CHAPTER 2

RESEARCH METHODOLOGY

The material, equipment, and method described below are used for Geothermal Resources study at Kanchanadit and Ban Na Doem District, Surat Thani Province.

2.1 Material

The materials used in this research are listed as follow;

2.1.1. Gravity and elevation measurements:

1) 3 inch nails for marking gravity station marks along the road.
2) Oil or plastic colors for writing station's name on the road.
3) The lids of aerate water for marking gravity station.
4) Pieces of cloths for labeling the station name.

2.1.2. Rocks density measurement:

1) Rock samples collected from study area.
2) Permanent pens for labeling rock samples.
3) Fresh water for weighing rock samples in the water.

2.1.3. Vertical electrical sounding measurement

1) Water for increasing ground contact of electrode.

2.1.4. The other material

1) Terrain correction note tables.
2) Notebooks
3) Diskettes/CD
4) Topography maps (Royal Thai Survey Department, 2000) 1:50,000 scale, several sheet below:

(a)	Sheet 4826 I	AMPHOE BAN NA SAN
(b)	Sheet 4826 II	AMPHOE WIANG SA
(c)	Sheet 4826 III	AMPHOE PHRASAENG
(d)	Sheet 4826 IV	AMPHOE KHIAN SA
(e)	Sheet 4827 II	CHANGWAT SURAT THANI
(f)	Sheet 4827 III	AMPHOE PHUNPHIN

(g) Sheet 4827 IV AMPHOE CHAIYA

(h) Sheet 4828 III AMPHOE THA CHANA

(i) Sheet 4927 III BAN PAK NAM THA THONG

(j) Sheet 4927 IV AMPHOE DON SAK

5) Geological maps (Geological Survey Division, 1985) 1:250,000 scale, sheet NC 47-11 CHANGWAT SURAT THANI and sheet NC 47-15 CHANGWAT NAKHON SI THAMMARAT

2.2 Equipment

2.2.1. Equipments for gravity and elevation measurement.

1) Aluminum level plate.

2) LaCoste & Romberg gravimeter (model: G-565), 0.01 mgal accuray (Figure 2.1), for measuring relative gravity.

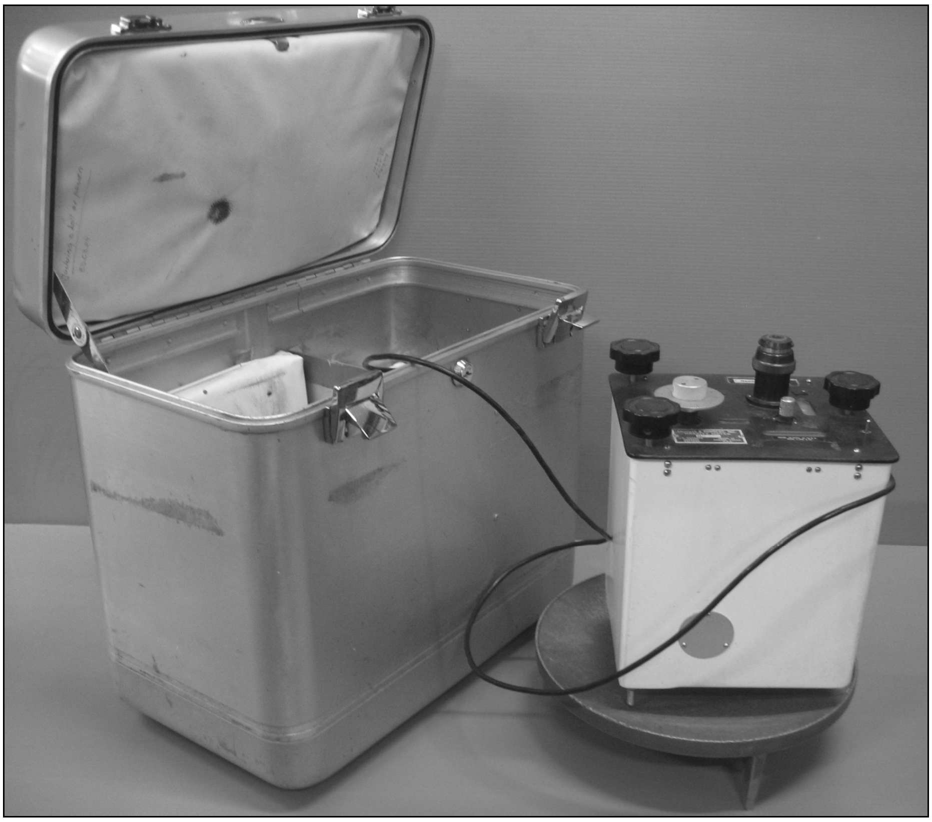

Figure 2.1 LaCoste-Romberg gravity meter model G-565

3) Watch/Timer for recording the measuring time.

4) The Trimble Basic Pathfinder GPS (Figure 2.2) for determining geographic positions of gravity stations.

5) The altimeter for measuring altitude of gravity stations. It is an American Paulin System model MDM-5 range -100 to 2,500 meters in intervals of 0.5 meter (Figure 2.3).

6) Thermometer (0 – 100 °C) for measuring air temperature at each gravity station.

Figure 2.2 Trimble Basic Pathfinder GPS

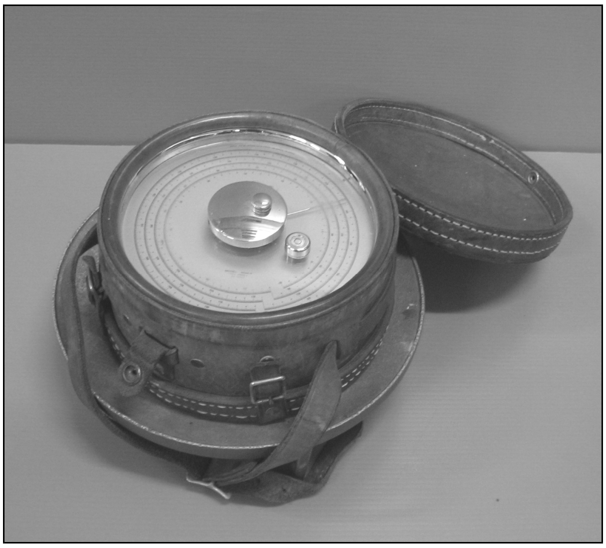

Figure 2.3 American Paulin System altimeter model MDM-5

2.2.2. Density measurement of rock samples.

1) METTLER digital balance (Model: BB3000). The balance can weigh a sample of up to 3,000 grams with a precision of 0.1 gram. It is modified for weighting rock sample in water by hitching the sample in water with hook under a balance plate.

