CHAPTER 1

Introduction

Mae On area is one of the political districts located about 40 km in the eastern part of Chiang Mai City center, northern Thailand. It is located in the foothill terrain with a long shape in north-south trend flanked by mountains on the west and east sides shown as the satellite Google map of Mae On area in Figure 1.1a (Google Earth Pro, 2017). The previous geology information of this area from Department of Mineral Resources (DMR) released in 2007 shows that Mae On area is mostly covered by Quaternary sediments related to recent fluvial and alluvial processes (Department of Mineral Resources, 2007) (Figure 1.2). The regional gravity survey had been carried out in northern part of Thailand by Department of Mineral Resources (DMR) in 2015 including the Mae On area (Figure 1.3). There was also an aeromagnetic anomalies data obtained from DMR which was a part of the nationwide aeromagnetic grid (Figure 1.4) (Hatch *et al.*, 1994). The previous gravity and magnetic maps show high anomalies in the study area with some evidences from ground survey, the basalt outcrop (Figure 1.1b) has been found in the area indicated by a black square zone on Figure 1.1a. In general, the sedimentary unit should provide the low anomalies of both maps because of the low-density and low-magnetic susceptibility. The basalt outcrop which found around field survey (Figure 1.1b) can be an evident that shown high anomalies in the potential field data (gravity and magnetic anomaly maps).

Moreover, the thickness of the Quaternary sediments from well data (Department of Mineral Resources, 2003) is about 80 m underlaid by the basaltic rock. However, the well location is about 6.5 km in South-West direction away from the study area (indicated by a black star in Figure 1.1a and Figure 1.2). Therefore, some geological information might be varied especially the sedimentary thickness. Consequently, the study area is interested in estimating depth of sediment. Although Mea On area was investigated by magnetic and gravity methods recently and show sensible result in geology, the area has never been surveyed by seismic method before. The study of sedimentary layer such as its physical properties and thickness could provide subsurface information that might be useful for planning the area future development.

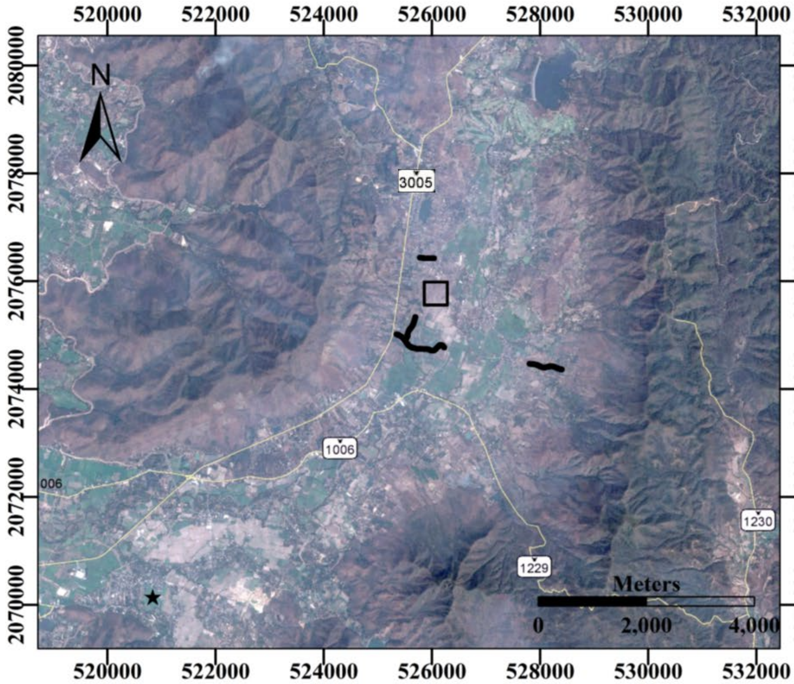
1.1. Problem and Methodology

The conflict between the surface geological map (Figure 1.2) and both potential field maps (Figure 1.3 and Figure 1.4) were leaded to curiosity. The previous interpretation presents the probability that there is sediment of overlaying basalt layer. It is still poorly understood about subsurface geometry. In order to confirm these contradictory that will be precluded about subsurface geometry underneath Mae On area, higher quality of geophysical data such as seismic reflection method is required. Consequently, to extricate this problem, the seismic surveys were conducted for the subsurface geometry. Both of previous potential field results are utilized for analysis with new two dimensions seismic surveys.

