5 Geophysical Investigation

5.1 Geophysical Investigations and Rock Salt

Several theories indicate that salinization may be related to the presence of rock salt layers in the Maha Sarakham Formation, which occur throughout the Khorat Plateau. Apart from the drilling of boreholes, rock salt can be detected in the underground by geophysical methods.

The thickness of the overlying sedimentary covering the Maha Sarakham Formation recorded by drilling boreholes data is in the order of only 50 to 300 m. This fairly thin cover of the rock salt formation, therefore, encourages using geophysical methods. Three different geophysical investigations were conducted in this study: electric resistivity, seismic and microgravity investigation to determine the thickness of overlying sediments and the depth to the top of the uppermost rock salt layer.

5.2 Electric Resistivity Investigation

An electrical resistivity survey is based on the principle of rock material acting as a resistor in a circuit. The basic idea behind the electrical geophysical method is that different geologic materials have different electrical properties. The layers in the subsurface can be identified on the basis of these properties. An electrical current is induced into the ground. The ability of that material to resist the current is measured. Because different materials exhibit characteristic resistivity values, they can be distinguished by using this method. Factors that affect the resistivity are degree of fluid saturation, porosity, pore-fluid content, temperature, salinity, and thickness of clay or sand layers. Soils are more conductive than rocks, and saturated clays are more conductive than dry sands. Changes in pore water salinity also have great impact on ground conductivity. Applications of the electrical resistivity method include locating aquifers, salt water intrusions, and other ground water contamination problems. They can characterize bedrock by locating weathered zones, fractures or voids attributed to solution activity or determine depth to bedrock, and thickness of clay or sand layers.

Based on Sharma (1986), Telford (1990) and Milsom (1996) the property of the electrical resistivity of a material is usually expressed in terms of its resistivity. If the resistance between opposite faces of a conducting cylinder of length land cross-section areas **A** is ***R*,** the resistivity is expressed as

$$\rho = \frac{RA}{L} \tag{5.1}$$

for an electrical circuit, Ohm's Law gives

$$\boldsymbol{R} = \frac{V}{I} \tag{5.2}$$

where V and I are the potential difference across a resistor and the current passing through it, respectively. The resistance (***R***) of the layer is specified by its length (**L**) area of cross-section (**A**), and the resistivity (ρ). By definition (Eq. 5.1), equation 5.2 can be rewritten as

$$\frac{\Delta V}{L} = \frac{\rho I}{A} \qquad (5.3)$$

or

$$\text{grade } V = \frac{\rho}{I} \qquad (5.4)$$

Measurements of ground conductivity or its inverse, resistivity can be used to delineate the boundaries between soil and rock, and between soil or rock strata of different water contents. The electrical current is directly introduced into the ground through current electrodes. The resulting voltage potential difference is measured between a pair of potential electrodes. The current and the potential electrodes are generally arranged in a linear pattern. The apparent resistivity is the bulk average resistivity of all soils and rock influencing the flow of current. The popular patterns are Wenner, Dipole-Dipole and Schlumberger configuration.

This study employed the simple Vertical Electrical Sounding (VES) in Schlumberger configuration because it penetrates deeper than other configurations. Equipment used was a fully automatic SYSCAL R2 resistivitymeter. In the generalized Schlumberger configuration pattern, the spacing between potential electrodes is smaller than current electrodes. The current electrodes **A** and **B** are at equal distances **L** in opposite directions from the center of the array. The potential electrodes **M** and **N** are between **A** and **B** at equal distances **b** from the center of the array. The current electrodes located distance **2L** from each other, and potential electrodes located distance **MN** from each other, **2L > 5MN** (Figure 5.1). The survey uses an arrangement with a maximum separation in **AB/2** electrodes of 650 m sufficient to reach the desired investigation depth, top of rock salt layer.

The measurement of apparent resistivity (ρ_a) is determined from Ohm's law using the potential difference (voltage) between two electrodes for a known current. At small spacing between electrodes, apparent resistivity is close to the resistivity of the upper layer. With increased space between electrodes, more current passes through the lower layer and apparent resistivity changes. Apparent resistivity never reaches the resistivity of the lower layer because some current always travels through the upper layer. Changes in apparent resistivity with electrode spacing depend on depth to the interface and the contrast in resistivity. Reynolds (1997) summarizes processes for the depth sounding. Measurements of the resistance (*R*) are made at the shortest electrodes separation and then at progressively larger spacing. At each electrodes separation, a value of apparent resistivity (ρ_a) is calculated using the measured resistance in conjugation with the appropriate **geometric factor** for the electrodes configuration and separation being used. The values of apparent resistivity are plotted on a graph (field curve) the X- and Y- axes of which represent the logarithm values of the current electrodes half-separation (**AB/2**) and the apparent resistivity (ρ_a), respectively.

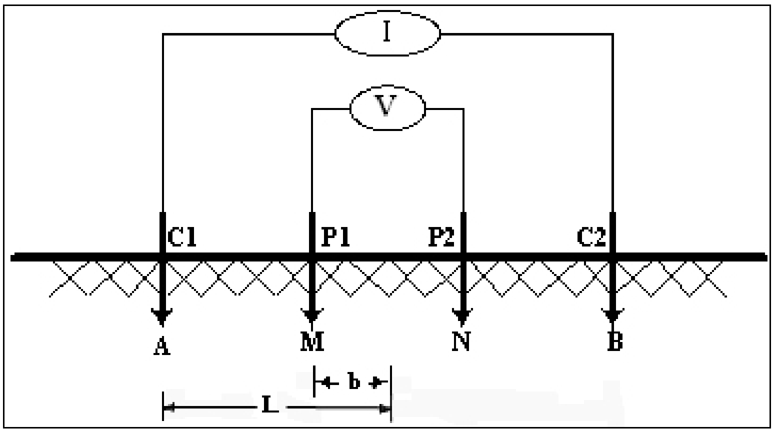

Figure 5.1 The Schlumberger configuration pattern.

In Figure 5.1, the source and sink electrodes are **A** and **B**, and the so-called potential electrodes are **M** and **N**. The **M** electrodes are at distances $\mathbf{d_1}$ and $\mathbf{d_2}$ from the source and sink, and the **N** electrodes are at distances of $\mathbf{d_3}$ and $\mathbf{d_4}$. According to Ohm's law, if the resistivity *R* is uniform, the electric potential $\mathbf{v_M}$ at the **M** electrodes will be

$$\mathbf{v_M = \mathit{IR}\ (1/d_1 - 1/\ d_2\ )/2\pi} \tag{5.5}$$

and the potential $\mathbf{v_N}$ at the N electrodes will be

$$\mathbf{v_N = \mathit{IR}\ (1/d_3 - 1/\ d_4\ )/2\pi} \tag{5.6}$$

Therefore, the difference in potential $\mathbf{v_{MN}}$ measured by the voltmeter will be

$$\mathbf{v_{MN} = v_M - v_N = \mathit{IR}\ (1/d_1 - 1/\ d_2 - 1/d_3 + 1/\ d_4\ )/2\pi} \tag{5.7}$$

Equation (5.7) would then be a weighted average of resistivities in the difference materials within the zone between these equipotentials. Such a weighted average is called the apparent resistivity. Since different materials are presented at the time when the electrical survey is underway, it is more appropriate to express a measurement as an apparent resistivity (ρ_a).

