Proceedings World Geothermal Congress 2015
Melbourne, Australia, 19-25 April 2015

Study of the Scaling Trend of Thermal Groundwater in Kangding County of Sichuan Province

WEI Mei -hua[1] ,WANG Junhao[2] and TIAN Tingshan[2]

[1].Shanxi Province No.1 Institute of Hydrogeology and Engineering Geololy ,Taiyuan 030024

[2].Chinese Institute of Geological Environment Monitoring, Beijing, 100081

weimeihua815@163.com or hpuwangjunhao@163.com

Keywords: Thermal groundwater; scaling; Water-rock balance, Kangding

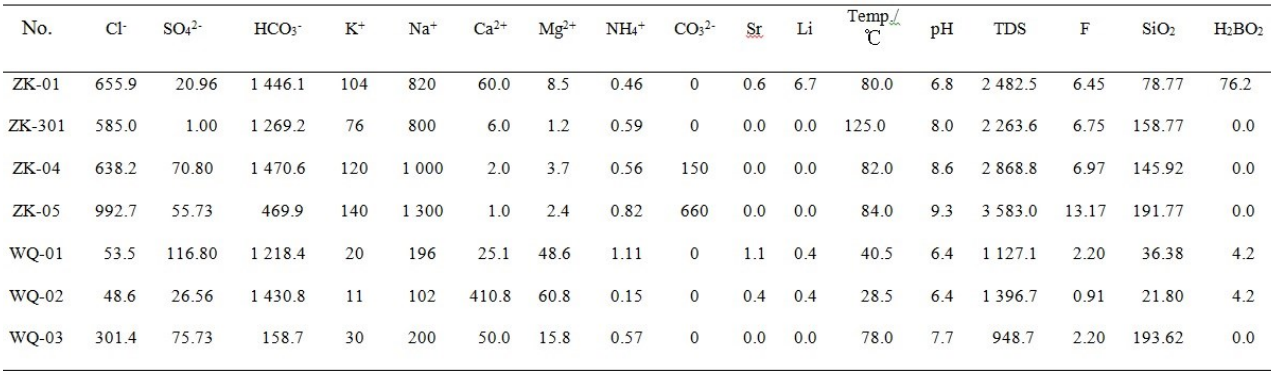
ABSTRACT

Water samples taken from 4 geothermal wells and 3 springs in Kangding's county geothermal fields, are examined in this paper. The scaling trend of the thermal groundwater is calculated and judged by the methods of Ruzner index and Larson index , the WATCH program and Na–K–Mg equilibrium diagram. The results show that thermal groundwater in part of the geothermal wells and springs in Kangding areas have a tendency to scale. The main precipitated scaling matter is calcite. And chrysotile, calcite and talc are responsible for the scaling.

1. INTRODCTION

In the using of geothermal system, scale substances will be attached to the inside of pipelines , producing wells and other ground equipment, thereby increasing the energy of transport consumption, so that greatly reduce the utilization of geothermal energy. Therefore, researching and analysis of the scaling tendency of geothermal water is not only of theoretical significance, but also of practical value. Zhou Xun(Zhou,2001), Fu bichang (Fu et al.,1998), conducted a comprehensive study about the causation of the corrosion and clogging in geothermal well. Wang Kuifeng studied the chemical characteristics and scaling corrosion of hot water in Guantao formation, Linqing Province (Wang, 2010). Many foreign chemical experts also study corrosion and scaling of the geothermal water. And much forecasting index, such as Ryzner index(Patzay,1998; Ryznar,1944), Larson index(Patzay,1998; Larson,1967) , driving force index , Langlier index(Patzay,1998; Langelier,1946)and Kiddick index(Riddick,1944) ,can be proposed. Arnórsson et al.(1982), proposed water chemical treatment program—WATCH, which can be used to predict certain chemical reactions in groundwater exploitation and recharge as well as scaling.

Table 1: Analytical results for major chemical components of geothermal water in the Kangding geothermal field (mg/L)



No.	Cl^-	SO_4^{2-}	HCO_3^-	K^+	Na^+	Ca^{2+}	Mg^{2+}	NH_4^+	CO_3^{2-}	Sr	Li	Temp./℃	pH	TDS	F	SiO_2	H_2BO_2
ZK-01	655.9	20.96	1 446.1	104	820	60.0	8.5	0.46	0	0.6	6.7	80.0	6.8	2 482.5	6.45	78.77	76.2
ZK-301	585.0	1.00	1 269.2	76	800	6.0	1.2	0.59	0	0.0	0.0	125.0	8.0	2 263.6	6.75	158.77	0.0
ZK-04	638.2	70.80	1 470.6	120	1 000	2.0	3.7	0.56	150	0.0	0.0	82.0	8.6	2 868.8	6.97	145.92	0.0
ZK-05	992.7	55.73	469.9	140	1 300	1.0	2.4	0.82	660	0.0	0.0	84.0	9.3	3 583.0	13.17	191.77	0.0
WQ-01	53.5	116.80	1 218.4	20	196	25.1	48.6	1.11	0	1.1	0.4	40.5	6.4	1 127.1	2.20	36.38	4.2
WQ-02	48.6	26.56	1 430.8	11	102	410.8	60.8	0.15	0	0.4	0.4	28.5	6.4	1 396.7	0.91	21.80	4.2
WQ-03	301.4	75.73	158.7	30	200	50.0	15.8	0.57	0	0.0	0.0	78.0	7.7	948.7	2.20	193.62	0.0

Note:The temperature of geothermal well refers to wellhead temperature and the temperature of hot springs refers to the temperature of the surface hot springs.

