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Characteristics of Geothermal Resources in the Mid Part of Vietnam

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ABSTRACT

Up to now, there have been dozens of the geothermal study projects of the state organizations and private economic organizations invested in the North-West Part, North-South Part, Mid Part and South Part of Vietnam with the mainly goal to find out the geothermal resources that can be used to generate the electricity but the data of geology, geophysics, hydrogeology, geochemistry and drilling of these geothermal study projects have shown clearly that there is no geothermal resource that can be used to generate electricity with current technology. But the geothermal resources of Vietnam have been considerately attractive to investment organizations and to tourists for bath, canning for drinking and sightseeing in recent years. Recently acquired data of geology, geophysics, hydrogeology, geochemistry and drilling have confirmed that the Mid Part of Vietnam has the most attractive geothermal resources for geothermal mud-bathing, hot water bathing and sightseeing of tourism.

1. GENERAL INTRODUCTION

Vietnam is a country that belongs to the Asian Southeast region, bordered in the North with China, in the West with Laos, Cambodia and in the South with the Eastern Sea. Vietnam area is about 331,210 km^2, population about 93,000000 people. The country is divided into four parts with 54 provinces of which the Mid Part of Vietnam composes six provinces such as Than Hoe, Nigh An, Ha Tin, Quant Bind, Quant Tri and Thus Thin – Hue with an area about 51,980 k m^e. The population in the project study area is about 9,5 million people with a density about 280 people per ka^{mi} in the north of the project and in the south of project about 110 people per km^2. The Kinh people are seen as the largest community and live in the plains areas, towns, cities. The minorities such as the Muong, Thai, Thanh, Ta Oi, Po Co, H'mong, Ruc, and Cao Lan people etc., live in remote mountainous areas with low population density. They live by rice farming, the mountainous rice, exploiting the forestry wood, collecting fruit, hunting.

Direct use of the geothermal resources in the tourism industry, canned drinking water industry and balneology is on the way to attract investment resources from Vietnam government organizations, neighbor countries and private companies in coming years.

The Mid Part of Vietnam is composed of six provinces such as Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, Quang Tri and Thua Thien – Hue, and has been seen the most attractive tourist areas in the tourist map. The geothermal mud bathing, water hot bathing and sightseeing are also seen as stopping points not to be missed by the tourists

2. THE STUDY HISTORY AND USE THE GEOTHERMAL RESOURCES IN VIETNAM

The geothermal study history of Vietnam in two provinces of Binh Dinh, Phu Yen can be found in the book set "The book set compiled by Vietnamese Feudal Government" edited by Le Quy Don in 1776. Next, it was in the book set "United Vietnam on the one way" edited by Nguyen Dynasty in History Nation Book Set (1865-1882) also listing 14 hot water resources in some provinces from Quang Binh to Khanh Hoa. The book sets have circulated up to now. In the study of the geothermal resources, an early primary study about "Strange Issues of Sky Earth" was not considered a systematically scientific geothermal resources study. In 1895, C. Madrolle carried out a study by collecting and analyzing chemical samples of the geothermal resources and this was seen as the first systematic scientific study in Vietnam in Phuc Tho commune, Phuoc Linh county, Quang Nam province.

3. TOPOGRAPHY CHARACTERISTICS OF MID PART

The topography of Mid Part has an elongated shape according to the NW- SE with narrow horizon. In the north, it is bordered with the North plain by mountain chains Tam Diep. In the south, it is bordered with South part by the Bach Ma mountain chain. In the west, it is bordered with Laos and in the east is bordered with the Eastern Sea.

Topography of the highly mountainous topography accounts for ¾ the study area, and is cut strongly, sloped, with different levels of topography. The structure of topography of the study area belongs to two different systems. In the north of Ca River, it is composed of the highly mountainous chains to run to the NW-SE from Phong Tho district of Lai Chau Province to Thanh Hoa province. This is the highly mountainous chain with mountainous tops from 1000 to 1500 m high. The highest mountainous top is P. Puoc in the NW of Nghe An province 1568 m (a.s.l). The south part of Ca River belongs to the Truong Son mountainous chain which runs NW-SE along the Vietnam-Laos border line. This is the low mountainous area with high topography levels above 600- 800m.