When define $$\rho_\mathbf{a} = \mathbf{v_{MN}K/\mathit{I}} \tag{5.8}$$

Where **K** is geometrical factor which is depends on the electrodes arrangement. For Schlumberger configuration pattern, the geometrical factor becomes

$$\mathbf{K = \pi(L^2 - b^2)/2b} \tag{5.9}$$

In the Schlumberger array, the depth to which the resistivity is averaged is roughly equal to half the separation between the current electrodes. From equation (5.8) and (5.9), the apparent resistivity is computed using the formula:

$$\rho_a = \pi(L^2 - b^2) \quad (5.10)$$

where

L	=	the half-separation between the current electrodes (**A, B**) measured in meters;
b	=	the half separation between the measuring electrodes (**M, N**), in meters;
v_{MN}	=	the voltage at the measuring electrodes, in volts;
I	=	the current between the current electrodes, in amperes.

This formula is based on the assumption that the ratio ***V/I*** is approximately equal to the voltage gradient, at the center of the electrode array. The resistivity as calculated from the above equation is not necessarily equal to the resistivity of the portion of the earth over which the measurement was made, due to the influence of the electrical properties of one layer on another layer. For that reason the value obtained from the above equation is termed the apparent resistivity.

The interpretation process consists of deducing a likely set of true resistivity values which would be compatible with the observed apparent resistivity values. In many cases, there exists no single set of true resistivities that correspond to a particular set of apparent resistivities, and as such, the true resistivity cannot be uniquely determined. The apparent resistivity which would be measured over a series of uniform horizontal layers presents a fairly simple case, and since this is frequently a good first approximation to geologic conditions, the first step in the interpretation process normally involves determining what layer thickness and resistivities can explain the measured apparent resistivities.

For conventional interpretation, the plotting of field data on graph paper, observed apparent resistivities against electrode spacing, of the same scale as the theoretical curves, the field data curve would be laid and moved over the theoretical curves until the field points correspond or match with the points of the theoretical curves. The only requirement is that both sets of curve axes must be kept parallel. The depths and corresponding true resistivities are then read off of the field matched theoretical curve. However, there are available many differing sets of theoretical curves for many types of geologic settings and the curve matching process may become time consuming. Therefore, the data in the field consist of a graph of resistivity with electrode spacing would be matched with a master curve on RESIST87 software for less human error and more convenient interpretation.

5.3 Seismic Investigation

Seismic sounding is based on differences in the elastic properties of the soil and rock. When conducting seismic surveys, acoustic energy is put into the ground. Sources of acoustic energy include a hammer impacting a metallic plate, weight drops, vibrators, and different types of explosive sources. The acoustic waves propagate into the ground at a velocity dependent upon the density and elastic properties of the material through which they travel. When the waves reach an interface where the layer velocities change significantly, a portion of the energy is reflected back to the surface, and the rest is transmitted into the lower layer. Where the velocity of the lower layer is higher than those of the upper layer, a portion of the energy is critically refracted along the interface. Critically refracted waves travel along the interface at the velocity of the lower layer and continually refract energy back to surface. Receivers, laid out on the surface, record the incoming refracted and reflected waves.

This study employed the reflection method. A portable seismic recording unit, OYO DAS 1, Japan, 24 channels and 6 geophones/string was employed to store seismic data in a SEG-Y digital format. The survey used an Off-end push configuration as shown in Figure 5.2.

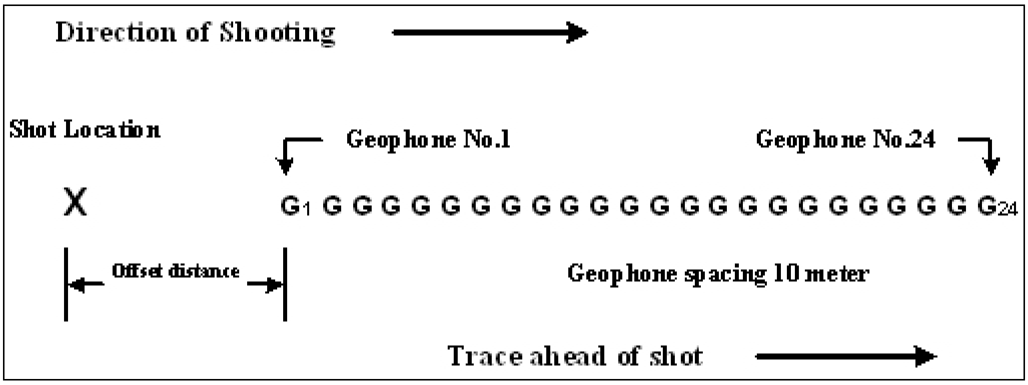

Figure 5.2 Off-end push spread configuration pattern.

The acquisition parameter and instruments used are as follow:

Source

Source type	Hydraulic accelerated-weight drop, 50 kg
Shot point interval	2.5, 10, and 20 meter depending on survey lines
Offset distance	2.5, 30, 40, 50 and100 meter depending on survey line
Coverage	12 folds

Receiver

Geophone	Land type, group geophone, 6 geophones/string

Recording unit

Brand	OYO DAS 1, 24 channel
Digital data format	SEG-Y

Low cut filter	35 Hz
High cut filter	150 Hz
Sample rate	500 microsecond
Power supply	DC battery, 12 Volt, 24 Ah

Configuration

Type	Off-end push
Line	Straight

The reflection data processing was performed using SEISTRIX version 3.4 software. A processing procedure included trace editing, spherical divergence correction, deconvolution, filtering, normal move-out, staking and depth conversion.

5.4 Microgravity Investigation

Gravity survey involves the measurement of variations in the Earth's gravitational field generated by differences of density between subsurface rocks for studying subsurface geology. The main control of rock density variation is its composition and porosity. Density increases with depth due to compaction and progressive cementation. Porosity is one of the main controls of density variation in sedimentary rocks.