The basic technique of seismic exploration consists of generating seismic waves into the ground and, then, the seismic energy disturbance several types of waves propagating within the Earth and along its surface. The generated waves can be divided into two main categories; body waves and surface waves. The body waves are transmitted through the interior of the Earth while the surface wave is traveling near surface and characterized by relatively higher amplitude with lower frequency in shot record. The propagating body waves are returned to the surface where encounter the layer of rock because of the velocity and density contrasts. The instrument collects the amplitude and time required for the waves to travel from the source to a series of the receiver (Telford *et al.*, 1990). The recorded seismic data will be processed with appropriate sequent to create seismic image of subsurface which provides the subsurface geometry.

It is also well known that the potential filed data will suffer from the non-uniqueness because several geological models could produce the same gravity and/or magnetic response. Furthermore, many solutions may not be geologically realistic. Because of this inherent ambiguity and the nonlinear nature of the geophysical problem, the result from seismic reflection method will be combined with the potential filed data to explore the subsurface geology.

(a)



(b)

Figure 1.1 shows (a) Satellite map of Mae On District, Chiang Mai Province in UTM coordinates is in 47Q zone (Google Earth Pro, 2017) black lines indicate seismic reflection surveys and black star marks well location, and (b) the basaltic tuff outcrop in black square zone. The pictures are facing west direction.

