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Overview of geothermal resources in North Part of Laos

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ABSTRACT

There are eleven geothermal resources discovered in the North Part of Laos. They are mainly distributed from west to east, formed in the magmatic, sedimentary and metamorphic formations from Devonian to Quaternary and closely related with large tectonic faults in the area. The measured geothermal resources temperatures range from 40^{o}C to 86^{o}C. The chemical analysis results of eleven water samples showed that SiO_2 content in all samples is not very high. Total mineral contents range from 0.07 to 13.6 mg/L and have trace element components, such as Bromine, Iodine, Fluorite and H_2S. They are classified into the low- temperature geothermal resources, and not used for the geothermal plant development with present technology. These geothermal resources can be directly invested into tourism, balneology, canning and fish farms to develop the economy of the North Part of Laos in the coming years.

1. INTRODUCTION

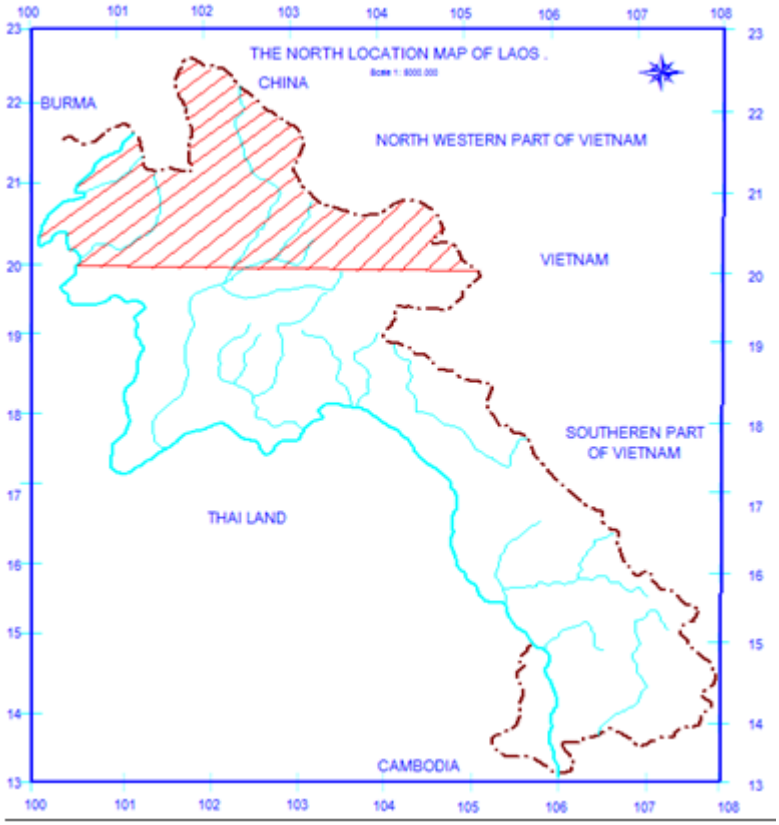

Figure 1: Location of Laos North Part in red color

The North Part of Laos is about 120,300 km^2 and is reckoned from coordinates 17^{o} 25’ 00’’ N to 22^{o} 30’ 00’’ E, 100^{o} 00’ 00’’ E to 104^{o}0000’’ E. It is the same as The North Part of Vietnam and accounts for the large section of total country land area. It is composed of highly mountainous topography regions, the developmental stream and rivers systems and the large river valleys. There are many minority communities such as Thai, Dao and, H’ Mong who live along the stream and river valleys. Their livelihood is based on farming, forestry products, hunting, and collecting forestry products.

Laos’s economy has received annually from international aid sources and new foreign investment (FDI) in many sectors such as in power development, infrastructure development, food processing, mining, wood processing, forestry planning and tourism. Among these, the tourism sector is seen as the fastest growing industry in the country. North Part of Laos has been an interesting destination for many international tours in SE Asia, EU and the US for many years. Use of geothermal resources in the tourism industry, canned drinking water and balneology will attract the investment resources from Laos’s government organizations, neighbor countries and private companies in the coming years.