From 'Newton's Law of Gravitation' as Newton framed it in 1686, the power with which 2 masses will attract one another is proportional to the given mass and conversely proportional to the square of the distance. This can be expressed mathematically as:

$$\mathbf{F} = \mathbf{G\, m_1 m_2 / r^2} \tag{5.11}$$

when, **F** = Force attraction,
$\mathbf{m_1, m_2}$ = 2 masses,
r = distance between two masses,
G = universal gravitational constant ($6.67 \times 10^{-11}\ m^3 kg^{-1} s^{-2}$)

Force is related to mass by acceleration. This acceleration, termed the 'acceleration of gravity' **(g)** was first measured by Galileo in his famous experiments at Pisa. The units which express the measurement of **g** are known as the Gal (in honor of Galileo). The Gal is derived from using the basic law of mechanics. From Newton's second law and gravity acceleration, the force can be written as:

$$\mathbf{F} = \mathbf{m_1 g} \tag{5.12}$$

when, **F** = Force attraction,
g = Gravity acceleration.

The force in equation (5.11) and (5.12) is the same, so it can be compared as:

$$\mathbf{F = G\ m_1 m_2/r^{\,2} = m_1 g}$$

therefore, $$\mathbf{g = G\ m_2/r^{\,2}} \qquad (5.13)$$

However, **g** does vary because the Earth is not a perfect homogenous sphere. If it was, then the gravity field at any point on the surface would be identical. Because variations in gravity are very small, units for gravity surveys are generally in milligals (mgal) where 1 mgal is one thousandth of 1cm/s^2. At sea level, the earth's gravitational acceleration is ~ 9.8 m/s^2 or equivalently ~980 000 mgal.

For the survey, the Lacoste-Romberg model D gravimeter was used because it is high sensitivity, thus, the small gravity differences as 0.01 mgal can be detected and the elevation of each station was also measured by traditional leveling.

For interpretation, the Bouguer gravity values were plotted as a profile. The available data of potash and rock salt exploration boreholes were used for helping interpretation.

Geophysics investigation in this study selected three areas located in study area as tested area as follows:

1) Site 1: Ban Sida Village, Khong District, Nakhon Ratchasima Province,
2) Site 2: Dan Khun Thot District, Nakhon Ratchasima Province and
3) Site 3: Ban Basiew Village, Jaturat District, Chaiyaphum Province.

The locations of the three geophysics investigation sites are shown on the False Color Composite image of Landsat 7 data acquired on December 27, 1999, bands 4, 3, 2 as red, green, blue in Figure 5.3. The results of geophysics investigation of all investigated sites are shown and discussed later in detail in Chapter 6.

1) Site 1: Khong District, Nakhon Ratchasima Province

The Site 1 is located approximately 60 km northeast of the city Nakhon Ratchasima. It can be characterized as a slightly undulating terrain with elevations ranging between 150 – 180 m above mean sea level. The three different geophysical investigation, geoelectric, seismic reflection and microgravity were conducted by the author and geophysicists from the Geotechnical Division, the Department of Mineral Resources, at this site during middle of May to end of June 2001. The investigations were conducted along lines trending approximately north-south across lineaments trending northeast observed from satellite imagery. The location of Site 1 and geophysical survey lines are shown in Figure 5.4 and also shown on the three dimensional surface image derived from the False Color Composite image of Landsat 7 data acquired on December 27, 1999, bands 4, 3, 2 as red, green, blue in Figure 5.5.

Eighteen vertical electric soundings were applied along a survey line from SSE to NNW and extended to E-W following lineament direction of satellite image as shown in Figure 5.4 and Figure 5.5. The main aims are to identify the top of the rock salt and to determine the thickness of the Phu Tok Formation as well as the fresh and salt water distribution.

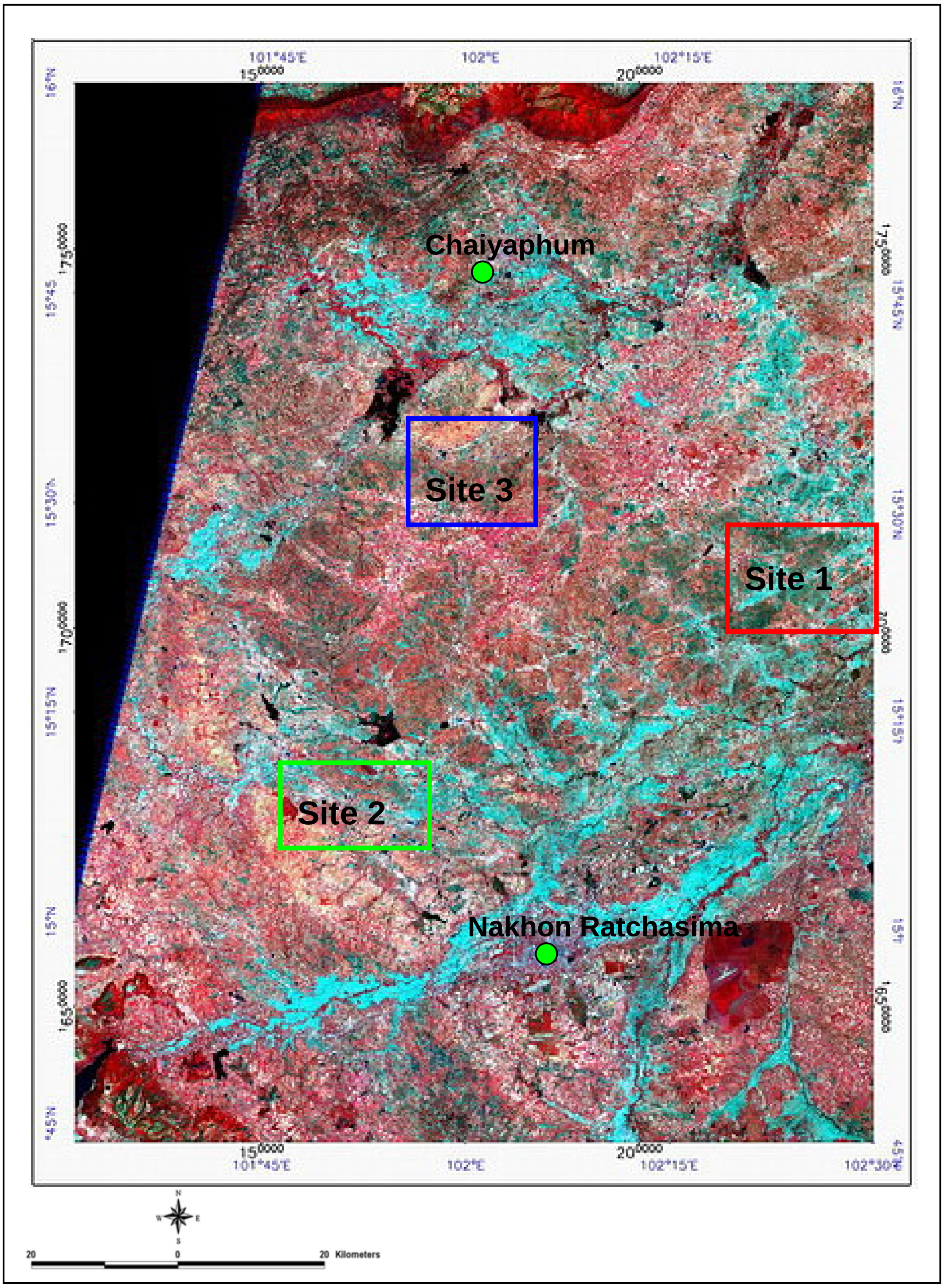

Figure 5.3 The False Color Composite image of Landsat 7 data acquired on December 27, 1999, bands 4, 3, 2 as red, green, blue showing the location of the three geophysics investigation sites: Site 1 (Khong District, within red rectangle), Site 2 (Dan Khun Thot District, within green rectangle) and Site 3 (Jaturat District, within blue rectangle).

