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To cite this article: Chulalak Sundod and Passakorn Pananont 2018 *J. Phys.: Conf. Ser.* **1144** 012021

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Subsurface fault investigation in Chiang Rai province, northern Thailand by integrated geophysical surveys

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Abstract. A magnitude 6.3 earthquake, the biggest instrumentally recorded earthquake in Thailand, occurred in Chiang Rai Province on 5 May 2014 and caused large damages in the affected area. The earthquake generated numerous aftershocks that could portray the location of the fault plane beneath the ground. In this work, we conducted integrated geophysical surveys consisting of 2D seismic reflection and 2D resistivity imaging surveys to explore for active faults that could have caused this earthquake. A seismic reflection survey line with a total length of 3,750 metres and resistivity survey with a total length of 1,975 metres were conducted along the Chiang Rai earthquake's aftershock locations. The subsurface fault geometry was imaged from this integrated geophysical survey. Numerous subsurface discontinuities detected from both seismic reflection and 2D resistivity imaging survey were interpreted as potential faults along the survey line with depths from a few meters to around 500 metres. These subsurface discontinuities correspond well with the aftershock locations which could suggest a fault rupture plane.

1. Introduction

On 5 May 2014, a magnitude 6.3 earthquake struck Chiang Rai province in Northern Thailand. The earthquake's epicenter was located in Phan district, 27 km southwest of Chiang Rai city, at 19.756°N 99.687°E with a hypocenter depth of 6 km ([1]: Figure 1). This earthquake is thought to be one of the biggest earthquakes ever recorded in Thailand. The earthquake caused significant damages to properties and infrastructures near the epicenter and affected in 5 provinces: Chiang Rai, Chiang Mai, Phayao, Nan, and Lampang, consisting of 10 districts, 16 sub-districts and 63 villages. One person died in this earthquake while 23 were injured [1]. Furthermore, the earthquake resulted in a number of collapsed buildings, large surface cracks and liquefaction. This earthquake generated numerous aftershocks which were not located on the Phayao fault zone and therefore may have been associated with the location of the potential unknown fault beneath the ground.

This work conducted two geophysical methods, 2D seismic reflection and 2D resistivity imaging surveys, in Phan district (Figure 1) in order to investigate the evidence produced by the earthquake and study the geometry of the possible fault. The geological images will be useful to inform the detection and effects of future seismic hazards.

2. Geological setting

The geology of Chiang Rai province includes complex high mountain ranges running from north to south and east to west, which are composed of various rock types. The study area is located in the



Phayao active fault zone in the Phan district of Chiang Rai province which mainly consists of fluvial deposit, sandstone, siltstone and clay stone, and contains the highest number of active faults in the country [2]. The study area is located in the Phayao active fault zone. A 1999 study by the Department of Mineral Resources [3] found that the Phayao active fault zone is orientate in a north-south direction. The fault has both right lateral and left lateral strike-slip motions. The Phayao fault zone is 90 km long and can be separated into 17 segments.