2. GEOLOGICAL SETTING

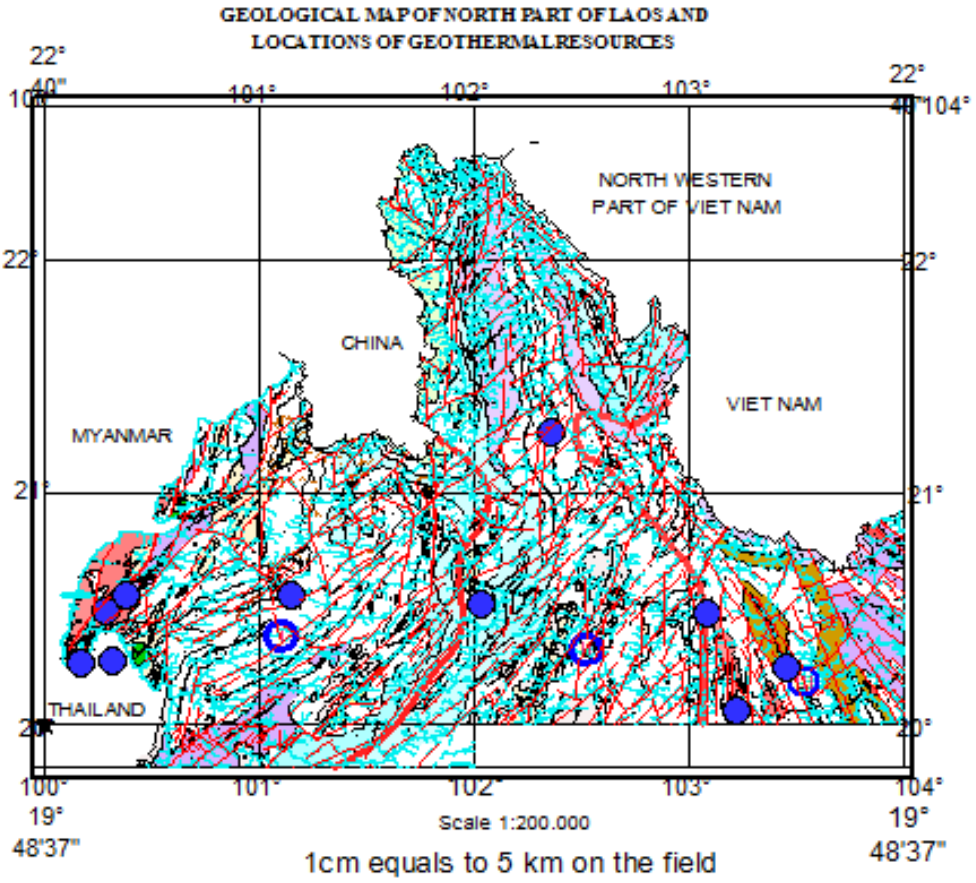

Figure 2: Geological map of North Part of Laos and location of geothermal resources

Table 1: Geological overview and location of geothermal resources in North Part of Laos.

No.	Zoning	Location	Overview of Lao North part geological characteristics	Magmatic overview
1	Nam Tha zone (I)	West part of Lao North part	The terrigenous formations are listed in C_1, C_1-P_1, P_{1-2}, the medium basal rocks are listed in P_2, the terrigenous formations are imbedded with rhyolite and tuff listed in T_2, the coarse-clastic sedimentation are listed in J_1-J_3, the red colored terrigenous sedimentations are listed in K_1-K_2, the terrigenous formations contains brown-colored coal beds, the unconsolidated sedimentation is listed in Quaternary	Pyroxenite bodies are listed in C_2, diorite, granodiorite, granite, and pegmatite bodies are listed in P_3-T_1, T_2
2	Nam Ou zone (II)	Center of Lao North part	The terrigenous formations are listed in C_1, C_1-P_1, P_{1-2}, the medium basal rocks imbedded with tuff beds , are listed in P_2, the terrigenous formations are listed in T1o and T_{2-3}, the terrigenous formations contains the coal beds listed in T_3n-r, the coarse-clastic terrigenous J_{1-2}, J_3, the red colored terrigenous sedimentations are listed in K_1-K_2, the terrigenous formations contains brown-colored coal beds listed in N_1, N_2 and unconsolidated sedimentation is listed in Quaternary	There is a small granodiorite body listed in P_3-T_1 in Houaylek village