The hot water study area—Simaqiao of Kangding in Sichuan Province,has developed many geothermal wells, which wellhead temperature is 80~125℃(Table 1). What's more,there are a lot of hot springs outcrop along Kangding-Moxi fracture (F1),Yulin River fracture (F2) , Bai Yangwan fracture (F3), Longtou River fracture (F4) and Zhuanjinglun River fracture (F5)(Figure 1), which surface temperature is 21~89℃ and total (incomplete) flow rate is about 196.6 L/s(Tong and Zhang,1994). The scaling of the hot water in Simaqiao,taking 4 geothermal wells and 3 springs for example,will be analyzed,in order to provide a reference for the local development and utilization of geothermal.

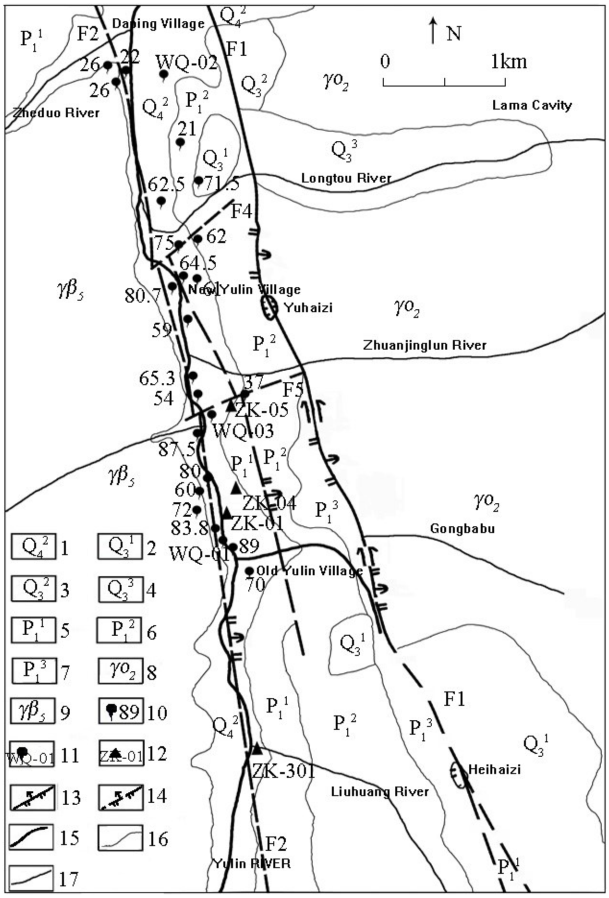


Figure 1: Simplified geologic map of the Kangding geothermal field

Legend:1- Holocene;2-Upper Section of Late Pleistocene;3-Middle Section of Late Pleistocene;4-Lower Section of Late Pleistocene;5-Upper Section of Early Permian;6-Middle Section of Early Permian;7-Lower Section of Early Permian;8-Granodiorite;9-Biotite Granite;10-Springs and the surface temperature;11-Springs and the No.;12-Drilling and the No.;13-Measured faults;14-Inferred faults;15-Yulin River;16-Stratigraphic contacts;17-Ditch

2. ANALYSIS OF GEOTHERMAL WATER SCALING

Geothermal water scaling is mainly due to destroying of the balance. Before the development of geothermal water, it is in a state of thermochemical equilibrium in the underground geothermal reservoir and rock. When drilling, geothermal water migrates upward along the pipe, then the pressure and temperature changes, thus the solubility of various minerals id affected in geothermal water. Consequently, with the development of geothermal water, the original chemical balance is destroyed and the solubility of solid substances decrease, which makes some minerals that originally dissolved in the geothermal water precipitated into the scale (Chai, 2004).

According to the main chemical ingredient, geothermal water scaling can be classified as calcite scaling, $CaSO_4$ scaling, silicate scale and iron oxide scale. In process of the use of geothermal water, the calcium carbonate is widespread.

2.1 Calcite scale trend analysis

On the issue of calcite scaling, American chemist Ellis who is engaged in geothermal application used Ryzner index in the judgment of the scaling trend of geothermal water for the first time. It is based on the principle of balance of calcite in water and the summary of actual operation result of various kinds of water. Since then, the index has been considered to be the only way to determine calcite scale almost in all geothermal literatures (Ellis, 1983). According to a number of analysis and studies, however, it is inappropriate to apply Ryzner index directly in judging the geothermal water scaling tendency (Meng et al., 1997). It is that Ryzner index is based on the theoretical trend of deposition or dissolution of calcite in water, and the solubility product of calcite, the second ionization constant of carbonic acid and it is inferred from the dissociation constant of water and the alkalinity and chemical equilibrium between protons corresponding to bicarbonate, carbonate and hydroxide. But the index doesn't take into account other ions in water, such as Cl^- and SO_4^-. Usually the Cl^- has higher levels. A comprehensive evaluation of geothermal water scaling of Kangding area was made in accordance with the relevant specification (GB/T 11615 -2010) and geothermal experience and test data.

2.1.1 Larson Index (LI)

It is relatively reasonable for the geothermal fluid of high Cl^- (mEq percentage> 25%) to judge the scaling tendency of calcite with Larson index (*LI*), and *LI* is defined as follows (GB/T 11615 -2010):

$$LI = \frac{[Cl]+[SO_4]}{ALK} \qquad （1）$$

[Cl]—the concentration of chloride or halide；

[SO_4]—the concentration of sulfate；

ALK——alkalinity, namely the concentration of HCO_3^-.

The above three are all represented as an equivalent amount of $CaCO_3$. If LI> 0.5, it is no scaling but corrosive; And if LI <0.5, it indicates a potential for scaling.

