indications are distributed. The local flow system is thought to be a flow in comparatively shallow alluvium deposits and in the weathered zone of the Paleozoic formation. It is inferred that this system has influence upon the flow of shallow hot spring aquifer and that it controls the distribution of ground temperature and the hot springs.

In this area, the intermediate flow system is thought to play an important role for the upflow and the accumulation of the geothermal fluid. The main direction of the underground flow of the intermediate flow system in the drainage basin of the Huai Pong River is thought to be from the upstream area to the downstream area (south to north). Assuming that the geothermal fluid is moving upward along the NW-SE fault branched from the Huai Pong fault, it is estimated to be the tendency that theupflowing geothermal fluid moves toward the downstream area in the north, by the influence of the lateral motion of the intermediate flow system. The change of the passages of the geothermal fluid, caught by the distribution of the alteration zones and by tha that of the area where the geothermal indications are distributed, shows good harmony with the above estimation (Fig. V.1-6).

V-1-4 Structural Model of the Geothermal Reservoir

1. Outline of the geothermal reservoir

Summarizing the geological structure, the geothermal structure and the hydrographical structure in the San Kampaeng area, to which the consideration was given in the former paragraphs, a model of the geothermal reservoir in this area is brought forward here.

The heat source in the San Kampaeng area is mainly the latent granite in the depth of the underground in the Doi Luang uplifted zone and along the marginal zone of the Ban Pong Hom subsided zone. The heat source in thought to include regional high heat flow common to the northern Thailand as well as upflow of geothermal fluid along the large scaled faults (such faults as dividing tectonic zones or the first class structural lineaments as is observable in the form of the letter S on the LANDSAT imaginary). The depth of the surface of the granite is estimated to be 3.5 ~ 4.0 km in the underground of the area where the geothermal indications are distributed, which is obtained by the analysis of the reflection surface in the seismic survey. The rainwater is thought to penetrate to this depth and to be heated while circulating in the hot rock body. Thus the geothermal fluid is formed. The temperature of the formation of this geothermal fluid is thought to be around 190° ~ 210°C, which is estimated by the Na-K-Ca thermometer using the hydrothermal solution.

The geothermal fluid formed in this way is thought to upflow along the Huai Pong fault, along its branch fault, along the Ban Mae Khu Ha fault and along other faults. The principal reservoir is thought to be clusters of these high angled faults. There is another possibility of reservoir, which lies horizontally along the layers, being diffused and admixed with underground water in the process of the upflow. The possible layers for the reservoirs with abundant fissilities are lithologically taken to be easily fractured chert, and shale and corroded limestone, and unconformity between the Mae Tha Formation and the Kiu Lom Formation as well as the contact surface of the granite with the Paleozoic formations. The layers between the horizons of L_2 and L_3, L_4 and L_5, L_6 and L_7' assumed by the seismic survey reveal high S-N ratio zone and low frequency domain. It is thought that fractures are developed in them, stratigraphically and lithologically.

The geothermal fluid is cooled mainly by conduction in the process of the up flow, but in the shallow part the temperature descends by the direct admixture of underground water. Considering the sensitivity of the seasonal variation of chemical ingredients contained in the hot spring waters, the admixture of underground water would be occurring in not so deep a portion. Viewing from the thickness of the weathering layer in the seismic survey and from the distribution of the low resistivity layers in the deep electric survey, the depth of the admixture of underground water is thought to be less than 500 meters. The temperature at this level is thought to be 160°C, which is estimated by the silica thermometer, or 139°C, which is the actual measured temperature in the well S-13.

It is inferred that the geothermal fluid after admixed with underground water has flown up through some narrow pass (part of fault planes) to the central part of the area where the geo-