2) Water tank (16 liters).
3) Hammer

2.2.3 Vertical electrical sounding measurement.

1) ABEM TERRAMETER SAS 1000 (Figure 2.4).
2) 12 volts car battery
3) Electric cables
4) Metal electrodes
5) Walkie-talkie
6) Measuring rope

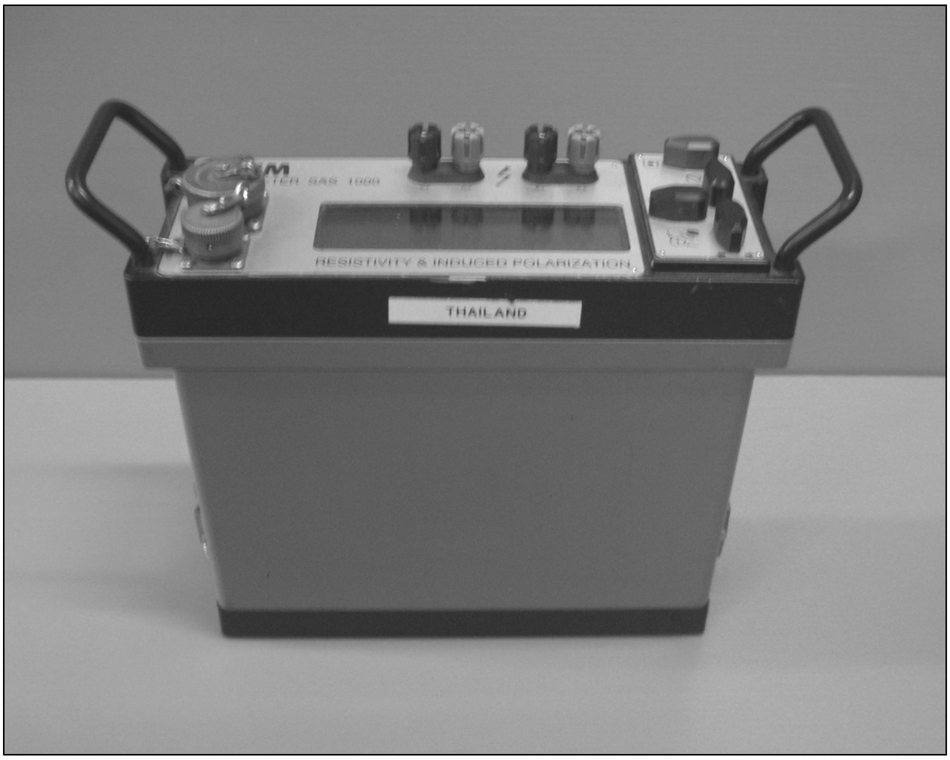

Figure 2.4 ABEM TERRAMETER SAS 1000

2.2.4 Analysis and interpretation software.

1) Microsoft® Office Excel 2003 software for data processing.

2) Surfer® version 7.00 software for drawing contour map.

3) Grapher® version 3.03 software for graphics.

4) Geo Vista AB- GMM® version 1.31 software for gravity modeling.

5) Resist87® version 1.0 software for resistivity sounding interpretation (Vander, 1988).

6) Mapinfo Professional® version 7.5 software for map drawing.

2.3 Methods

In this research, the study comprises of three parts:

Part I Field study
Part II Laboratory
Part III Data processing

2.3.1 Part I Field study

In the field work, this research is carried out in the following steps.

1) Four hundred and sixty two measuring station were placed along roads which are available in the study area (Figure 2.5). The spacing between measuring stations is 1 to 2 kilometers. They are all together 462 stations, namely; A53 – A64, A124 – A205, B1 – B296, T1 – T72 (Appendix A). UTM and latitude-longitude coordinates of measuring stations were determined with the Trimble Basic Pathfinder GPS system.

2) The measuring station were marked with a nail on a lid of aerate of water, station ID was labeled on the piece of cloths attached to the nail on the road. Nearly trees or power piles were painted as identification mark.

3) Place the base plate firmly on the ground at a selected measuring point and level it. Check that the temperature of the gravimeter is at 50 °C and that the instrument still has power (flip on switch and see light in bubble level and in gauge). Level the gravimeter by the leveling screws located beneath the meter. Release the beam of the gravimeter by turning the arrestment knob counter-clockwise to the limit.

The reading is made when the hair line just touches the measuring line ‘2.3’ on scale. Reading the gravity value from the counter and dial on the gravimeter. Lock the instrument, double-check this. Turn off the instrument light. Record the station ID, time, and temperature. Put the instrument back in its case.

4) Level the barometric altimeter on the base plate, turn the measuring screw until its index lies exactly on “0” point, and take the reading.

5) Estimate of average relative height of topography around gravity point on zone B, C, D, and E of hammer chart shown in Table 2.1.

6) Keep the instruments in the car and determine the next measuring station with car mileage reader.

7) Repeat measurement at base stations every 2 – 3 hours in order to close a loop of measurement (Figure 2.7). The example of data reading is shown in Table 2.2.

8) Collect rock samples for density measurement after finishing the gravity data correction from four rock ages, Triassic granite, Carboniferous-Devonian-Silurian sediment, Permian limestone, and Jurassic-Triassic sediment (Figure 2.6).

9) Label ID of rock samples and determined their locations on topographic maps.