3	Nam Xam zone (III)	East part of Lao North part	The metamorphosed formations are listed in Mesoproterozoic, Cambrian and O_3-S_1, S-D_1, the carbonate formations that they are imbedded with the terrigenous formations listed in D_{1-2}, C_1,carbonate formations listed C-P_1, the medium basal rocks are imbedded with their tuff listed in P_2, the terrigenous formations are imbedded with rhyolite and tuff listed in T_2, the terrigenous formations contain the brown-colored coal beds listed in T_3n-r and unconsolidated sedimentation is listed in Quaternary	The diorite, granodiorite- biotite-horblend, pegmatite listed in P_3-T_1. Apline granite, granite listed in T_2

3. TECTONIC SETTING

The tectonic study area of North Part of Laos is limited from latitude 20^o N to the end border line with Myanmar, China and Vietnam (Figure 02). The large faults can be clearly seen on the Google Earth, Arial photo, at scale 1/30.000, 1/20.000, on the Indochina geological maps at scale 1/000000, Laos North part geological maps at scale 1/200000, and some geological maps at scale 1/50000. Almost all the large faults are controlled by tectonic phases of large Indochina region from Cambric to Holocene. Mostly, the large faults are developed along the large rivers; large streams along the NE-SW and the small faults are usually developed in the stream valleys and streams along NW-SE. They are suitable with tectonic map of Vietnam, Laos and Cambodia. There are some tectonic phases that can directly be related the geothermal resources in North Part of Laos. 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 fault-large tectonic phases, the deeper 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 and tectonic map.

4. GEOTHERMAL MANIFESTION IN SITE

Table 2: Geology descriptions of geothermal resources in site

No	Geo. resources name	Abb. name	Coordinates	Geography location	Geological description of geothermal resources in site	Containing H_2S
1	Xiang dao	XD	$20^0$49'10" N $100^0$29'00" E	B. Xiang dao, M.Meung, Bokeo	The geothermal water flows out from the tectonic brecciate zones that it is related the SE-NW depth tectonic fault to across the granite magmatic body (γ_3 P_3-T_1).	Yes
2	Xiang kheng	XK	$20^0$48'50" N $100^0$28'50" E	B. Xiang kheng, M. Meung, Bokeo	The geothermal water flows out from the tectonic brecciate zones that it is related the SE-NW tectonic fault to across the granite magmatic body (γ_3 P_3-T_1).	yes
3	Xiang Kok	XiK	$20^0$55'10" N $100^0$38'12" E	B. Xiangkok, M. Long, Louangnamtha	The geothermal water flows out is closely related the tectonic fault that it cut across the olivine basal body (β N_2-Q_1).	yes
4	Nam Louang	NL	$20^0$55'20" N $101^0$00'15" E	B. Nam loung, M. Long, Louangnamtha	In area about 40m^2, there are four geothermal resources flow out in the tectonically sheared zones that it is closely related the SE-NW tectonic fault.	yes
5	Nam keung - kao	NKK	$20^0$26'10" N $100^0$17'05" E	B. Nam keung-Kao, M Tonpheung, Bokeo	The geothermal water flows out is closely related the tectonic fault that it cut across the granite magmatic body (γ_3P_3-T_1).	yes
6	Tong Pha Lan	TPL	$20^0$27'10" N $100^0$32'48" E	B.Tongphalang, M.Houayxai, Bokeo	The geothermal water flows out is closely related the tectonic fault that it cut across the andesitic body (P_2) in area about 42 m^2.	yes
7	Ta Liao	TL	$21^0$26'30" N $102^0$36'35" E	B. Taliao, M. Mai, Phongsali	The geothermal water flows out in the terrigenous sediment (J_2-K_1) that it is closely related the SE-NW tectonic fault in largely area about 200m^2.	yes
8	Muang La	ML	$20^0$52'00" N $102^0$03'50" E	B.Muongla, M.La, Oudomxay	The geothermal water flows out in the joint systems of the red colored sandstone, siltstone (K_2). The joint system is closely related the SE-NW tectonic fault.	yes
9	Poung Hon	PH	$20^0$48'08" N $103^0$08'25" E	B. Poung Hon, M.Viangkham, Luoangphabang	The geothermal water flows out in the sheared zones that it is closely related the SE-NW tectonic fault in carbonate formation (D_{1-2}).	yes