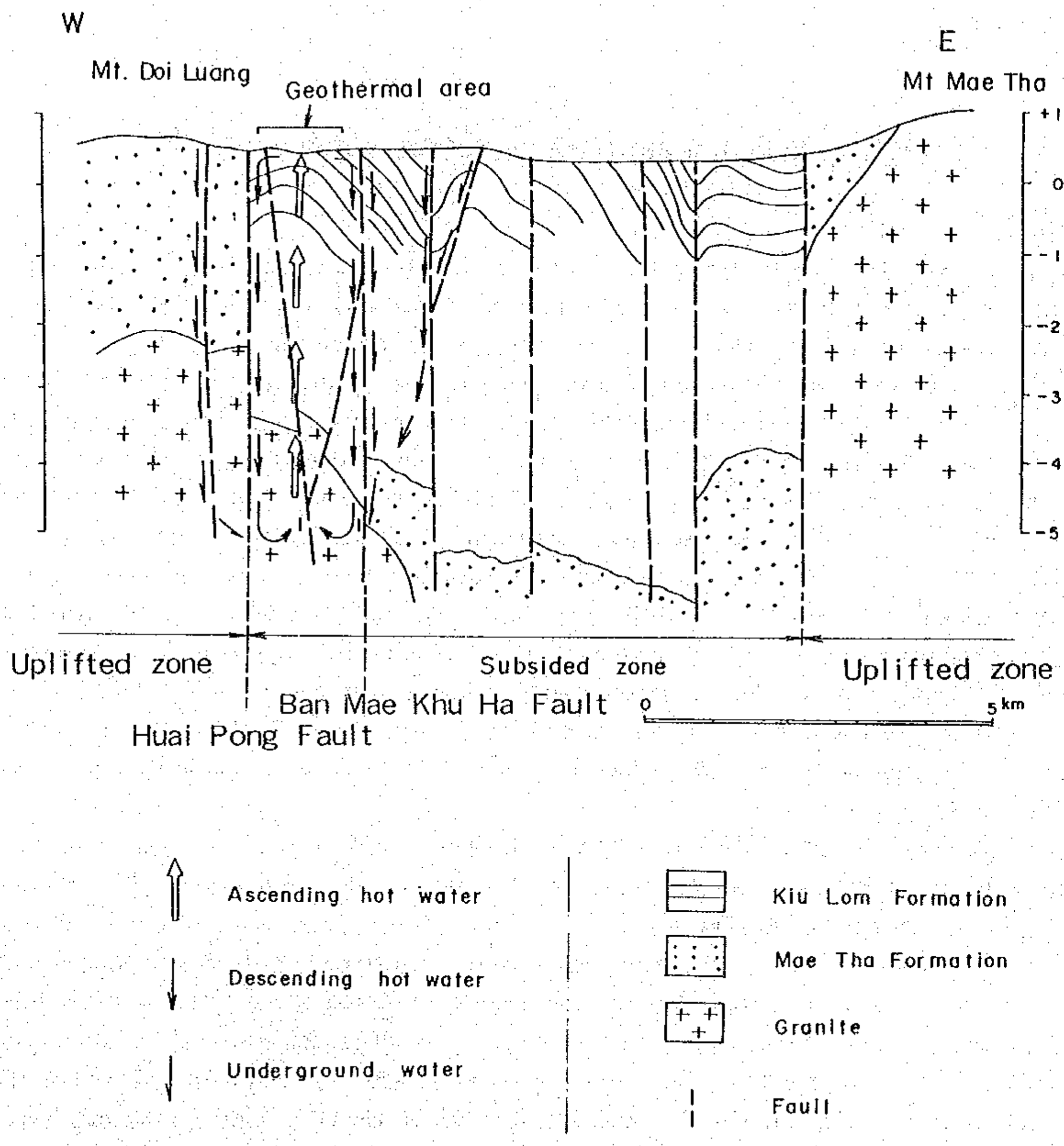


Fig. V.1-7 Geothermal system of San Kampaeng area thermal indications are distributed (around the hold of S-13), and that it has diffused laterally in the alluvial deposits which are composed of sands, pebbles and muds as well as in the thick weathered fracture zones, where aquifers for the thermal water near survace have been formed.

By the deep electric survey, low resistivity zones have been detected at the depth of less than 500 meters (first conductive layer) and at the depth of 1,000 ~ 3,000 meters (second conductive layer), in the area between the Huai Pong fault and the Ban Mae Khu Ha fault. This result is in good harmony with the result which has been obtained by the seismic survey. Especially, the second conductive layer is corresponding to the most remarkable reflection surface among the horizons from L_2 to L_8 (surface of the granite body). Accordingly, it is conceivable for the San Kampaeng geothermal to be divided into two sub-system of shallow and deep geothermal reservoirs. Summarizing the above-mentioned items, San Kampaeng geothermal reservoir model is brought forward as follows (Fig. V.1-7).

2. Extent of the geothermal reservoir

The extent of the San Kampaeng geothermal reservoir is thought to be confined to the Ban Pong Nok area, where the actual geothermal indications are found, considering from the geological structure, the underground temperature, the gravity anomalies, the distribution of the low resistivity layers and the distribution of the low S-N ratio zones of elastic waves.

As for the geological structure, the area where the alteration zones are distributed and the area where the actual geothermal indications are distributed are defined by the Ban Mae Khu Ha fault of N-S trend, the Huai Pong fault of the same trend and its branch fault of the NW-SE fault. The alteration zones are the sum of the past geothermal activity. The fact that the alteration zones are fairly broadly distributed in this area, including the area where the present geothermal indications are found, is thought to suggest that the geothermal activities have been there in wide area and for long period. This geothermally indicated area is located on the east wing of the anticline, in a small distance from the axis, which is composed of shale, sandstone and chert of the lower part of the Kiu Lom Formation.

From the results of the deep electric survey, a surface rise of the electric basement, Rc layer, is recognized, which is correspondent to the anticlinal zone detected by the seismic survey. In such part as the wing of anticline, sheared zones are generally developed by tectonic movement. The sheared zones are thought to compose passages for the geothermal fluid from the depth.

By the results of the gravity survey, the area is, as a whole, composed of the eastern high gravity zone, the central high gravity gradient zone and the western low gravity zone. The area where the geothermal indications are distributed is located in the western low gravity zone, and is corresponding to the periphery of the low residual gravity area of third order polynomial. This is thought to be due to the lowering of the rock density by the alteration and the fracturing, and this low gravity area is delineating the extent of the geothermal reservoir as a whole.

By the 10 m depth temperature distribution map, high temperature zone of over 40°C is confined to the area where the geothermal indications are distributed. Its extension is approximately in an area of 0.4 km × 0.6 km. This is suggesting that the high temperature zone has been formed by the discharge of the hot springs. Also, the anomaly of the 10 m depth temperature of over 30°C has been found in a small area including a part of the survey line E of the seismic survey. It is not certain by what this anomaly of the temperature has been brought about. No evidence has yet been found for this anomaly to be related to the existence of the geothermal fluid. In all the area, except for the above two anomalous zones, the 10 m depth temperature is 20° ~ 30°C, which is at the same level of the annual average temperature, and no geothermal anomaly has been recognized.