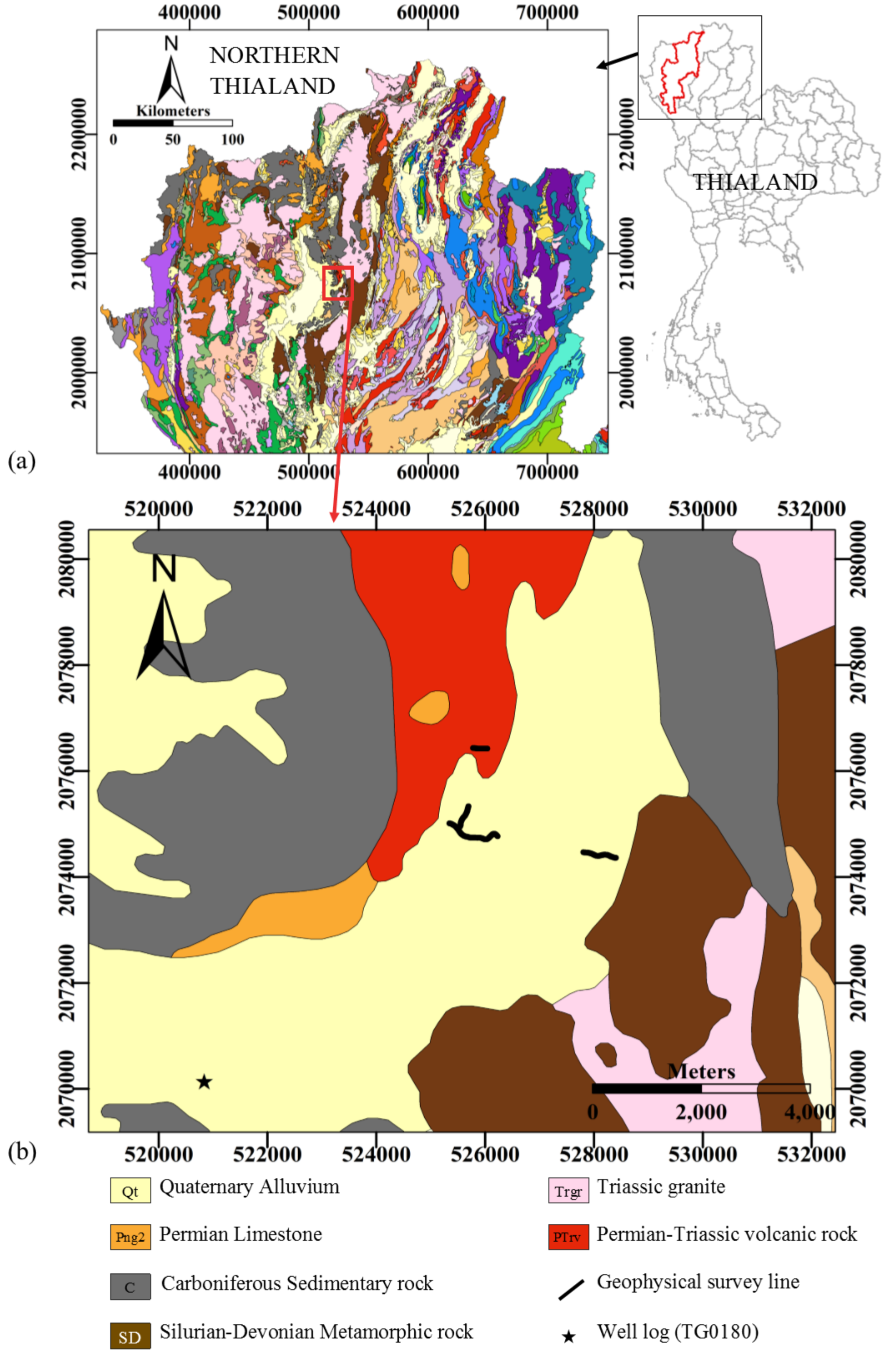


Figure 1.2 shows (a) The geological map of northern Thailand and that of (b) Mea On District, Chiang Mai Province (Department of Mineral Resources, 2007), black lines indicate seismic reflection surveys and black star marks well location.

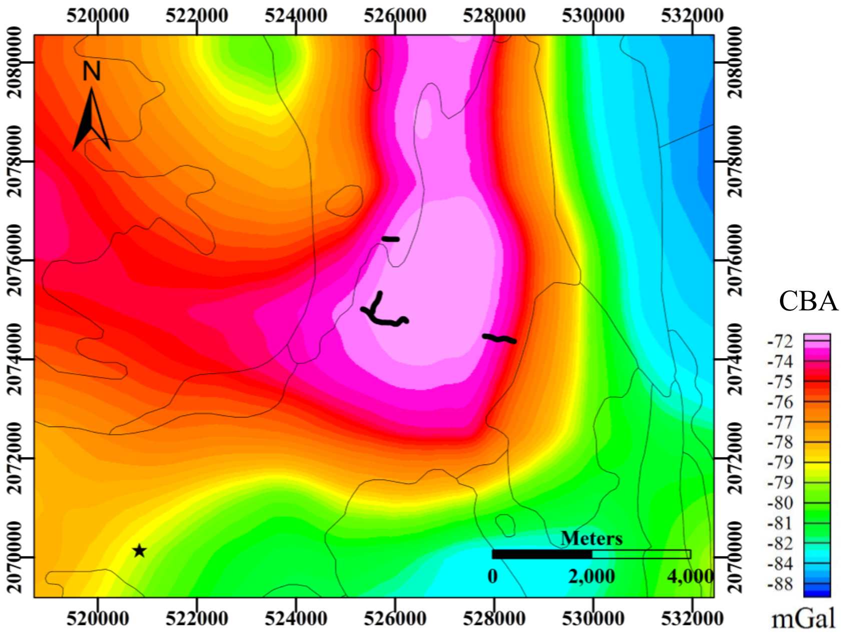


Figure 1.3 indicates the gravity anomaly map from the ground survey of Mae On area (Department of Mineral Resources, 2015) overlapped with boundary of geological units (Figure 1.2), black lines are geophysical survey lines and black star presents well log location.