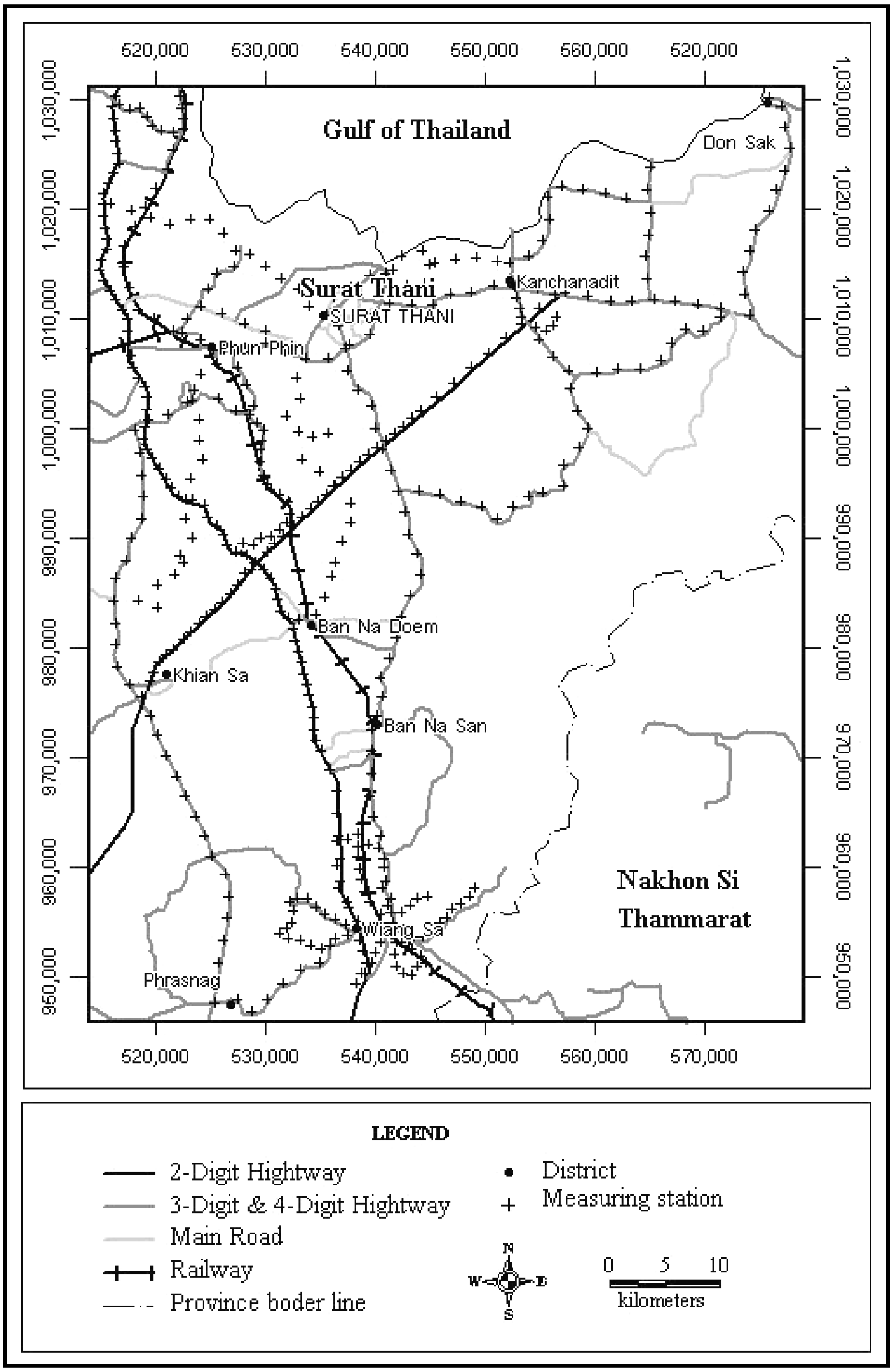

Figure 2.5 Locations of gravity and elevation measuring stations

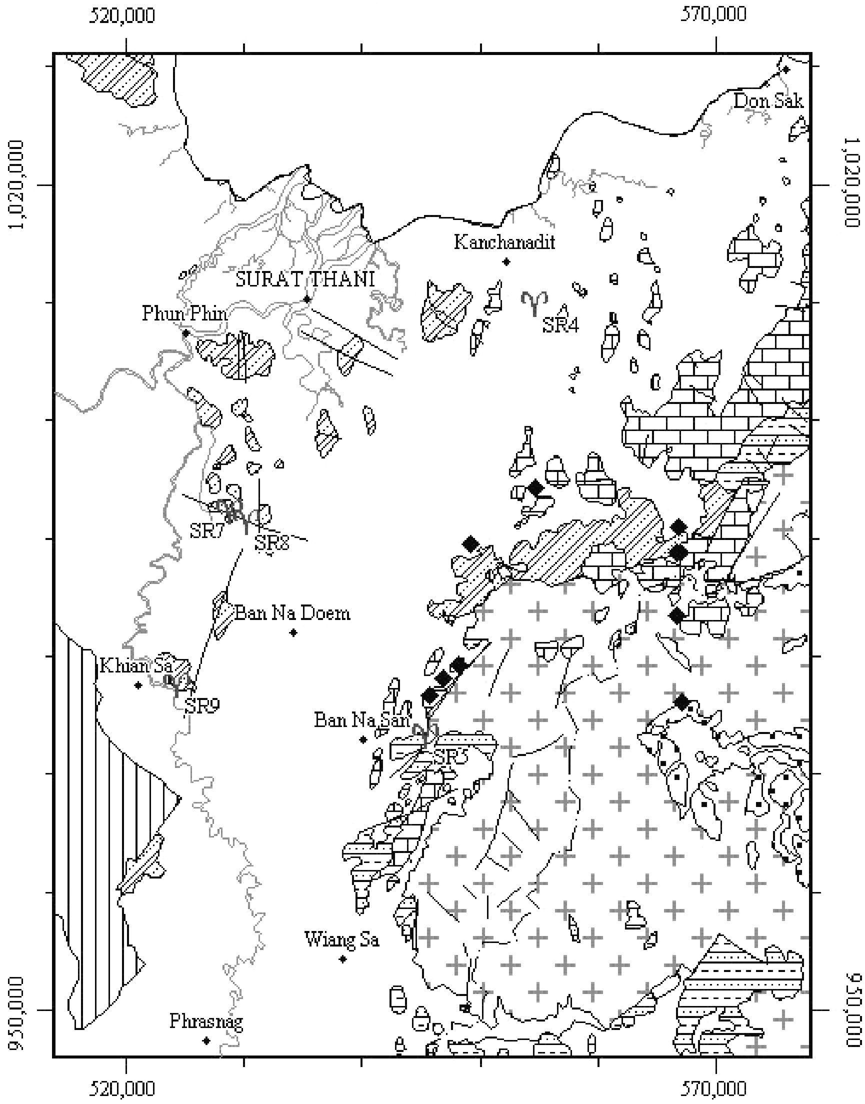

Figure 2.6 Locations of rock sample (solid rhombus)

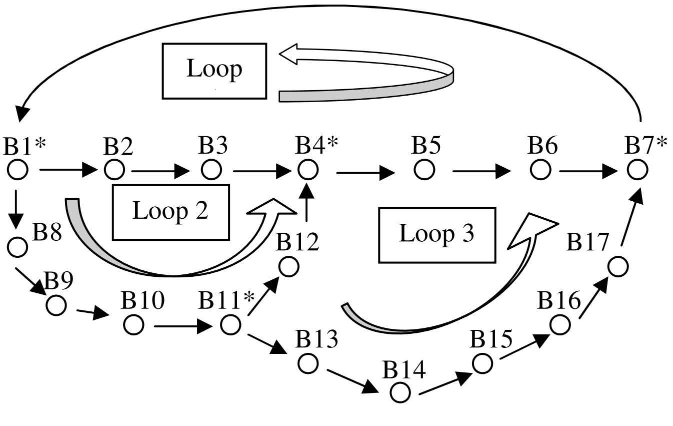

Figure 2.7 Leap-frog Loops, * is Base station.