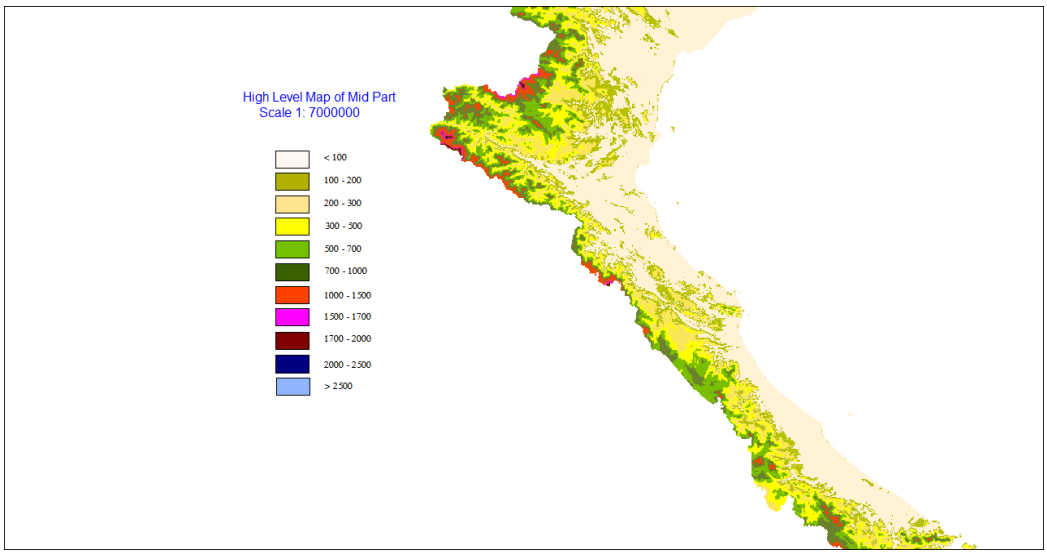

Figure 1: The high level map of Vietnam

The stream and river system is distributed throughout the study area. The large rivers are Ma River, Song Chu River, Song Ca River, Song Gianh River, Song Quang Tri River, and Song Huong River, which have length from 300- 400 km. In the north part of the study area, the river systems flow in the NW-SE direction, in the south of the study area, the river systems flow W-E.