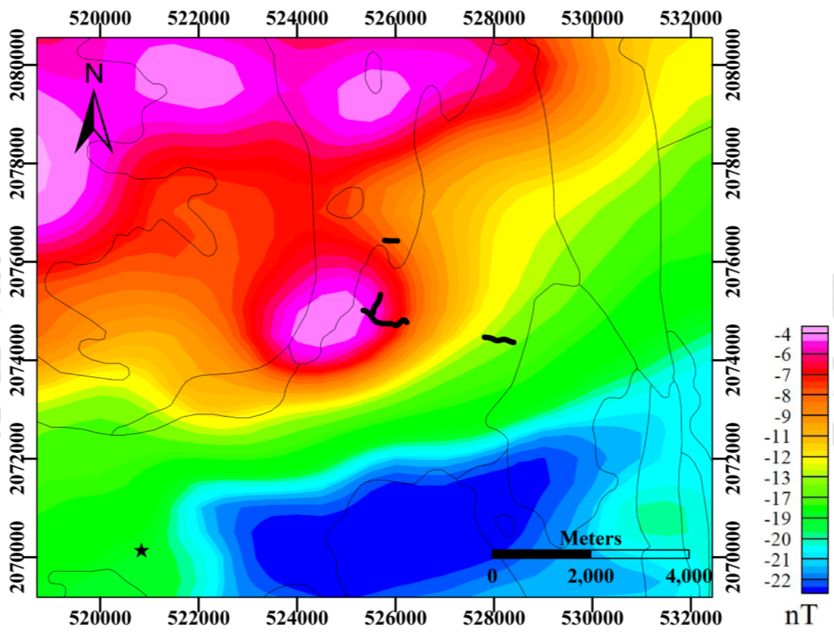


Figure 1.4 indicates reduction to the pole of residual aeromagnetic map from Mae On area (Department of Mineral Resources, 1989) overlapped with boundary of geological units , black lines are geophysical survey lines and black star presents well log location.

1.2. Research Scope and Objectives

There are two main objectives in this study. The first objective is to create two-dimension seismic interpretation base on seismic reflection surveys. The second is to find subsurface geometry in the study area by geophysical data integration of gravity data and two-dimension seismic profiles.

This study will be scoped with four seismic reflection lines. The reflection seismic surveys were acquired in three zones (Figure 1.3, Figure 1.4); (1) two survey lines were surveyed on Quaternary geology zone with high anomalies from both potential field maps, (2) one survey line was investigated on the volcanic rock zone with high anomalies from both potential field maps, and (3) one survey line was examined on Quaternary geology zone with high gravity anomalies and moderate magnetic anomalies. There are three survey lines parallel oriented in west-east directions and one perpendicular in north-south direction. Seismic reflection data will be processed and interpreted. Gravity data will be reprocessed for interpretation and modeling with seismic constrain control.

1.3. Study area and Geological setting

The study area is located between UTM 524000E to 534000E and UTM 20768000N to 2082000N in 47Q Zone and covers approximately 8 km^2. Mae On area is considered as a basin structure in the horse and graben system in the northern Thailand. It is geomorphologically similar to a basin structure because it is a lowland area located within surrounded high areas which there are mountain ridges separate between Mae On area and Chiang Mai basin. The geological map released from DMR (Figure 1.2) shows that Mae On lowland area is covered by recent sediment deposits.

The Figure 1.2b represents the local geological map of Mae On area. It is giving information that the western side of study area involves three Pre-Cenozoic basement units. The oldest unit is Carboniferous sedimentary rocks which consist of conglomerate, sandstone, shale, slate, chert, and limestone. The younger unit, Permian limestone rocks overlay Carboniferous sedimentary rocks which consist of gray to black limestone, bedded and massive limestone, and limestone interbedded with shale and sandstone. The youngest unit, volcanic rocks had suddenly occurred in Permian-Triassic period. The eastern side of the study area involves three Pre-Cenozoic basement units. Carboniferous sedimentary rocks have also emerged the eastern part as well which underlaid by the older rock unit, Silurian-Devonian metamorphic rocks. The Silurian-Devonian metamorphic rocks comprise phyllite, carbonaceous phyllite, and quartzitic phyllite. There are Triassic intrusion granite rocks that consist of biotite granite, tourmaline granite, granodiorite, and biotite-muscovite granite. The center of Mae On area covered by Quaternary sediments that includes alluvial and floodplain sediments.