Table 2: Prediction of Calcite scaling trend of thermal groundwater in Kangding geothermal field using Larson index

No.	Cl^- （mg/L）	SO_4^{2-} (mg/L)	HCO_3^- （mg/L）	CO_3^{2-} （mg/L）	LI=([Cl]+[SO_4]) /ALK	Scaling trends	Cl^- meq%
ZK-01	655.9	20.96	1 446.1	0	0.80	No scaling	43.2
ZK-301	585.0	1.00	1 269.2	0	0.79	No scaling	44.2
ZK-04	638.2	70.80	1 470.6	150	0.67	No scaling	39.0
ZK-05	992.7	55.73	469.9	660	0.98	No scaling	47.5
WQ-01	53.5	116.80	1 218.4	0	0.20	Possible scaling	6.3
WQ-02	48.6	26.56	1 430.8	0	0.08	Possible scaling	5.4
WQ-03	301.4	75.73	158.7	0	3.87	No scaling	66.9

Larson Index is used to calculate the water of 4 geothermal wells and 3 springs (table 1), the result is shown in table 2. The LI is between 0.08~3.87, LI of sample (WQ-01,WQ-02, Cl^- ＜25%) are 0.20 and 0.08 respectively ,both＜0.5, is possible scaling; and LI of others (Cl^- ＞25%) are over 0.5, mean no scaling.

2.1.2 Ryzner Index (RI)

When the content of Cl^- in thermal fluid flow is low, that is< 25 %(mol eq), it can be qualitatively estimated the tendency of the calcite scaling by Ryzner Index (RI) as follow (Chai,2004):

$$RI=2pH_s-pH_a \qquad （2）$$

Where pH_a is the measured values of pH of geothermal fluid and pH_s is the calculated values of pH of geothermal fluid. How was the pH calculated is showed by Formulas (3) or (4).

$$pH_s=-\log[Ca^{2+}]-\log[ALK]+K_c \qquad （3）(Chai,2004)$$

or ,

$$pH_s=-\log[Ca^{2+}]-\log[ALK]+K_e \qquad （4）(GB/T\ 11615\ -2010)$$

Where: [Ca^{2+}]—Mol concentration of Ca2+ in the Geothermal fluid;

Kc —the complex constant that including two constants related to temperature equilibrium constants and activity coefficients (Figure 2).

Ke— the constant that if TDS is 200 ~ 6000mg / L, Ke is 1.8 to 2.6. And if temperature >100 ℃, Ke is the low value 1.8. Otherwise, the temperature <50 ℃, is the high value 2.8.

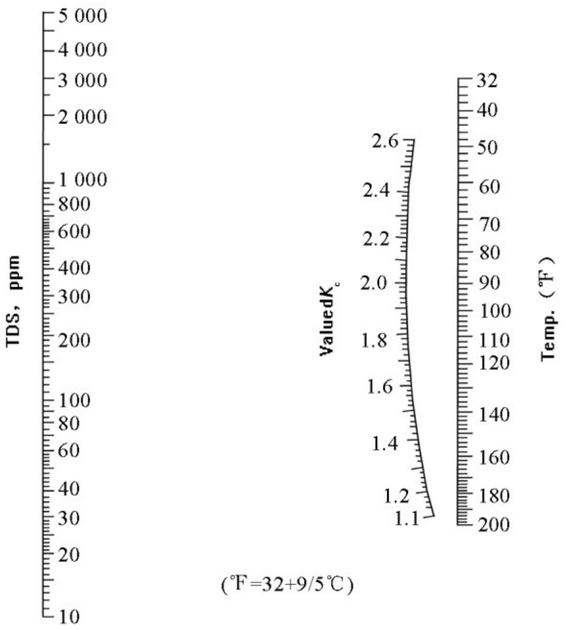


Figure 2:The valued K_c while TDS ＜6000ppm (Lund，1976)

And the relation between *RI* and scaling is much serious scaling when *RI* <4.0; serious scaling when *RI* 4.0~5.0; Medium scaling when *RI* 5.0~6.0; slight scaling when *RI* 6.0~7.0; and no scaling when *RI* >7.0.

Take ZK-01 for example, $pHa = 6.8$; the wellhead temperature geothermal water t =80℃ (176℃), while TDS=2482.5mg/L,and as it can be seen from Figure 2 ,K_c =1.36. Accordingly the calculated result is pH_s =5.81 by formula (3) ， and RI=4.82; So the scaling is serious.

But if $K_e = 2.6-(2.6-1.8)/(100-50)\times(80-50) = 2.12$; the calculated result is pHs =6.57 by formula (4)，and RI=6.34;So the scaling is slightly scaling .Thereby, the judgment results are inconsistent by different methods as different parameter values.

Table 3: Prediction of Calcite scaling trend of thermal groundwater in the Kangding geothermal field using Ryzner Index (*RI*)

No.	HCO_3^- mol/L	Ca^{2+} mol/L	TDS ppm	pH_a	$RI=2\,pH_s-pH_a$ $pH_s=-\log[Ca^{2+}]-\log[ALK]+K_c$				$RI=2pH_s-pH_a$ $pH_s=-\log[Ca^{2+}]-\log[ALK]+K_e$			Cl^-meq%
					℉=32+ 9/5℃	K_c	RI	Scaling trends	K_e	RI	Scaling trends	
ZK-01	0.0237	0.0015	2 482.5	6.8	176.0	1.36	4.82	serious	2.12	6.34	slight	43.2
ZK-301	0.0208	0.0002	2 263.6	8.0	257.0	1.20	5.41	medium	1.80	6.61	slight	44.2
ZK-04	0.0241	0.0001	2 868.8	8.6	179.6	1.34	5.92	medium	2.09	7.41	no	39.0
ZK-05	0.0077	0.0001	3 583.0	9.3	183.2	1.33	6.79	slight	2.06	8.24	no	47.5
WQ-01	0.0200	0.0006	1 127.1	6.4	104.9	1.92	7.25	no	2.60	8.61	no	6.3
WQ-02	0.0235	0.0103	1 396.7	6.4	83.3	2.17	5.18	medium	2.60	6.04	slight	5.4
WQ-03	0.0026	0.0013	948.7	7.7	172.4	1.35	5.98	medium	2.15	7.58	no	66.9

Unlike *LI*, *RI* does not involve the role of Cl^- and SO_4^{2-}.But it considers the solubility of calcite. The calcite scaling of the geothermal water samples can be analysed as the results in Table 3.

