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ASSESSING THE GEOTHERMAL POTENTIAL OF MODUC AREA QUANG NGAI PROVINCE (CENTRAL VIETNAM)

Hoang Huu Quy and Ho Huu Hieu

Research Institute of Geology and Mineral Resources
Thanh Xuan - Hanoi - Vietnam

ABSTRACT - The location and surface features of the two centres of activity in the Moduc area are described. The geological features of the area are set out and the spring chemistry is documented and interpreted. The potential for electricity generation is stated.

1. INTRODUCTION

The Moduc thermal area is located approximately 30 km south of Quangngai city, 6 km from the coast and just west of the national highway. The elevation is 11m ASL. The nearest village on the national highway is Duc Lan. There are two centres of thermal activity at Moduc, located north and south of a small hill (Nui Tho). Both areas are situated within rice fields. The more active area to the south is called Thach Tru and the area to the north: Tu Son. Because of the proximity of these two areas (1.5 km apart) and the similarity of their chemistry, they are grouped together in Table 1 as Moduc.

The thermal activity at Thach Tru covers an area of about 500 m^2 and consists of several hot springs and shallow pools atop a flat rock outcrop. Hope *et al.* (1983) describes the outcrop as sinter deposited from springs, although the measured silica concentrations, which are significantly below amorphous silica saturation, do not support this. If sinter is present, it must be relict. Temperatures of 69 and 77^{o}C were measured in the two springs sampled and 81^{o}C in the sediment beneath the pools. The total flow from the Thach Tru area is about 1.5l/s.

The thermal activity at Tu Son, approximately 1.5 km to the north, is minor in comparison to Thach Tru and consists of one 54^{o}C spring with a flow of about 0.2 l/s and several other warm pools with small flows. No scale was seen in any of the springs.

2. GEOLOGY

As noted in Part 1, the thermal activity at Thach Tru is located on top of a low, flat-topped outcrop. The outcrop is capped by cemented, sorted, medium grained clastics. Petrographic analysis showed the cement to be pyrite, opal and cristobalite (recrystallised from opal) in one of the two samples collected, and clinoptilolite, opal and cristobalite (recrystallised) in the other. Clinoptilolite and opal indicate neutral to acid conditions at fluid temperatures of less than 150^{o}C and 120^{o}C respectively. They are therefore likely to reflect deposition from historic hydrothermal activity.

The coastal plain is flanked to the west by hills which rise to more than 400m. These are mapped as Mesozoic intrusives and it is likely that the thermal area is underlain by faulted intrusives although there is currently little field evidence to support this. A north-south trending quartz vein is exposed at the foot of the small hill Nui Tho adjacent to the railway line on its northern side, and it is possible that the two thermal areas are connected under the small hill Nui Tho which is the only significant host rock outcrop in the area. Quaternary plateau basalts lie less than 10 km to the south of the thermal areas.

3. GEOCHEMISTRY

The water chemistry of Moduc approaches the true Na-Cl character typical of high-temperature magmatic geothermal systems. Sodium and chloride account for most of the mineralization (4800-5300 mg/kg TDS) and SO_4^{-2} and HCO_3^{-} are relatively minor constituents (Table 1). However, the high calcium concentration, lower boron and the proximity of the coast (about 6 km) suggest the salinity is due to a seawater component. This being the case the Cl concentration of 2600-3000 mg/kg compared with 19000 mg/kg in seawater indicates a 15% seawater fraction. Significant thermal re-equilibration is indicated by the minor element chemistry:-

- SO_4 is lost from solution (Cl/Ca=45-52 compared with 19 in seawater)

- Ca has been added (Cl/Ca=8.3-8.6 compared with 54 in seawater)

- most Mg has been lost (Mg = 3.5-4.0 mg/kg compared with 1270 mg/kg in seawater)

- K, Rb and Li have all increased.

These changes are more pronounced than is seen at the geothermal Binh Chau area (nearest beach to Vung Tau).

Measured silica concentrations at Moduc are the highest of all the sites of the Central Part of Vietnam. They indicate quartz saturation temperatures of 154^{o}C and chalcedony temperatures of 131^{o}C. The presence of opal (amorphous silica) in the cemented quartz sands surrounding the hot spring suggests the spring have been boiling in the past and possibly historically.