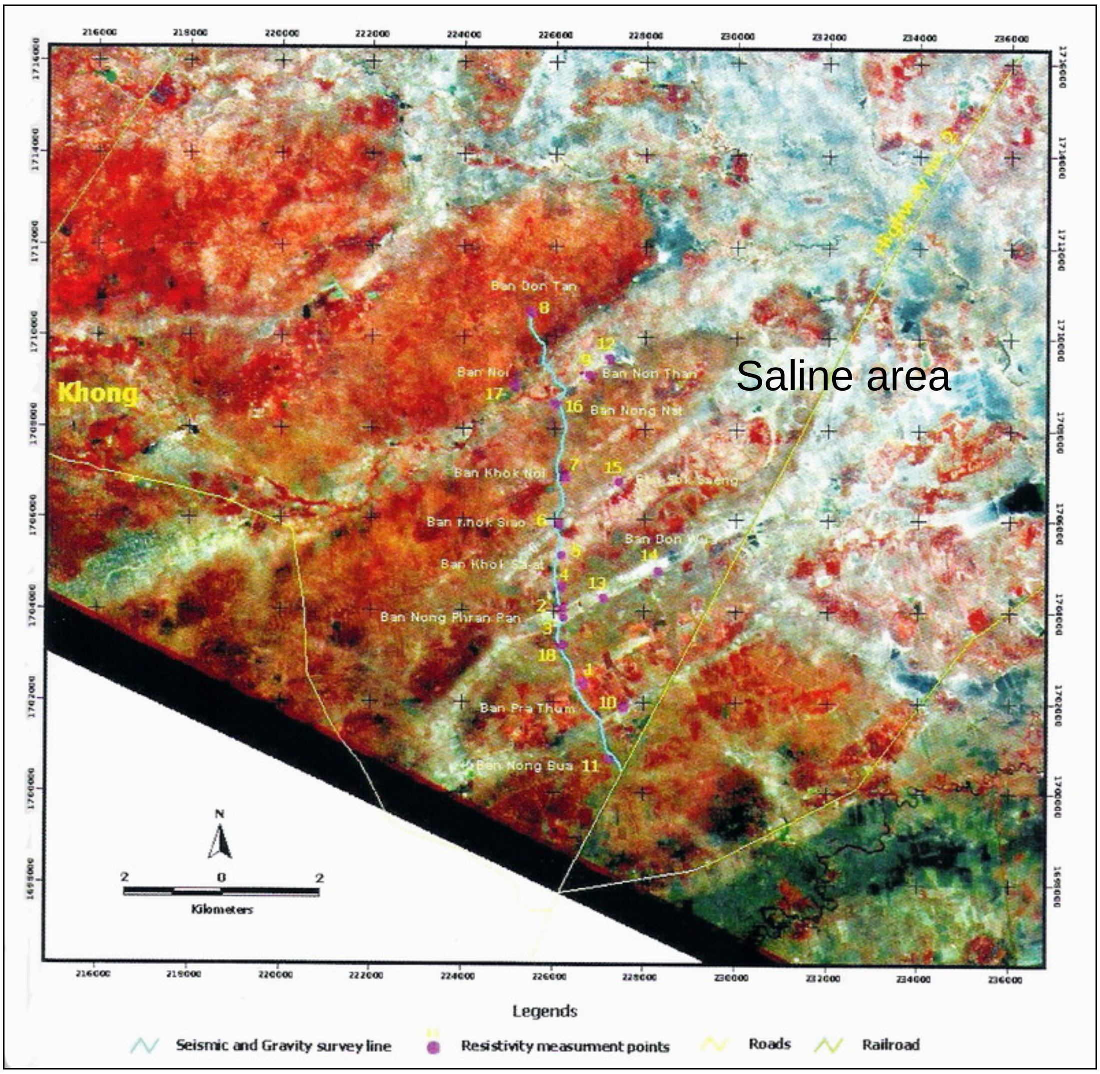

Figure 5.4 Location of geophysical measurements at Site 1 (Khong District) on MOMS satellite image (after Khundee *el al.*, 2002). Lineaments are shown in white color trending in approximately northeast-southwest.

Seismic investigation was designed to investigate lineaments seen on satellite image by trying to lay out the survey line mostly perpendicular to the lineament. The seismic reflection method was used in this investigation. It was conducted along a 10 035 m line with an off-end push spread of 100 m shot spacing and 10 m geophones spacing with a total of more than 500 stations. Seismic reflection data were recorded on OYO Geospace DAS-1 and then processed with SEISTRIX version 3.4 software.

For the gravity investigation, the measurement stations were located along the same seismic investigation line at 20 m spacing in 10 000 m distance. Gravity data from 517 stations were read and collected. For the survey the topographic elevation was also measured along the gravity survey line by conventional leveling techniques and the results of measuring are shown in Figure 5.6.