2.2 CaSO4 scaling trend analysis

The scaling trend of $CaSO_4$ in geothermal water can be estimated by the relative saturation(*R.S.*) of Gypsum($CaSO_4 \cdot 2H_2O$) .It is complicated to calculation the solubility products of gypsum .The approximation graphic make it much easy as Figure 3 shown .The calculation of *R.S.* is as follow:

$$R.S.=10^{(\lg ppmCa+\lg ppmSO4-\lg K_{CaSO4\cdot 2H2O})} \qquad (5)$$

Where:

$ppmCa^{2+}$—the content of Ca^{2+} expressed in ppm

$ppmSO_4^{2-}$—the content of SO_4^{2-} expressed in ppm

$\lg K_{CaSO4\cdot 2H2O}$— the solubility product of gypsum calculated by TDS (in ppm) and temperature.

If *R.S.* <1,it represents unsaturation and it' impossible to make $CaSO_4$ scale ;Otherwise *R.S.* ＞1, it represents super saturation, and $CaSO_4$ may be scaling(Chai,2004).

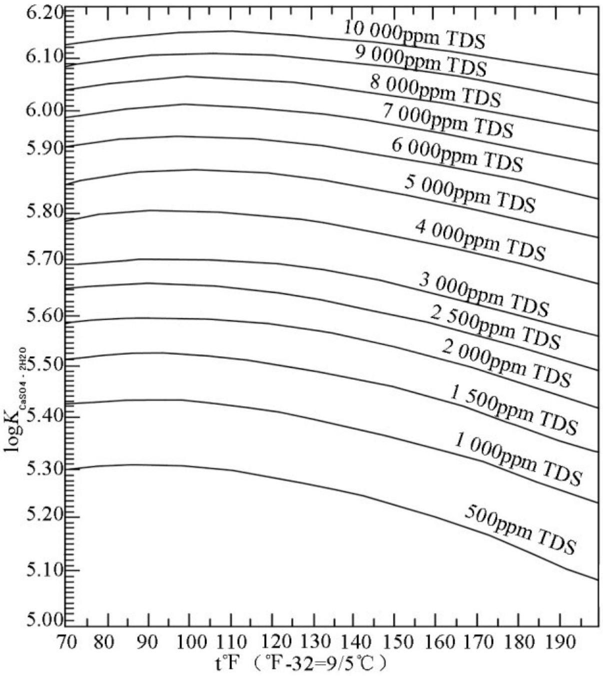


Figure 3: The solubility product of CaSO4 · 2 H2O in geothermal water with low temperature

The results of calculations for $CaSO_4$ scaling of the seven geothermal water samples are presented in Table 4, which indicate that there is no $CaSO_4$ scaling.

Table 4: Prediction of $CaSO_4$ scaling trend of thermal groundwater in the Kangding geothermal field

No.	log[Ca]	log[SO4]	℉=32+9/5℃	TDS ppm	$\lg K_{CaSO4\cdot 2H2O}$	*R.S.*	Scaling trends
ZK-01	1.778	1.321	176.0	2 482.5	5.540	0.00363	no
ZK-301	0.779	0.000	257.0	2 263.6	5.515	0.00002	no
ZK-04	0.301	1.850	179.6	2 868.8	5.585	0.00037	no
ZK-05	0.000	1.746	183.2	3 583.0	5.665	0.00012	no
WQ-01	1.399	2.067	104.9	1 127.1	5.450	0.01038	no
WQ-02	2.614	1.424	83.3	1 396.7	5.549	0.03082	no
WQ-03	1.699	1.879	172.4	948.7	5.295	0.01920	no

2.3 Silicate scaling trend analysis

Components of silicate scaling is complex, generally 40% ~50% of which is SiO_2 , other 25% ~ 30% is iron-aluminum oxide, and the other 10% ~ 20% is Na_2O.Silicate scaling trends can be determined by the relative saturation *R. S* of amorphous SiO_2,and the formula is(Wang et al.,2010):

$$R.S= SiO_2 (mg/L) / (2.466\times 10^4\times e^{-1553/T}) \qquad (6)$$

Where T represents the absolute temperature of geothermal water. If *R. S* <1, the silicate scaling is not generated; But if *R. S*>1, silicate scaling may be generated.

The results of calculations for silicate scaling of the seven geothermal water samples are presented in Table 5, which indicates that there is no silicate scaling.

Table 5: Prediction of silica scaling trend of thermal groundwater in the Kangding geothermal field

No.	H_2SiO_3(mg/L)	SiO_2（mg/L)	T=(273.15+t)K	$e^{-1553/T}$	*R.S*	scaling trend
ZK-01	102.4	78.769	353.15	0.012	0.260	no
ZK-301	206.4	158.769	398.15	0.020	0.318	no
ZK-04	189.7	145.923	355.15	0.013	0.469	no
ZK-05	249.3	191.769	357.15	0.013	0.601	no
WQ-01	47.29	36.377	313.65	0.007	0.209	no
WQ-02	28.34	21.800	301.65	0.006	0.152	no
WQ-03	251.7	193.615	351.15	0.012	0.654	no

2.4Calculation results of scaling trend analysis

From the above analysis, we can see, part of geothermal water may scale Kangding .And there is mainly calcite scaling, but no $CaSO_4$ scaling and silicate scaling. As the Cl^- percent of WQ-01 and WQ-02 < 25%, by Using Ryzner Index *RI*, the judge result is the WQ-01 of no scaling, but WQ-02 scaling. And Cl^- percent of others > 25%, judging by Larson Index, all LI> 0.5, means no scaling. IN fact, it can be seen different levels of scaling on equipment of geothermal wells. Obviously, it is the limitation of Index. There are some reasons. On the one hand, the Index is applicable to low-temperature geothermal water. On the other hand, if the groundwater contains free CO_2, with the pressure and temperature decreasing, CO_2 will escape from the water, causing precipitation of calcite. Thus, Ryzner index or Larson index, did not consider CO_2 and hydrodynamic conditions in hot water, so the judge scaling trend with index just give a preliminary forecast.