10	Muang Hiam	MH	$20^0$05'20" N $103^0$22'15" E	B. Muanghiam, M.Viang Thong, Houaphan	The geothermal water flows out from the tectonic brecciate zones that it is related the SE-NW tectonic fault to across the granite magmatic body (γ_3 P_3-T_1) around the M. Hiam district	yes
11	Muang Nut	MN	$20^0$24'00" N $103^0$45'15" E	B. Muangnua, M.Xamnua, Houaphan	The geothermal water flows out from the tectonic brecciate zones in the terrigenous sediment rocks (T_2) that it is related the SE-NW tectonic fault.	yes

Table 3: Geology characteristics of geothermal resources

No	Abb. Name	Hosted rock composition characteristics	Flow rate l/s	TDS, mg/l	Temp. (^{o}C)	Heat > 35^{o}C (kW)
1	XD	(γ_3 P_3-T_1) the medium grain-muscovite biotite granite	1.0	0.26	70	34.5
2	XK	(γ_3 P_3-T_1) the medium grain-muscovite biotite granite.	2.0	0.33	70	69.16
3	XiK	(β N_2-Q_1) basalt	0.04	1.48	61	1.02752
4	NL	(J_3)The green grey colored, pebbstone, gritstone, sandstone, shale	0.2	0.07	40	0.988
5	NKK	(γ_3P3-T1) the medium grain-muscovite biotite granite.	2.5	0.35	65	74.1
6	TPL	(P_2) basal, andesitobasal, andesite.	0.03	1.7	62	0.8
7	TL	(J_2-K_1) the red-brown colored, sandstone, siltstone, pebble stone, grit stone, carbonate clay,	1.5	0.54	60	37.05
8	ML	(K_2)) the red-brown colored, sandstone, siltstone, pebble stone, grit stone, carbonate clay.	0.6	13.6	64	17.1912
9	PH	(D_{1-2}) the micro grained limestone	0.05	0.6	40	2.47
10	MH	(γ_3 P_3-T_1) the medium grain-muscovite biotite granite.	1.01	0.19	86	50.89188
11	MN	(T_2) the thinly bedded, grey colored, lightly green Sandstone, siltstone, clay stone	0.5	0.4	70	17.29

5. GEOTHERMAL WATER RESOURCES CHEMISTRY

Table 4: chemistry characteristics of geothermal resources

Abb.name	XD	XK	XiK	NL	NKK	TPL	TL	ML	PH	MH	MN
Temp. ^{o}C	70	70	61	40	65	62	60	64	40	86	70
pH	7.12	8.13	6.95	7.0	8.2	7.0	7.0	8.5	6.9	8.13	8.2
Ca^{++}	1.8	1.8	57.91	6.21	2.20	63.72	8.02	749.73	60.72	11.31	56.54
Mg^{++}	1.82	1.09	3.77	2.8	0.73	0.97	5.45	37.56	8.36	0.57	13.29
T. (Fe^{+2} + Fe^{+3})	0.15	0.05	0.09	0.29	0.06	0.22	0.136	0.005	0.11	0.00	0.00
Al^{+3}	0.03	0.00	0.01	0.02	0.03	0.02	<0.005		<0.01	0.01	0.01

NH^{4+}							< 0.005			<0.005	<0.005
$(Na+K)^{+}$ (mg/l)	80.73	129.95	419.75	13.57	138.23	567.87					
Na^{+} (mg/l)							194.58	4.473	152.03	47.20	65.60
K^{+} (mg/l)							5.85	63.83	12.09	4.08	11.42
HCO_3^{-}	195.24	176.94	256.25	61.01	219.55	610.13	549.00	414.92	620.98	150.01	387.26
Cl^{-}	17.76	13.32	84.36	4.44	8.88	532.8	17.75	7999.50	15.20	10.67	23.11
NO_2^{-}				0.00	0.00		0.013	0.007	0.003	0.08	0.005
SO_4^{-2}	0.0		703.69			136.78		23.77		0.00	0.00
SO_2^{-2}									0.96		
NO_3^{-}	1.72		0.06			1.32	3.106	1.080	0.001	0.370	0.34
CO_3^{-2}		1.8			12.00						
PO_4^{-3} (mg/l)	1.12	2.26	6.82	0.48	0.54	1.95	1.028	0.429	< 0.001	0.079	0.872
H_2SiO_3 (mg/l)	52.21		74.16	7.46		92.94					
SiO_2 (mg/l)							34.38	45.07	3.18	43.71	37.67

Many reports and publications concern the chemistry of water in geology mappings in many scales 1/10000000, 1/200000, 1/50000 in North part of Laos in crystalline basement such as magmatic, sedimentary and metamorphic rocks. The chemical data of eleven geothermal resources are shown up in Table 04. The geological data, tectonic setting, geochemistry, temperature and mineralization are the important information needed to assess the potential of the geothermal resource. The geothermal locations are the blue colored circles on the geological map, tectonic fault distribution map. On the diagram, the name of the geothermal resources is the blue colored abbreviated capital letter. The geochemical type is mainly defined by the most important cations and anions. Moreover, the Total Dissolved Solids (TDS) of waters tends to increase with depth.

