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Characteristics of geothermal resources of Vietnam

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ABSTRACT:

There have been more the little-large 800 hydropowers, 47 solar energy electricity farms, 144 wind energy electricity farms, and 10 biogas electricity plants to build in the North Part, South Part and along the sea shore line of Vietnam. Up to now, there have not been any the business geothermal electricity plant to build in Vietnam in whole 269 geothermal resources that have been discovered. Many geothermal study projects of state organizations and privates have been deployed on all territory with goals to find some geothermal resources for the business electricity generation but there have not been any the geothermal resources can be used to generate the business electricity. Data of geology, geophysics, hydrogeology, geochemistry and drill of the these geothermal study projects have clearly showed up all geothermal resources of Vietnam belongs to the lower temperature geothermal resources and the average temperature geothermal resources (30-100^{O}C) can not be used to generate the business electricity with nowadays technology. Many the lower temperature geothermal resources, the average temperature geothermal resources that they are located near to the large cities such as Ha Noi, Sai Gon, Da Nang, Quang Ninh etc., have been become the attractive tuorist centres for bathing, balneology, sanatorium, canned geothermal water and sight-seeing. The economic effect of direct use of these geothermal resources is bigger much more than others goals. Some real estate areas that they are surrounded by these geothermal resources next to the big cities have been become the highly profits - born real estate investment centers of the private companies, the economics groups, FDI , etc.,

1. GENERAL INTRODUCTION.

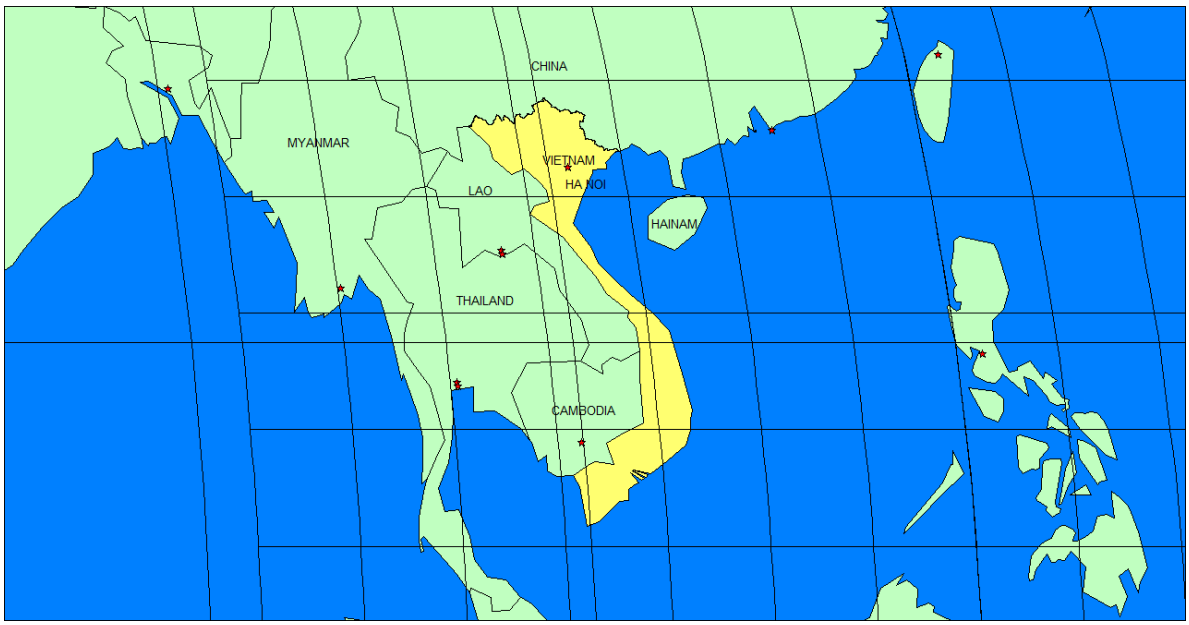

Figure 1: The location map of Vietnam in Asia

Vietnam locates in the SE region, is bordered in North with China, in West with Lao, Cambodia, in Eastern with Eastern Sea. The area of the whole territory of Vietnam is about 331,210 km^2; the population is about 94,000000 people. According the geography, geology, geomorphology and topography etc., Vietnam is divided into five parts including of Northwestern Part, Northeastern Part, Central Part, Central South Part and South Part. There are two large river systems to flow into Vietnam that are originated from the North, Northwestern part of China. Attached large river systems are two large plains of Vietnam in which one is North Part that is called "North Part Plain", the other is called "South Part Plain".