The Pre-Cretaceous volcanic belts in Thailand are generally divided into four volcanic belts including Chiang Rai–Chiang Mai Volcanic Belt, Chiang Khong-Tak Volcanic Belt, volcanic rocks along the Nan-Chanthaburi Suture Zone and the Loei-Phetchabun-Phai Sali Volcanic Belt. The volcanic rocks in the study area were assigned to Chiang Rai-Chiang Mai Volcanic Belt. Field survey and petrography by Barr and Cooper (2013), Barr *et al.* (1990) and Phajuy *et al.* (2004), described types of volcanic rock that are the Permian tuff and basalt unit composed of green tuff, gray to dark green basaltic flows, hyaloclastite, pyroclastic and pillow breccia. This volcanic belt formed in back-arc basin, ocean-island and mid-ocean ridge environment. The back-arc basin was made up the successive layers of volcanic ashes deposited on each eruption (Phajuy *et al.,* 2004).

1.4. Previous geophysical and related works

The Department of Mineral Resources (DMR) had obtained the first aeromagnetic data during 1984-1989 as one of products under the Mineral Resource Development Project (MRDP) (Hatch *et al.*, 1994). The regional gravity data were collected as random points with spacing of 1-2 kilometers by DMR in 2015. The regional gravity data were conventional corrected with terrain correction.

Furthermore, undergraduate students under the geophysical research laboratory, Chiang Mai University, completed previous gravity ground survey. It is part of their senior project in 2013 (Chaiyamongkon, 2014 and Siri, 2014) that unpublished and only internal program reports. The gravity anomalies map shows high anomalies in the center of Mae On area which are surrounded by low anomalies. Their gravity map is compatible with that from DMR, but gravity data from DMR cover more of the study area.

The main acquisition in this study is seismic reflection method. However, the resistivity and Multichannel Analysis of Surface Waves (MASW) surveys were also acquired along survey line in north-south direction about the same time period of seismic reflection acquisition for this study. The objective of both surveys are to explore shallow subsurface geometry and combine that with seismic reflection section for the subsurface interpretation. Appendix C gives the short explanation and parameters used in both methods.

Another previous subsurface information of this area from DMR is well log data (Department of Mineral Resources, 2003). It indicates that there are the Quaternary sediments with 80 m thickness underlaid by the basaltic rock. Nevertheless, the well is located about 6.5 km in south-west direction away from the study area, therefore, some geological information might be varied especially the sedimentary thickness. However, the primary information in Mae On area were obtained by outcrops, gravity and magnetic surveying. It is believed that the basaltic layer is overlaid by the sediment layer in the center of Mae On area, which has large difference properties of material.

Bannister and Melhuish (1997) and Davy and Bibby (2005) used seismic reflection method to study the volcanic area in New Zealand which has similar basalt accumulation to this research area. According to the study, the high contrast of medium properties such as density and velocity between the basaltic layer and sediment layer cause poor quality of seismic reflection survey. Moreover, there are researches focus on the volcanic layer as well, Carcione *et al.* (2013) used seismic refraction method to determine the sediment layer thickness overlying the basaltic layer and Osella *et al.* (2015) utilized the electrical resistivity data to support some part of their seismic reflection section interpretation.

Bannister and Melhuish (1997) proved that seismic techniques have ineffective in the young volcanic strata that occur in the Taupo Volcanic Zone (TVZ) due to near-surface reverberation within surficial layers of contrasting seismic velocities which can obscure the signatures of deeper sequences and generally reduces data quality. They used 14 Hz respond frequency geophones with 48 channels system and the 3-6 kg explosive sources. In 2004, Davy and Bibby (2005) explored seismic survey in an adjacent area base on the imperfection information from previous study by Bannister and Melhuish (1997). The study area was located in Okataina volcanic center tracks across Lake Tarawera. They used higher frequency sources, airgun and EG&G “uniboom” for seismic reflection surveys. The airgun sources were used for deep profiling which show seismic profile up to 1 s or equivalent to 1100 m depth. Whereas, the uniboom source can illustrate seismic profile only 200 ms or approximately 170 m depth. The problems associated with sub-basalt imaging is the strong reflection of seismic signal from high impedance contrast between the overlying sediment and the basaltic layer. The high frequency source and high-resolution survey configuration are needed but with high frequency signal, seismic profile can review shallow subsurface zone only.