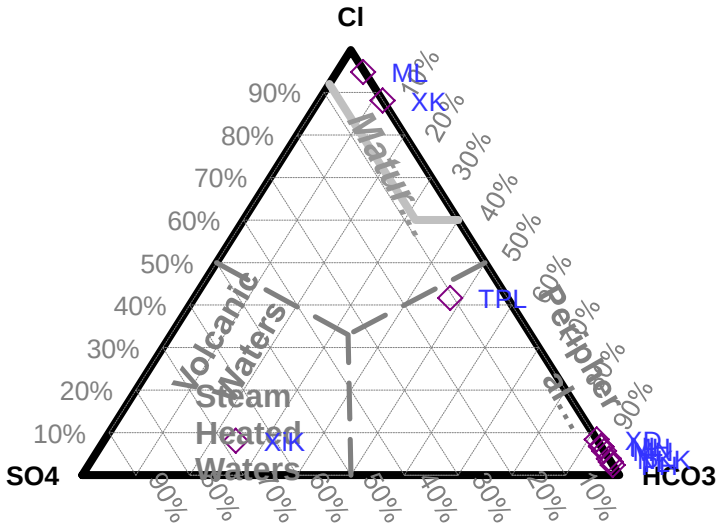

Figure 3

6. GEOTHERMAL WATER GEOTHEROMETER

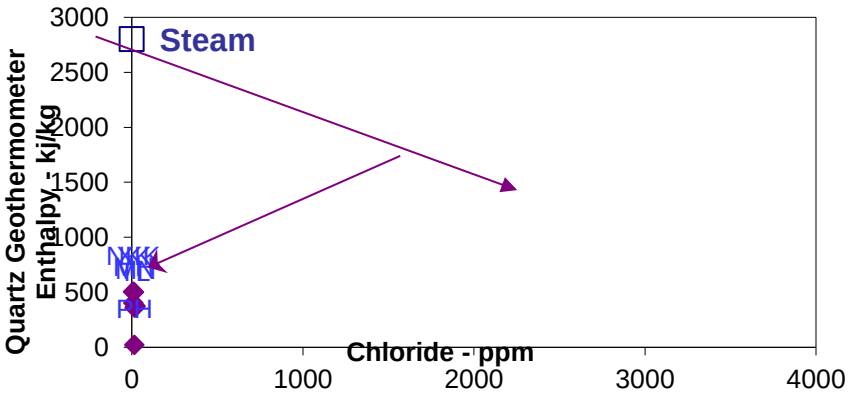

Figure 4

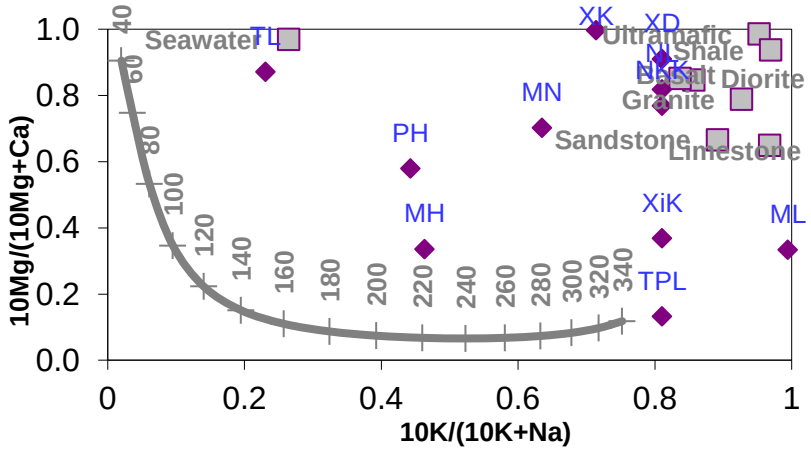

Figure 5

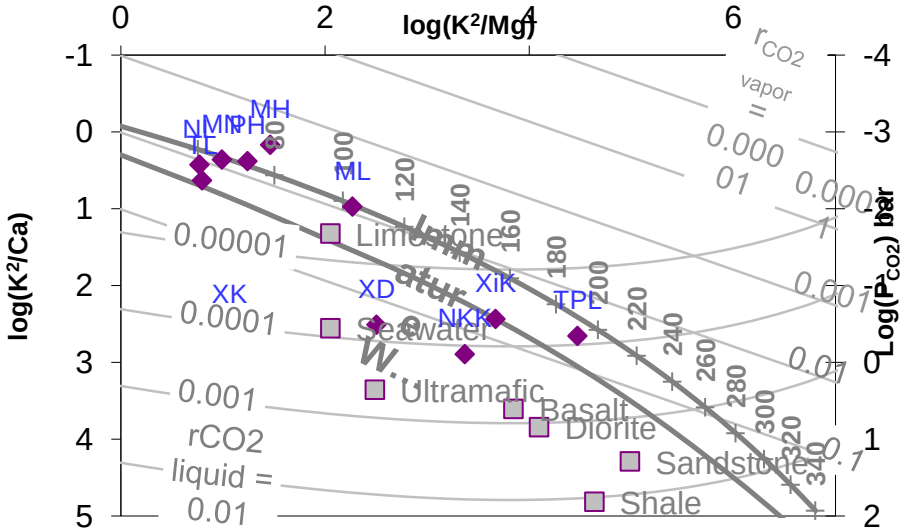

Figure 6

The Ca-Mg geothermometer of Marini et al. (1986) was also taken into account and is specific for carbonate- evaporates geothermal reservoirs. Thereby, it was interesting to test this geothermometer for geothermal fluids in carbonate-evaporate aquifers of the Mesozoic sedimentary cover. The presence of dolomite in the sedimentary cover allows having thermal waters with magnesium concentrations up to 1 mg/L, and thus, K/Ca ratios tend to decrease gradually compared to crystalline waters poor in magnesium (< 1 mg/L). Data plotted of selected waters in Figure 05, 06 show differences due to their geological setting. Points for the sedimentary cover are clearly closer to the Ca-Mg geothermometer than points representing crystalline waters.

