060	0.010	4.61
97°56′	24°03′	Ruili	95/20.0	136(K)	163(A)	202(H)	1/1	2/1.5	3/2.5	1.31±0.36	0.066	0.012	6.07
98°07′	24°44′	Humeng	94/19.2	135(I)	153(B)	162(A)	1/1	2/1.5	3/2.5	1.18±0.34	0.069	0.010	4.62
98°16′	24°47′	Longwozhai	96.5/18.5	128(I)	134(B)	138(A)	1/1	2/1.5	3/2.5	1.07±0.33	0.064	0.009	8.80
98°24′	24°55′	Langpu	96.2/14.8	161(A)	209(H)	221(I)	3.4/0.17	4.5/1.5	9.5/2.7	4.05±1.84	0.203	0.046	19.02
98°26′	24°57′	Rehai(Hot Sea)	95.5/14.8	140(A)	230(I)	276(M)	8/0.5	8.5/1.5	18/2.4	S.21±0.a4	0.461	0.111	48.9
98'27'	24°43′	PauZhihua—Xiaotang	96.8/14.8	164(A)	187(I)	205(H)	1/1	2/1.5	6/2.5	2.26f0.94	0.113	0.023	9.72
98°27′	24°42′	Heishenhe	77.5/14.8	125(I)	145(A)	173(I)	1/1	2.5/1.5	3/2.5	1.25±0.a7	0.ma	0.011	4.66
98°28′	25°27′	Ruidium	87/14.8	118(K)	138(I)	160(A)	1/0.1	3.2/1.5	6.4/2.7	1.39±1.13	0.094	0.016	6.64
98°38′	24°37′	Bolaghang	97/14.9	184(K)	207(A)	225(H)	1/1	2/1.5	3/2.5	1.66f0.46	0.083	0.016	6.76
99°53′	24°04′	Quanqiaohe	97/17.2	146(I)	153(B)	163(A)	1/1	2/1.5	3/2.5	1.23±0.39	0.061	0.011	4.66
99°54′	24°46′	Yong Xin	97/17.2	125(I)	144(B)	154(A)	1/1	2/1.5	3/2.5	I.07±0.a4	0.064	0.009	a.94
99°57′	24'07'	Malutianba	96/19.4	162(B)	181(I)	218(H)	1/1	2/1.5	3/2.5	I.51±0.34	0.076	0.017	7.09
99°08′	25°53′	Yonshandeng	94.5/13.2	97(K)	172(I)	180(A)	1/1	2/1.5	3/2.5	1.23±0.24	0.062	0.011	4.68
99°57′	26'07'	Yuhuzhen	68.3/13.9	122(K)	138(A)	220(H)	1/1	2/1.5	3/2.5	1.26f0.40	0.063	0.011	4.66
99°59′	24°10′	Xingfu	96/19.4	139(K)	193(A)	235(H)	1/1	2/1.5	3/2.5	1.47±0.43	0.074	0.016	6.64
99°59′	25°15′	Niuji—Sanpy	74.3/13.9	108(K)	153(A)	196(I)	2/1	3/1.5	4/2.5	1.92±0.as	0.096	0.020	8.46
99°59′	22°40′	Yunnunchang	99/20	122(I)	147(B)	155(A)	1/1	2/1.5	3/2.5	1.09±0.44	0.064	0.007	a.30
100'02'	26'44	Sanmei	84/13.9	112(C)	150(A)	205(I)	1/1	2/1.5	3/2.5	1.27±0.a7	0.064	0.011	4.83
100'08'	22'14	Mengman	99/21.6	140(K)	178(B)	245(H)	1/1	2/1.5	3/2.5	1.48±0.46	0.M4	0.016	8.64
100°18′	24°29′	Bingleng	94/19.4	126(K)	164(A)	217(I)	1/1	2/1.5	3/2.5	1.35±0.44	0.067	0.013	6.60
100°23′	21°52′	Manzhao	97/21.6	108(K)	155(A)	204(I)	1/1	2/1.5	3/2.5	1.19±0.40	0.060	0.011	4.65
100°03′	24°23′	Nanhe	96/19.4	155(K)	169(B)	256(H)	1/1	2/1.5	3/2.5	1.41±0.44	0.071	0.015	6.26
100°42′	21°43′	Xiaojiebengman	100.7/21.0	121(K)	153(B)	176(I)	1/1	2/1.5	3/2.5	1.13±0.36	0.059	0.011	4.62
103°30′	22°55′	Menping	102.2/26	111(K)	165(B)	181(I)	1/1	2/1.5	3/2.5	1.14±0.33	0.067	0.010	4.a4
West Sichuan													
99°23′	30°24′	Chaluo	88/	126(K)	194(B)	207(H)	1/1	2/1.5	3/2.5	1.42±0.44	0.071	0.014	5.76
99°31′	30°28′	Zhangke	90/	141(B)	205(H)	210(I)	1/1	2/1.5	3/2.5	1.65	0.083	0.016	6.76
100°05′	31°34′	Ganyingkuo	90/	172(B)	188(I)	232(H)	1/1	2/1.5	3/2.5	1.58±0.41	0.079	0.017	7.09
100°07′	30°05′	QuKailong	86.5/3.0	119(C)	140(B)	233(I)	1/1	2/1.5	3/2.5	1.34±0.42	0.067	0.013	5.44
100°57′	29°57′	Yulinhe	85/7.1	99(K)	154(B)	234(I)	1/1	2/1.5	3/2.5	1.36±0.47	0.068	0.013	5.36
101°37′	30°33′	Kenbaohaqu	71/4.6	102(K)	156(A)	210(I)	1/1	2/1.5	3/2.5	1.28±0.24	0.64	0.012	4.87

Note: geothermometers (After Fournier, 1981)

(A) SiO_2(no steam loss); (B) SiO_2(max. steam loss); (C) chalcedony;

(I) Na—K—Ca; (K) K/Mg; (H) Na/K; (M) chloride—enthalpy diagram.

Area(a), thicbness(b) (After Brook, 1978)

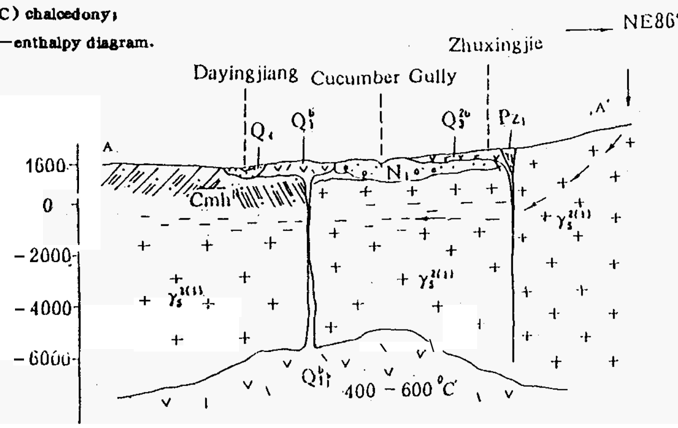

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Fig. 3 Sketch map showing geologic cross section of Rehai—Langpu geothermal Field

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