Carcione *et al.* (2013) applied a preliminary near-surface seismic survey carried out at Llacanelo Lake (Argentina) with the aim of mapping the quaternary layers which composed of sedimentary layers overlying basalt. The study focuses on analysis travel time from a few shot gathers which had been processed with the standard processing technique to improve first break signal quality. Later on, a shallow reflection seismic survey reaching depths of 700-800 m was performed for the first time in the Llancanelo Lake region (Southern Mendoza Province, Argentina) by Osella *et al.* (2015). The study involved the characterization of the lake's substrate geometry including the recognition of buried structures like faults and volcanic features, as well as obtaining details about the regional distribution and facies variations of the surface and near subsurface stratigraphic (sedimentary and volcanic) sequences. The seismic survey depicted a stratigraphic sequence composed of sedimentary deposits with basaltic units up to depths of at least 700 or 800 m. The previous electrical resistivity data was used to help the interpretation.

The integrated geophysical methods were applied to a lot of subject such as petroleum basin (Demir *et al.*, 2012), hot spring (Neawsuparp *et al.*, 2010), caldera complex (Davy and Caldwell, 1998), belt zone (Pinet, 2013), joint modeling (De Castro, 2011). The previous geophysical data such as gravity and magnetic anomaly maps were utilized with seismic data for subsurface geometry interpretation as follow.

De Castro (2011) has presented the modeling that combined geophysical methods of the gravity and magnetic data, seismic data, well logs and geologic map. This integrated approach allowed to determine the internal architecture that show joint in complex tectonic and structural framework.

Pinet (2013) shown interpretation that is substantiated by potential field data (gravity and magnetic) that put additional control on seismic and field cross-sections by confirming the location of faults and ensuring that cross-sections are balanced for gravity and magnetism in Gaspé Belt zone.

Davy and Caldwell (1998) shown the 2D models that are an attempt to conceptualize the deep zone of the gravity and magnetic data for the purposes of discussion and have been made to conform the constraints on the shallow structure provided by the seismic reflection and refraction data in the caldera complex zone.

Neawsuparp *et al.* (2010) presented that a geologic model of the Pong Kum studied hot spring area was visualized according to the overall results of the ground geophysical surveys. There are electrical resistivity, magnetic and seismic methods for ground investigation. Geophysical surveys were concerned to visualize the main factors of the reservoir for geothermal development in this area.

Demir *et al.* 2012 presented the useful of geophysical investigation. Thrace Basin is numerous of geophysical and geological data that has been explored more than 40 years. However, this basin is not clearly about subsurface geometry until the integrated analysis of the gravity, aeromagnetic and seismic data together with the composite logs of selected wells in the Thrace Basin.

1.5. Thesis summary

This thesis is outlined as follow:

Chapter 1, the introduction chapter, summaries of the background geological, the previous study and literature review that can be apply for thesis and outlines main techniques employed to achieve the goal of the objective of this study.

Chapter 2, seismic method chapter, describes the basic theory of seismic waves and the seismic reflection method including seismic data processing. The seismic data acquisition, briefly processing step and final interpretation are explained in this chapter as well. The electrical resistivity and S-wave velocity models are included for integrated interpretation.

Chapter 3, potential method chapter, describes the potential data source which is magnetic and gravity data and then briefly explain the data analysis. Moreover, this chapter provides integrated seismic results from chapter 2 for construct the pseudo-geological model.

Chapter 4 discusses the result from seismic and potential method chapter including the conclusion of this study.