Table 2.1: Sample of recording data for terrain corrections in B to E zone, ALT., DIF., and COR. denoted the altitude, altitude difference, and correction respectively.

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GRAVITY TERRAIN
CORRECTION HAMMER FORM

CLIENT *Geothermal Resources in Surat* AREA *B* OBSERVER *Prayoot Khawdee* DATE 23/7/48

STATION..*239*..ALTITUDE..*0.28*..TOTAL CORRECTION……………………..									
COMPARTMENT		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
ZONE									
A									
B	ALT.					▨	▨	▨	▨
	DIF.	0.5	0	0	-0.5	▨	▨	▨	▨
	COR.					▨	▨	▨	▨
C	ALT.							▨	▨
	DIF.	-2	0	-2	-2	0	-2	▨	▨
	COR.							▨	▨
D	ALT.							▨	▨
	DIF.	-0.5	-0.5	-0.7	-0.7	0	0.5	▨	▨
	COR.							▨	▨
E	ALT.								
	DIF.	-0.5	-0.5	-0.7	-0.7	-0.7	-0.7	-0.5	-0.5
	COR.								

Table 2.2: Details of zone B, C, D, and E of Hammer chart for terrain correction in the field.

ZONE	Sector radii		Number of sectors
	Inner	Outer	
B	2	16.6	4
C	16.6	53.3	6
D	53.3	170.1	6
E	170.1	390.1	8

Table 2.3: A sample of gravity and elevation data recorded in the field.

Date	Station	E	N	Time (hr.min)	Reading (mgal)	Level (m)	Temp (°C)
29-Apr-05	A186*	535066	970659	11.23	1725.918	120.0	38.0
	B1	536002	968841	11.41	1721.265	120.0	38.0
	B2	536487	966919	11.59	1718.820	127.5	37.5
	B3	536629	964877	12.09	1719.530	127.5	37.0
	B4	536770	962875	12.18	1720.370	120.7	38.5
	B5	536824	960812	12.28	1720.070	122.0	38.0
	B6	536821	958743	12.38	1719.453	124.5	38.5
	B7	537481	956872	12.47	1717.412	129.5	38.0
	B8	538427	955127	12.57	1713.840	134.7	38.0
	A186*	535066	970659	13.57	1725.885	146.5	39.0

10) Determine locations for placing electrical resistivity sounding points, by considering geological models obtained from gravity interpretation, finally twenty one electrical resistivity soundings with Schlumberger electrode configuration were conducted in the study area (Figure 2.8).

11) The resistivity soundings with Schlumberger electrode configuration method were carried out in following steps.

(a) Place four electrodes along a straight line with fixed midpoint (Figure 2.10). The outermost two electrodes are current electrodes (A and B), and innermost two electrodes are potential electrodes (M and N). The measurement begins with half of spacing between potential electrodes (MN/2) and current electrodes (AB/2) were set at 0.5 m and 1 m respectively.

(b) Measure and record the resistance, or V/I, reading from ABEM Terrameter SAS1000 (Table 2.4)

(c) Increase half of current electrodes spacing (AB/2) to 1.5, 2, 3, …, 350 m, and some stations to 500 m, and repeat step (b). When the resistance reading was vary low, increase half of potential electrodes spacing (MN/2) to 2, 10, 50 m.

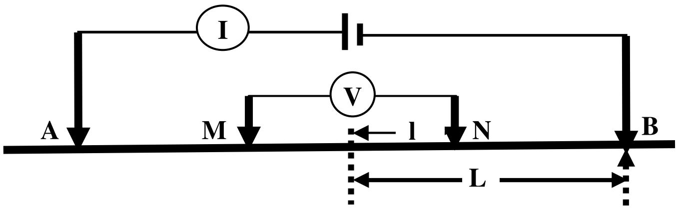

Figure 2.8 Schlumberger electrode configuration array

(d) Apparent resistivity of each current electrode spacing was calculated from eq. (1).

$$\rho_a = \frac{\pi L^2}{2l} \cdot \frac{\Delta V}{I} \qquad (1)$$

$$= k \cdot \frac{\Delta V}{I}$$

An example of the calculation of apparent resistivity is shown in Table 2.4.

(e) Resist-87 software (Vander, 1988) was used for sounding interpretation to determine electrical model ground layers and physical parameters of each layer (ρ and t).

(d) Modeling result was verified by geological log obtained from groundwater wells in the study area.