3. CHEMICAL EQUILIBRIUM OF UNDERGROUND GEOTHERMAL RESERVOIR

3. 1Na-K-Mg triangular diagram method

Na-K-Mg triangular diagram method is used to evaluate the water - rock equilibrium and distinguish different types of water samples which were first proposed by Giggenbach (1988). The most important advantage of this method is that the mixed trend and group properties can be judged according to the position of the water samples.

Na-K-Mg triangular diagram shows that geothermal water ZK-301, ZK-04, ZK-05 are partial equilibrated waters (Figure 4). And it demonstrates that the reactions can reach chemical equilibrium in some high-temperature environment could also be in balance in these three geothermal water. Others are immature waters. Except ZK-01, the other three hot springs locating near the $Mg^{1/2}$ corner which belongs to shallow water area. It indicates the water-rock reaction equilibrium temperature is low and indicates that the area is likely to be influenced by the mixing action of atmospheric precipitation and cold water. And ZK-01 cannot reach equilibrium in hot environment because of immature state. It also indicate that hot water may come from a hot environment in this area, and diluted with surface water in the process of rising, making WQ-03, WQ-01 and WQ-02 elements content decrease. Therefore, action temperature cannot be used to evaluate the geothermal reservoir temperature.

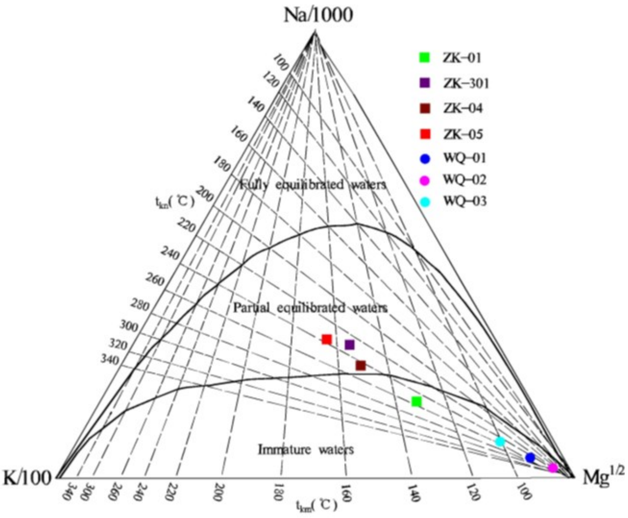


Figure 4: Na-K-Mg diagram of the Kangding geothermal field

3.2 WATCH program method

The saturation index for mineral of geothermal water is defined as：

$$\text{Saturation Index (SI)}=\lg(Q/K)=\lg Q-\lg K \qquad (7)$$

Where:

lgQ—the activity product of mineral；

lgK—the solubility product of mineral.

The saturation index gives the saturation degree of mineral. If the saturation index $\lg(Q/K)<0$，that is the activity product (lgQ) of mineral is lower than the solubility product (lgK) of mineral , then the geothermal water is under saturated for mineral and no mineral scaling is predicted. If the saturation index $\lg(Q/K)>0$, that is ,the activity product (lgQ) of mineral is higher than the solubility product (lgK) of mineral, then the geothermal water is supersaturated and the potential for mineral scaling exists.

The calculation of the saturation index can be done by a chemical model, the WATCH program (Bjarnason, 1994). Available chemical analyses were entered into the WATCH program and the ion activity product (lgQ) and solubility product (lgK) of mineral are computed. Then corresponding saturation indices (lg (Q/K)) were calculated by Eq. (7).

Some water chemical analysis data of the geothermal water samples, which is used to calculated the temperature range between 20~130 with WATCH program ,show in Table 6.Some kinds of minerals to determine the equilibrium state. That are anhydrite, chrysotile, calcite, fluorite, microcline, muscovite, Silamorph, chalcedony, quartz, talc, respectively. Table 7 shows the calculated results. The lg(Q/K) values of calcite are as high as 109.15 and 109.18 of ZK-04 and ZK-05 respectively. These values are all over 100, and the reason may probably be the Ca^{2+} contents are too low which are 10mg/L and 20mg/L respectively, and the free CO_2 content is 0; What is more, it is caused by temperature and pressure changes in the process of collecting water samples for water quality analysis. Therefore, only other five water samples are used to make the minerals' Lg(Q/K)-T diagram (Figure 5).

Table 6:Comparison of brine sample analyses and liquid chemistry as calculated using WATCH

Analysis[a]	ZK-01	ZK-301	ZK-04	ZK-05	WQ-01	WQ-02	WQ-03
pH	6.80	8.00	8.60	9.30	6.40	6.40	7.70
CO_2	104.30	42.32	0.00	0.00	390.10	478.50	44.67
H_2S	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NH_3	0.43	0.56	0.53	0.77	1.05	0.14	0.54
B	19.14	0.00	0.00	0.00	1.04	1.03	0.00
SiO_2	78.77	158.77	145.92	191.77	36.38	21.80	193.62
Na	820.00	800.00	1000.00	1300.00	196.00	102.00	200.00
K	104.00	76.00	120.00	140.00	20.00	10.60	30.00
Mg	8.51	1.22	3.65	2.43	48.64	60.80	15.81
Ca	60.12	6.01	2.00	1.00	25.05	410.80	50.10
F	6.45	6.75	6.97	13.17	2.20	0.91	2.20
Cl	655.90	585.00	638.20	992.70	53.54	48.57	301.40
SO_4	20.96	1.00	70.80	55.73	116.80	26.56	75.73
Al	0.02	0.02	0.08	0.06	0.05	0.02	0.02
Fe	0.58	0.05	0.05	0.05	0.05	0.05	0.05
TDS	2428.50	2263.60	2868.80	3583.00	1127.10	1396.70	948.70

a In mg/kg except pH.