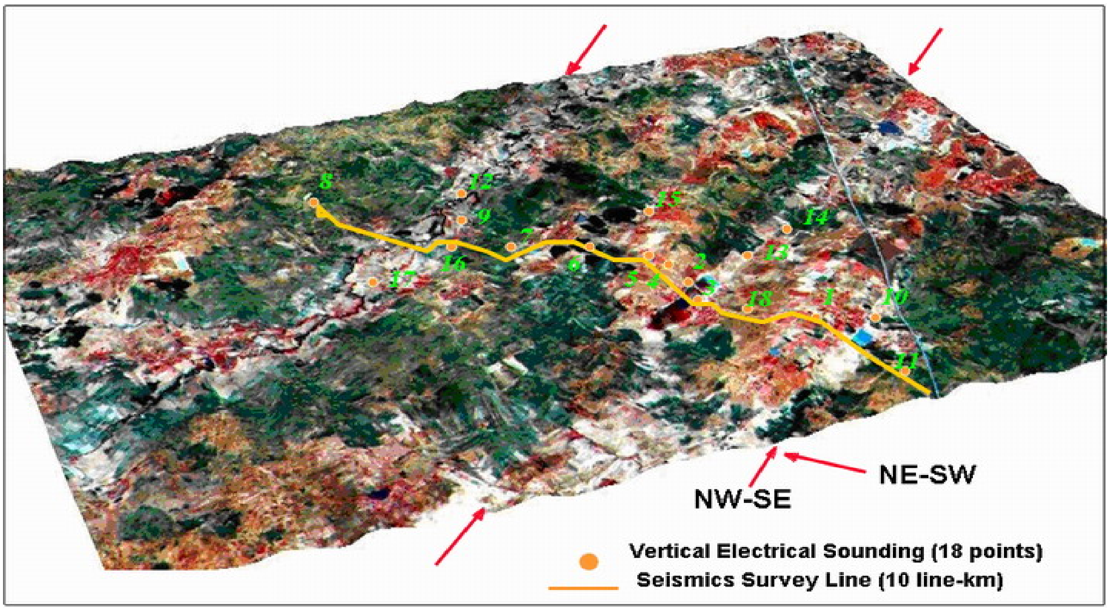

Figure 5.5 Three-dimensional surface image of Site 1 (Khong District) showing the location of the 18 points Vertical Electrical Sounding (VES) and seismic survey line across the trough and low hill identified as lineament on satellite image. The troughs are mostly oriented in northeast-southwest and in northwest-southeast.

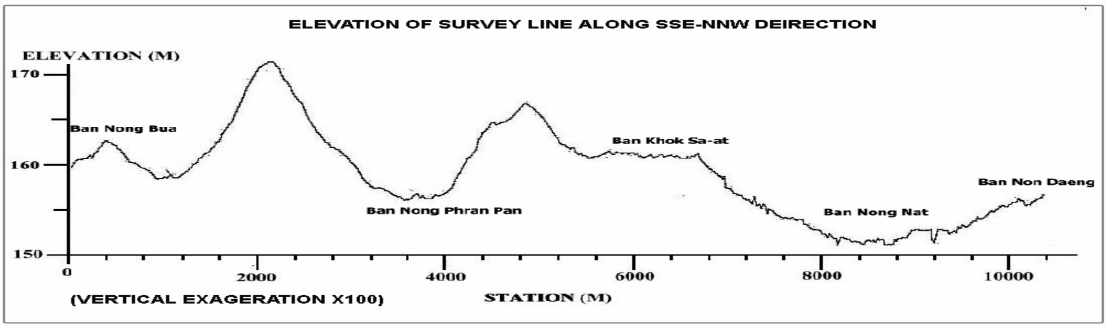

Figure 5.6 Topographic elevation along the survey line (electrical resistivity, microgravity and seismic reflection) in SSE – NNW direction.

2) Site 2: Dan Khun Thot District, Nakhon Ratchasima Province

The Site 2 is the investigated site of the Thai-German Technical Cooperation Project in 2002 (the Federal Institute for Geosciences and Natural Resources, BGR, and The Department of Mineral Resources, DMR). The site is located at the western margin of the Khorat Basin and also located in the vicinity of this study. Two seismic investigation lines, Line 4 in north-south direction and Line Ban Bu in approximately east-west direction together with 14 measurements of Vertical Electrical Sounding (VES) in Schlumberger configuration were conducted by the geophysicists of BGR and DMR at this site. The location of Dan Khun Thot site and the two seismic lines in this area are shown in Figure 5.7, and the three dimensional surface image derived from the False Color Composite image of Landsat 7 data acquired on December 27, 1999, bands 4, 3, 2 as red, green, blue with the locations of the 14 points Vertical Electrical Sounding (VES) is also shown in Figure 5.8.

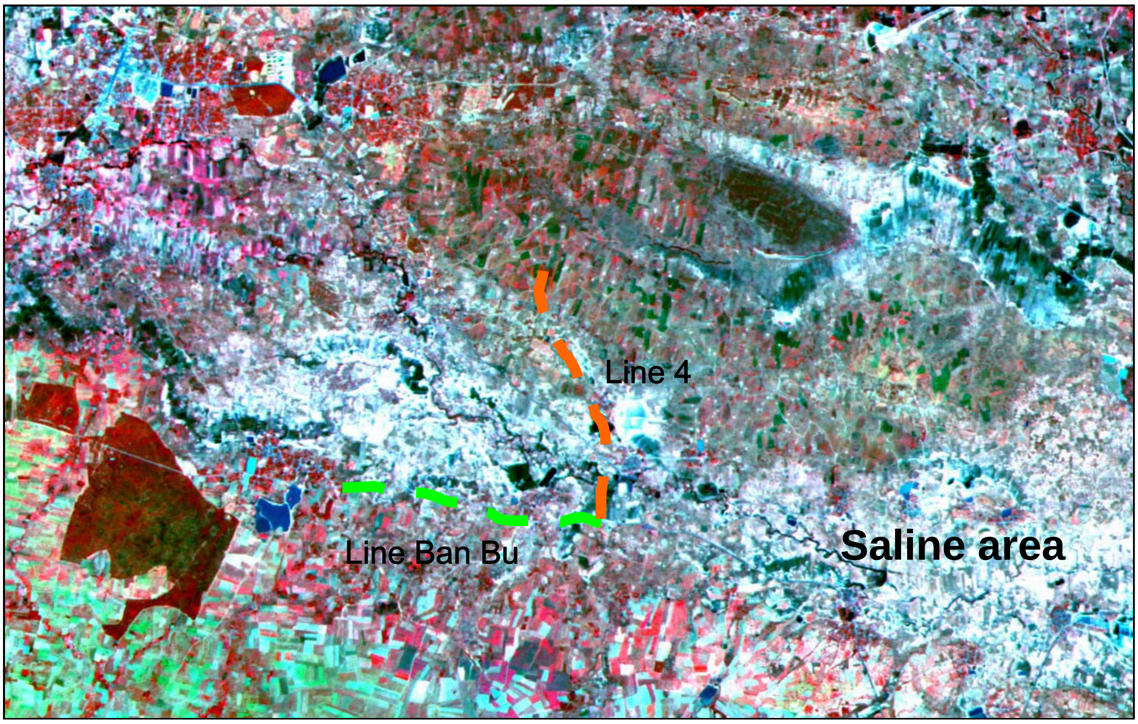

Figure 5.7 False Color Composite image of Landsat 7 data acquired on December 27, 1999, bands 4, 3, 2 as red, green, blue showing the location of Site 2 (Dan Khun Thot District) and showing the two seismic investigation lines: Line 4 (orange line) and Line Ban Bu (green line).