It is thought that the distribution of the total conductance and the apparent resistivity is indicating the extent of the geothermal reservoir appropriately. Most of this area is underlain by low conductive layers of the total conductance values of less than 220 mhos, but there are two highly conductive zones of the values of more than 200 mhos. The one is around the survey point 2-2 in Wat Pong Hom, and the other is the area from Wat Hong Hoi to Wat Hua Fai in the southeastern part of the surveyed area. The former is obviously related to the area where the present geothermal indications are distributed, and the iso-value contour line of 200 mhos is closed there. However, viewing in detail, the distribution of the alteration zones indicating past geothermal activities, the location of the area where the present geothermal indications are found and the highly conductive zone of the total conductance values of more than 200 mhos are not coincident one another completely, but they are distributed toward north overlapping. It is not certain how they are related to the extent of the geothermal reservoir at the depth in the underground. The highly conductive zone found in the southeastern part of the surveyed area is obviously a part of fairly large scaled high conductive anomaly. But because the geothermal anomalies, such as the 10 m depth temperature distribution and the distribution of hot springs, and the permeable zones due to faults and fractures are not recognized in the area of the total conductance values of over 200 ~ 300 mhos, the geothermal potentiality in this area is not known yet.

By the analysis results of the seismic survey, the geological structure is different in the eastern area and in the western area, bounded by a narrow zone, in the direction of north and south, from Ban Mae Khu Ha in the south to Doi Tham (roughly corresponding to the ⊗ fault). As is shown by the structural contour lines of the L_4 horizon, the western area is an uplifted zone while the eastern area composes a subsided zone. Also, in the western area the low frequency zones are widely recognized. They are especially remarkable along B line, C line and along the northern part of A line. However, low frequency zone is rarely recognized in the eastern part. As the area where the geothermal indications are distributed is included in the low frequency zones at the levels of −1,000 meters and −2,000 meters above the datum level, it is pointed out that the low frequency zones would represent fractured zones and that geothermal fluid would be existed in such part.

As stated above, it has been clarified that the area where the present geothermal indications are distributed on the surface has very direct relation spacially with the low gravity anomaly detected in the gravity survey, with the highly conductive zone in the deep electric survey, with the low frequency zone in the seismic survey and with the fault zone or alteration zone in the geological survey. The problem is how the surface indications (the area where termal fluid springs out) are connected to the geothermal reservoir in the underground. According to the survey results, extension of the faults, fractures and low frequency zones is almost vertical, and it is estimated that the geothermal reservoir is continuous to the depth in such high angle as to be almost vertical.

V-2 Possibility of the Geothermal Development and Future Program of Investigation

As previous-mentioned, it may be inferred that the San Kampaeng geothermal reservoir is confined to the present geothermal manifestation area of Ban Pon Nok. The surface geothermal manifestations are taken to be a leak from the reservoir.

Judying from low resistivity distribution on the deep electric survey (MT method), the width of the geothermal reservoir is estimated about 400 meters. Also the low resistivity layer in the resistivity profile indicates that the geothermal reservoir occupies at the depth of around 500 meters and at the depth of 1,000 to 3,000 meters approximately. Because this, it seems possible that the San Kampaeng geothermal reservoir can be devided into the shallow part and deep part. The width in north and south is not cartain without profile, but the reservoir is thought to be extending to the depth probably in a form of cylinder. The temperature of the geothermal fluid in the deep reservoir is estimated to be 190° ~ 210°C by the Na-K-Ca chemical thermometer.

Viewing from the above results, it is concluded that the further investigations of the San Kampaeng area, especially of present geothermal manifestation area, should be recommended as to the detailed extension of the geothermal reservoir and the temperature of thermal fluid, for the confirmation of the possibility of the geothermal development.

As the contents of the future survey program, the exploratory well is recommended to drill in the depth of about 1,500 meters in the geothermal manifestation area for the confirmation of the existence of geothermal fluid and its temperature. In case the geothermal fluid blows out, it is desirable to carry out the production test to estimate the reservoir and well property as to pressure, temperature, permeability and so on, discharge characteristic curve for steam and thermal water.

Before starting the third phase investigations including the above-mentioned drilling of exploratory well, it is thought to be necessary to grasp more precisely the extention, the depth and the center of the geothermal reservoir in the San Kampaeng area. For this purpose, it is desirable to carry out supplementary deep electric survey (MT method) in the subject area. Although a high conductance zone (over 200 mhos) is recognized in the southeastern part of the surveyed area (around Ban Mae), the extension has not been confirmed yet, as lacking the sufficient numbers of the survey points. Therefore, further the deep electric survey is also recommended to confirm the forms and the extension of this high conductance zone of Ban Mae area, giving some additional survey points.

It is desirable to give final evaluation for the development of the San Kampaeng area, after analysing the results of the above-mentioned various surveys.

VI CONCLUSION

VI CONCLUSION

From the results of the primary and the secondary investigations carried out in 1982 fiscal year, and from the results of the technical analysis performed in 1983, it has been confirmed that the potential area for geothermal reservoirs in this San Kampaeng geothermal area would be confined to Ban Pon Nok area, where the actual geothermal indications are found on the surface.

This area is situated between the N-S trending Huai Pong fault and the NW-SE trending fault branched from the Ban Mae Khu Ha fault. In addition to the favorable characteristics that many superior geothermal indications are distributed on the surface in this area, the Ban Pong Nok area is the area where anomalies of subsurface temperature, gravity survey, resistivity and seismic survey are concentrated.