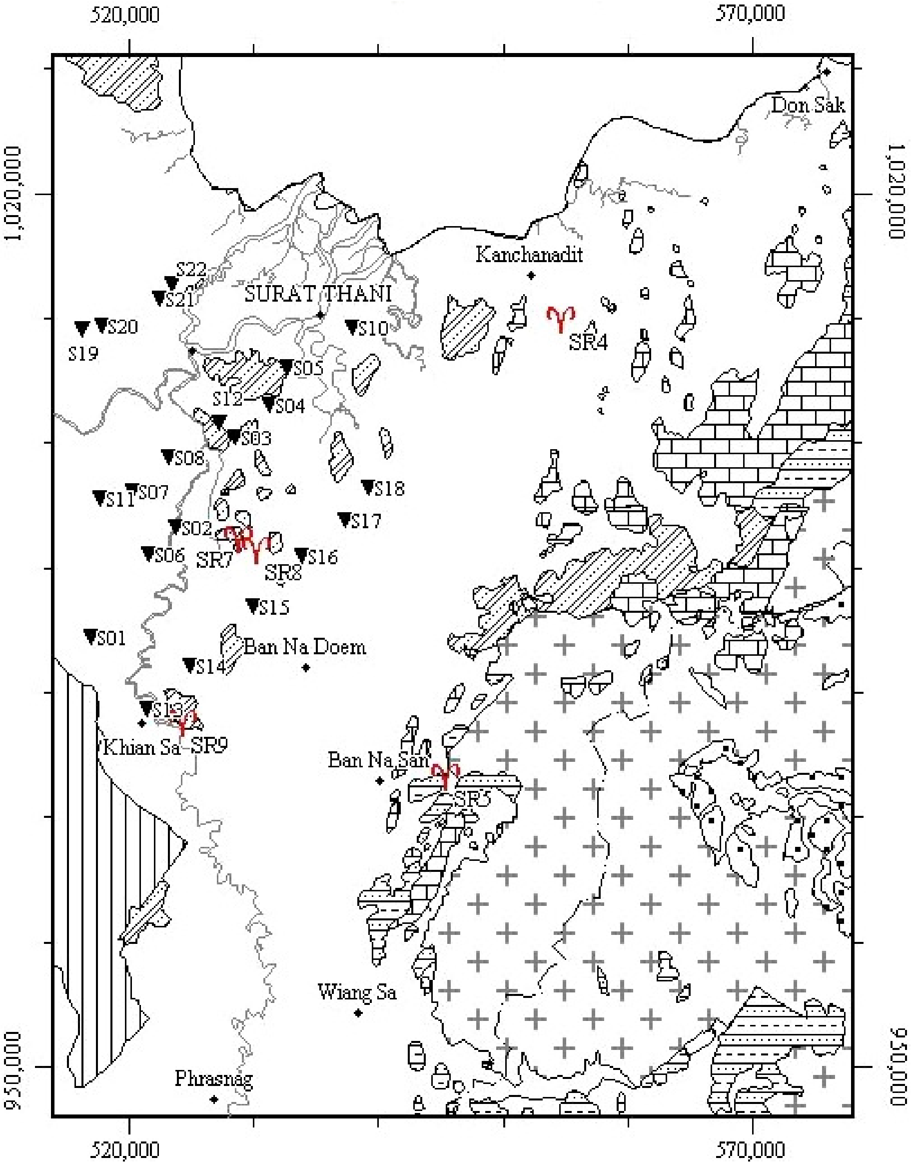

Figure 2.9 Locations of electrical resistivity soundings (solid triangle)

Table 2.4: An example of Resistivity sounding data sheet

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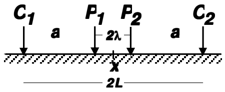
Resistivity Sounding



Survey no. *B4*	**Location** E 533836 N 990957	**Date 20/4/49**
Line no. *S16*	**Operator** *Prayoot Khawdee*	**Time 16.30**

Electrode spacing in meters		**TERRAMETER Reading in Ohms**		**K**	**Calculated Apparent Res. in Ohm-Meters**			**Comments**
AB/2	**(MN/2)**	**R_1**	**R_2**		ρ_{a1}	ρ_{a2}	ρ_{ave}	
1.5	**0.5**	489.050		**6.3**	3081.02			
2.0	**0.5**	329.030		**11.8**	3882.55			
3.0	**0.5**	159.670		**27.5**	4390.93			
4.5	**0.5**	46.143		**62.8**	2897.78			
7.0	**0.5**	9.250		**153.2**	1417.04			
7.0	**2.0**	36.343		**35.3**	1282.91			
10.0	**0.5**	2.262		**313.4**	709.04			
10.0	**2.0**	7.774		**75.4**	586.14			
15.0	**2.0**	0.890		**173.6**	154.53			
20.0	**2.0**	0.218		**311.0**	67.94			
20.0	**6.0**	1.260		**95.3**	120.09			
30.0	**6.0**	0.121		**226.2**	27.31			
45.0	**6.0**	0.031		**520.7**	16.19			
45.0	**10.0**	0.064		**302.4**	19.48			
60.0	**10.0**	0.034		**549.8**	18.48			
60.0	**20.0**	0.073		**251.3**	18.31			
90.0	**20.0**	0.053		**604.8**	31.96			
90.0	**30.0**	0.054		**377.0**	20.17			
150.0	**30.0**	0.035		**1131.0**	39.90			
150.0	**50.0**	0.054		**628.3**	34.23			
225.0	**50.0**	0.036		**1511.9**	54.43			
225.0	**30.0**	0.029		**2603.6**	76.24			
350.0	**50.0**	0.014		**3769.9**	51.57			
500.0	**50.0**			**7775.4**				

2.3.2 Part II Laboratory

Measuring density of rock samples

Density of rock and known is a constraints gravity modeling. Archimedes's principle was employed in density determination of rock samples.

According to Archimedes's principle, an object immersed in a fluid is buoyed up by a force equal to the weight of the fluid displaced by the object (McCormick, 1969). This causes the weight of the object in water less than its weight in air. The change in weight of the object is then equal to the buoyed force.

The buoyed force is related to volume of the object by the following equation.

$$F = \rho_w V g = m_{air} - m_{water} \tag{2}$$

Where F is the buoyant force in Newton.

ρ_w is density of fluid, in this case about 0.996 g/cm^3

V is the rock sample volume in cm^3

m_{air} is weight of object weighing in air

m_{water} is weight of object weighing in water

Then the volume of object is determined, the density of the object can be calculated from the following equation,

$$\rho_d = \frac{M_{air}}{V} \tag{3}$$

Where ρ_d is the density of rock

M_{air} is mass of rock weighing in air.

The following steps are procedures employed in determining density of rock samples in a laboratory.

1) Rock samples are cleaned to eliminate dust and rock remnants.
2) Place the balance on a stable table, adjust the level, weigh the rock sample in air, and record the data.

3) Rock samples are weighed in water and data are recorded.
4) Density of a rock sample is calculated by eq. (4).

$$\rho_d = \frac{W_{air}}{(W_{air} - W_w)} \times \rho_w \qquad (4)$$

Where ρ_d is density of rock sample in g/cm^3

ρ_w is density of water which used for weight rock sample in water in g/cm^3

W_{air} is weight of rock sample weighing in air in gram

W_w is weight of rock sample weighing in water in gram

And then, convert the density of rock from g/cm^3 to kg/m^3.