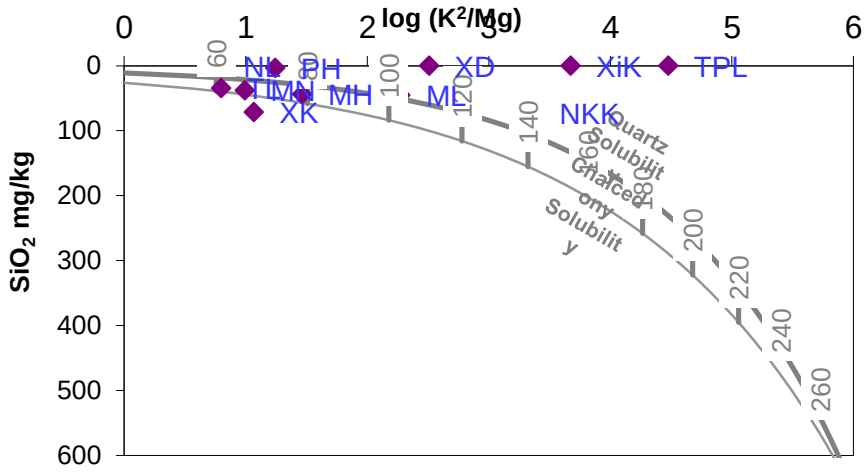

Figure 7: Dissolved silica vs. measured temperature in Northern Part of Laos. Curves correspond to selected silica geothermometers.

Ion exchange between feldspars is limited for ground waters of the sedimentary formations covering the basement because rocks are carbonates, magmatic, metamorphic or detrital deposits. The source of sodium and potassium comes from other minerals such as clays and precipitated minerals from seawater evaporation. Consequently, these two elements are not controlled by the feldspar ion- exchange reaction, and associated points on the plot in Figure 07 representing K/Mg vs. measured temperature at depth are widely dispersed. Concerning selected data in the crystalline basement, values of K/Mg ratios are better correlated with a general tendency to the decrease of K/Mg ratios with temperature and thus depth.