Table 7: The values for logK and logQ

minerals	Temp	ZK-01		ZK-301		ZK-04		ZK-05		WQ-01		WQ-02		WQ-03	
	℃	logK	logQ	logK	logQ	logK	logQ	logK	logQ	logK	logQ	logK	logQ	logK	logQ
Anhydrite	20	-5.33	-7.23	-5.97	-9.56	-5.36	-8.14	-5.39	-8.62	-4.86	-6.67	-4.74	-6.29	-5.31	-6.59
	60	-5.33	-7.23	-5.97	-9.57	-5.36	-8.14	-5.39	-8.63	-4.86	-6.67	-4.74	-6.29	-5.31	-6.59
	100	-5.33	-7.23	-5.97	-9.58	-5.36	-8.15	-5.39	-8.64	-4.86	-6.67	-4.74	-6.29	-5.31	-6.59
	140	-5.33	-7.23	-5.97	-9.59	-5.36	-8.15	-5.39	-8.66	-4.86	-6.66	-4.74	-6.29	-5.31	-6.58
Chrysotile	20	25.40	23.11	21.74	24.51	25.21	28.13	25.03	31.74	29.60	22.64	31.11	22.63	25.59	28.29
	60	25.40	23.78	21.74	26.02	25.21	32.06	25.03	35.01	29.60	23.26	31.11	23.47	25.59	29.86
	100	25.40	23.56	21.74	27.89	25.21	34.51	25.03	37.35	29.60	22.82	31.11	23.44	25.59	31.86
	140	25.40	22.66	21.74	29.24	25.21	36.47	25.03	39.11	29.60	21.65	31.11	22.88	25.59	33.23
Calcite	20	-9.12	-9.43	-9.89	-10.30	-9.15	100.00	-9.18	100.00	-8.62	-9.76	-8.56	-8.57	-9.09	-9.11
	60	-9.12	-9.30	-9.89	-10.02	-9.15	100.00	-9.18	100.00	-8.62	-9.61	-8.52	-8.38	-9.09	-8.83
	100	-9.12	-9.34	-9.89	-9.69	-9.15	100.00	-9.18	100.00	-8.62	-9.71	-8.52	-8.38	-9.09	-8.47
	140	-9.12	-9.53	-9.89	-9.45	-9.15	100.00	-9.18	100.00	-8.62	-10.00	-8.56	-8.51	-9.09	-8.26
Fluorite	20	-10.58	-10.26	-10.53	-11.25	-10.58	-11.67	-10.57	-11.47	-10.81	-11.46	-10.93	-11.09	-10.59	-11.14
	60	-10.58	-10.26	-10.53	-11.26	-10.58	-11.67	-10.57	-11.48	-10.81	-11.45	-10.93	-11.08	-10.59	-11.15
	100	-10.58	-10.26	-10.53	-11.27	-10.58	-11.67	-10.57	-11.49	-10.81	-11.45	-10.93	-11.08	-10.59	-11.15
	140	-10.58	-10.26	-10.53	-11.28	-10.58	-11.68	-10.57	-11.51	-10.81	-11.45	-10.93	-11.09	-10.59	-11.16
Microcline	20	-19.60	-17.53	-17.56	-16.81	-19.50	-16.13	-19.39	-16.15	-22.12	-18.79	-23.04	-20.17	-19.71	-16.86
	60	-19.60	-17.53	-17.56	-16.85	-19.50	-16.38	-19.39	-16.93	-22.12	-18.79	-23.04	-20.17	-19.71	-16.88
	100	-19.60	-17.53	-17.56	-16.95	-19.50	-16.83	-19.39	-18.14	-22.12	-18.79	-23.04	-20.17	-19.71	-16.93
	140	-19.60	-17.53	-17.56	-17.08	-19.50	-17.54	-19.39	-19.68	-22.12	-18.79	-23.04	-20.17	-19.71	-16.98
Muscovite	20	-22.48	-18.13	-19.88	-19.92	-22.33	-17.52	-22.19	-19.26	-25.92	-15.96	-27.14	-17.53	-22.63	-18.51
	60	-22.48	-18.36	-19.88	-20.48	-22.33	-19.13	-22.19	-21.32	-25.92	-16.17	-27.14	-17.81	-22.63	-19.05
	100	-22.48	-18.28	-19.88	-21.23	-22.33	-20.50	-22.19	-23.64	-25.92	-16.02	-27.14	-17.80	-22.63	-19.78
	140	-22.48	-17.98	-19.88	-21.85	-22.33	-22.04	-22.19	-26.23	-25.92	-15.62	-27.14	-17.61	-22.63	-20.31
Silamorph.	20	-2.33	-2.89	-2.10	-2.60	-2.32	-2.64	-2.31	-2.62	-2.59	-3.22	-2.68	-3.44	-2.34	-2.50
	60	-2.33	-2.89	-2.10	-2.61	-2.32	-2.72	-2.31	-2.88	-2.59	-3.22	-2.68	-3.44	-2.34	-2.51