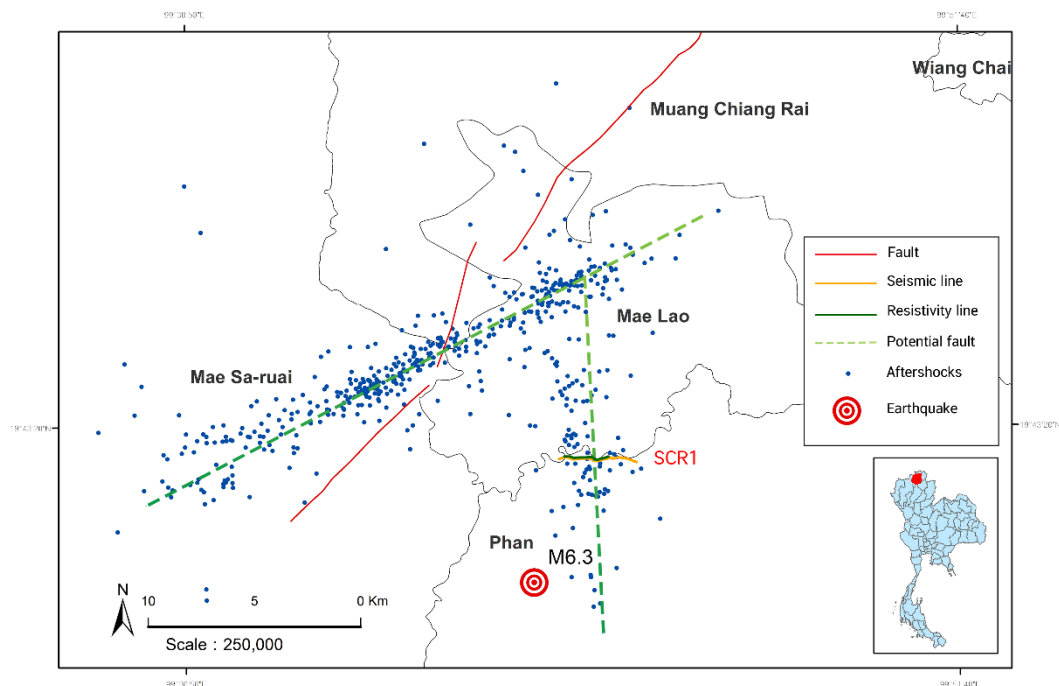


Figure 1. Location map of the M6.3 Chiang Rai earthquake epicentres. Red circle is the epicentre of the main shock and the blue dots are its' aftershocks. Red lines represent the Phayao fault zone. Location of the 2D seismic reflection and 2D resistivity imaging surveys are shown in yellow and green lines (SCR1) respectively. Green dash lines are potential fault.

3. Geophysical surveys

3.1. 2D Seismic reflection survey

The seismic reflection method is based on bouncing or reflecting seismic waves of the boundaries between different types of rock in the subsurface [4]. The energy source sends seismic waves down and some will reflect at the boundaries between the rocks below the surface, and travel back to the geophones that are recording the seismic waves. Each geophone along the cable sends the received signal from reflected seismic wave to the recording seismograph that records and stores the data.

In this study the seismic reflection survey was conducted in Phan district, Chiang Rai province (Line SCR1 in Figure 1). The geophones were planted directly into the ground surface with 10 m geophone spacing. A weight drop was used as a seismic source with minimum offset of 10 m. Acquisition parameters are shown in Table 1. The 2D seismic reflection survey line is 3,750 m long. To process the data, we used the seismic data processing software VISTA®. The data processing was designed using the following procedure: (1) SEG-2 input; (2) Application of geometry; (3) Traces Editing; (4) Automatic Gain Control; (5) Band-pass filter; (6) F-K filter; (7) Deconvolution; (8) Preliminary velocity model interactively picked from CMP gathers, semblance panels and common velocity stacks; (9) Normal Move Out (NMO) correction; (10) Stack; and (11) Display.

Table 1. Data acquisition parameters of the 2D seismic reflection survey.

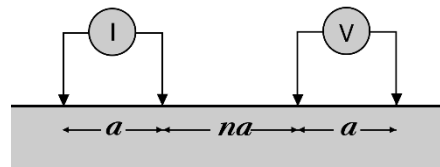
Characteristic	Measurement
Seismic source	Weight Drop (70kg)
Seismograph	Geometrics' Geodes
Survey type	Roll along spread
Geophone type	28 Hz
Number of active geophone	48 channels
Geophone spacing	10 m.
Shot spacing	10 m.
Record length	1 s
Sample rate	0.5 ms
Stacking shots	20

3.2. 2D resistivity imaging survey

The 2D resistivity imaging survey is used to detect the difference in electrical resistivity between different rock types. They are able to detect features such as swallow holes or underground cavities, and analysis of the results can establish the thicknesses and depths of the various sub-strata. The resistivity of the ground depends on geological parameters such as minerals, porosity and degree of water saturation in the rock [5].

The 1,975 metre 2D resistivity imaging survey was conducted in the same location as a 2D seismic reflection survey (Figure 1). We used multi-electrode (48 channels) resistivity meter with 5 m electrode spacing using Dipole-Dipole array (Figure 2). The appearance resistivity for Dipole-Dipole array can be calculate by [5]:

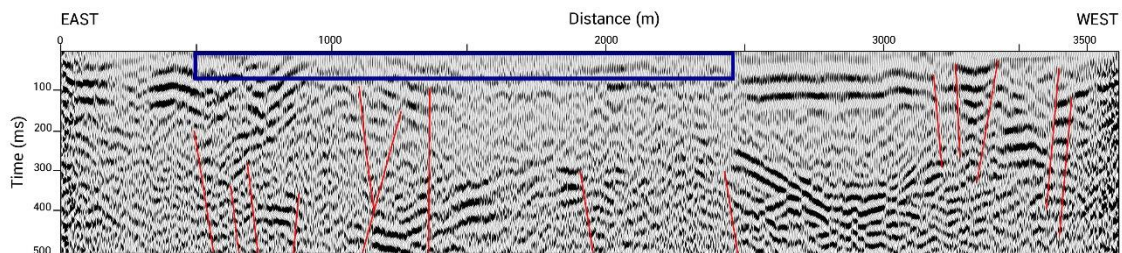
$$\rho_a = \frac{V}{I} \pi a n(n+1)(n+2)$$

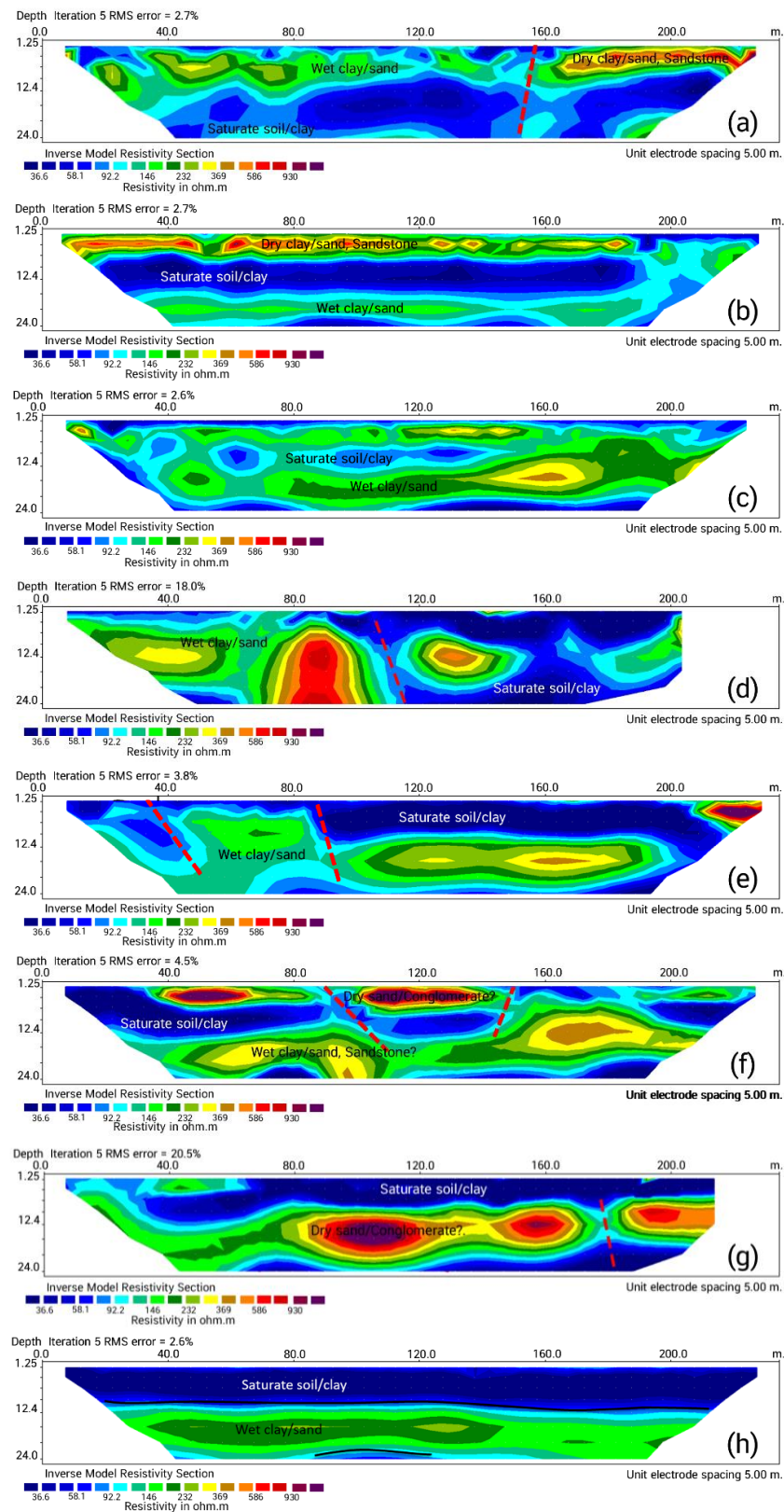
**Figure 2.** Dipole-Dipole configuration used in 2D resistivity survey in this work

Where n is the depth of the data when a is increased. V and I are voltage and current respectively [5]. In the processing stage, resistivity data was then processed by Res2Dinv software.