Cation geothermometry can be applied with some confidence at Moduc because of the relatively mineralized Na-Cl character of the water. The Na-K geothermometer gives temperatures up to 160^{o}C-187^{o}C.

Overall, geothermometry suggests the fluid last equilibrated at temperatures of 160^{o}-180^{o}C.

4. CONCLUSIONS

After comparing this area with the Brady geothermal area in the United States, we assume the geothermal potential of Moduc is prospective and estimate that the geothermal reservoir volume is about 45 km^3 (6km x 5km x 105km). From economic consideration by experts the potential of the geothermal resource for electricity generation is by binary cycle plant with gross power of about 20 MWe.

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0N^{o}	Date	Type	Flow l/s	Temp. ^{o}C	pH	Li	Na	K	Rb	Ca	Fe	Mg	Cl	F	Br	SO_4	HCO_3 (total)	B	SiO_2	NH_3	ION BAL	CATS	ANS	TDS
						mg/kg															%	mEq/L	mEq/L	mg/kg
1	27-Feb-1993	spring	0.5	69	7.5	3.2	1390	71	0.93	360	0.04	3.6	2630	3.7	45	158	60	0.44	126	0.070	2.2	81.0	79.2	4850
2		spring	0.1	77	7.49	3.1	1260	70	0.88	347	0.07	3.5	2560	3.7	45	153	61	0.43	120	0.069	3.3	74.7	77.2	4630
3		outflow	1.0	42	7.99	3.3	1340	73	1.1	371	0.07	3.7	2770	4.1	46	168	60	0.45	123	0.022	4.9	79.5	83.4	4960
4		spring	0.2	54	7.51	3.5	1440	99	1.2	389	0.08	4.1	2910	3.7	51	151	77	0.44	127	0.055	2.2	85.4	87.4	5260
5		spring	<0.1	47	7.27	3.5	1420	94	1.1	389	0.16	4.0	2950	3.8	49	155	76	0.45	136	0.121	4.7	84.4	88.5	5280

Notes: CATS-Sum of cation charge (mEq/L); ANS- Sum anion charge (mEq/L); ION BAL- Percent difference between cations and anion charges; TDS- Total Dissolved Solids (mg/kg)

N^{o}	Date	Type	Flow	Temp.	Cl -----	Cl -----	Cl -----	Cl -----	Cl -----	Na -----	Na -----	QTZ	CHAL	TNK (A83)	TNK (A79)	TKM	TNa-K-Ca		TMg
			l/s	^{o}C	Li	Rb	Ca	B	SO_4	K	Ca	^{o}C	^{o}C	^{o}C	^{o}C	^{o}C	β	^{o}C	^{o}C
1	27-Feb-1993	spring	0.5	69	161	6818	8.3	1822	45.1	33	7	151	125	135	165	133	0.33	157	-
2		spring	0.1	77	162	7014	8.3	1815	45.3	31	6	148	122	1452	171	133	0.33	160	-
3		outflow	1.0	42	164	6071	8.4	1877	44.7	31	6	149	124	140	170	134	0.33	160	-
4		spring	0.2	54	163	5847	8.5	2016	52.2	25	6	151	126	160	187	142	0.33	172	-
5		spring	<0.1	47	165	6466	8.6	1999	51.6	26	6	155	131	156	184	141	0.33	170	-

Notes: Chemical ratio are molar values: QTZ- Quartz Geothermometer, no steam loss (Fournier and Potter, 1982); CHAL- Chalcedony Geothermometer (Henley et al, 1984); TNK (F79)- Sodium - Potassium, empirical (Fournier, 1979); TNK (A83)- Sodium-Potassium, empirical (Amorsson et al, 1983); TMK- Potassium- Magnesium, theoretical (Ksp-MuscoClinochlore) (Giggenbach) 1988; TNa-K-Ca- Sodium-Potassium-Calcium, empirical (Fournier and Truesdell, 1973); TMg-TNa-K-Ca corrected for magnesium (Fournier and Potter, 1979).

Table 1 Analytical data and calculated results of Moduc thermal waters (KRTA Survey 1993)