4. GEOLOGICAL CHARACTERISTICS

4.1 Geological characteristics.

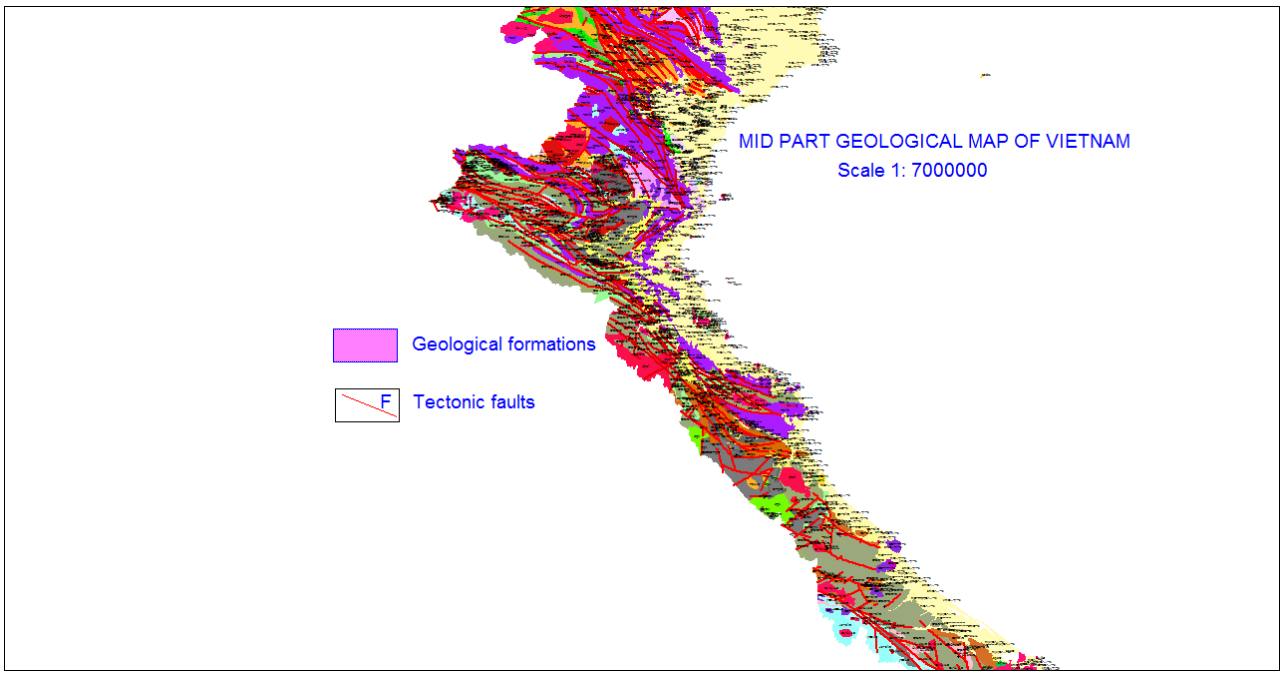

Figure 2: the geological map of Mid Part.

Table 1: Overview of mid part geological characteristics

No.	Strati.Age	Overview of the geological formation characteristics	The intrusive Magmatic overview
1	PALEOZOIC	The terrigenous formations are listed in $Є_2$ *sm*, $Є_3$-O_1 *hr*, O_1 *ds* located in Thanh Hoa, $Є_2$-O_1*av* in A Luoi, Binh Tri Thien. The mainly compositions are the carbonate-terrigenous rocks inserted with green grey colored basal rocks imbedded that they thickens up about 2500m. The O_3-S_1 aged rocks are shale, quartzite mica shale, siliceous shale, quartzite rock mixed with metamorphic andesitic basal rock. The formation thickens up about 3500 m. The O_3-D_1 aged formations compose of O_3-S_1 sc Song Ca, O_3-S_1 *ld* Long Dai, S_2-D_1 Houi Nhi, S_2-D_1 *dg* Dai Giang. The D_{1-2} aged formations: they compose of the terrigenous sediments, the sub-terrigenous sediment such as sandstone, siltstone, and shale. The D_3-C_1 formations compose of the terrigenous sediment such as the siliceous limestone, siltstone, carbonate-containing shale, the coal-containing shale. The C-P aged formation composes of the carbonate rocks, the imbedded limestone mixed with the mafic basal rock.	The chain-shape supper mafic intrusive magmatic bodies The gabbro, gabrodiorite bodies
2	MESOZOIC	The formations compose of the terrigenous sediments such as the coal-containing siliceous shale aged P_2 *yd* located in Thanh Hoa, Khe Tre, Quang Binh, Dak Rong, A Luoi and the mafic basal formations such as the Doc Cun complex P_2 *dc*, Cam Thuy complex P_2*ct*, The upper part of the formation is the Triassic aged shale, the limestone shale, the black-colored siltstone, sandstone. The J_3-K aged formations compose of the basal sediment mixed with the rhyolite porphyry, dacite, felsite to thicken up 700-800m.	The biotitic granite, granite porphyry, granodiorite are aged T_3-J,and aged T_2, T_3 n-r in Quan Son, Lang Chanh - ThanhHoa There are series of the batholitic granite bodies age γ T_3*bp* in the Phi Bioc complex, γ T_3*hv* in Hai Van complex,
3	KAINOZOI	The Neocene formations are listed in Kanoizoi to contain the grey colored terrigenous sediment composed pebble, sandstone, siltstone, kaolin clay stone.	