Vietnam has 54 ethnic groups in which Kinh people accouter for the largest population mainly live in the large plains, hilly topography and the sea line areas with highly density. The minority is mainly lived in hilly topography areas, the highly rocky mountainous and remote- highly mountainous area in Northwest part, Northeastern Part, Central Part with the thinly density.

The direct use of the geothermal resources of Vietnam includes of tourist, canned geothermal water and balneology is gradually increased according to the GDP of Nation. Nowadays, the geothermal resources are located in or next to the large cities have been become the highly profits - born real estate investment centers of private companies, economic groups, FDI etc.,.

2. THE STUDY HISTORY OF THE GEOTHERMAL RESOURCES OF VIETNAM

Table 1: Over view of geothermal study of Vietnam

No	Geothermal study time marks	Name of the study organizations	Geothermal resources study level	The published data and books	The study location
1	1776, 1865-1882	Nguyen Dynasty-Vietnam Feudal Government	Writing and listing 14 geothermal resources	History Nation Book Set of Nguyen Dynasty	Central Part of Vietnam
2	1895	Geological Department of France-France	Mapping the geology, Collecting the samples, analyzing the chemical samples of the geothermal resources	Data of Geological Department of France	In whole territory of Vietnam
3	1986	Water resources Institute – Vietnam	Mapping geology,geophysics, collecting and analyzing the geothermal samples and drill	Data of Water Resources Institute –Vietnam	Central Part of Vietnam
4	1990	Research Institute of Geology and Mineral Resources-Vietnam	Mapping geology, geophysics, collecting and analyzing the geothermal samples	Data of Research Institute of Geology and Mineral Resources-Vietnam	South Part of Vietnam
5	1995	Research Institute of Geology and Mineral Resources-Vietnam	Mapping geology, geophysics, collecting and analyzing the geothermal samples	Data of Research Institute of Geology and Mineral Resources-Vietnam	Central Part of Vietnam
6	2001	Research Institute of Geology and Mineral Resources-Vietnam	Mapping geology, geophysics, collecting and analyzing the geothermal samples	Data of Research Institute of Geology and Mineral Resources-Vietnam	Northwestern Part of Vietnam

6	2002	Research Institute of Geology and Mineral Resources-Vietnam	Evaluating the whole geothermal resources in territory of Vietnam for renewable energy goal.	Data of Research Institute of Geology and Mineral Resources-Vietnam	Whole territory of Vietnam
7	2008	Research Institute of Geology and Mineral Resources-Vietnam	Mapping geology, geophysics, collecting and analyzing the geothermal samples	Data of Research Institute of Geology and Mineral Resources-Vietnam	Northeastern Part of Vietnam
8	2015-2020	Geophysics Institute in Vietnam Acadamy Institute	Geophysics, collecting and analyzing the geothermal samples	Data and reports of geophysics Institute in Vietnam Acadamy Institute	Central Part of Vietnam

3. TOPOGRAPHY CHARACTERISTICS

Table 2: topography level distribution

No.	Highly level (m)	Color index in topography map	Distribution areas of topography levels in the topography map	topography characteristics
1	1000-1500	Red	These areas are mainly distributed in Western Part, North Part, Central Part, and South Central Part. They are usually characterized by the highest mountainous topography or the highest mountainous chains in the area.	Very slope is strongly cut by the large stream, river systems in the areas.
2	700-1000	Dark grey	They are distributed in the Western Part, Northern Part, Central Part zone, South Central Part. They usually surround the highest mountainous topography or the highest mountainous chains	The topography is very slope, is strongly cut
3	500-700	green	They are distributed in the Western Part, North Part, Central Part, and South Central Part of Vietnam. They also surround the higher topography and the higher mountainous chains in the areas	The topography is slope
4	300-500	Lightly yellow	The types of this topography accounted for the large area are distributed in North Part, Central Part, and South Central Part of Vietnam.	The topography is slightly slope
5	200-300, 100-200 < 100,	Pinkly yellow	This is the general topography of Vietnam, is mainly developed in hilly areas, plains area in North Part, Central Part, South Central Part, South Part	flat