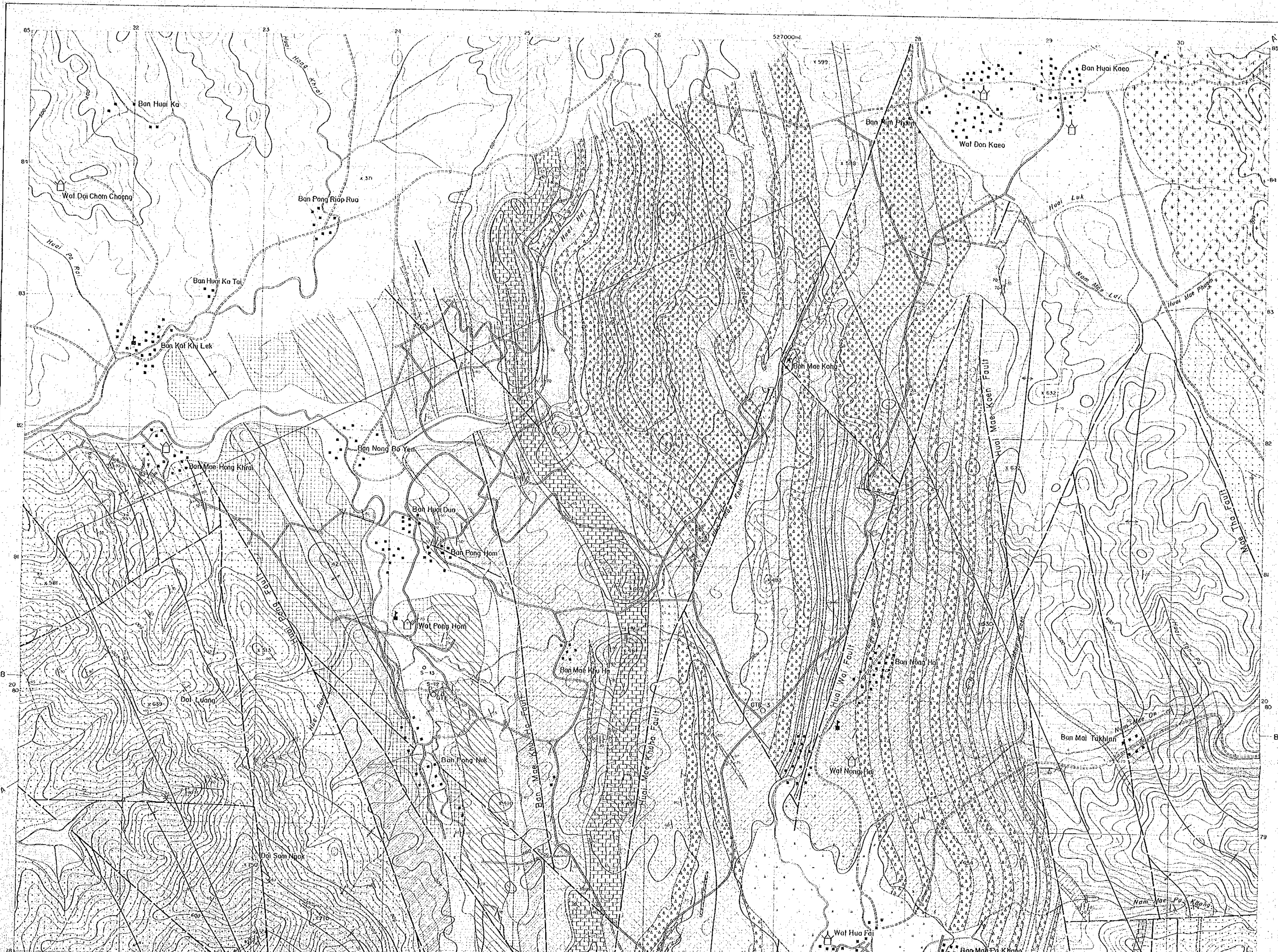
Further informations on the extent of the geothermal reservoir and on the temperature of the geothermal fluid will be required for the determination whether the area would warrant actual geothermal development. On this point, the following suggestions have been obtained through the present investigations.

As for the extent of the geothermal reservoirs, there are informations by the deep electric survey. Below the surface around the Wat Pong Hom area, two layers of low resistivity are recognized at the depth of less than 500 meters and at the depth between 1,000 and 3,000 meters. Regarding these low resistivity layers as the geothermal reservoirs, the width is approximately 400 meters. This width is taken in the direction of northeast and southwest. However, judging from the distribution of the total conductance, the width of the low resistivity layers in the direction of northwest and southeast is estimated to be 400 ~ 500 meters, as well, differing not so much from the above. Therefore, as far as the result of the deep electric survey concerns, the idea can be held that the reservoir in this area is extending vertically to the depth in a shape of pipe, while the geothermal indications found on the surface are located on the top of it.

As for the temperature of the geothermal fluid, there is an information of the temperature of 139°C, which was actually measured, in the 30 m depth temperature survey carried out by the Thailand side, in the drill hole of S-13 in the area where the present geothermal indications are distributed. Viewing from this actual measured value, it is thought that the temperature of the geothermal fluid in the deeper portion will reach at least more than 139°C. By the chemical thermometer, the value of about 160°C was obtained by SiO_2 method and that of 192 ~ 207°C was obtained Na-K-Ca method. It is inferred that the temperature of the geothermal fluid at the depth of more than 1,000 meters would be 200°C more or less.