Tectonic characteristics

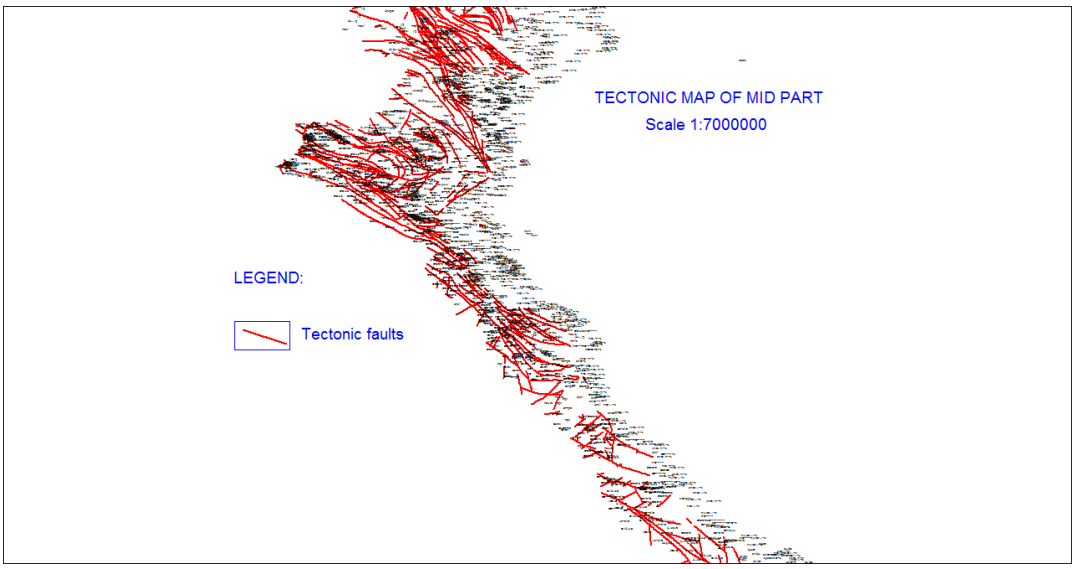

Figure 3: The tectonic map of mid part of Vietnam

The tectonic study area of the Mid North Part is limited from Song Da fault in Thanh Hoa province to the Bach Ma fault of Quang Nam province (Figure 3). The large faults can be seen clearly on Google Earth, aerial photo, at scale 1/30.000, 1/20.000, on the Indochina geological maps at scale 1/000000, Mid North part geological maps at scale 1/200000, and some geological maps at scale 1/50000. Almost all of the large faults are controlled by tectonic phases of the large Indochina region from Cambric to Holocene. Mostly, the large faults are usually developed along the large rivers or large streams running NE-SW and the small faults are usually developed along streams and stream valleys running NW-SE. They are visible on tectonic maps of Vietnam at scale 1000.000, 200.000. Of course only some tectonic phases can be related directly to the geothermal resources in Mid North part of Vietnam. These young tectonic phases are closely related to earthquakes, seismicity born faults in the earthquake distribution map of Vietnam, Lao and Cambodia (USG published data). It can be explained that all geothermal resources are closely related to the deep faults - large tectonic phases, the deepened magmatic rock-forming stage. It is easy to see that the distribution of geothermal resources is mainly focused on the large faults in the geological map, tectonic map.