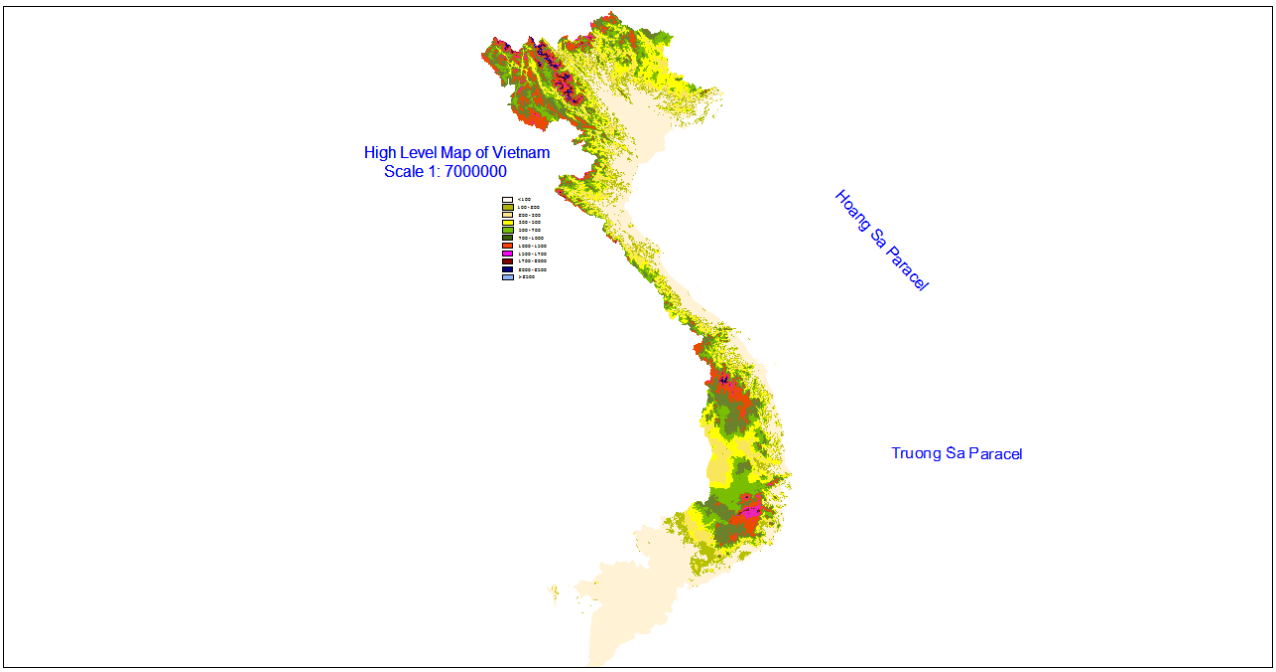

Figure 2: The topography map of Vietnam

4. GEOLOGY CHARACTERISTICS AND TECTONICS

4.1 Geological characteristics.

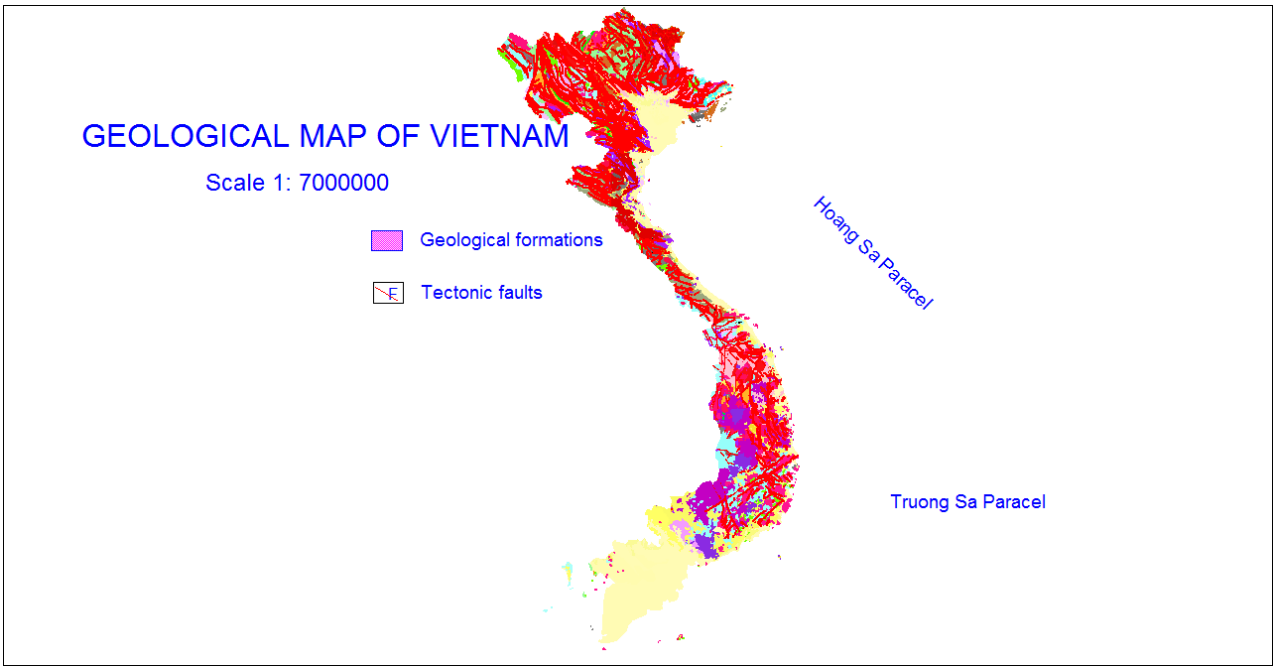

Figure 3: the geological map of Vietnam.

Table 3: Overview of the geological formation characteristics

No.	StratiAg	Overview of the geological formation characteristics	The intrusive magmatic overview
1	PROTEROZOIC	- Granulite, crystalline, schist and marble - Gneiss, amphibolites, quartzite and marble - Schist, quartzite and dolomite	- Gabbro-amphibolite - Granodiorite, granite, migmatite- - Alkali granite, granosyenite, alkali syenite
2	PALEOZOIC	- Limestone, shale, quartzite in some place greenstone, chert in West Part of Vietnam - Conglomerate, sandstone, shale, chert - Sandstone, shale, limestone, rhyolite, chert. - Conglomerate, sandstone, shale, limestone. - Limestone, chert, shale - Shale, limestone, chert with andesine, basalt in West Part, in South Central Part.	- Grabbro-diabase, gabbro, dunite - Granite, diorite, plagiogranite, granodiorite - Nepheline, syenite, granosyenite - Biotite granite