As afore mentioned, the extent of the geothermal reservoir estimated by the surface survey seems rather small, but because the fracturing is supposed to be developed well in the layers in this area, being surrounded by the faults, it is possible to anticipate the reservoir would occupy unexpectedly broad area, as suggested by the extensive alteration developed in the neighbouring zone to the south of the area where the geothermal indications are distributed. Also, as for the subsurface temperature, there is a record of 139°C at so shallow a depth of 30 meters, and the temperature of the geothermal reservoir would be expected to be more than 160°C, presumably about 200°C according to the chemical thermometer. Therefore, it is thought that further investigation will be warranted in this area for the possibility of geothermal development.

The contents of the future program to be recommended are to carry out drilling of the exploratory well in the potantial area where the reservoirs are expected, as caught by deep electric survey, targetting the low resistivity layers at the depth of 1,000 ~ 3,000 meters as well as the low frequency zone obtained by the seismic survey, in order to confirm existence of the geothermal fluid and its temperature. In case the fluid is shooting up, it is necessary to carry out discharge characteristic test of vapor and hydrothermal liquid. And it is recommended to give final evaluation of the possibility of the geothermal development in this project after the synthetic analyses of all-round data of various investigations.



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B
B'
Ban Huai Ka
Wat Doi Chom Chaeng
Ban Pong Riap Rua
Huai Hong Khrai
Huai Pa Rai
Ban Huai Ka Tai
Ban Kat Khi Lek
Ban Nong Bo Yen
Ban Mae Hong Khrai
Ban Huai Dua
Ban Pong Hom
Wat Pong Hom
Doi Luang
Ban Pong Nok
Ban Mae Khu Ho
Ban Mae Khu Ho Fault
Huai Mae Khuha Fault
Ban Mae Kong
Ban Huai Kaeo
Wat Don Kaeo
Nam Mae Lai
Huai Mae Koen Fault
Mae Tho Fault
Huai Wai Fault
Ban Nong Hai
Wat Nong Hai
Ban Mai Takhlan
Nam Mae On
Nam Mae Pa Khong
Wat Hua Fai

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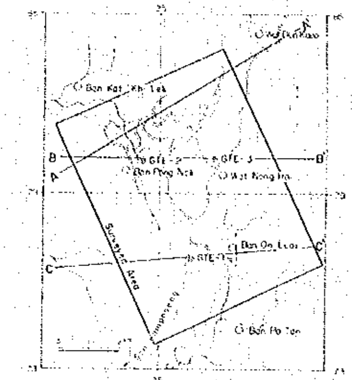
PL. II.1.1-1

THE PRE-FEASIBILITY STUDY ON THE SAN KAMPAENG GEOTHERMAL DEVELOPMENT PROJECT IN THE KINGDOM OF THAILAND

GEOLOGICAL MAP



JAPAN INTERNATIONAL COOPERATION AGENCY
ELECTRICITY GENERATING AUTHORITY OF THAILAND
DEPARTMENT OF MINERAL RESOURCES
CHIANG MAI UNIVERSITY