5. GEOPHYSICAL CHARACTERISTICS

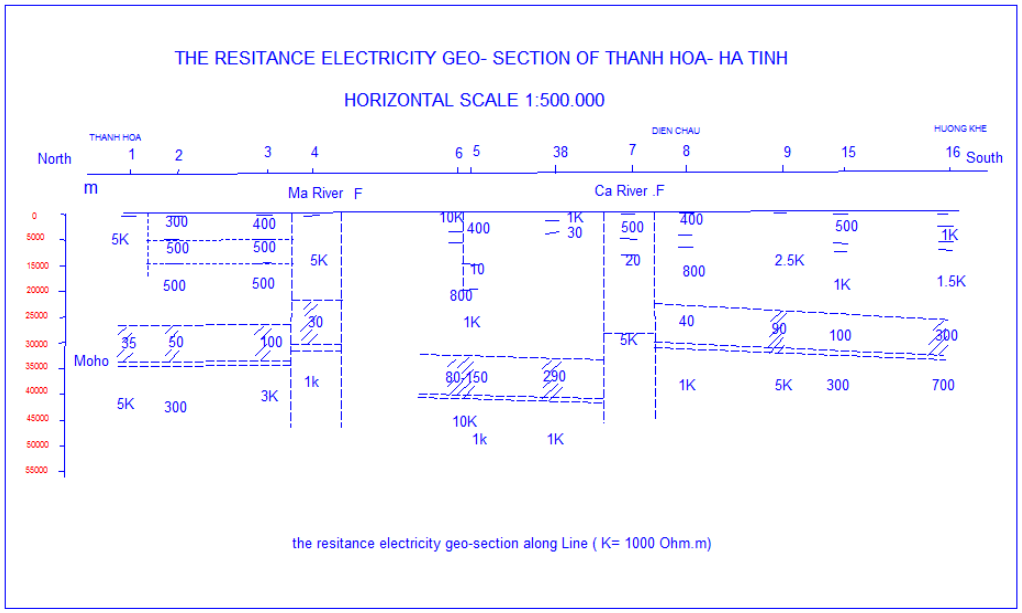

Figure 4: The resistance electricity geo-section of Thanh Hoa-Ha Tinh along the Line L

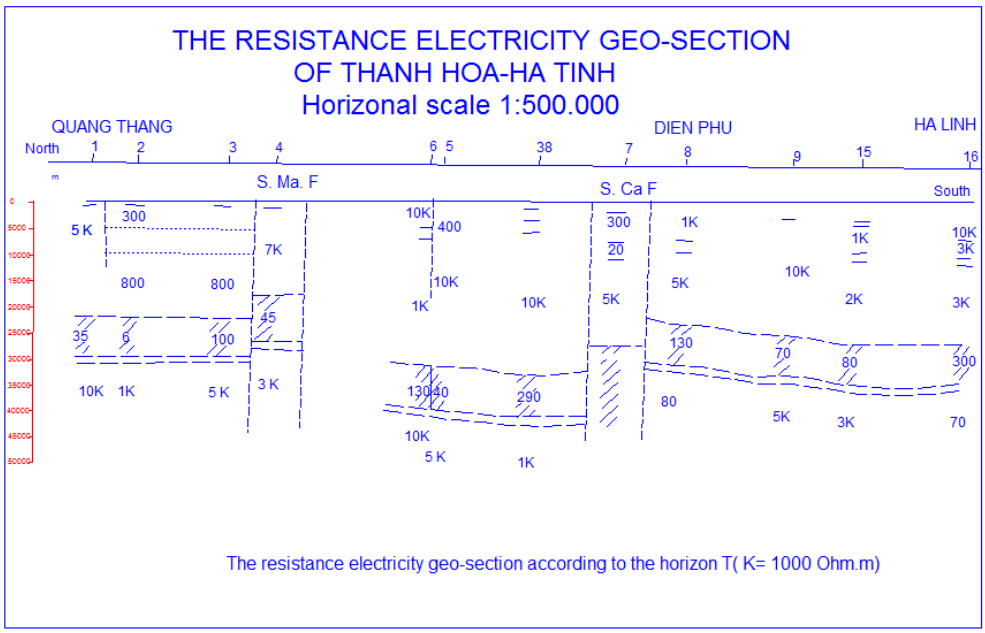

Figure 5: The resistance electricity geo-section of Thanh Hoa-Ha Tinh along the Line T

The electricity conductivity along the L in the deep measured points almost is suitable with the geological structure direction of the measured geological map. The difference of the electricity conductivity along the L (long line) and the T (horizon line) reflects the isotropic essence or the non-isotropic essence of the rocky setting in the measured point.