2.3.3 Part III Data processing

Data processing in gravity and electrical resistivity sounding methods comprise the followings,

1) Temperature and drift correction for altimeter reading.
2) Gravity reduction
3) Interpretation of electrical resistivity sounding curves.

1) Temperature and drift correction for altimeter reading.

Because altimeter reading is changed with ambient temperature, field reading should be corrected in the following steps.

(a) The relative elevation of two adjacent stations was corrected for the effect of temperature by eq. (5) (Somporn, 1999).

$$\Delta H_n = (H_{obs_n} - H_{obs_{n-1}}) \times \left\{1 + 0.036 \times \left[\left(\frac{T_n + T_{n-1}}{2}\right) - 10\right]\right\} \qquad (5)$$

When n = 1, 2, 3, …

ΔH_n is relative elevation between stations nth and (n-1)th which is already corrected for temperature effect.

$H_{obs_n}, H_{obs_{n-1}}$ are observed elevation in meter obtained from altimeter reading at station nth and (n-1)th,

T_n, T_{n-1} are ambient temperature in Celsius degree reading at stations nth and (n-1)th, the unit is Celsius degree.

(b) Knowing the true elevation of the starting station is a measuring loop, elevations of each measuring station are calculated from eq. (6).

$$H_n^T = \Delta H_n^T + H_{n-1}^T \tag{6}$$

When n = 1, 2, 3, …

H_n^T, H_{n-1}^T are true elevations in meters at nth and (n-1)th measuring stations.

(c) In case that there is a difference in true elevation of the base station at the beginning and the end of the loop drift correction should be applied. The drift of elevation in a loop can be calculated from true elevations of the base at the beginning and the end of the loop by eq. (7).

$$Drift = \frac{H_E^T - H_B^T + Dr}{t_E - t_B} \tag{7}$$

Where $Drift$ is a drift in meter per hour of a measuring loop.

H_B^T is true elevation in meter of the base station at the beginning of a loop

H_E^T is true elevation in meter of the base station at the end of the loop

Dr is a difference between absolute elevation in meter of Bases at the beginning and the end of the loop.

t_B, t_E are measuring time in hour at the beginning and the end of the loop.

(d) Drift corrected elevation of a station is calculated from eq. (8) as follows.

$$H_n^D = H_n^T - \left[Drift \times \left(t_n - t_B\right)\right] + Hsc \tag{8}$$

When n = 1, 2, 3, …

H_n^D is drift corrected elevation in meter of the nth station.

H_n^T is true elevation in meter of the nth station.

t_n, t_B are measuring time in hour of the nth station and Base station.

Hsc is the absolute elevation in meter of the referenced base point in the study area.

In this research, gravity and elevations measurement were extended from Chaiya (Khawtawan, 2004). An example for temperature and drift correction on altimeter data is shown in Table2.5.

Table 2.5: An example of temperature and drift correction for altimeter data

Stn	Time T (hr:min)	Time Δt (hr)	Elevation H_{obs} (m)	Temperature T (°C)	Difference ΔH^T (m)	Elevation H^T (m)	Absolute elevation H^D (m)	Drift (m/hr)
A186*	11.23	0.00	120.0	38.0		24.50	24.50	11.38
B1	11.41	0.30	120.0	38.0	0.00	24.50	21.09	
B2	11.59	0.60	127.5	37.5	8.25	32.75	25.92	
B3	12.09	0.76	127.5	37.0	0.00	32.75	24.03	
B4	12.18	0.92	120.7	38.5	-7.48	25.27	14.84	
B5	12.28	1.08	122.0	38.0	1.43	26.70	14.38	
B6	12.38	1.25	124.5	38.5	2.75	29.46	15.24	
B7	12.47	1.40	129.5	38.0	5.51	34.96	19.04	
B8	12.57	1.57	134.7	38.0	5.72	40.69	22.87	
A186*	13.57	2.57	146.5	39.0	13.01	53.70	24.50	

2) Gravity data reduction

In all gravity surveys the vertical component of gravity, g_z, is measured. The precission of the gravimeter is about 0.01 mgal or roughly 1 part in 10^8 of g_z. In addition to lateral change in subsurface density or subsurface geological structure, the variation of g_z can be caused by the following factors; latitudes of measuring stations, elevation of measuring station, surround terrain, earth tides.

Therefore gravity reduction must be applied to the observed gravity data to screen out gravity anomaly of the about factors, except the anomaly caused by lateral change in subsurface density or subsurface geological structures.

The following corrections were applied to observed gravity data. They are drift correction, latitude correction, elevation correction, and terrain correction.

(a) Drift correction

The Drift correction was conducted in the following steps.

(1) Change unit of time to hour.

(2) Convert the counter reading by the calibration factor of gravimeter (Table 2.6) to milligal unit with eq. (9).

$$g_{obs} = B + (S - A) \times C \tag{9}$$

When g_{obs} is observed gravity in milligal (10^{-5} m/s^2)

S is reading taken from a gravimeter

A is reading range of a gravimeter

B, C are constant related to A as shown in table 2.6

An example of the calculation is shown in Table 2.7.

Table 2.6: Conversion factors of LaCoste-Romberg gravimeter model G-565

Counter reading A	Value in milligals B	Factor for interval C
1500	1527.25	1.01856
1600	1629.10	1.01860
1700	1730.96	1.01874
1800	1832.84	1.01877
1900	1934.71	1.01891

(3) Drift of observed gravity within a loop of measurement due to creeping of gravimeter spring and tides is calculated by eq. (10).

$$Drift = \frac{\left(g_{obsE} - g_{obsB}\right) + Dr}{t_E - t_B} \tag{10}$$

Where $Drift$ is drift of measuring loop in milligal per hour

g_{obsB} is gravity of a base station in milligal at the beginning of the loop

g_{obsE} is gravity of a base station in milligal at the end of the loop

Dr is the difference in absolute gravity in milligal between base stations at the beginning and the end of the loop

t_B, t_E are measuring time in hour of base stations at the beginning and the end of the loop.

(4) Gravity of each measuring station is corrected for drift by eq. (11).

$$g_n^{cor} = g_n - Drift \times (t_n - t_B) \tag{11}$$

When n = 1, 2, 3, …

g_n^{cor} is drift corrected gravity in milligal of nth station

g_n is gravity in milligal of the nth station in milligal

t_B, t_E are measuring time of the nth station and the base station at the beginning of a loop.