MARCH 1983

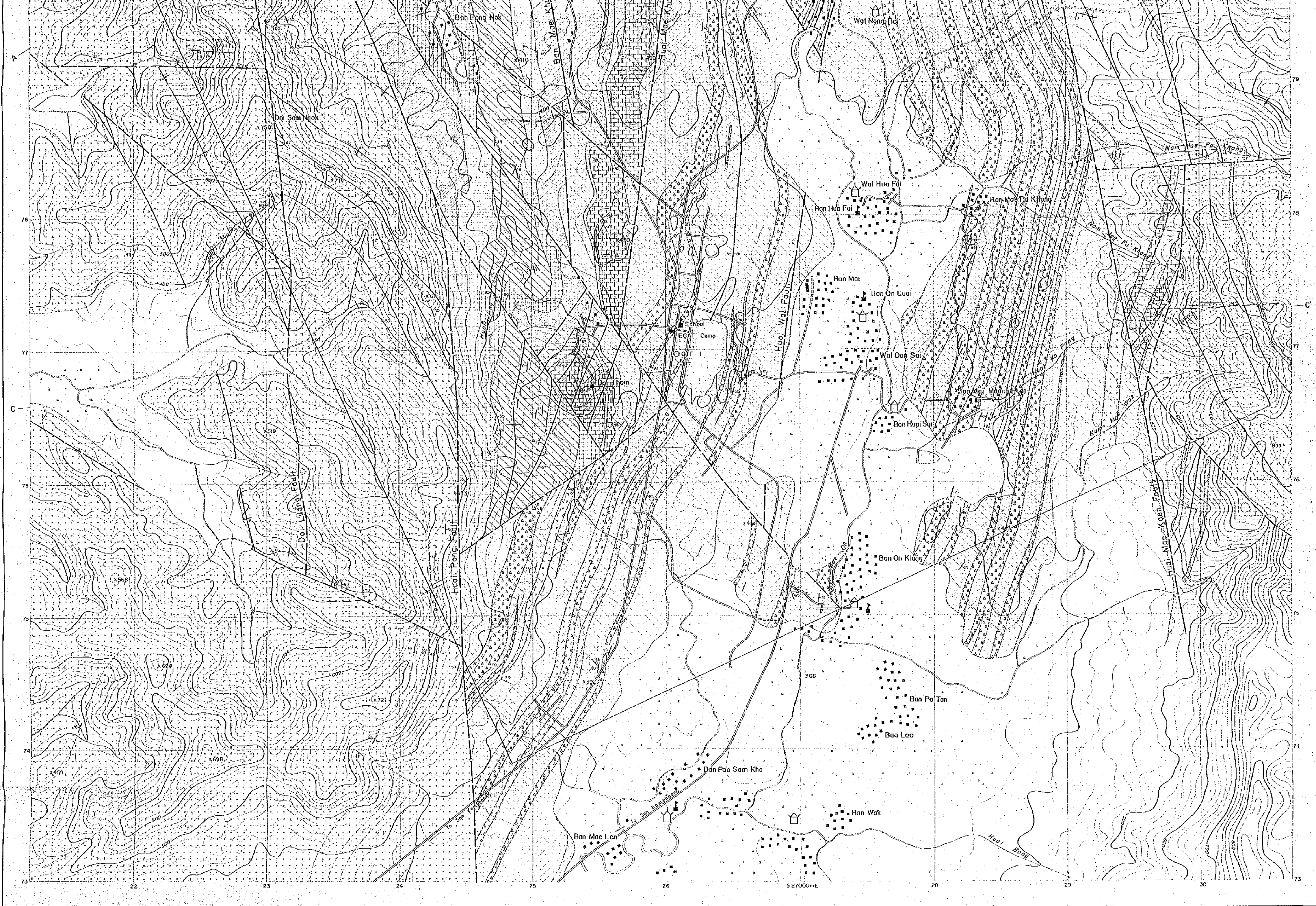
0 500 1000m

LEGEND

Alluvium	Alluvial deposit
Permian Kiu Lom Formation	Basaltic tuff
	Basaltic tuff breccia, Lapilli tuff
	Basalt
	Shale
	Siltstone ≫ Sandstone
	Sandstone
	Chert
	Sandstone ≫ Chert
	Chert ≫ Sandstone
	Shale ≫ Sandstone > Chert
	Limestone
Carboniferous Mae Tha Formation	Shale
	Sandstone
	Porphyritic granite

Bedding plane
Joint
Fissure
Quartz vein
Fault
Anticline axis
Syncline axis
Structure line

A —— A' Location of geological Profile


A
C
C'
Ban Pong Nok
Wat Nong Fai
Doi Sam Ngok
Wat Hua Fai
Ban Hua Fai
Ban Mae Pa Khang
Nam Mae Pa Khang
Ban Mai
Ban On Luai
School
EGAT Camp
Wat Don Sai
Doi Thom
Ban Huai Sai
Huai Wat Fault
Doi Luang Fault
Huai Pong Fault
Huai Mae Koen Fault
Ban On Klang
Ban Po Tan
Ban Lao
Ban Pao Sam Kha
Ban Wak
Ban Mae Len
Huai Bong
368
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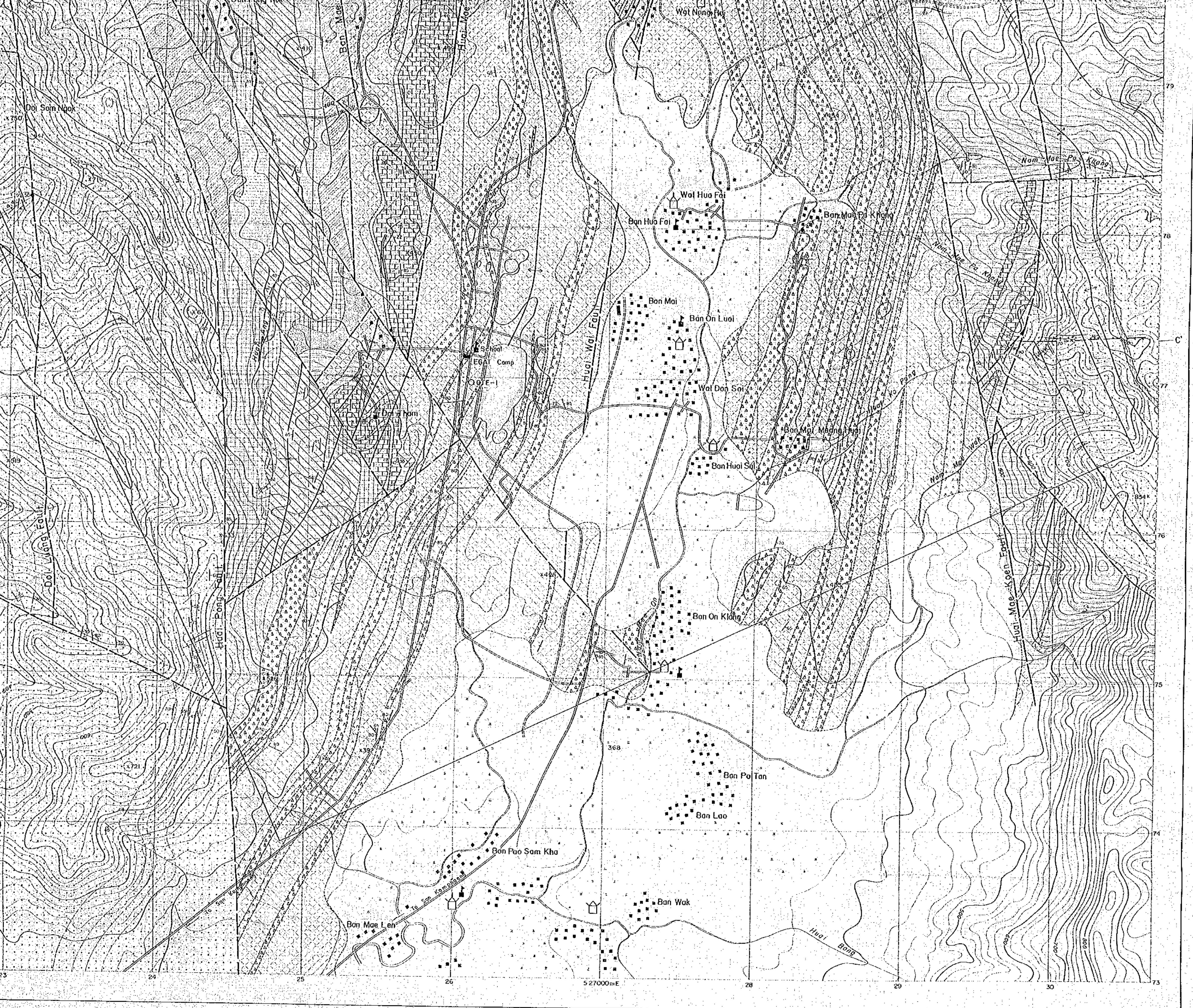