3	MESOZOIC	- Conglomerate, siltstone, secilous limestone shale with basalt in West Part, with limestone in South Part. - Conglomerate, sandstone, shale, limestone in North Part, in Central Part - Shale, limestone, sandstone, basalt in West Part, conglomerate, sandstone, shale, limestone, rhyolite in North Part, and Central Part - Conglomerate, sandstone, marly shale. - Continental deposits of conglomerate, sandstone, siltstone in North Part of Vietnam, marine deposits of conglomerate, sandstone, siltstone, shale, and marly shale in the South Part. - Orthophyre , tuff, basalt in West Part, andesine in South Central Part, rhyolite in Eastern Part and South Part, sandstone, grit stone, conglomerate in West- South Part	- Dunite, peridotite. - Gabbro, granophyres - Biotite granite, granite, granitephyre, granodiorite, grabbro-diorite, diorite, granodiorite - Diorite, granodiorite, granite, granodiorite, granite, granosyenite. - Gabbro-norite, gabbro-dolerite
4	KAINOZOI	- Red continental deposits-conglomerate, sandstone, siltstone - Trachyte, leucitophyre, - Conglomerate, sandstone, claystone, lignite - Basalt, gravel, clay, pebble, laterite - Alluvium, proluvium with marine deposits in coastal areas, and coral limestone.	