(5) Absolute gravity of the nth station can be determined when the absolute gravity of a base station is known by using eq. (12)

$$g_n = (g_n^{cor} - g_B^{cor}) \times 10 + g_B \tag{12}$$

When n = 1, 2, 3, …

g_n, g_B are absolute gravity values in g.u. of the nth and the referenced base stations

g_n^{cor}, g_B^{cor} are drift corrected gravity value in milligal of the nth and the referenced base stations.

The referenced gravity base at Faculty of Science, Prince of Songkla University (E 665699 N 774888) of which absolute gravity is 9781219.8 g.u. (μm/s^2) was used as referenced base station for absolute gravity value in this research study.

Table 2.7: An example of drift correction and absolute gravity calculation within a loop of gravity measurement

Station	Time t (hr:min)	Time Δt (hr)	Counter reading S (mgal)	Gravity of measuring station g_{obs} (mgal)	Corrective drift gravity g^{cor} (mgal)	Absolute gravity g (g.u.)	Drift (mgal/hr)
A186*	11.23	11.38	1725.918	1757.36	1757.36	9781685.24	-0.0131
B1	11.41	11.68	1721.265	1752.62	1752.63	9782088.62	
B2	11.59	11.98	1718.82	1750.13	1750.14	9782086.14	
B3	12.09	12.15	1719.53	1750.86	1750.87	9782086.86	
B4	12.18	12.30	1720.37	1751.71	1751.72	9781628.88	
B5	12.28	12.47	1720.07	1751.41	1751.42	9781625.85	
B6	12.38	12.63	1719.453	1750.78	1750.79	9781619.59	
B7	12.47	12.78	1717.412	1748.70	1748.72	9781598.81	
B8	12.57	12.95	1713.84	1745.06	1745.08	9781562.44	
A186*	13.57	13.95	1725.885	1757.33	1757.36	9781685.24	

(b) Latitude correction

Because the Earth is not a perfect sphere but flattened at the poles, on the Earth their varies with its latitude. Mathematically, a referenced ellipsoid is used for representing the Earth's surface at its mean sea level. According to the International Association of Geodesy (IAG) of the absolute gravity at the mean sea level of the Earth, or on a surface of the referenced ellipsoid, is determined from eq. (13) (Parasnis, 1997).

$$g_{\phi} = 9780318 \times (1 + 0.0053024 \sin^2 \phi + 0.0000059 \sin^2 2\phi) \tag{13}$$

Where g_{ϕ} is gravity in g.u. at latitude ϕ

The observed gravity of stations is corrected for the effect of latitude as shown in table 2.10.

(c) Elevation correction

The gravity corrections for the effect of elevation comprise Free-air correction and Bouguer correction as following;

(1) Free-air correction

In Free-air environment, the gravity decreases when the elevation of the measuring station in creases. Therefore a correction called "*FAC*" is applied to the observed gravity to determine gravity value at a datum level, for example, a mean sea level (*Figure 2.10* (a)). The Free-air correction (*FAC*) is defined by eq. (14)

$$FAC = 3.072 \times h \tag{14}$$

When FAC is free-air correction,

It must be added to an observed value if the station lies above the datum level and be subtracted if it lies below.

h is height of measuring station above the datum level in meter.

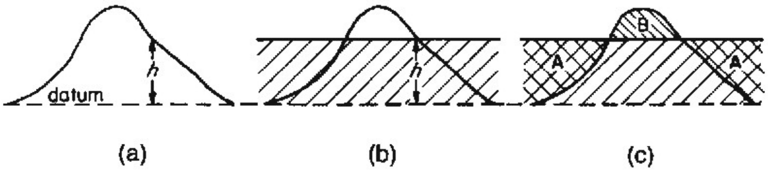


Figure 2.10 (a) The free-air correction for an observation at a height *h* above datum. (b) The Bouguer correction. The shaded region represents an infinite slab of thickness *h*. (c) The terrain correction. (Kearey, et al, 2002)

(2) Bouguer correction

The Bouguer correction accounts for the attraction of material between the station and datum plane that is ignored in the free-air calculation (*Figure 2.10* (b)). The Bouguer correction is given by (Parasnis, 1997).

$$BC = 0.0004191 \times \rho \times h \qquad (15)$$

Where BC is Bouguer correction in g.u.

ρ is density of a slap in kg/m^3

h is height of measuring station above the datum level in meter.

The Bouguer correction must be subtracted from the observed gravity if a station lies above the datum level station and be added if it lies below.

(3) Terrain correction

The terrain correction must be made to account for topographic relief in the vicinity of the gravity station. This correction is always positive as may be appreciated by considering Figure 2.11(c). The regions designated A form part of the Bouguer correction slab although they do not consist of rock. Consequently, the Bouguer correction has overcorrected for these areas and their effect must be restored by a positive terrain correction. Region B consists of rock material that has been excluded from the Bouguer correction. It exerts an upward attraction at the observation point causing gravity to decrease. Its attraction must thus be corrected by a positive terrain correction.

Terrain correction is applied by using a circular graticule known as a Hammer chart (Figure 2.11). The chart is divided by radial and concentric lines into a large number of compartments (Table 2.8). The Hammer chart is laid on topographic map with its centre on the gravity station and the average topographic elevation of each compartment is determined. The elevation of the gravity station is subtracted from these value and record in a terrain correction data sheet (Table 2.9), and the gravitational effect of each compartment is determined by eq. (16) and Table 2.8.

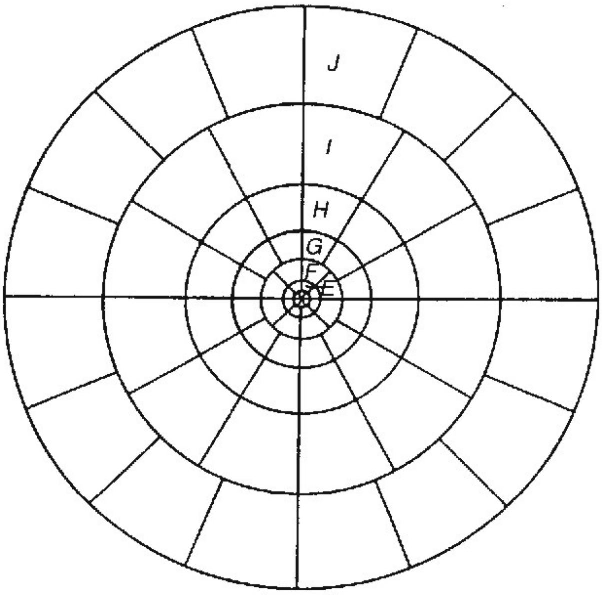


Figure 2.11 A typical graticule used in the calculation of terrain corrections. A series of such graticules with zones varying in radius from 2 m to 21.9 km is used with topographic maps of varying scale. (Kearey, et al. 2002)