Wat Nong Pai
Doi Sam Ngok
Ban Mae
Huai Mae
Nam Mae Pa Khong
Wat Hua Fai
Ban Hua Fai
Ban Mae Pa Khong
Ban Mai
Ban On Luai
School
EGAT Camp
Wat Don Sai
Doi Lang Fault
Huai Pong Fault
Huai Wai Fault
Ban Mai Mong Thai
Ban Huai Sai
Nam Mae Wak
Huai Mae Koen Fault
Ban On Klang
368
Ban Pa Tan
Ban Lao
Ban Pao Sam Kha
Ban Wak
Ban Mae Len
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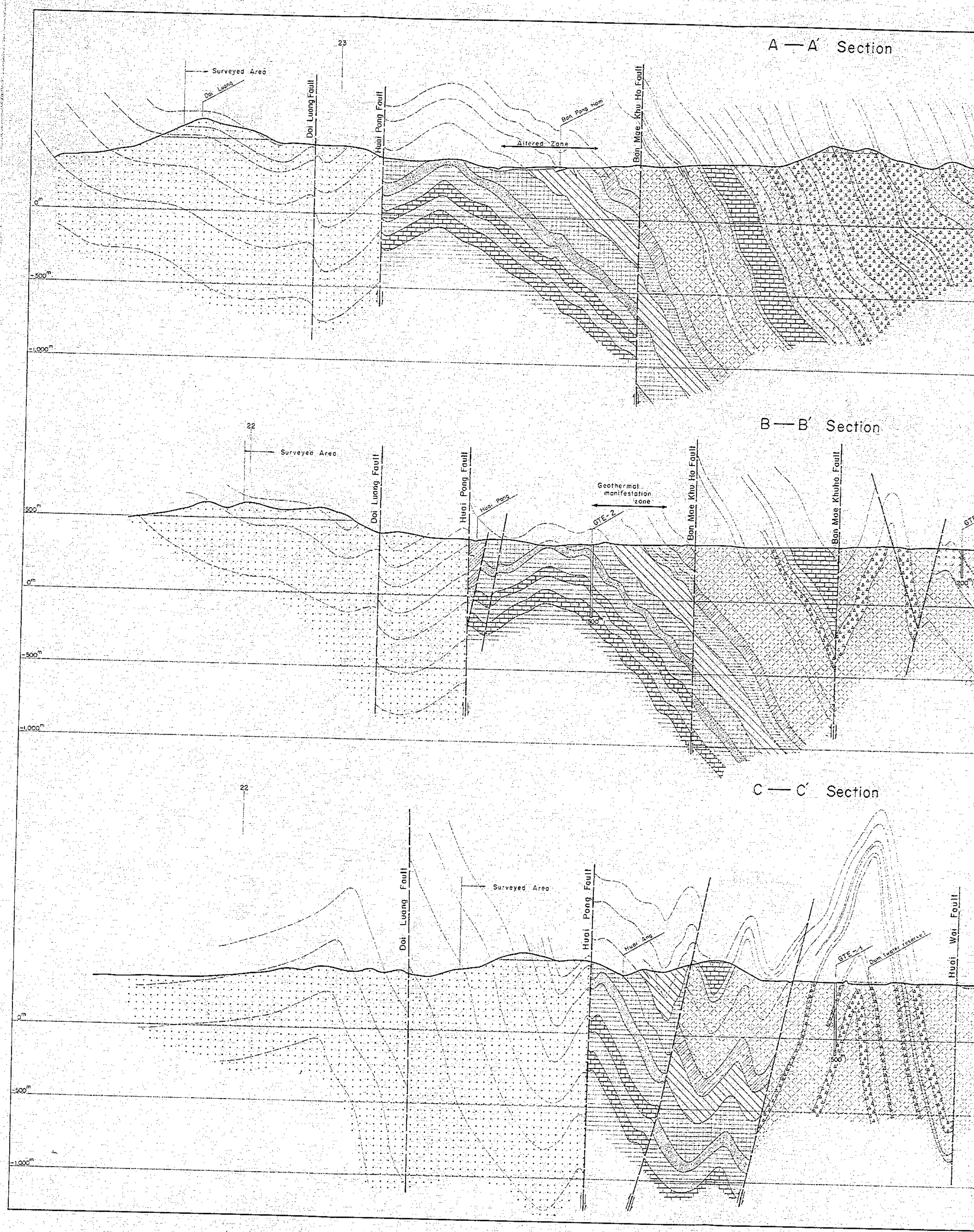
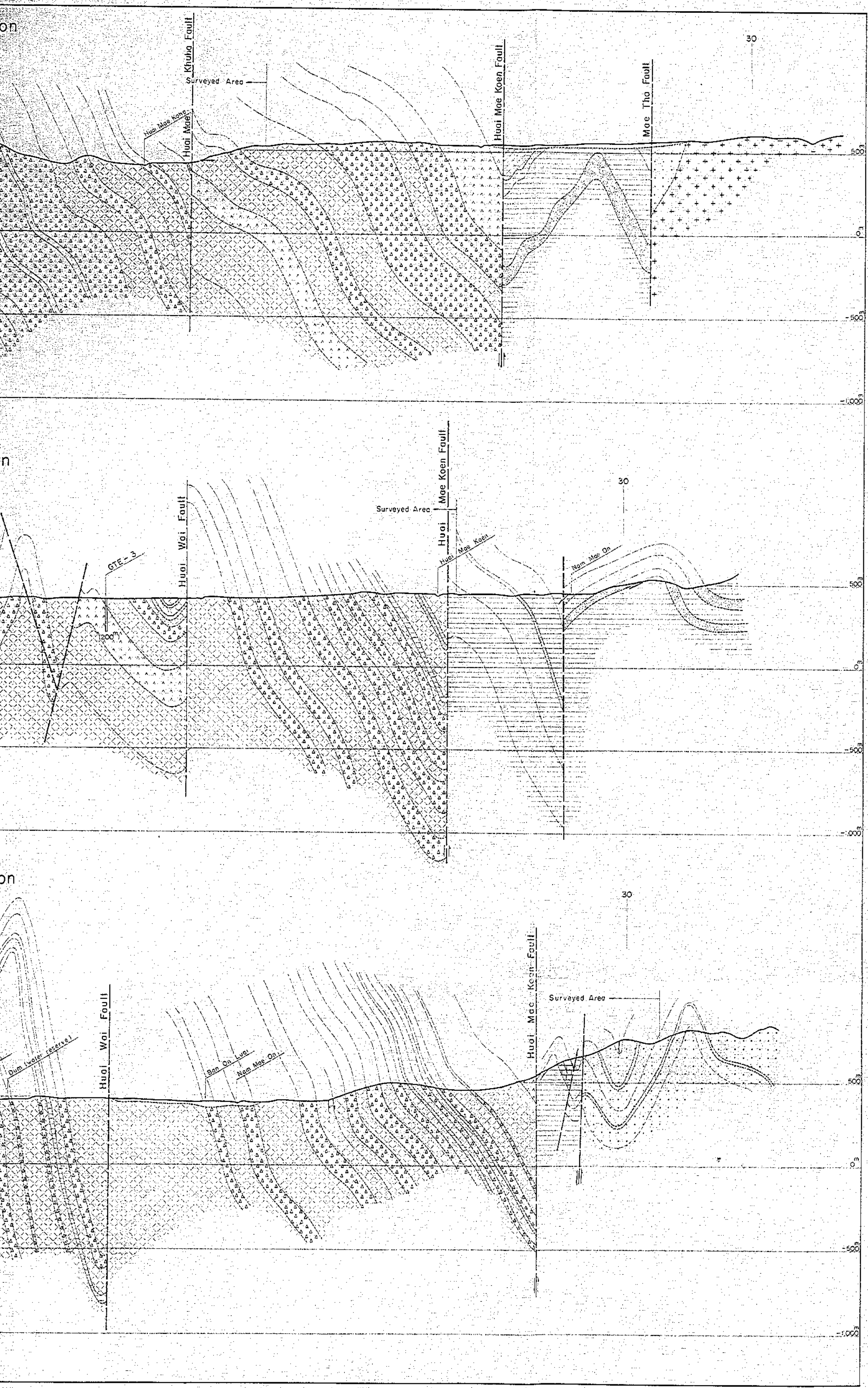