4.2 Tectonic characteristics

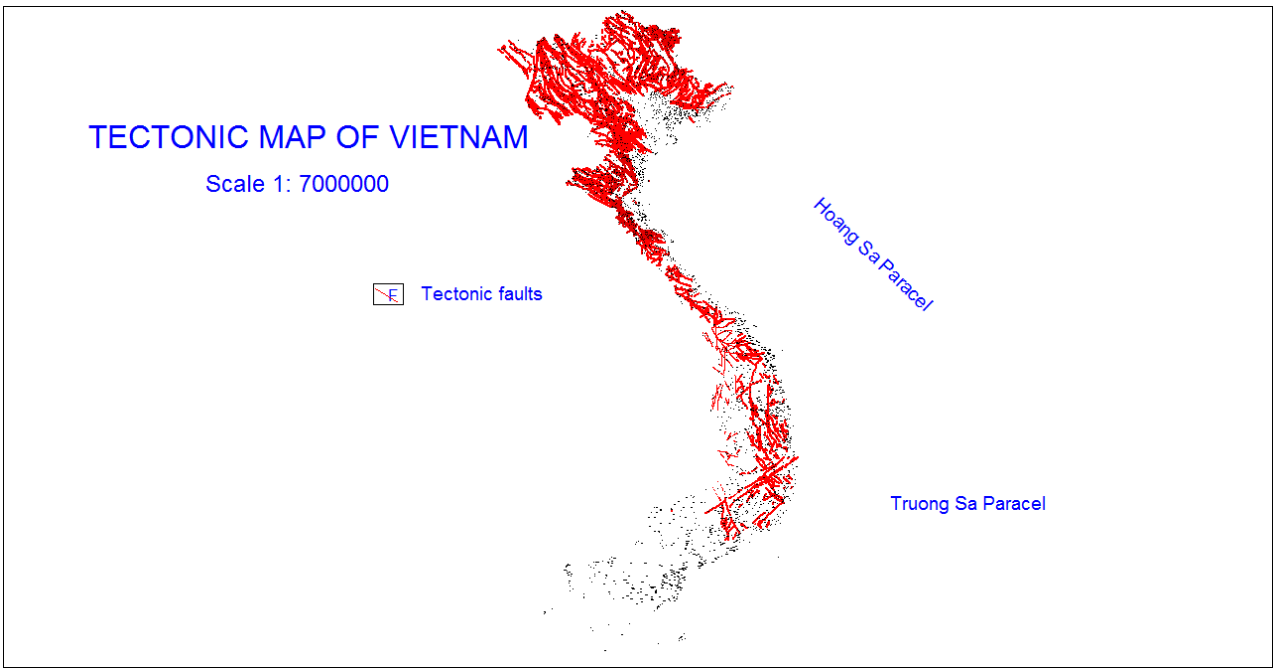

Figure 4: the tectonic map of Vietnam

The fault systems on the Tectonic Map of Vietnam are clearly seen on the Google Map, Indochina Geological Map, and Structure Map of Vietnam at scales 1:1000000, 1: 500000, 1: 200000, 1: 50000 etc., and on the arial photoes . The faults systems are mainly developed according to the NW-SE direction to originate from the highly mountainous topography areas, the highly mountainous chains of China, Lao, Cambodia etc., and they are usually developed along to the large streams valley , large river systems in the areas such as Da River, Ma River, Hong River, etc.,. Mostly, the large faults systems are closely controlled by the tectonic phases of the large Indochina region to Cambric to Holocene. The small faults systems are usually developed according to NW-SE, NE – SW, sub-meridian direction and they are also developed a long the small stream valley, river systems in the study areas. These tectonic fault systems are seen to be suitable with Tectonic Map at scale 1:1000000, 1: 500000, 1: 200000 on the whole territory of Vietnam. Of course, there are some young tectonic phases can directly be related to the geothermal resources in the area (Fig 5, Fig 6 and Fig 7). These young tectonic phases are closely related earth quakes, seismicity born faults in the earthquake distribution map of Vietnam, Lao and Cambodia (USG published data). It is clear that all geothermal resources are closely related to the deep fault-large tectonic phases, the deepened magmatic rock-forming stage.

5. GEOPHYSICAL CHARACTERISTICS

According to the USGS (USA), NW area of Vietnam has been hit by many the largest earthquakes with Max shake intensity 6.6 - 7.0 and the smaller occurred earthquakes with max shak intensity 5, 5 - 6.0. These earthquakes are mainly developed according to NW- SE, and run parallel with the large river systems, the large stream valleys in the area (many geothermal resources are discovered related directly to these depth faults such as depth fault of Pomlot geothermal resources in Dien Bien). The depth of these largest earthquakes is estimated about 28-33 km (Figure 5, 6). The Northeastern and Cental Part are listed into the smaller occurred earthquakes areas with the measured max shake intensity about 5.0-5.9. These earth quakes also are developed along to the large rivers, the large stream valleys of area to run according to NW-SE, NE-SW. Many geothermal resources of the lower temperature, average temperature are also discovered related directly to these tectonic faults systems. The South Part is the area that there is no any earthquake bigger than 5.0-5.9 and 6.6-7.0 measured.

Based on the geological structure, geological mapping, the earthquakes distributed map and aerial photograph interpretation concluded that almost geothermal resources of Vietnam can be directly related to the tectonic faults and hidden magmatics.