Table 2.8: Terrain correction; n is number of compartments in a zone, r_1 is inner radius of a zone in meter, r_2 is outer radius of a zone in meter

Zone	**r_1**	**r_2**	**n**	**Zone**	**r_1**	**r_2**	**n**
B	2	16.6	4	H	1529.4	2614.4	12
C	16.6	53.5	6	I	2614.4	4468.8	12
D	53.5	170.1	6	J	4468.8	6652.2	16
E	170.1	390.1	8	K	6652.2	9902.5	16
F	390.1	894.8	8	L	9902.5	14740.9	16
G	894.8	1529.4	12	M	14740.9	21943.3	16

Table 2.9: Sample of recording table for terrain correction in F to J zone

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GRAVITY TERRAIN CORRECTION HAMMER FORM

TEL.074-211030 EXT.2676,2677 FAX.074-212601

CLIENT…*Geothermal Resources in Surat*..AREA…*B*..OBSERVER…Prayoot Khawdee..DATE..23/7/48

STATION..*232*..ALTITUDE..*24.8*..TOTAL CORRECTION……									***0.66***	g.u.								sum
COMPARTMENT		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	
ZONE																		
F	ALT.	34.8	46.8	34.8	29.8	49.8	74.8	24.8	24.8									
	DIF.	10.0	22.0	10.0	5.0	25.0	50.0	0.0	0.0									
	COR.	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0									**0.29**
G	ALT.	34.8	84.8	54.8	34.8	74.8	64.8	59.8	104.8	50.8	34.8	24.8	24.8					
	DIF.	10.0	60.0	30.0	10.0	50.0	40.0	35.0	80.0	26.0	10.0	0.0	0.0					
	COR.	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0					**0.28**
H	ALT.	34.8	54.8	54.8	44.8	27.8	64.8	36.8	40.8	44.8	34.8	24.8	24.8					
	DIF.	10.0	30.0	30.0	20.0	3.0	40.0	12.0	16.0	20.0	10.0	0.0	0.0					
	COR.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					**0.04**
I	ALT.	44.8	44.8	74.8	44.8	74.8	64.8	24.8	24.8	24.8	24.8	24.8	24.8					
	DIF.	20.0	20.0	50.0	20.0	50.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0					
	COR.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					**0.04**
J	ALT.	44.8	49.8	34.8	104.8	34.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	
	DIF.	20.0	25.0	10.0	80.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	COR.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.01**

$$T = 0.0004191\frac{\rho}{n}(r_2 - r_1 + \sqrt{r_1^2 + z^2} - \sqrt{r_2^2 + z^2}) \tag{16}$$

Where T is terrain correction of compartment in g.u.

ρ is Bouguer correction density in kg/m^3

n is number of compartments in a zone

r_1 is inner radius of a zone in meter

r_2 is outer radius of a zone in meter

z is elevation difference in meter between observation point and mean elevation of a compartment (Kearey, et al. 2002).

Note that, z is determined in the field for zones B to E and from topographical map for zones F to J.

b) The terrain correction is then computed by summing the gravitational contribution of all compartments (in topic a)).

$$TC = T_B + T_C + T_D + T_E + T_F + T_G + T_H + T_I + T_J \tag{17}$$

Where TC is a terrain correction in g.u. of gravity station

$T_B, T_C, T_D, T_E, T_F, T_I, T_J$ are terrain corrections in g.u. of each zone.

(d) Bouguer anomaly

Bouguer anomaly is the gravity value which is corrected for the effects of drift, tides, latitude, elevation and surrounding topography. It can be computed by eq. (18). An example of Bouguer anomaly calculation is shown in Table 2.10.

$$\Delta g_B = g_{obs} - g_\phi + FAC - BC + TC \tag{18}$$

Where g_B is Bouguer anomaly in g.u.

g_{obs} is observed absolute gravity in g.u. at a measuring station determine by eq. (12)

g_ϕ is the absolute gravity calculated from eq. (13)

FAC is the free-air correction in g.u.

BC is the Bouguer correction in g.u.

TC is the terrain correction in g.u.

Map of Bouguer anomaly was drawn by using the Surfer software version 7.00 with the following operation parameters; Kriging gridding method, Search radius: 15,000 m., Number of sector: 4, Maximum number of data: 6, Minimum number of data: 5, Blank node: 4, Spacing: 1,000 m., and then Matrix Smooth method, Average method, Weight of Matrix Centre: 2, Rows: 2, Columns: 2.

Seven profiles in East-West direction of Bouguer anomaly, namely; AA′, BB′, CC′, DD′, EE′, FF′, and GG′ were chosen for gravity modeling with Geo Vista AB-GMM software version 1.31 to determine subsurface geological structures of the study area.

Table 2.10: Sample of Bouguer anomaly calculation

Stn	Lat ϕ (degree)	Level H (m)	Absolute gravity g_{obs} (g.u.)	Latitude correction g_{ϕ} (g.u.)	Free-air correction FAC (g.u.)	Bouguer correction BC (g.u.)	Terrain correction TC (g.u.)	Bouguer anomaly BA (g.u.)
A186	8.781	24.5	9781685.2	9781521.3	75.22	25.65	0.29	214
B1	8.765	21.1	9782088.6	9781516.8	64.78	22.09	0.15	615
B2	8.747	25.9	9782086.1	9781512.1	79.64	27.16	0.33	627
B3	8.729	24.0	9782086.9	9781507.1	73.81	25.17	0.39	629
B4	8.711	14.8	9781628.9	9781502.2	45.59	15.55	0.52	157
B5	8.692	14.4	9781625.8	9781497.2	44.17	15.06	0.15	158
B6	8.673	15.2	9781619.6	9781492.2	46.80	15.96	0.13	158
B7	8.656	19.0	9781598.8	9781487.6	58.48	19.95	0.12	150
B8	8.641	22.9	9781562.4	9781483.4	70.24	23.96	0.17	126
A186	8.781	24.5	9781685.2	9781521.3	75.22	25.65	0.29	214