There is the existence of electricity conductive layer fairly thickened up to 6-8 km (the jointed zone) in the changed depth in the middle distance from 20-30 km, to 38-40 km (this resistive electricity layer changes from some Ω m to 300 Ωm and it clearly depends on the electricity conduct along the line L or line T and based on the measured point geological structure). The relative electricity conduct extract can explain that there is the existence of a fluid layer in the depth of the Earth cover layer. This fluid is born from the tectonic metamorphic origin and the massive tectonic movements. The bottom of the electricity layer is consistent with the Mohorovicic discontinuity.

There is the interrupted Mohorovicic discontinuity face (the deep electrically conductive layer) which can be seen in the deep faults of Song Ca fault, Song Ma fault. The interrupted electrically conductive layer is from 1-5 Ωm. The good electrically conductive layers in the depth confirmed that there is existence of a highly temperature zone from 600- 700 ^{o}C.

6. HYDROGEOLOGY AND GEOTHERMAL RESOURCES CHARACTERISTICS

The pore water containing layer

- The water containing layer in the Quaternary sediment
- The water containing layer in the Neocene sediment

The cracking water containing layer

- The pore water containing layer in Mid Triassic aged sediment
- The pore water containing layer in Carbon-Permi age sediment

Table 2: Ground water levels in the tectonic faults

No	Name of fault	fault containing rock	Flow (l/s)	Mg/l	Type of water
1	Ma river Thanh Hoa	Cracking limestone $Є_2$ *sm* , cracking shale limestone $Є_2$ *sm*	17.22 17.23	< 0,5 < 0,5	HCO_3-Cl-Na HCO_3-Cl-Na
2	Nghia Trang Thanh Hoa	Cracking limestone $Є_2$ *sm*	15.99	< 0,5	HCO_3-Cl-Mg
3	Tho Xuan Thanh Hoa	Cracking pebble stone, grit stone K_2 *yc*	18.45	< 0,5	HCO_3-Cl-Mg
4	Hoang Mai-Nhu Xuan Nghe An	Cracking rock T_2 a *dt*$_2$	18.5	0.3	HCO_3-Cl-Ca-Na
5	Cua Lo (Nghe An)	Pebble stone, grit stone, sandstone O_3-S_1ld	0.3-3.1 11.1-13.6	< 0,5 < 0,5	Cl-HCO_3-Na HCO_3-Ca-Mg
6	Song Rac (Ha Tinh)	The pebble stone, sandstone T_2 a*dt*$_1$	5.056 6.25	Sub-salt water Salt water	Cl-Na-Ca Cl-Na-Ca
7	Thien Nhan (Nghe An)	The pebble stone, sandstone T_2 a*dt*$_1$	3.16 5.28	< 0.3 <0.3	HCO_3-Cl-Na HCO_3 –Ca-Ma

Table 3: The mid part geothermal resources characteristics.

No	Name of geothermal resources.	location	Discharge	Hosted rock and age	Q, L/s	T°C	M (mg/l)	Type of water	Use goal
1	Ngoc Lac	Pho Cong, Ngoc Lac-Thanh Hoa	Joint and kaster	Sandstone, limestone P_2	0.05	32.9	251.00	HCO_3-Ca	
2	Dong Son	Dong Son-Thanh Hoa	bore hole	Sandstone, pebble stone N_2	3.5	35	1680	Cl-Na	
3	Nghia Trang	Ga Nghia Trang-Thanh Hoa	bore hole	sandstone, clay stone P_2-T_1	16	30	280	HCO_3-Ca-Mg	