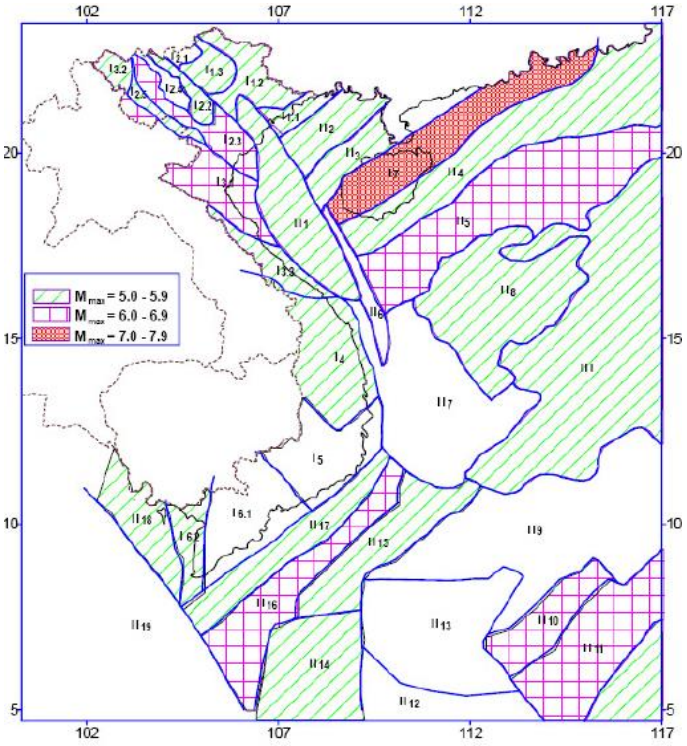

Figure 5: Maximum credible earthquakes in Vietnam (Cao 2006)

(According the data of Cao and et al)

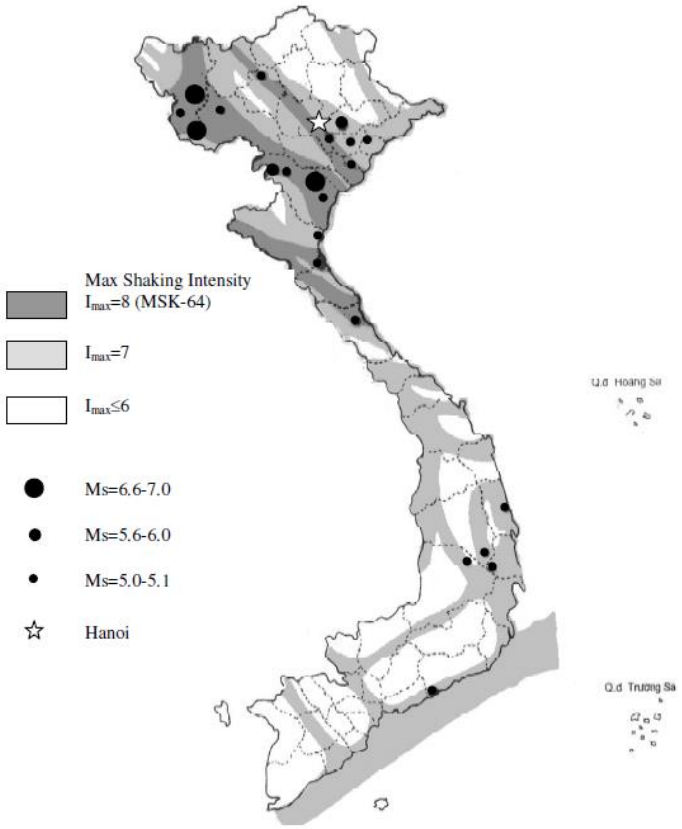

Figure 6: Ground acceleration zone map of Vietnam (Cao 2006)

(According the data of Cao and et al)