	100	-2.33	-2.89	-2.10	-2.64	-2.32	-2.87	-2.31	-3.28	-2.59	-3.22	-2.68	-3.44	-2.34	-2.52
	140	-2.33	-2.89	-2.10	-2.69	-2.32	-3.11	-2.31	-3.79	-2.59	-3.22	-2.68	-3.44	-2.34	-2.54
Chalcedony	20	-3.01	-2.89	-2.66	-2.60	-2.99	-2.64	-2.97	-2.62	-3.40	-3.22	-3.54	-3.44	-3.03	-2.50
	60	-3.01	-2.89	-2.66	-2.61	-2.99	-2.72	-2.97	-2.88	-3.40	-3.22	-3.54	-3.44	-3.03	-2.51
	100	-3.01	-2.89	-2.66	-2.64	-2.99	-2.87	-2.97	-3.28	-3.40	-3.22	-3.54	-3.44	-3.03	-2.52
	140	-3.01	-2.89	-2.66	-2.69	-2.99	-3.11	-2.97	-3.79	-3.40	-3.22	-3.54	-3.44	-3.03	-2.54
Quartz	20	-3.30	-2.89	-2.88	-2.60	-3.28	-2.64	-3.26	-2.62	-3.75	-3.22	-3.89	-3.44	-3.32	-2.50
	60	-3.30	-2.89	-2.88	-2.61	-3.28	-2.72	-3.26	-2.88	-3.75	-3.22	-3.89	-3.44	-3.32	-2.51
	100	-3.30	-2.89	-2.88	-2.64	-3.28	-2.87	-3.26	-3.28	-3.75	-3.22	-3.89	-3.44	-3.32	-2.52
	140	-3.30	-2.89	-2.88	-2.69	-3.28	-3.11	-3.26	-3.79	-3.75	-3.22	-3.89	-3.44	-3.32	-2.54
Talc	20	16.97	17.34	14.11	19.31	16.83	22.85	16.68	26.51	20.16	16.20	21.28	15.75	17.11	23.29
	60	16.97	18.01	14.11	20.80	16.83	26.62	16.68	29.26	20.16	16.82	21.28	16.59	17.11	24.85
	100	16.97	17.78	14.11	22.61	16.83	28.77	16.68	30.79	20.16	16.38	21.28	16.56	17.11	26.82
	140	16.97	16.89	14.11	23.87	16.83	30.26	16.68	31.52	20.16	15.22	21.28	16.00	17.11	28.15

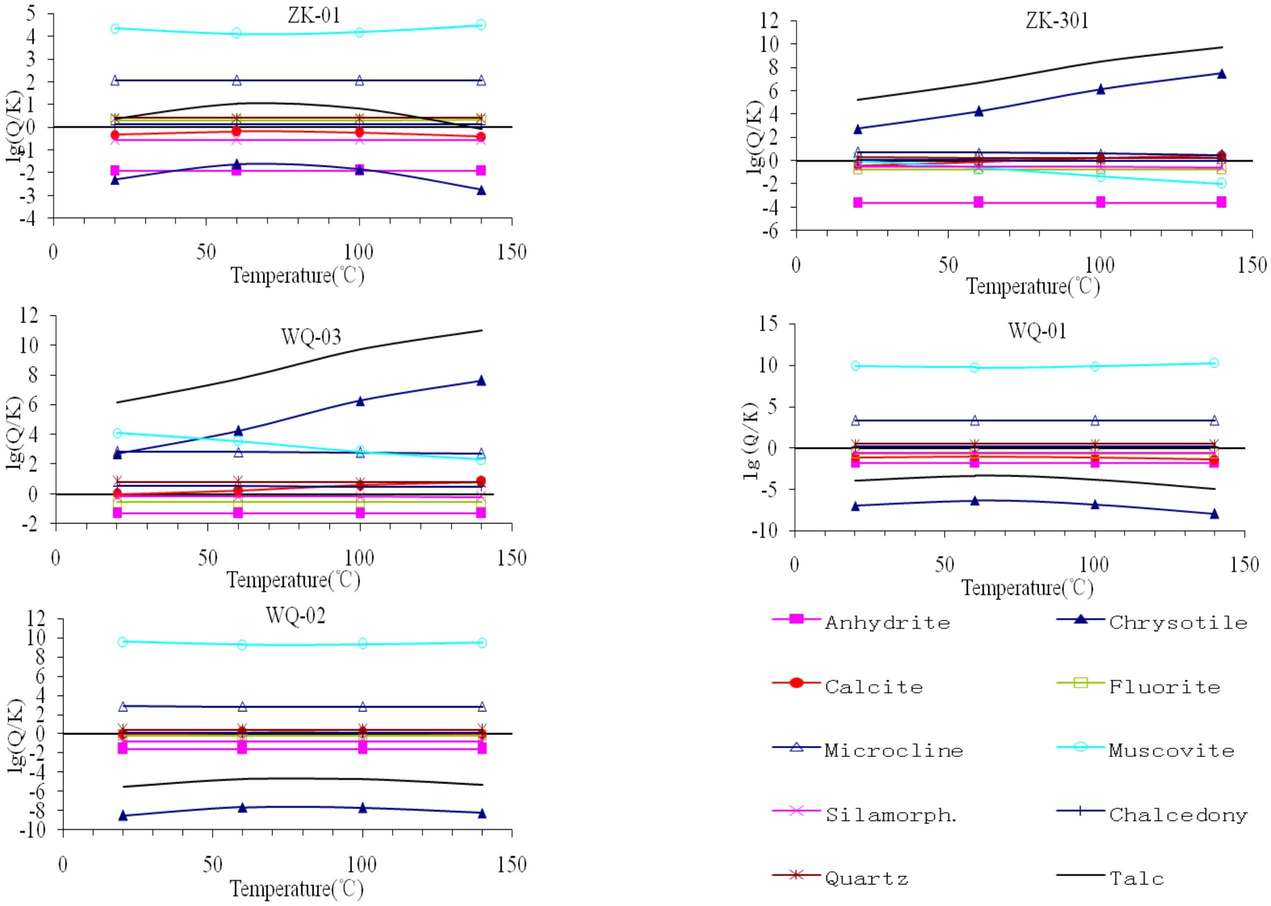


Figure 5 :Lg(Q/K) vs T diagrams for the Kangding thermal water samples

The analysis results are as follows:

1) ZK-01, WQ-03, WQ-01, WQ-02 geothermal water are over-saturated with muscovite and microcline, and the saturation curve are almost horizontal, ie lg(Q/K) changes little with temperature variation. For ZK-01, lg(Q/K) of talc intersects in the lg(Q/K) = 0, and the temperature of the intersection is near the measuring temperature 125℃. ZK-301, WQ-03 are all over-saturated with talc and chrysotile, and log(Q/K)-T diagrams is upward obviously, so it is considered that there is potential scaling possibilities. In addition, WQ-03 Water sample are over-saturated with calcite within the reference temperature range, which the lg(Q/K) curve has an upward trend, and the value of lg(Q/K) is more than 1 with the measurement temperature. Therefore, it considers that calcite is likely to cause WQ-03 geothermal water to scale.

2) All water samples are in non-saturation with anhydrite within the reference temperature range, and it is impossible to form precipitations. It is the same as ZK-01 with chrysotile, WQ-01, WQ-02 with chrysotile and talc are all non-saturated.

3) All the geothermal water samples are equilibrium with quartz, fluorite, amorphous silicon, chalcedony reach under the discharge temperature, and the four minerals' lg(Q/K) values are close to the saturation line. The four water samples except WQ-03 are also in the state of equilibrium with calcite, the same as ZK-301 with muscovite and microcline.

4 .CONCLUSION

From the above analysis, we can see, part of geothermal water may scale Kangding .And there is mainly calcite scaling, but no $CaSO_4$ scaling and silicate scaling. As the Cl^- percent of WQ-01 and WQ-02 < 25%, by Using Ryzner Index *RI*, the judge result is the WQ-01 of no scaling, but WQ-02 scaling. And Cl^- percent of others > 25%, judging by Larson Index, all LI> 0.5, means no scaling. However, whether Ryzner index or Larson index, was not considered CO_2 and hydrodynamic conditions in hot water, so the judge scaling trend with index just gives a preliminary forecast.

The result of water - rock balancing calculation shows that thermal wells and hot springs may reach or near water - rock balance with high temperature in geothermal areas, but the warm springs (eg WQ-01 and WQ-02) is generally in an unbalanced state as medium-low temperature geothermal resources. SiO_2, quartz, fluorite, amorphous silicon and chalcedony remain balanced with all kinds of geothermal water in this study area. ZK-301 and WQ-03 are all over-saturated with talc and chrysotile. WQ-03 Water sample is over-saturated with calcite within the reference temperature range, which the lg(Q/K) curve has an upward trend. It indicates the scaling possibility of ZK-301 and WQ-03.The main minerals for ZK-301 scaling are talc and chrysotile, and WQ-03 major scaling minerals are calcite, talc and chrysotile.

It is possible to form scaling in the using of Kangding geothermal resources, scale *substances* will be attached to the inside of pipelines , producing wells and other ground equipment, thereby increasing the energy of transport consumption, so that greatly reduce the utilization of geothermal energy. Therefore, researching and analysis of the scaling tendency of geothermal water is not only of theoretical significance, but also of practical value.

REFERENCES

Zhou X.,2001:The elementary understanding on the causes of corrosion and clogging in deep geothermal wells. Ground water, 23(2) ,95- 96.(in Chinese)

Fu B.C.,Fang L.P.,1998: The study of hydrochemical characteristics and the corrosion mechanism of the geothermal water in Tengchong. Hydrogeology ＆ Engineering geology,25 (3), 1-3.(in Chinese)

Wang K. F.,Yang D. P.,Song X. S.,et al.,2010:Chemical characteristics and encrustment and erosion of geothermal water in the Guantao Formation in Linqing.Hydrogeology ＆ Engineering geology,37 (1) ,130-134.(in Chinese)

Patzay, G.,Stahl, G.,Karman, F.H.,et al.,1998:Modeling of scale formation and corrosion from geothermal water:Electrochimica Acta，43(1-2), 137-147.

Ryznar, J. W.,1994:A new index for determining amount of calcium carbonate scale formed by water.Washington D C:AWWA.

Larson, T. E.,Sollo, F. R,,1967: Loss in water main carrying capacity.AWWA,59(12),1565 -1572.

Langelier, W. F.,1946:Chemical equilibrium in water treatment.Washington D C:AWWA.

Riddick, T. M.,1944:The mechanism of corrosion of water pipes.Water Work Sand Sewerage:91,133-138.

Arnórsson, S.,Sigurdsson,S.,Svavarsson, H.,1982:The chemistry of geothermal waters in Iceland.I.Calculation of aqueous speciation from 0℃ to 370℃.Geochim Cosmochim Acta,46,1513 -1532.

Tong W.,Zhang M. T.,1994: Thermal springs in Hengduan (traverse) mountains.Beijing: Science Press.(in Chinese)

Chai Y. H,2004:Geothermal Direct-Use.Tianjin: University of Tianjin Press.(in Chinese)

Ellis,P.F.,1983:Review of shell and Tube Exchanger Fouling and Corrosion in Geothermal Power Plant Service Radian Corporation .

Meng X.J.,Bai L.P.,Qi J. Sh.,1997:The judgment of scaling tendency in geothermal water in China. Water Treat,17(5), 6- 7.(in Chinese)

GB/T 11615 -2010, Geologic exploration standard of geothermal resources(in Chinese).

Giggenbach,W.F.,1988:Geothermal solute equilibria,derivation of Na-K-Mg-Ca geoindicators.Geochim Cosmochim Acta，52(12), 2749-2765.

Bjarnason, J.1994: The speciation program WATCH,Version 2.1.Iceland: Orkustofnun，Reykjavík.