4. Results

The 2D seismic reflection survey in this work provides images of numerous discontinuities (red lines in Figure 3) down to 500 ms (approximately 500 m in depth). The result of the 2D resistivity imaging survey also shows a number of discontinuities as shown in Figure 4.

**Figure 3.** Interpreted seismic profile showing several discontinuities in subsurface which could indicate possible faults. Box indicates the coverage of the 2D resistivity imaging survey in Figure 4.



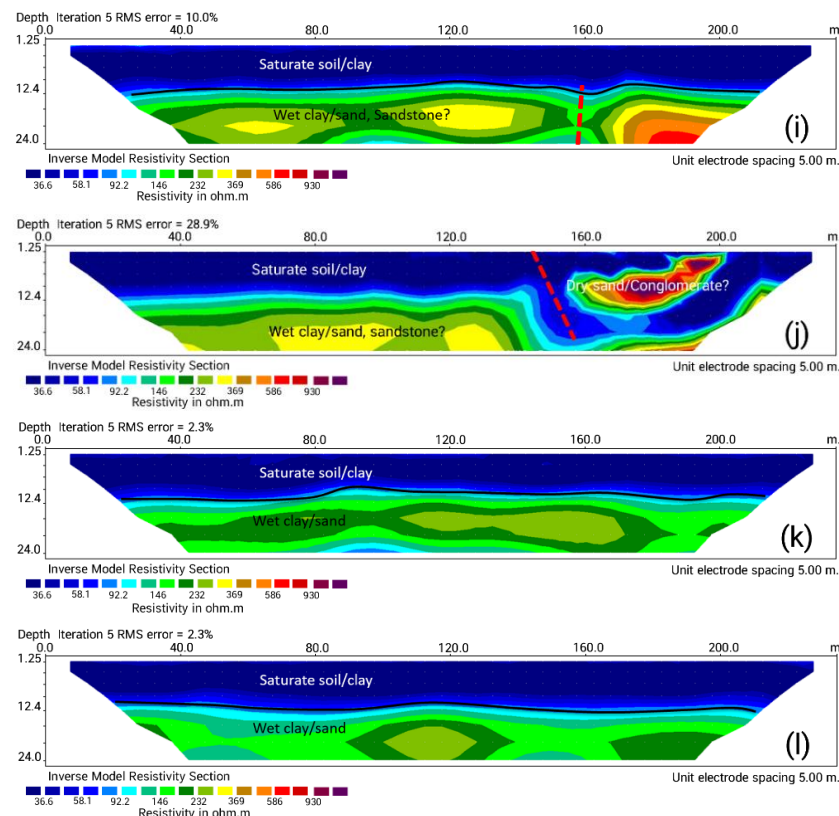


Figure 4. A result of a 2D resistivity imaging survey. The red line indicate the location of discontinuities which could be faults

5. Conclusion

Integrated geophysical survey were conducted in Chiang Rai province in order to detect potential faults. The result from both 2D seismic reflection and 2D resistivity imaging suggest several discontinuities that could potentially be considered faults underneath the survey lines. Employing both methods lead to a greater degree of certainty that faults actually do exist in the SCR1 survey line. The faults are seen at the depth from a few meters to 500 meters from 2D seismic reflection image (Figure 3), some faults are seen at the 2D resistivity images, which are 25 meters deep (Figure 4 (a), (e), (f), (g), (i) and (j)). After compared by the survey location of the images from two methods, the location of faults found in 2D resistivity images are fit well with the data from 2D seismic reflection image. The location of these potential faults are located in the vicinity of the known aftershock of the M6.3 Chiang Rai earthquake which could indicate that these potential faults are in fact part of the fault planes that ruptured during this earthquake. The findings from this work can be used for planning a proper seismic hazard mitigation of the Chiang Rai province in the future.

References

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