A — A′ Section
B — B′ Section
C — C′ Section
Surveyed Area
Doi Luang
Doi Luang Fault
Huai Pong Fault
Ban Pong Hom
Altered Zone
Ban Mae Khu Ho Fault
Geothermal manifestation zone
GTE-2
Huai Pong
Ban Mae Khuha Fault
Huai Ang
GTE-1
Dam (water reserve)
Huai Wai Fault
23
22
500m
0m
-500m
-1,000m



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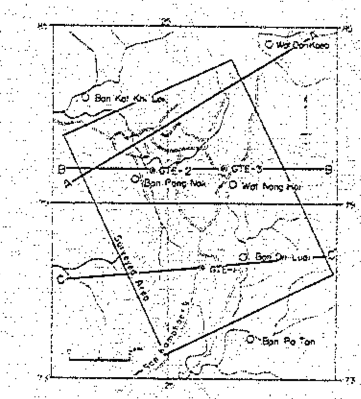
PL.II.1.1-2

THE PRE-FEASIBILITY STUDY
ON
THE SAN KAMPAENG GEOTHERMAL DEVELOPMENT PROJECT
IN THE KINGDOM OF THAILAND

GEOLOGICAL PROFILE



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	Shale ≫ Sandstone ≫ Chert
	Limestone
Carboniferous Mae Tha Formation	Shale
	Sandstone
	Porphyritic granite
	Bedding plane
	Fault
	Structure line