Seismic investigation was conducted at this site with the aim to investigate any correlation of the two structural features, a large swampy area and lineaments, with the depth and shape of the rock salt. Landforms of this site mostly consist of several small lakes and ponds in low-lying areas. These lakes may have been originated by sinkholes that were caused by salt dissolution in the underground. Salt crusts can be seen throughout the low-lying areas.

The first seismic line named "Line Ban Bu", 4.7 line-km long, was designed to resolve the depth and shape of the salt reflector crossing a major swampy area with NW-SE running lineament features observed on satellite imagery.

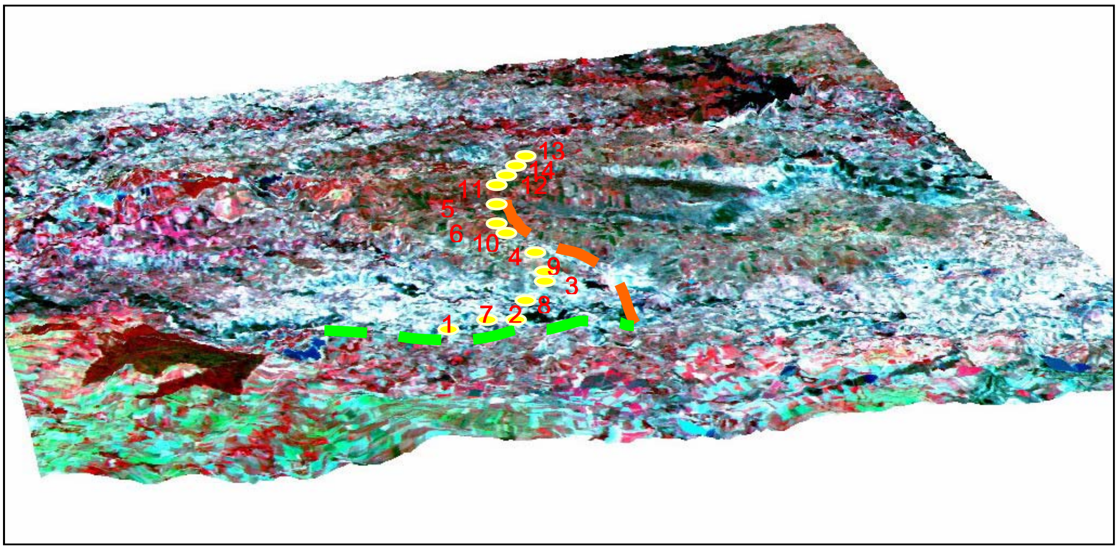

Figure 5.8 Three-dimensional surface image derived from the False Color Composite image of Landsat 7 data acquired on December 27, 1999, bands 4, 3, 2 as red, green, blue showing the location of the 14 points Vertical Electrical Sounding (VES) at Site 2.

This line starts at the east of Ban Bu Village and ends at road No.2148. The second line named "Line 4", 4.7 line-km long, runs in approximately N-S direction from south of Ban Kradan Village toward the south to the east end of Line Ban Bu, and also runs over a narrow hill with 20 m elevation of the Maha Sarakham Formation.

For the Vertical Electrical Sounding (VES) investigation, the 14 VES points were located along seismic Line 4 with the aim to delineate the depth to the uppermost rock salt layer and its shape along the seismic survey line.

3) Site 3: Jaturat District, Chaiyaphum Province

A seismic reflection investigation was conducted by the author at Site 3, Jaturat District, Chaiyaphum Province, during November, 1st – December, 25th 2005. This seismic reflection investigation was budgeted by the BGR. The aim of this investigation was to investigate any correlation of the circular structural feature present on satellite imagery, which is supposed to mark a boundary between the unconsolidated rock-bearing salt and the consolidated rock of the Khok Kruat Formation in this area with the depth and shape of the rock salt.

The study area is located in Chaiyaphum Province, northern part of the Khorat Basin. The study area is bounded by longitudes 101^{o}55' and 102^{o}05' E, and between latitudes 15^{o}30' and 15^{o}40' N and covers an area about 180 km^{2}. The topographic map of the study area is shown in Figure 5.9. The study area can easily be reached by Highway No.201 and some of local roads in any seasons. The study area consists of a small hill to the north, which is surrounded by the river to the east and north, and a big natural pond to the west named "Nong Laharn". The south of the study area consists of a sloping area which is tilted to the north. Landforms in the study area mainly consist of small flood plains and dip-slope sediment deposits at foothills. These small floodplains are limited in extent and formed mainly along the foothill both from the north and south of study area. There are some small ponds scattered throughout the study area. A dendritic drainage pattern dominates the study area. Rice fields and small forests cover major parts of the study area.

Data acquisition was done by using an OYO-Geospace data acquisition system (DAS-1) with 24 channels. The field records were stored in SEG-Y format on its hard disk, and then were transferred and written to 3.5 inch floppy disk.

A total of over 1 000 stations was measured and marked by spraying red color on the road surface with 10 meters interval. Of each shot point station the elevation was measured by 2 Garmin XL-GPS units. The elevations were averaged and calibrated to each other. The survey employed an Off-end push configuration with receiver spacing of 2.5 and 10 m, and the offset between the shot point and the first receiver range between 2.5, 40 and 50 m for comparing the results and trying to get the proper seismic reflection survey configuration to detect the shallow deep rock salt layer in the study area. The five seismic survey lines were conducted in this site: Line BS50, Line BS501, Line BS502 and its extended Line BS503, and Line BS25, respectively. Locations of the five seismic survey lines in this site are shown on the False Color Composite of Landsat 7 data acquired on December 27, 1999, bands 4, 3, 2 as red, green, blue in Figure 5.10 and on the three dimensional surface image derived from the False Color Composite of Landsat 7 data acquired on December 27, 1999, bands 4, 3, 2 as red, green, blue to present their topographic conditions in Figure 5.11. Details of each survey line are shown in Table 5.1.