6. GEOTHERMAL RESOURCES CHARACTERISTICS

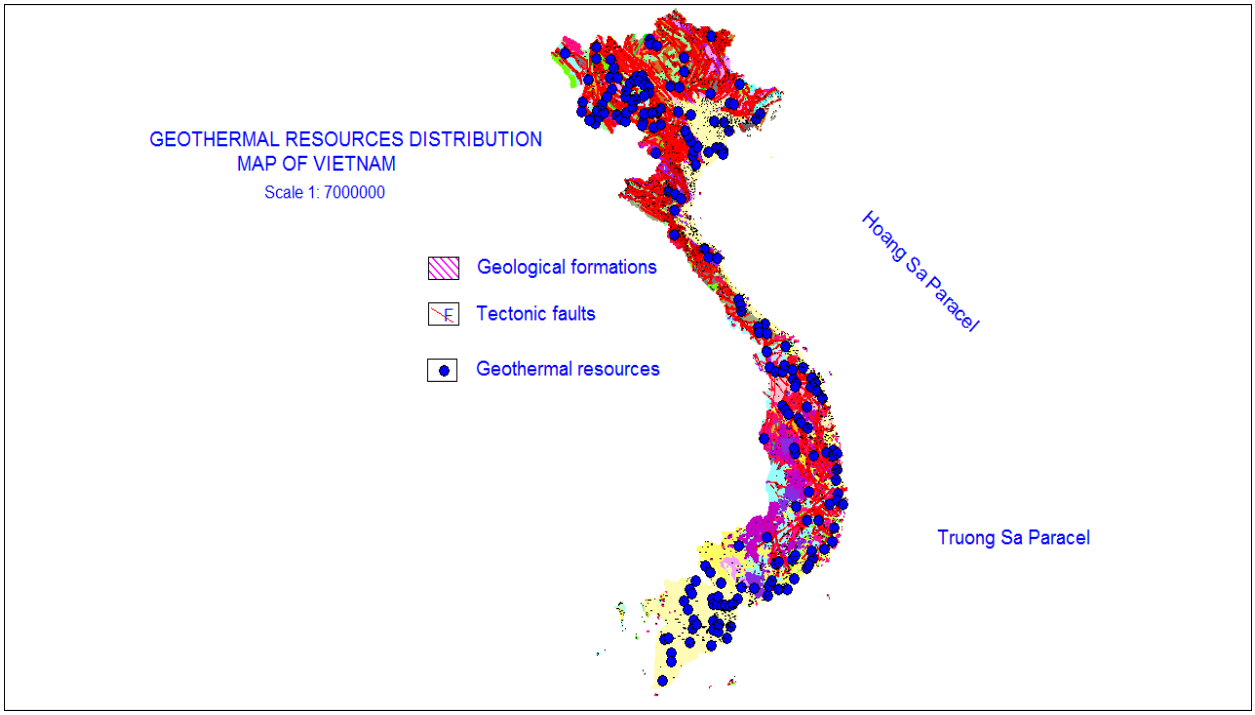

Figure 7: Geothermal resources distribution map of Vietnam on the geological base.

Table 4: The geothermal resources chacracteristics and use goals up to now

No	Locality	Type of water	Flow rate (kg/s)	Temperature ^{O}C of Inlet	Use goals up to now (direct use)
1	Hoi Van	I	8,6	83	Balneology, canning and sightseeing.
2	Quang Ngan	B	1	60	Balneology, canning and sightseeing.
3	My Lam	B	13,2	64	Balneology, canning and sightseeing, argicultutral products heating such as cassava.
4	Tam Hop	B	22,05	55	Balneology, canning and sightseeing.
5	Tien lang	B	1,4	54	Balneology, canning and sightseeing.
6	Nam Hai	B	10	104	Balneology, canning and sightseeing.
7	Keng Ga	B	1,5	55	Balneology, canning and sightseeing.
8	Son Kim	B	5	78	Balneology, canning and sightseeing.
9	Bang	B	40	100	Balneology, canning and sightseeing.
10	My An	B	1,2	50,9	Balneology, canning and sightseeing.
11	Thach Bich	B	5	68	Balneology, canning and sightseeing.

12	Mo Duc	B	6	80	Balneology, canning and sightseeing.
13	Hoi Van	B	8,5	71	Balneology, canning and sightseeing.
14	Tu Bong	B	7,3	73	Balneology, canning and sightseeing.
15	Truong Xuan	B	4,5	69	Balneology, canning and sightseeing.
16	Vinh phuong	B	18	48	Balneology, canning and sightseeing.
17	Danh Thach	B	7,9	72	Balneology, canning and sightseeing.
18	Ba Ngoi	B	7	55	Balneology, canning and sightseeing.
19	Tan My	B	2,2	50	Balneology, canning and sightseeing.
20	Binh Chau	B	15	82	Balneology, canning and sightseeing.

****** take note: Whole 20 geothermal resources that are bigger than 50^{o}C are selected to calculate

(According the data of Hoang Huu Quy, Cao Duy Giang, Nguyen Thac Cuong and et al.)

7. ORIGINS OF GEOTHERMAL WATER IN VIETNAM.

Based on the water analyzed results of geothermal resources, regionally geological mapping data, regionally tectonic mapping data, photo geology map, geophysical data, hydrogeology map, geochemistry map, petro logical sampling result, conceptual modeling results of geothermal resources in whole 269 geothermal resources to show that all geothermal resources of Vietnam are listed into the origin of the meteoric water.