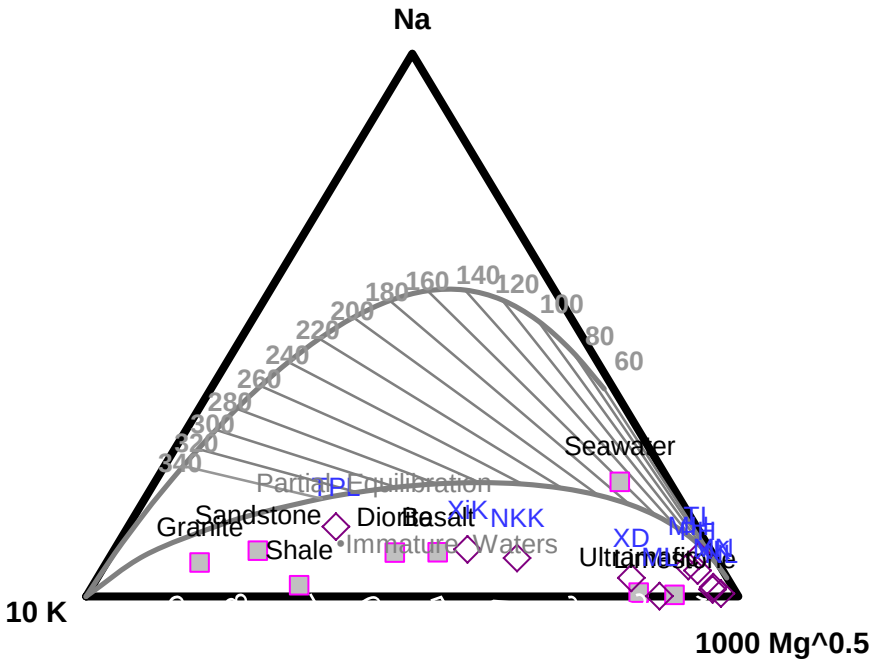

Figure 8: Giggenbach diagram of deep fluids in Northern Part of Laos. The data are listed in Table 3. The plot represents the full equilibrated line determined by variations of the Na/K geothermometer equation of Giggenbach (1988).

The abbreviated names are listed in Table 02, the geothermal resources manifestations is listed in Table 01; the analytical results are listed in Table 04. There is no considerable variation in temperature, chemical compositions of the geothermal resources in the area. The geochemical data collected from the geothermal resources show that they broadly change in mineral content from 0.07 to 13.6. The pH values range from 6.9 to 8.5. The temperatures of geothermal resources range from 40 to 86 ^{o}C.

The major element concentrations tend to have Na concentration appropriately 5 to 10 times Ca concentrations similar to all geothermal resources in Laos North Part. The geochemical data of Laos North Part are similar to the geochemical data of North Part of Vietnam published in WGC 2005.

7. GEOTHERMAL WATER ORIGIN IN NORTH PART OF LAOS

Based on the geological mapping, tectonic study, photo-geology, rock sampling results, and results of water samples that are collected in the site, shows that the origin of geothermal water in North Part of Laos originates from meteoric water.

8. CONCLUSION

Eleven geothermal resources are discovered in large mountainous area 120,300 km^2 in North Part of Laos. They are the low temperature geothermal resources that formed in existence in an area of young tectonics, and hidden magmatic activities.

The geothermal resources have temperatures ranging from 40 to 86 ^oC, pH= 6.9 to 8.5 and mineral content from 0.07 to 13.6 mg/L.

Five geothermal resources in western area of Laos North Part are located near the border with Thailand, Myanmar (The tourism - Travel line on the Mekong River to Gold Triangle Area) will be attractive to tourists in the coming years.

Most the geothermal resources are good for farming, planting, heating, tourism sectors, balneology and canning and but are not useful for running geothermal electricity plants.

The five geothermal resources in western part of Laos North Part are being taken care of to develop the farming, planting, heating, tourism sectors, balneology and canning for export to Thailand, Vietnam, Myanmar, and China in the coming years.

The geothermal resource study is mainly based on the general geological investigation as geological mappings, the large scale hydrological mapping, engineering geological map, attached mineral resources explorations. The assessment of geothermal resources has many errors. It needs to invest into the detailed geological mapping, geophysics, geochemistry investigations, water sampling analysis and exploration drilling to assess the potential geothermal resources accurately in the coming years to serve the Laos economic development program.

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