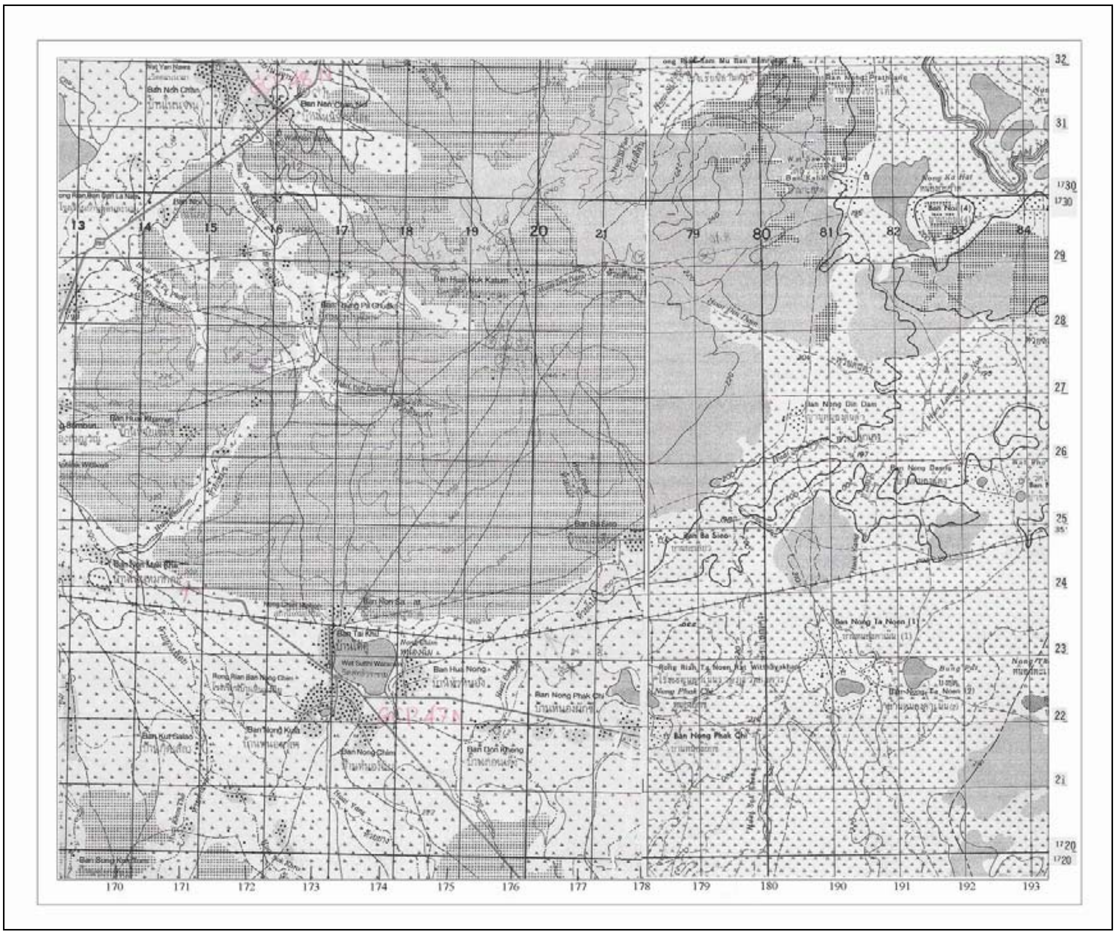

Figure 5.9 Topographic map of the Jaturat District site, Chaiyaphum Province (scale 1:50 000).

Table 5.1 Details of seismic survey lines in Site 3 (Jaturat District), November, 2004- January, 2005

Line Name	Line length (m)	Geophone Spacing (m)	Start of Line		End of Line		Reference Datum Above MSL (m)
			UTM Easting	UTM Northing	UTM Easting	UTM Northing	
BS50	1690	10	180322	1724918	178940	1726017	220
BS501	2440	10	178228	1723705	177509	1726156	235
BS502+BS503	1020	10	178319	1722456	821714	1723663	235
BS25	202.5	2.5	178069	1724180	178019	1724375	210

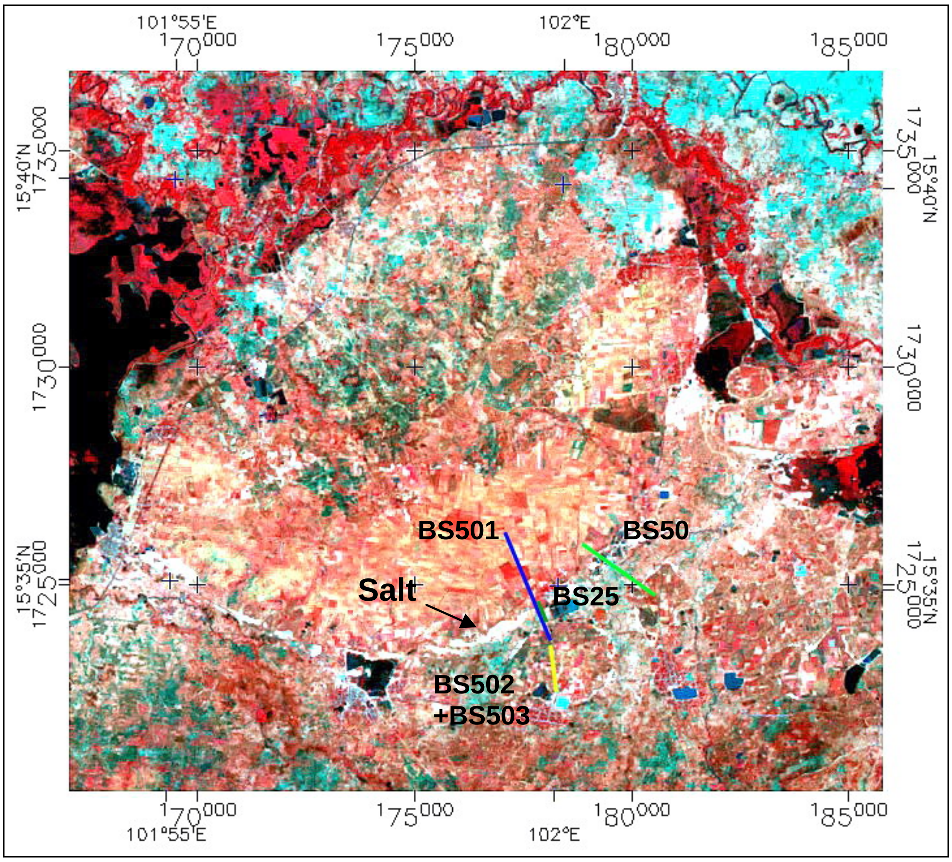

Figure 5.10 Locations of the seismic survey lines at Jaturat District site, Line BS50 (light green), Line BS501 (blue), Line BS502+BS503 (yellow), and Line BS25 (dark green).