4	Cua Dat	Cua Dat-Thuong Xuan-Thanh Hoa	Alluvial discharge point	sandstone, clay stone T_2	0.18	50.8	416.00	HCO_3-Na	
5	Ban Bo	Yen Hop-Quy Hop-Nghe An	Joint	Marble PR_3-$Є_2$ *bk*	5	30	58.90	HCO_3-Ca	
6	Ban Khang	Yen Hop-Quy Hop-Nghe An	bore hole	Granite, Marble PR_3-$Є_2$ *bk*	0.13	30.8	828.31	HCO_3-Ca	
7	Ban Tat	Yen Hop-Quy Hop-Nghe An	bore hole	Granitization PR_3-$Є_2$ *bk*	1	38.8	367.23	HCO_3-Ca	
8	Nam Ron	Dong Van-Tan Ky- Nghe An	Alluvial discharge point	Limestone C-P	0.44	57	276.00	HCO_3-Na-Ca	
9	Kim Da	Kim Da-Tuong Duong-Nghe An	Joint	Pebble stone, quartzite O_3-S*sc*	1.5	73.5	1059.00	HCO_3-Na	
10	Giang Son	Giang Son-Do Luong-Nghe An	In the valley	Granite pebbles tone O_3-S*sc*		41	150.00	HCO_3-Na	
11	Son kim	Son Kim Huong Son- Ha Tinh	Bore hole	Granite γ C_1*ts*	1	78	225.57	HCO_3-Na	Canning, bathing
12	Ngam Thep	Son Kim Huong Son- Ha Tinh	Granitic joints	Granite γ C_1*ts*	0.31	35.5	236.30	HCO_3-Na	
13	Rao Mac	Son Kim Huong Son- Ha Tinh	Granitic joints	Siltstone, shale S_2-D_1 *dg*		61	114.00	HCO_3-Na	
14	Quan Khu 4	Son Kim Huong Son- Ha Tinh	Bore hole	Siltstone, shale S_2-D_1 *dg*	0.1	44.5	238.30	HCO_3-Na	
15	Ha Tan	Son Kim Huong Son- Ha Tinh	Joint	Granite γ C_1*ts*	0.15	44.5	381.00	HCO_3-Na	
16	Khe Tre	Son Kim Huong Son- Ha Tinh	Joint	Siltstone, shale S_2-D_1 *dg*	0.1	44	338.00	HCO_3-Na	
17	Tram 5	Son Kim Huong Son- Ha Tinh	Joint	Granite γ C_1*ts*		30	203.5	HCO_3-SO_4-Na	
18	Ngu Hoa	Ngu Hoa-Tuyen Hoa-Quang Binh	Alluvial site	Quart shale T_3	0.1	67	417.15	HCO_3-Na	

19	Vuc Tron	Phuc Thach-Bo Trach-Quang Binh	Sandstone joint	Limestone, sandstone D_2	0.2	42.8	684.43	Cl-HCO_3-Na-Ca	
20	Bang	Le Thuy – Quang Binh	Bore hole	Limestone-siliceous shale O_3-S *ld*	2	100	530.70	HCO_3-Na	Canning, bathing
21	Tan Lam	Cam Lo - Quang Tri	Alluvial site	Limestone D_2		45.2	418.80	HCO_3-Na	
22	Lang Eo	DaKrong-Quang Tri	Joint	Limestone, granite D_1	0.13	50.7	413.43	HCO_3-Na	
23	Huyen Co	DaKrong-Quang Tri	Joint	Granite γ C_1*bg*	3	70.2	512.33	HCO_3-SO_4-Na	
24	Da Krong	DaKrong-Quang Tri	Joint	Sandstone, shale O_3-S*ld*	0.2	55.7	224.90	HCO_3-Cl-Na	
25	Thanh Tan	Phong Son-Phong Dien-Hue	Bore hole	Limestone D_1*tl*	1.5	67.3	691.50	SO_4-HCO_3-Ca	
26	LK HU 7	Phu Vang-Hue	Bore hole	Sandstone, siltstone N	0.5	38.9	1787.67	Cl-Na	
27	My An	Phu Vang-Hue	Bore hole	Sandstone, siltstone N	1.2	50.9	2933.67	Cl-Na	Canning, bathing
28	Pa Rinh	Ho Ha-Aluoi-Hue	Alluvial site	Massive limestone O_3-S*ld*	0.1	49.6	578.50	HCO_3-SO_4-Ca-Na	
29	A Roan	A Roan-Aluoi-Hue	In the valley	Sericite shale D_1*tl*	0.3	49.6	311.97	HCO_3-Na	
30	Duong Hoa	Duong Hoa-Duong Thuy-Hue	Alluvial site	Granite γ T_3 *hv*	3	68	848.47	Cl-Na	