8. CONCLUSIONS

Whole 269 geothermal resources have been discovered in West north Part, Northeastern Part, Central Part, South- Central Part, South part of Vietnam. They are listed into the low temperature geothermal resources, the average temperature geothermal resources from 30- 100^{o}C.

Based on the modeling results of geothermal resources, geology, tectonics, geophysics, hydrology, geochemistry, petrology of reservoir rock to show that all geothermal resources of Vietnam are mainly formed from young tectonics areas, and hidden magmatic activities.

The geothermal resources that they are located in the central cities, the large economic centers such as Ha Noi, Ha long, Da Nang, Ho Chi Minh City to has been more and more attractive to tourism sectors, balneology, canning and sightseeing.

The GDP of Vietnam has been increased to lead the tourism sectors, balneology, canning and sightseeing also to increase, also to lead to the real estate price that they surround the geothermal resources to increase such as Thanh Thuy hot water, Quang Hanh hot water, and Vinh Hao hot water etc.,

The some geothermal resources in Central Part, North Part, and South Part develop the farming, heating, and canning for exporting to Laos, Cambodia, Thai land, Myanmar, and China.

From the study results above to show that 269 geothermal resources of Vietnam have been economically used up for the direct use such as tourism sectors, balneology, canning, sightseeing, heating and farming etc., and they have been largely contributed into the Vietnamese economic development programmers. These geothermal resources have been are not valuable to develop the business electricity.

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REFERENCES

Hoppe P., Drorak J. and Kass A. (1986). *Assessment of sources of Mineral Waters in the Vietnam SR with a view to Their Use in Balneology and Mineral Water Management*. Czech state Department of Geology. Prague.

Koeing J. (1981*). Evaluation of the Potential for Geothermal Energy Resources in Vietnam.* A report by geothermex Inc. California.

Le Vinh Hong and Hoang Huu Quy (1994*). The summary Report of Results on Geothermal Potential in the South Vietnam Step II of Geothermal Project* (in Vietnamese) GSO Hanoi – Vietnam.

Le Vinh Hong (1991). *Some Primary Information of Geothermal Potential in Vietnam*. Demeguete Workshop in Philippines.

Nghiep V.C.; Dung C. T. (1986). *Geothermal Resources in Vietnam and the Neighboring countries. Perspective of Their Use for Energy Purposes. Abstract of papers*. First conference on Geothermal Energy in Indochina. Ho Chi Minh, Vietnam.

Vo Cong Nghiep, Cao The Dung, Chau Van Quynh, Vu Ngoc Phuong and Tran Dinh Cac (1987). *Evaluation of Geothermal energy as basis for design, exploitation and utilization for energy purposes*. Report

Flyn,T., Hoang Huu Quy, Phan Cu Tien and Schchet, D. (1997): Assessment of the Geothermal Resources of Socialist Republic Vietnam. *Geothermal Resources CouncilTransaction*, Vol.21.

Founier, R.O. and Truesdell, A.H. (1973): An empirical Na- K- Ca geothermpmeter for natural water. *Geochim. Cosmochim.Acta*, 37, 515-525.

Geological Survey of Vietnam (1996): *Geology and Mineral Resources of Le Thuy- Quang Tri Sheet. Geology and Mineral Resources Map at scale1: 200000.*

Koenig, J. (1981): *Evaluation of the Potential for Geothermal Energy Resources in Vietnam*. A report by Geothermex Inc., California

Nguyen Thac Cuong, Cao Duy Giang and Tran Trong Thang (2005): General Evaluation of the Geothermal Potential in Vietnam and the Prospect of Development in the Near Future. *Proceeding World Geothermal Congress 2005*, Antalya, Turkey.

Geology Survey and Mineral Resources of Vietnam (1999). *Mapping the Geological Map and Prospecting the Mineral Resources in Vit Thu Lu Maps Group scale 1: 50.000.*

Shigetaka Nakanishi, Shigeo Tezuka, Nguyen Tien Hung, (2006): *Geothermal Reconnaissance at the Mo Duc and the Bang site in Vietnam.*

Hoang Huu Quy and et al: *General Evaluation of the Geothermal Potential in Central part of Vietnam and the Prospect of Development*

Cao Duy Giang and et al: *General Evaluation of the Geothermal Potential in WestNorth Part of Vietnam and the Prospect of Development.*

Cao Duy Giang and et al: General Evaluation of the Geothermal Potential in Northeastern Part of Vietnam and the Prospect of Development