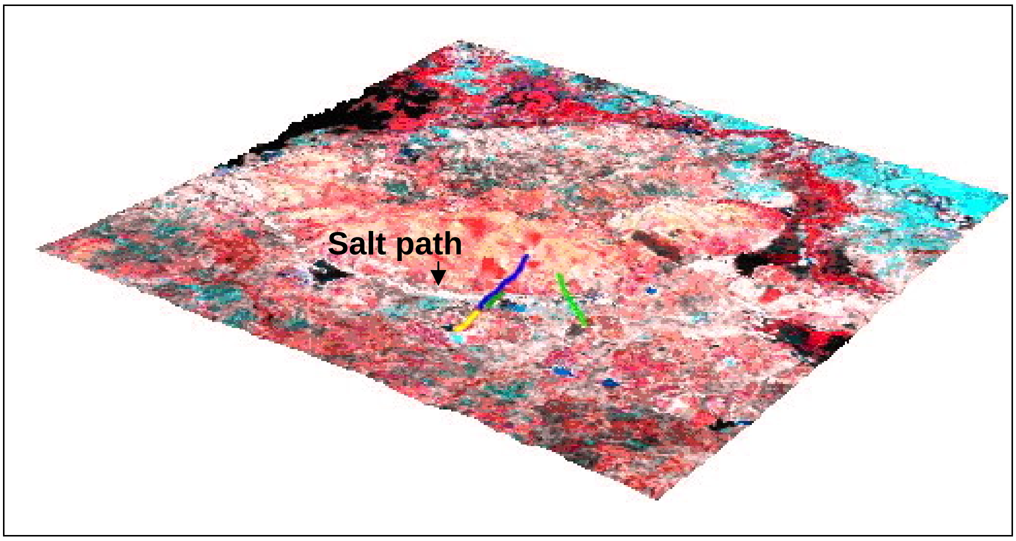

Figure 5.11 Locations of the seismic survey lines on the three-dimensional surface image derived from the False Color Composite of Landsat 7 data acquired on December 27, 1999, bands 4, 3, 2 as red, green, blue covering Site 1: Jaturat District.

The first seismic investigation line named “Line BS50” was designed to detect the depth and shape of the rock salt layer crossing a major NE-SW running curvilinear feature observed on satellite image. This line starts at the north of Ban Nong Tanern Village and end at the south of Ban Nong Din Dam Village covered about 1.69 line-km (the green line shown on Figure 5.10 and 5.11). The second line named “Line BS501”, a longest line of this investigation of 2.44 line-km long, runs in N-S direction from the north of Ban Ta Nern Village towards the north, and also runs over a narrow lineament identified as salt-path lineament, and ends at the highest point of the circular feature on the satellite image (the blue line shown on Figure 5.10 and 5.11). The third line is a combination between the 2 sub-lines, “Line BS502” and “BS503” having the same survey configurations. This line survey is separated into 2 sub-lines because of problems to lay out the survey line over the path of the road used by local people to waste disposal, which obstructed the Line BS502 on the left and side of the road. Thus, the Line BS503 then was shifted to the right hand side of the same road and runs further to the north and ends at the railways line. These 2 sub-lines are designed to investigate the subsurface structure and the shape and depth of the rock salt layer beneath the small circular feature identified on satellite imagery. Line BS502 and Line BS503 are shown together as the yellow line in Figure 5.10. The last line named “Line BS25”, the shortest line, was designed to run across the salt-path feature again with the different seismic reflection configuration from the Line BS501 to detect the shape and the depth of rock salt layer supposed to be located at very shallow depth, 60-80 m, derived from the borehole data of well K56 and K79 located about 15 km west of the survey line. The borehole log descriptions of the well K-56 and K-79 showing the presence of shallow and very thin rock salt layer are shown in Figure 5.12 and 5.13.

The results of the resistivity, seismic reflection and microgravity investigations of these three sites are presented and discussed in detail in Chapter 6.

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K - 56

Chaturat Town Hall, Chaturat District
Chaiyaphum

Start drilling : February 18, 1977
Stop drilling : February 26, 1977
Start coring : 50 ft (15.2 m)
Core recovery : 96 percents

Elevation : 195 m
Depth : 1,1000 ft (335.3 m)
Thickness of potash : 40.4 m
Logged by : Parkorn Suwanich

Intervals (m)	Thickness (m)	Description
0 - 0.30	0.30	Top soil - Dark grey clay.
0.30 - 15.24	14.94	Sand & Clay - Fine grained sand of well rounded quartz grains, with some rock fragments. Clay is yellowish grey color at few intervals.
15.24 - 69.34	54.10	Mudstone - Reddish brown, with greyish green mottling, fracturing is abundant. Gypsum occurs as clear plates and sugarly grains along fractured surfaces. Breccias of mudstone and anhydrite was also found near the end of the interval
69.34 - 71.63	2.29	Anhydrite - Greyish white, carbonaceous matter as films is abundant.
71.63 - 76.20	4.57	Rock salt - Mostly halite of colorless to white interbedded with pale brown and dark smoky halite.
76.20 - 76.45	0.25	Anhydrite - White-grey, with some black carbonaceous matter associated.
76.45 - 80.89	4.44	Rock salt - Same as 71.63 - 76.20 m, but some pale orange halite appears at the bottom of the bed.
80.89 - 108.20	27.31	Clay - Reddish brown, with greyish green mottling. Halite as veins and veinlets showing fibrous structure Greyish green clay locally inter-bedded, with some veinlets or net structure of anhydrite in clay. Traces of orange-red carnallite was also found as small veinlet.

Figure 5.12 Borehole well log description of the well K-56 (DMR, 1987)

A 148

K - 79

Ban Khok, Amphoe Jaturat
Chaiyaphum

Start drilling : March 20, 1981
Stop drilling : April 2, 1981
Start coring : 68 m
Core recovery : 100 percents

Elevation : 200 m
Depth : 221 m
Thickness of potash : 25.59 m
Logged by : Phitaks Ratanajaruraks

Intervals (m)	Thickness (m)	Description
0 - 12.00	12.00	Top soil - Yellowish grey sandy clay and sand associated and interbedded together, subangular to subrounded, poor sorted.
12.00 - 37.18	25.18	Clay & Claystone - Reddish brown clay and claystone interbedded together, calcareous, some sand grains.
37.18 - 41.15	3.97	Rock salt - No sample. Depth and thickness as shown on gamma-ray log.
41.15 - 68.88	27.73	Clay & Claystone - Same as from 12 - 37.18 m depth, but some greenish grey clay was found interbedded, and some halite grains.
68.88 - 136.80	67.92	Rock salt - Mostly halite of colorless, with smoky dark bands and anhydrite stringers. Milky white halite grains were found from 80 m depth, and formed bands from 90 - 104 m depth, and decreasing to disappear from 104 - 112 m, and were found again from 113 - 129 m. Smoky halite and anhydrite stringers are increasing at greater depth. The thickest anhydrite stringer was found from 135.73 - 135.81 m. Halite grains are coarse (1 - 1.5 cm).
136.80 - 138.07	1.27	Carnallite & Halite - Pale orange -white carnallite of about 80 %, with colorless halite of about 20 % associated as intergranular.
138.07 - 152.39	14.32	Rock salt - Mostly halite of honey color in the upper part and change to honey orange from 142 m depth, smoky halite bands (1-3 cm thick are locally interbedded. Orange to orange-red carnallite was found as small lenses or

Figure 5.13 Borehole well log description of the well K-79 (DMR, 1987)