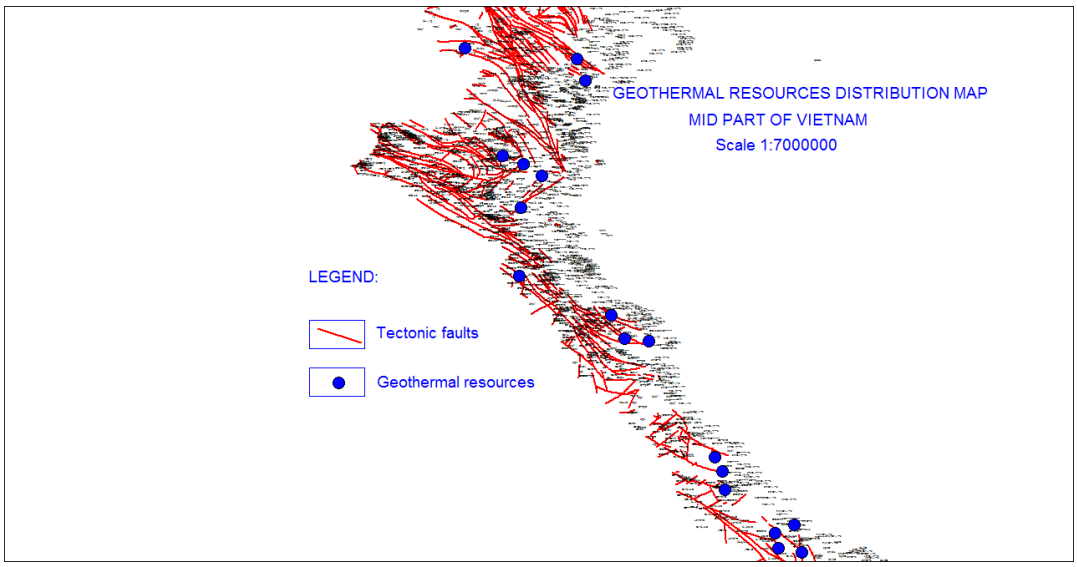

Figure 6: Geothermal resources distribution location in Mid Part of Vietnam

7. GEOTHERMAL WATER ORIGINS IN MID PART OF VIETNAM.

Based on the geological mapping data, tectonic study, photogeology, geophysical data, hydrogeology, geochemistry, rock sampling results, water sampling, modeling results that have been collected in the site, it has been shown that the origin of geothermal water in Mid Part of Vietnam belongs to the meteoric water.

8. CONCLUSIONS

Thirty geothermal resources have been discovered in the large mountainous area 151,980 k m^2 in the Mid Part of Vietnam. They are low temperature geothermal resources that formed in existence area of young tectonics, and hidden magmatic activities. The geothermal resources have temperature ranges from 30 to 100^{o}C.

The geothermal resources are located in the Mid Part near big economic centers, in long coast line in the North-South tourist travel line of Vietnam, in the West-Eastern tourist travel line with Laos, Cambodia and Thailand will be more and more attractive to tourists in coming years.

All or most of the geothermal resources are good for farming, heating, tourism sectors, balneology, canning and sightseeing. They are not useful for geothermal electricity plant.

The some geothermal resources in the Mid Part are used to develop the farming, heating, tourism sectors, and balneology and canning for exporting to Laos, Cambodia, Thai land, Myanmar, and China in coming years.

The geothermal resource study is mainly based on the results of geological mappings, the large scale hydrological mapping, engineering geological map, geophysical survey, water sampling in the site, analyzing the samples in the lab and modeling. The assessment of geothermal resources has many errors. Greater investment is needed into the detailed geological mapping, geophysics, geochemistry investigations, collecting sample, water sampling analysis and exploration drilling to assess the potential geothermal resources accurately in future years to serve for the Mid Part economic development programme of Vietnam.

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GEOTHERMAL RESOURCES USE PHOTO IN MID PART OF VIETNAM:

The geothermal mud bathing

The geothermal swimming pool

The geothermal collecting tank for living people

The geothermal water collecting lorry for canning